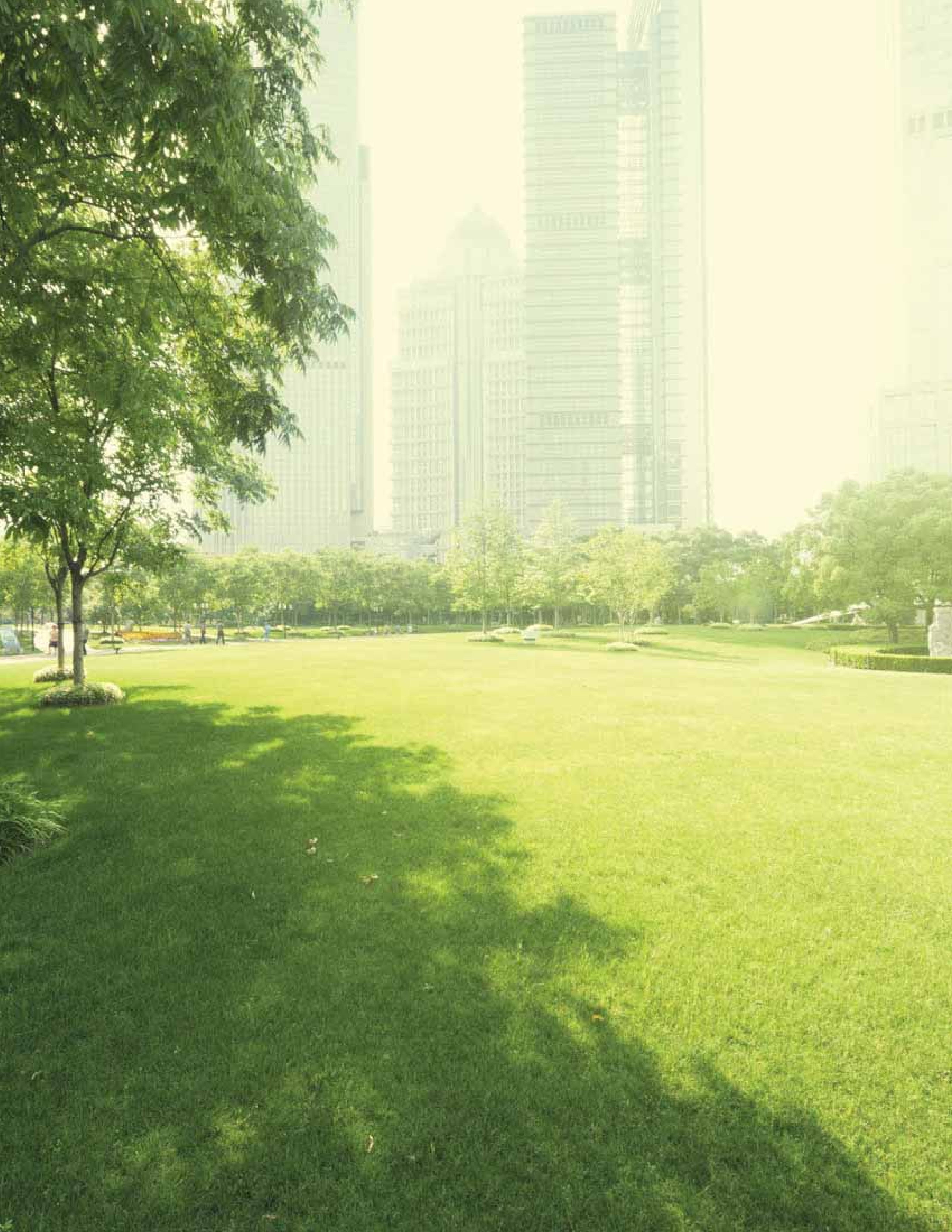
Energy Sector Management Assistance Program

TECHNICAL REPORT 011/17

ASSESSING AND MEASURING THE PERFORMANCE OF ENERGY EFFICIENCY PROJECTS



ESMAP MISSION

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank. It provides analytical and advisory services to low- and middle-income countries to increase their know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth. ESMAP is funded by Australia, Austria, Denmark, the European Commission, Finland, France, Germany, Iceland, Japan, Lithuania, the Netherlands, Norway, the Rockefeller Foundation, Sweden, Switzerland, and the United Kingdom, as well as the World Bank.

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ABBREVIATIONS

€	Euro (currency)
ADB	Asian Development Bank
AMI	Advanced metering infrastructure
CCMS	Centralized control & monitoring system
CDM	Clean Development Mechanism
CER	Certified emission reduction
COMBI	Calculating and Operationalizing the Multiple Benefits of Energy Efficiency in Europe
DSM	Demand-side management
ECM	Energy conservation measure (equivalent to energy efficiency measure)
EE	Energy efficiency
EESL	Energy Efficiency Services Ltd.
EM&V	Evaluation, measurement, and verification
EMS	Energy management system
EPC	Energy performance contracts
ESCO	Energy service company
G20	Group of Twenty (international forum)
GEF	Global Environment Facility
GHG	Greenhouse gas
HVAC	Heating, ventilation, and air conditioning
IEA	International Energy Agency
IGEA	Investment Grade Energy Audit
IMF	International Monetary Fund
IPMVP	International Performance Measurement and Verification Protocol
kWh	Kilowatt-hours
LED	Light-emitting diode
M&V	Measurement and verification
MBEE	Multiple benefits of energy efficiency
MRV	Measurement, reporting, and verification
Mtoe	Million tonnes of oil equivalent
NEB	Non-energy benefit
NEI	Non-energy impact
O&M	Operation and Maintenance
OECD	Organisation for Economic Co-operation and Development
PM10	Particulate matter 10
R2E2	Renewable Energy and Energy Efficiency Fund
RCT	Randomized control trial
SEforALL	Sustainable Energy for All (United Nations initiative)
SLCP	Short-lived climate pollutant
T&D	Transmission and distribution
UNFCCC	United Nations Framework Convention on Climate Change
WAP	US Weatherized Assistance Program
WHO	World Health Organization

All currency in United States dollars (USD, US$, $), unless otherwise indicated.

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EXECUTIVE SUMMARY

Energy efficiency is a cost-effective solution to meet energy, climate change, and sustainable development goals and critical for supporting access to affordable, reliable, and sustainable energy services in developing countries. The energy efficiency potential is vast and largely untapped across the world. This is widely recognized by most governments, the development community, and international organizations, and forms the foundation of global initiatives such as Sustainable Energy for All. The benefits of improving energy efficiency are multiple, but so are the barriers. There is no silver bullet, but recognizing the multiple benefits of energy efficiency (MBEE)—including energy savings, as well as others (Table ES.1)—and making them more visible and credible is an integral part of the solution. If demonstrated suitably, these multiple benefits can motivate stakeholders to invest and participate in energy efficiency programs.

An intrinsic challenge facing energy efficiency projects is that the benefits are not physically visible. The difficulty in reliably predicting and measuring the energy that will be saved and quantifying the associated nonenergy benefits (e.g., environmental benefits or increased comfort levels in the case of energy efficiency in buildings) can make it more difficult or less interesting for policy makers, investors, and energy users in general to focus efforts and resources to scale up energy efficiency.

This report seeks to make a contribution to scaling up energy efficiency through improved planning and design of energy efficiency interventions in developing countries by starting with the basic management principle of "What gets measured gets done." It includes a review of global experience with the measurement and verification (M&V) of energy efficiency and the emerging field of assessing the multiple benefits of energy efficiency. Through the references, examples, data, and practices highlighted, this reports seeks to help practitioners demonstrate the performance of energy efficiency interventions.

The report makes the case that M&V should be a critical aspect of any energy efficiency project or program in order to ensure value for money, justify continued or increased funding, as well as provide the basis of performance-based payment mechanisms. M&V is essential to assess resource savings and to ensure that savings persist over time. Energy efficiency practitioners use M&V for several reasons, such as, to:

- Improve engineering design and project costing
- Enhance energy savings through adjustments in facility operations and maintenance
- Document financial transactions (e.g., for energy efficiency projects where financial payments are performance based)
- Enhance financing for energy efficiency projects
- Support development of broader energy efficiency programs

TABLE ES.1

Most Commonly Cited Multiple Benefits of Energy Efficiency

DESCRIPTION	INDICATORS	METHODS
Participant Benefits		
Energy savings	Unit of energy saved (e.g., kWh) and monetary value	Measurement
O&M cost reductions	Replacement and inspection rate of equipment and monetary value	Measurement
Health impacts	Hospitalization and mortality rates, medical costs	Measurement
Labor productivity	Days off work, days off school	Measurement
Comfort	Indoor temperature, humidity level, and monetary value	Survey of willingness to pay or comparison
Energy access	Energy services provided (lumen-hours in the case of lighting, useful energy in the case of heating or cooling)	Measurement
Water savings	Quantity of water saved (liters) and monetary value	Measurement
Property values	Monetary value	Measurement
Safety	Number of accidents prevented	Measurement
Competitiveness	Market share, cost per unit of output, energy intensity	Measurement
Avoided capacity	Avoided capacity (kW) and saved monetary value	Power sector modeling
Avoided T&D	Avoided kWh losses and saved monetary value	Power sector modeling
Avoided peak load	Avoided peak capacity (kW) and saved monetary value	Power sector modeling
Reduced credit and collection costs	Saved monetary value	Measurement
Increased reliability	Value added ($) produced, number of avoided power outages	Modeling measurement
Energy security	Avoided energy imports (terajoules, etc.) and saved monetary value	Modeling
Public budget savings	Saved monetary value	Measurement
Avoided energy subsidy	Saved monetary value	Modeling
Indirect public budget	Saved monetary value	Modeling
GHG emissions	Tonne of CO_2 equivalent and saved monetary value of avoided damages	Measurement and emissions factors
Pollutant emissions	Tonne of pollutants reduced and saved monetary value of avoided damages	Measurement and concentration modeling
Ozone Depleting Substance	Tonne of ozone depleting potential and saved monetary value of avoided damages	Measurement and emissions factors
GDP growth	Monetary value	Macroeconomic modeling
Job creation	Net number of jobs created	Macroeconomic modeling
Energy Price	$/kWh reduction	Macroeconomic modeling
Energy poverty	Number of households	Survey

CO_2—carbon dioxide; GDP—gross domestic product; GHG—greenhouse gas; kWh—kilowatt-hour; O&M—operations and maintenance; T&D—transmission and distribution

- Provide opportunities to capture climate change mitigation benefit and emission reduction credits
- Increase public and market awareness of energy efficiency

The report provides an overview of M&V practices for energy efficiency, noting that different terms are used to describe the process to measure and verify the performance of energy efficiency activities: Measurement and Verification (M&V), Evaluation, Measurement, and Verification (EM&V), or Measurement, Reporting, and Verification (MRV). They share the common objective to "assess the outcome" of an energy efficiency intervention and provide a framework for measuring and verifying project outcomes in a transparent, reliable, and consistent manner. Energy professionals and stakeholders use established protocols and methodologies to develop project-specific measurement and verification plans. These documents are not standards, hence, there is no compliance mechanism associated with the protocols. Practitioners have to decide to what degree their energy efficiency activities would conform their energy efficiency activities to the protocols, with decisions typically depending on the projects' scope, cost of M&V, and the use/value/benefits of a more rigorous M&V system.

> **Measurement and Verification.** M&V is crucial to establish the credibility of the benefits of energy efficiency and build confidence in the performance of energy efficiency activities. Accounting for energy efficiency's multiple benefits can help drive more energy efficiency actions. With greater confidence that theoretical energy savings and nonenergy benefits are realized in practice and a better understanding by governments and stakeholders of the value of energy efficiency, a stronger case can be made for investments, as well as for the replication and scaling up of energy efficiency interventions.

The effort and rigor associated with M&V of energy efficiency projects or programs should typically be commensurate with the project capital investment and savings risk. The appropriate level of M&V rigor can often be determined by considering three factors: (i) the predictability of equipment operation; (ii) the magnitude of M&V costs in relation to the value of the energy savings and nonenergy benefits produced by the project; and (iii) technical capacity of the operators.

A review of publicly available documentation for select energy efficiency projects undertaken by the World Bank and other organizations indicates that while preparation documentation for energy efficiency projects typically include methods for estimating energy savings ex ante, very few projects include, from the start, the provisions or methods to systematically measure and assess, ex-post, the actual performance of energy efficiency projects and programs. This can lead to: (i) potential under- or overestimation of energy savings; (ii) possibly undermining the credibility of energy efficiency interventions and their potential replication or scale up; (iii) missed opportunities for learning from the actual performance of the energy efficiency interventions and; (iv) making it difficult to develop and enable energy performance contracts. **Evidence indicates that projects involving ex-post payment for energy efficiency performance often have a greater incentive to undertake rigorous M&V.**

This report highlights that energy efficiency projects should include, from the beginning, the elaboration of an M&V plan that outlines how the performance of the project will be monitored and assessed. It is important to strike a delicate balance between cost, rigor, and complexity. Factors that can influence the M&V costs include: project complexity, levels of uncertainty, existing energy management systems, and the risk allocation for achieved savings. Providing adequate accuracy while ensuring a reasonable cost of M&V can be challenging.

In the case of projects where parameters are fairly constant and actual measurements may not be possible for the baseline development and energy savings calculation, a "deemed savings" approach may be considered. While such an approach typically has less precision (as it consists of multiplying the number of installed energy efficiency measures by a "deemed" value of savings per measure) and may increase the level of uncertainty of the achieved energy savings, it has greater simplicity and lower associated costs. In order to address the higher uncertainty levels, it is typically recommended to use a conservative approach to reduce overestimation of impact. Combining deemed or "default" input assumptions with some site-specific inputs and/or sample measurements can contribute to enhancing the robustness of the estimated energy savings.

There is no empirical formula or easy way to define a point where rigor and M&V costs intersect. One must rely on judgment and experience to determine a cost-effective approach. A few strategies for keeping M&V costs low while maintaining the rigor include the following:

- Use extensive metering in the baseline period and stipulate values for the parameters that cannot be metered.
- Verify key performance items using periodic rather than continuous data collection (not to be confused with continuous M&V) to reduce data collection and management issues.
- Rely upon existing instrumentation, energy management systems, and energy management behavioral practices wherever possible.

For the assessment and evaluation of the performance of energy efficiency projects in developing countries, this report highlights the importance of also considering whether there is unsatisfied (suppressed) and growing energy demand. Such situations should be taken into account with baseline assumptions reflecting increasing energy consumption in the future. An increase in energy consumption following the implementation of energy efficiency measures—compared to the baseline energy use—is typically referenced as a rebound effect (or "take-back effect"). **In the case of developing countries, and in particular emerging economies, improving energy efficiency often comes along with increasing energy consumption (to meet unmet and growing demand for energy services). Thus, the performance of energy efficiency is not so much about "doing more with less [energy]" (which was applicable to industrialized countries), but rather "doing even more [energy services] with more [energy]" and contributing to raising standards of living and promoting prosperity.** This shift in how energy efficiency should be considered is reflected in the increased focus on the multiple benefits generated by energy efficiency investments and policies.

Inclusion of the multiple benefits of energy efficiency (MBEE) can play a crucial role in enhancing the value of M&V for stakeholders. In many instances, the nonenergy benefits from an energy efficiency project could be higher and/or have a greater influence on decision making than the energy saved. For example, an energy efficiency streetlight project can improve visibility, contributing to fewer road accidents while increasing the perception of security among pedestrians and leading to lower energy consumption per light point. The topic of MBEE encompasses a wide range of impacts, including economic; health and physical comfort; social; and environmental (locally and globally), among others. Identifying and assessing all of the direct and indirect benefits of energy efficiency is an evolving field; nonetheless, the existing body of evidence and analysis already highlights its relevance and is leading a growing number of practitioners wanting to take MBEE into account in their assessments of energy efficiency activities.

From a direct benefit perspective, multiple beneficiaries can be identified. **Recipient benefits** refer to the benefits that accrue to the participants of a program (end-users). The importance of these benefits also varies according to recipients' income levels. Low-income households tend to receive greater health and comfort benefits from energy efficiency programs because their baseline conditions before improvements are generally lower than those of average-income households. **Benefits to electricity supplier** (the power sector) are numerous. They include deferring the need to build new infrastructure to meet growing demand and increasing grid reliability. Important benefits of energy efficiency programs accrue in the **public budget**. This is most pronounced when government agencies are the recipients, such as with public buildings or street lighting energy efficiency retrofits. However, additional nonenergy benefits to public budget exist. In economies that subsidize end-use energy tariffs, energy efficiency programs reduce fiscal expenditures on energy subsidies, which enable them to lower deficits or increase spending in other priority areas, such as health and education. Energy efficiency improvements can deliver **benefits across the whole economy,** with direct and indirect impacts on economic activity, employment, trade balance, and energy prices.

MBEE are often omitted from assessments of the benefit of energy efficiency programs for three main reasons: lack of data, lack of consensus for quantifying their impact and monetary values, and lack of resources to conduct the analysis. However, MBEE significantly contribute to economic growth, social welfare, and environmental health, justifying policy makers and program administrators in overcoming these barriers and including MBEE in evaluations of energy efficiency programs so that the socio-economic benefit of these programs can be optimized.

The following steps are recommended for incorporation of MBEE in analysis of energy efficiency projects:

1 | Identify the benefits most relevant to the overarching programs goals and to the stakeholders

2 | Determine the goal of quantifying the benefits (advertising, stakeholder engagement, program decision, impact evaluation)

3 | Consider MBEE at the beginning of program design and planning

4 | Determine the form in which benefits will be quantified (monetized or not)

5 | Develop the evidence base and establish reference studies

6 | Streamline the quantification process by adopting/developing appropriate model and tools

Ability to improve understanding and demonstration of the social and economic benefits would strengthen the incentives for government agencies to undertake effective **measurement and verification** (M&V) of the energy efficiency benefits. This is part of a learning process. As more data and evidence are collected from ongoing projects, it will improve the design and performance of future projects and provide insights into effective assessment.

OVERVIEW

This report seeks to make a contribution to scaling up energy efficiency through improved planning and design of energy efficiency interventions in the developing countries by starting with the basic management principle of "What gets measured gets done." The report reviews global experience with the measurement and verification (M&V) of energy efficiency and the emerging field of recognizing the multiple benefits of energy efficiency (MBEE). Through the references, examples, data and practices highlighted in this report, this reports seeks to help practitioners demonstrate the performance of energy efficiency interventions. The overarching objective is to enable project developers, policy makers and investors to better consider energy efficiency as a cost-effective solution to meet energy, climate and key development objectives.

This report builds on the existing body of work on energy efficiency M&V within and outside the World Bank Group.

Chapter 1 provides a brief introduction. Chapters 2 and 3 are intended to serve as guidance to improve the assessment of energy efficiency interventions in a transparent and consistent manner. The report presents a review of major M&V protocols used by the energy efficiency community across the world. The review compiles a lexicon of the commonly used terminologies and compares the M&V protocols, in terms of scope, application, and key features. In the context of the MBEE, the opportunity for expanding the current M&V approaches is presented for further research. An analysis of select energy efficiency projects identifies key issues with M&V of energy savings and opportunities to improve demonstration of actual performance of energy efficiency interventions, focusing on energy efficiency in lighting and buildings.

Chapter 4 presents a review of the latest practices in capturing MBEE. This report seeks to lay the foundation to a systematic approach of integrating MBEE in project documents by identifying main MBEE (focusing energy efficiency in buildings and public lighting) and giving examples of metrics developed to account for MBEE. It gives a brief overview of the experience of institutions that are increasingly seeking to support incorporating MBEE in investment decisions and communication strategies. A few methods of quantifying the MBEE investments are outlined, with recommendations for stakeholders interested in pursuing quantification and incorporation of MBEE in decision making and for future research. Chapter 5 provides an illustration of the key steps in ensuring effective M&V of energy efficiency projects.

M&V of the MBEE is an evolving field. Nonetheless, the existing body of evidence and analysis already highlights its relevance and is leading a growing number of practitioners wanting to take MBEE into account in their assessments of energy efficiency activities. This report is intended to provide a comprehensive review of the current landscape. Readers are encouraged to build on this report to share emerging experiences, insights and new research questions with the global energy efficiency community.

ENERGY EFFICIENCY: THE FIRST FUEL

Energy efficiency is a cost-effective solution to meet energy, climate change, and development goals. Energy efficiency is also central to the overall World Bank Group engagement in the energy sector aimed at supporting developing countries' access to affordable, reliable, and sustainable energy services, recognizing that modern energy services can help improve the quality of life for millions around the world and underpin progress in all areas of development.[1] **Literature describes energy efficiency as "the hidden fuel" given its inherent lack of visibility. The narrative around energy efficiency is changing to position it as the "first fuel,"[2] given its significant contribution to meeting energy demand, as well as the large market for energy efficiency investments (IEA 2015). In the case of developing countries, energy efficiency provides an opportunity to sustainably grow energy services and support development and economic growth.** The International Energy Agency's (IEA) "Bridge Scenario"—which proposes a set of energy actions to raise climate ambition, in line with the world's climate goal of limiting global temperature rise below 2°C—identifies energy efficiency as one of the five measures, and largest contributor, to achieve a peak in emissions around 2020, using only proven technologies and without harming economic growth (IEA 2015).

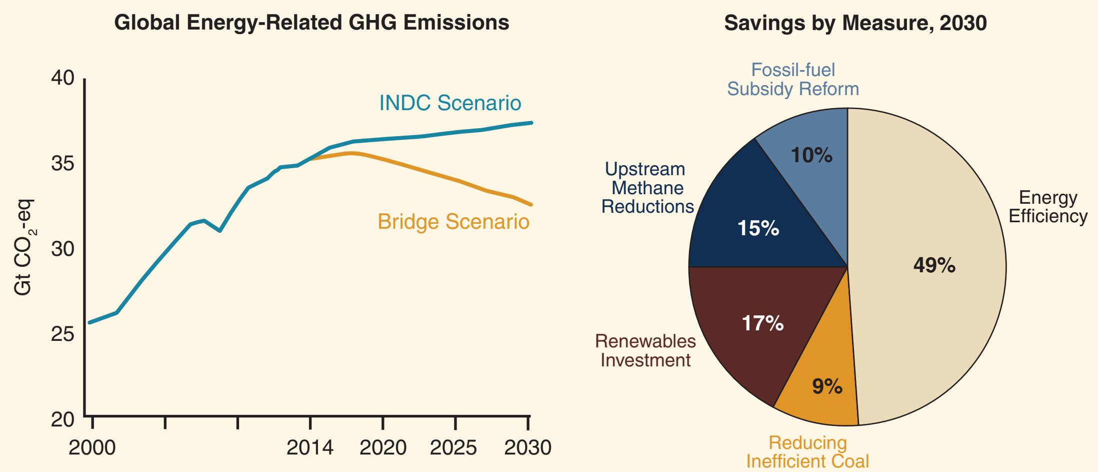
Investments in energy efficiency can curb energy demand growth and emissions growth in the near term while fueling economic growth and without compromising goals of greater access to reliable and affordable energy services. These attributes are making energy efficiency attractive propositions for national governments, as well as subnational entities. In fact, as urban areas account for two-thirds of global energy consumption (and greenhouse gas emissions), cities have become a key focus of energy efficiency policy.

Global energy demand is projected to increase by about 32 to 45% above 2013 levels by 2040,[3] with all of the net growth coming from non-OECD (Organisation for Economic Co-operation and Development) countries—already responsible for 58% in 2013 and increasing 55% in 2040 (IEA 2015).[4] According to the IEA Energy Efficiency Market Report, in 2014, energy efficiency investments since 1990 were estimated to have enabled countries to avoid primary energy imports of at least 190 Mtoe (given existing import patterns), with an estimated value of $80 billion. The potential and importance of energy efficiency in the context of global energy demand trends in general, and for the developing world in particular, is huge and merits renewed attention.

Notwithstanding this emerging role for energy efficiency, projections reveal that under existing policies, the vast majority of economically viable energy efficiency investments (e.g., in buildings, transport, etc.) may remain unrealized. No country has fully utilized the potential to improve the energy efficiency of its economy and most still have scope to go considerably further. There are a number of recommended enabling conditions to address barriers to energy efficiency financing and perceived risks,[5] including the need for clear and easy measurement.[6]

FIGURE 1.1

Energy Efficiency and the Global Climate Goals



Source | *World Energy Outlook Special Report: Energy and Climate Change 2015.*

"What Gets Measured, Gets Managed"

An intrinsic challenge facing energy efficiency projects is linked to the particular feature that their benefits—energy savings and others—are not physically visible. The difficulty in reliably predicting the energy that will be saved and quantifying the associated nonenergy benefits (e.g., environmental benefits or increased comfort levels in the case of energy efficiency in buildings) can make it more difficult/less interesting for policy makers, investors, and energy users in general to focus efforts and resources to scale up energy efficiency. This report seeks to make a contribution to scaling up energy efficiency through the planning and design of energy efficiency interventions in the developing countries by starting with the basic management principle of "what gets measured gets done."

Effective measurement and verification (M&V) systems are crucial not only to capture the energy efficiency gains but also to appropriately capture multiple benefits of energy efficiency (MBEE) so investment and policy decisions are better informed and enabled. Given that the bulk of energy consumption takes place in urban areas combined with significant energy efficiency potential,[7] this report focuses on urban public lighting and buildings, which can also offer demonstration and replication potential.

M&V is recognized as a crucial confidence building tool for assessing the performance of energy efficiency interventions. It is also key for sustaining energy efficiency over time. Moreover, M&V can be the basis of certain contracts in cases where payments for energy efficiency investments are

Energy Efficiency is the ratio of the energy service provided (output) by a system compared to the amount of energy used (input). This implies that two sets of benefits would accrue to a typical energy efficiency project: first, reduction in energy consumption by the system; second, a potential improvement in the level of service (e.g., lighting, heating, cooling) delivered by the system without a corresponding increase in energy consumption. Traditionally, measurement and verification systems focus on the first which, from an electricity sector perspective, is a primary benefit. However, as typical demand-side energy efficiency interventions also closely involve the consumer, the second benefit is equally (if not more) important. This is particularly relevant for consumers in the developing countries, where level of service in the baseline scenario (i.e., the scenario against which the performance of energy efficiency activities is assessed) may be low, and in many cases involve suppressed (unmet) demand, meaning that a key development objective is to improve the level of service. This needs to be properly evaluated when appraising energy efficiency investment decisions.

In the context of developing countries and emerging economies in particular, the concept of energy efficiency requires shifting from the notion that energy efficiency is about "doing more with less" to "doing even more [energy services] with more [energy]" to recognize and take into account the full productive impact and contribution of energy efficiency. For the purpose of this report, these nonenergy, co-benefits are being called "Multiple Benefits of Energy Efficiency."

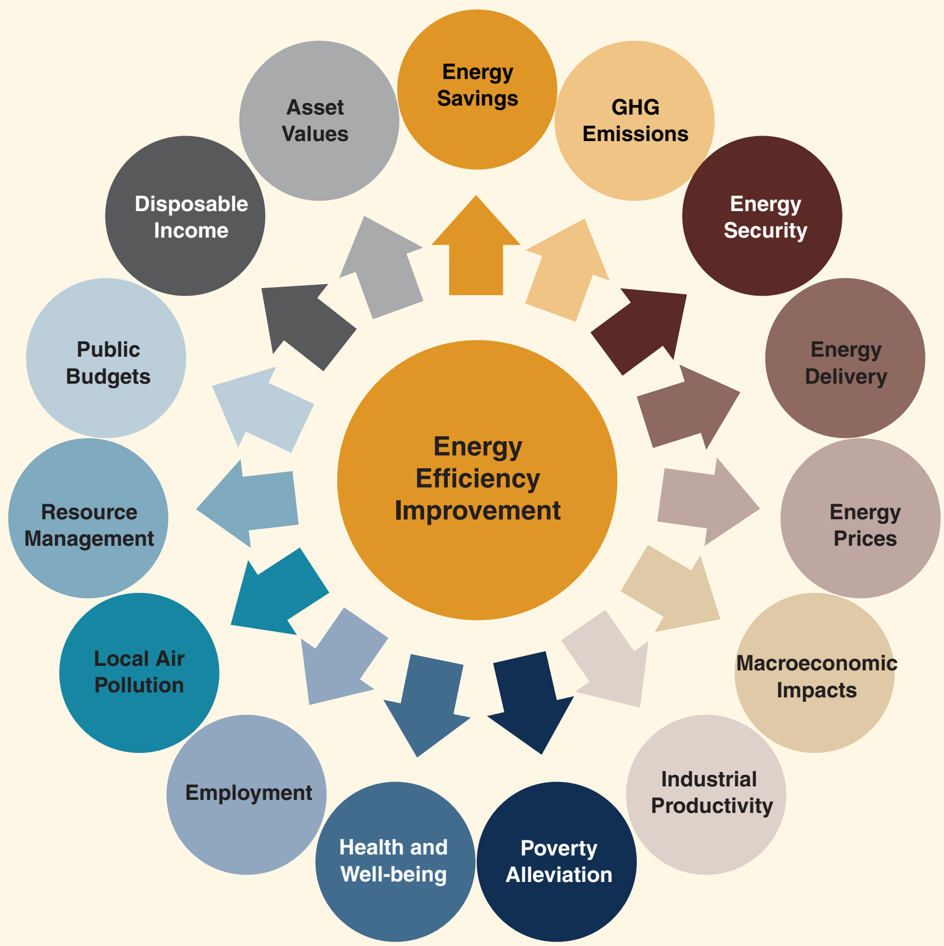
performance based (e.g., energy performance contracts). Globally, tools and protocols for M&V of energy efficiency projects have flourished and have continually improved in range of applications and level of precision. Recent years have seen a rapid emergence of new technology solutions that seek to simplify and streamline the M&V process. In developing countries, actual energy savings achieved by localized energy efficiency interventions are often accompanied by growing electricity demand.

The literature on energy efficiency, which is predominantly based on experiences in the United States and Europe, identifies factors such as rebound effects (i.e., greater energy use enabled by increased disposable income resulting from energy efficiency measures) as having a negative impact on the overall benefit from energy efficiency projects. This makes sense from a purely energy use perspective. However, the so-called rebound effect may also signify an improvement in the overall level and/or quality of energy service to the consumer. For example, the IEA notes that **in the case of emerging economies countries, the performance of energy efficiency is not so much about "doing more with less [energy]" (which was applicable to industrialized countries), but rather "doing even more [energy services] with more [energy]" and contributing to raising standards of living and promoting prosperity.**[8]

Systematic Measurement of Multiple Benefits of Energy Efficiency

The literature of the past 20 years has identified a wide range of MBEE with varying classifications applied to different world regions or by different organizations. Terminology also varies among regions, studies, and organizations. IEA (2014) uses the term "multiple benefits" for MBEE; other terms used include: "co-benefits," "ancillary benefits," "nonenergy benefits," and "nonenergy impacts." This report uses the IEA term to acknowledge and recognize the multitude of benefits that can be generated with scaling up energy efficiency (Figure 1.2). In developing countries where energy demand is constrained by insufficient supply to meet energy service needs because of low income, inadequate infrastructure, high technology costs, or a combination of these factors, energy efficiency benefits can include reducing poverty; increasing energy access; and contributing to economic development,

FIGURE 1.2
The Multiple Benefits of Energy Efficiency



Source | *IEA 2014.*

public health, and environmental preservation. Failure to recognize these multiple benefits leads to an underestimation of the value of energy efficiency. However, many questions remain regarding how to account for MBEE in practice and how to integrate them into policy and program investment decisions and evaluations. Development institutions, including the World Bank Group, have for many years used MBEE to describe the additional benefits of energy efficiency in project information documents. However, the reference to MBEE has generally remained anecdotal and has not been systematically integrated in project outcome indicators or project appraisals.

MBEE are often characterized from the perspective of the beneficiary to which a particular MBEE accrues. For example, MBEE can be assessed for the recipients of an energy efficiency measure, for specific stakeholders such as energy providers or building owners, or for society as a whole. For recipients of an energy efficiency measure, benefits may include, for example, reduced water usage expenditures from water-saving measures or increased comfort after a building retrofit. For energy providers or utilities, benefits include the avoided cost of building new power plants and avoided maintenance cost of transmission and distribution lines. For society, the most often-cited benefits are environmental, economic, and social. In some cases, benefits are classified at the level at which their impacts are assessed, for example micro, macro, local, national, or global. Identifying each party's perspective or level of analysis helps to differentiate benefits, reduce the risk of double counting, and ensure a comprehensive approach.

Information about benefits can be used in different ways. Quantified information about benefits can be part of a communication strategy to raise awareness and increase support for activities that enhance energy efficiency from industrial, environmental, health, development, or road security stakeholders. It can be used as part of a marketing strategy to convince potential participants to opt into an energy efficiency program, or to increase the level of private investment in energy efficiency measures, or to demonstrate the achieved impacts. To effectively inform and influence policy and investment decisions based on cost-benefit analysis, it is important to estimate the monetized value of the benefits. The biggest challenge of estimating MBEE is due to the multidisciplinary nature of MBEE which also requires engineering, economic, environmental, and health impact assessments. A considerable number of MBEE have been considered in the literature. Table 1.1 lists the most often-cited MBEE, along with associated indicators and assessment methods. **Effective M&V systems are crucial not only to capture the energy efficiency gains but also to appropriately capture the MBEE so investment and policy decisions are better informed and enabled.**

TABLE 1.1

Most Commonly Cited Multiple Benefits of Energy Efficiency

DESCRIPTION	INDICATORS	METHODS
Participant Benefits		
Energy savings	Unit of energy saved (e.g., kWh) and monetary value	Measurement
O&M cost reductions	Replacement and inspection rate of equipment and monetary value	Measurement
Health impacts	Hospitalization and mortality rates, medical costs	Measurement
Labor productivity	Days off of work, days off school	Measurement
Comfort	Indoor temperature, humidity level, and monetary value	Survey of willingness to pay or comparison
Energy Access	Energy Services Provided (lumen-hours in the case of lighting, useful energy in the case of heating or cooling)	Measurement
Water savings	Quantity of water saved (liters) and monetary value	Measurement
Property values	Monetary value	Measurement
Safety	Number of accident prevented	Measurement
Competitiveness	Market share, cost per unit of output, energy intensity	Measurement
Avoided capacity	Avoided capacity (kW) and saved monetary value	Power sector modeling
Avoided T&D	Avoided kWh losses and saved monetary value	Power sector modeling
Avoided peak load	Avoided peak capacity (kW) and saved monetary value	Power sector modeling
Reduced credit and collection costs	Saved monetary value	Measurement
Increased reliability	$ of value added produced, number of avoided power outage	Modeling measurement
Energy security	Avoided energy imports (terajoules, etc.) and saved monetary value	Modeling
Public budget savings	Saved monetary value	Measurement
Avoided energy subsidy	Saved monetary value	Modeling
Indirect public budget	Saved monetary value	Modeling
GHG emissions	Tonne of CO_2 equivalent and saved monetary value of avoided damages	Measurement and emissions factors
Pollutant emissions	Tonne of pollutants reduced and saved monetary value of avoided damages	Measurement and concentration modeling
Ozone Depleting Substances	Tonne of ozone depleting potential and saved monetary value of avoided damages	Measurement and emissions factors
GDP growth	Monetary value	Macroeconomic modeling
Job creation	Net number of jobs created	Macroeconomic modeling
Energy Price	$/kWh reduction	Macroeconomic modeling
Energy poverty	Number of households	Survey

CO_2—carbon dioxide; GDP—gross domestic product; GHG—greenhouse gas; kWh—kilowatt-hour; O&M—operations and maintenance; T&D—transmission and distribution

ENDNOTES

[1]The World Bank approach is in line—and supportive of—the goals of the UN's Sustainable Energy for All (SEforALL) which includes the goal of doubling the improvement rate of energy efficiency, along with achieving universal access to modern energy service and doubling the share of renewable energy in the energy mix. The tracking of progress of all countries towards the SEforALL three energy goals, is enabled by the Global Tracking Framework which consists of a suite of indicators and an accompanying data platform. For more information, see http://trackingenergy4all.worldbank.org

[2]IEA analysis has shown that energy efficiency is not just a "hidden fuel" but is also the "first fuel" in many large economies. For example, in 2014, global final energy consumption expanded by 0.7%, but without efficiency improvements the growth would have been around three times higher (IEA WEO 2015).

[3]Under the IEA's 2015 World Energy Outlook "Current Policies Scenario"—taking into account only those policies that were enacted as of mid-2015—global energy demand is projected to increase 45% between 2013 and 2040; under its "New Policies Scenario"—describing a pathway for energy markets based on the continuation of existing policies and measures, as well as the cautious implementation of announced policy proposals, even if they are yet to be formally adopted—global energy demand increases by 32% from 2013 to 2040.

[4]Under the IEA's New Policies Scenario (IEA 2015).

[5]As is highlighted in the IEA's World Energy Investment Outlook 2014.

[6]The other listed conditions are: (i) stable and favorable regulatory frameworks; (ii) clear price signals; (iii) increased knowledge about energy efficiency across stakeholders; and (iv) standardization of the energy efficiency investment process.

[7]For example, according to the IEA, more than 80% of the global economic energy efficiency potential in buildings remains untapped under its "new policies" scenario, which assumes that countries follow policy commitments and plans they have announced (IEA 2015).

[8]The IEA (2016) notes that targeting "increased energy *productivity,*" which seeks to increase the value of each unit of energy consumed in an economy, resonates better with policy makers in emerging and developing economies than "reducing energy *intensity.*"

2

MEASUREMENT & VERIFICATION: A REVIEW

This chapter provides an introduction to the definitions, terminologies, and existing measurement and verification (M&V) protocols for energy efficiency activities. A lexicon of terminologies and key concepts is provided in Annex 1.

All protocols share the common objective, which is to "assess the outcome" of an energy efficiency intervention. The three most common terms for the process to measure and verify the performance of energy efficiency activities are: Measurement and Verification; Evaluation, Measurement, and Verification; or Measurement, Reporting, and Verification. The terminologies reflect the evolution and expansion of the scope for M&V over the past three decades. A summary is provided in Annex 2.

Measurement and verification (M&V) approaches continue to share some fundamental principles, which include quantification of key parameters, such as electricity consumption and greenhouse gas (GHG) emissions before and after implementation of the energy efficiency interventions and a check of the reliability of the measured data and methodology. In evaluation, measurement, and verification (EM&V), "evaluation" is introduced to check if the project/program has met its goal. In measurement, reporting, and verification (MRV), "reporting" is introduced for communicating the progress in achieving objectives and implementing project related activities. The terminologies are also equally applicable to single projects or to a portfolio of projects or programs. This report uses the term M&V as the focus is on quantification of benefits of energy efficiency.

M&V is essential to assess resource savings and to ensure that savings persist over time. It can also be used to mitigate different challenges that arise in energy efficiency projects. Energy efficiency practitioners use M&V for several reasons,[9] including:

- **Improve engineering design and project costing.** The preparation of a comprehensive project design and costing should include all M&V activities and costs in the assessment of a project's economics. Good M&V can also inform future project designs.
- **Enhance energy savings through adjustments in facility operations and maintenance.** M&V can help discover and manage operation and maintenance (O&M) problems and improve functional efficiency of the facility, as well as sustain the energy and cost savings over time.
- **Document financial transactions.** In energy efficiency projects where financial payments are based on performance (e.g., energy performance contract (EPC) projects), the M&V plan forms the basis for documenting performance in a transparent manner (which can be subject to independent, third-party verification).
- **Enhance financing for energy efficiency projects.** Good M&V increases the transparency and credibility of the performance of energy efficiency project investments. Such credibility can enhance the confidence of investors and financiers in the energy efficiency project's performance.

- **Support development of broader energy efficiency programs.** The performance of energy efficiency activities at selected sites, determined by their M&V, can help predict the performance at unmeasured sites and potentially justify an expansion of the energy efficiency program.
- **Provide opportunity to generate emission reduction credits.** Robust M&V for energy efficiency is essential for the documentation and accounting of associated emission reductions that could be sold in carbon markets (where these exist).
- **Increase public and market awareness of energy efficiency potential.** Clear and transparent M&V can help raise awareness on the potential of energy efficiency investments and help encourage investments.

2.1 OVERVIEW OF EXISTING MEASUREMENT & VERIFICATION PROTOCOLS

This section presents an overview of the key M&V protocols used around the world. Most of the protocols were developed to assist energy professionals and stakeholders in measuring, computing, and reporting savings achieved from energy efficiency projects and programs. The protocols provide a framework for measuring and verifying project outcomes in a transparent, reliable, and consistent manner.

Energy professionals and stakeholders use M&V protocols to develop project-specific M&V plans. These documents are not standards, hence, there is no compliance mechanism associated with the protocols. Practitioners have to decide to what degree their energy efficiency activities would conform to the protocols; a decision that typically depends on the projects' scope, the use/value/benefits of more rigorous M&V, and the associated M&V cost. The effort required and rigor achieved associated with M&V of energy efficiency projects or programs should typically be commensurate with the project capital investment and savings risk. In fact, the appropriate level of M&V rigor can often be determined by considering three main factors: (i) the predictability of equipment operation; (ii) the magnitude of M&V costs in relation to the value of the energy savings benefits produced by the project; and (iii) technical capacity of the operators.

The M&V protocols reviewed are limited to those published and available in the public domain and have been categorized by application. A list of the M&V protocols is provided in Annex 3 and a descriptive summary of the protocols is provided in Annex 4. Individual energy efficiency *project*-based M&V is used to determine the savings of an individual energy efficiency project (e.g., replacement of inefficient lamps with energy efficient light-emitting diodes (LED) in a building). The *program*-based M&V activities involve evaluating a large number of individual projects leading to impact/performance evaluation at the program level (e.g., an appliance replacement program covering a particular geographic area). For emission reduction market-based systems, M&V determines the energy savings of eligible energy efficiency activities and their associated GHG emission reductions which can subsequently be sold. A comparison of M&V protocols by their applications is provided in Annex 5.

2.2 REVIEW OF MEASUREMENT & VERIFICATION EXPERIENCE

This section presents the findings of a review of energy efficiency projects to understand the type and extent of M&V provisions for determining the energy performance and whether and how other associated social, economic, and environmental benefits have been documented. The review process primarily focused on the lighting and public building sector projects.

World Bank Energy Efficiency Projects Reviewed

- Energy Efficiency Project, Armenia
- Energy Efficient Lighting Carbon Offset Project, India
- Energy Efficiency Project, Bosnia & Herzegovina
- Montenegro Energy Efficiency Project

2.2.1 World Bank Projects

The World Bank has implemented a number of energy efficiency projects in the public sector, with an objective to achieve energy savings and to contribute to social and environmental benefits. This section has reviewed the publicly available details of the M&V plans or guidelines used in a sample of World Bank projects.

An overview of the M&V provisions outlined in the reviewed World Bank energy efficiency projects is presented below and summarized in Table 2.1.

1 | **The Energy Efficiency Project, Armenia (2012)**[10] was aimed at energy efficiency improvements in public sector buildings (e.g., administrative buildings, schools, hospitals) and street lighting. The energy efficiency benefits included reduced energy cost, improved comfort level, and nonstructural upgrade of facilities. The publicly available project document provided detailed M&V guidelines to develop a site-specific M&V plan. The M&V guidelines included the formulas to calculate the heating comfort levels and boiler efficiencies. They also included the measurement periods, energy pricing, data requirements, and expected impacts. Post-installation M&V activities were also specified along with provisions for baseline adjustments. The overall monitoring and evaluation of the program was linked to the Renewable Resources and Energy Efficiency (R2E2) Fund. It covered the financial viability of energy efficiency subprojects; energy savings from the implementation of energy efficiency measures; the project pipeline; disbursed, committed, and invested amounts; defaults; and GHG reductions. The reporting from the R2E2 Fund was based on the commissioning and O&M reports provided by the contractors. Emission reductions were estimated based on the observed reduction in heating/energy intensity of retrofitted public and other social facilities after implementation of energy efficiency measures. In addition, the R2E2 Fund regularly reviewed a sample of subprojects to monitor the progress.

2 | **The Energy Efficient Lighting Carbon Offset Project in India (2003–06)**[11] was a bundled street lighting energy efficiency project covering seven municipalities. The energy efficiency improvements in street lighting infrastructure consisted of replacing inefficient street lighting fixtures (T12 fluorescent tube lights and sodium and mercury vapor high-intensity discharge light bulbs) to more efficient T5 fluorescent tube lights, including changing magnetic ballasts to electronic ballasts. The project also consisted of installing a load management system to improve energy

TABLE 2.1

Key Features Observed in Reviewed World Bank Energy Efficiency Projects

ENERGY EFFICIENCY PROJECT, ARMENIA (2012–)	ENERGY EFFICIENT LIGHTING CARBON OFFSET PROJECT, INDIA (2003–06)	ENERGY EFFICIENCY PROJECT, BOSNIA AND HERZEGOVINA (2014–)	MONTENEGRO ENERGY EFFICIENCY PROJECT (2008–14)
Key Features			
The M&V guidelines in the bidding document provide detailed engineering calculations. This reduces ambiguity and clarifies the level of effort. The Energy Service Agreement has provisions for baseline adjustment, payment schedule, and energy savings, which are understood to be in the M&V plan as well. This is essential with respect to resolving potential conflicts.	M&V is based on a standard methodology approved under CDM, which makes the M&V plan robust and transparent. The M&V methodology provides details on ex ante and ex post calculations, data and parameters measured, duration, environmental impact, etc.	A detailed M&V plan is in place based on the TOR for hiring an M&V consultant. The scope of work details the necessary activities such as energy audits, actual pre- and post-measurements, and also energy modeling.	The M&V activities have been assigned to an independent third-party consultant. Social impact is analyzed under this initiative through social monitoring and target evaluation survey.
Opportunities to Strengthen M&V Aspects (based on review of publicly available documents)			
1. Inclusion of specific M&V plan for each individual project type. 2. Inclusion of clearly defined roles and responsibilities for M&V activities. 3. Clearly defined duration of M&V (This is important when energy consumption is affected by seasonal variations). 4. Inclusion of an overall plan, ex ante, for the program evaluation and analysis of impacts.	1. The M&V methodology used was CDM AMS-II.C (version 9), which is for demand-side energy efficiency activities for specific technologies such as lamps, ballasts, refrigerators, motors, fans, air conditioners, pumping systems, and chillers. Moving forward, a more suitable methodology, AMS-II.L, developed for demand-side activities for efficient outdoor and street lighting technologies can be used.	1. Development of an overall M&V plan (to accompany the presentation of M&V requirements which is included in the reviewed project documentation). It is good practice to develop the M&V plan at the same time as the project design.	1. Inclusion, in the technical M&E report, of information on the methodology, data sources, equipment used, etc., in order to enable a better understanding and assessment of the results of M&E activities. 2. Presentation of the analysis methodology underpinning the technical M&E report. 3. Extension of the data collection period beyond the 14 days (on average) specified in the report. 4. Quantification of the social satisfaction which has been evaluated under the program.

Note | *This analysis is based on publicly available project documents. It is possible that there are other documents, which were not publically available at the time of this review, where some of the issues may or may not be addressed.*

consumption. Dimming of lights was also incorporated in this project. The project yielded energy savings up to 60% and improved power factor of 0.95 compared to 0.70 for old installations. As it was developed as a Clean Development Project to benefit from carbon finance,[12] the project followed the specific Clean Development Mechanism (CDM)[13] M&V methodology associated with "Demand-Side Energy Efficiency Activities for Specific Technologies (AMS-II.C, Ver. 9)" to monitor and verify the project's emission reductions. The project design document included calculations of baseline and project emissions based on the same CDM methodology.

3 | **The Bosnia and Herzegovina Energy Efficiency Project (2014–18)**[14] supports energy efficiency investments in public facilities. The project aims at demonstrating benefits of energy efficiency improvements in public-sector buildings (such as schools, hospitals, and government buildings) and supporting a scalable energy efficiency financing model. Project documentation includes plans for M&V activities. It also includes detailed terms of reference (TOR) for conducting the detailed energy audit, monitoring and evaluation, developing technical designs, and supervising the retrofitting of public buildings. The TOR spells out the activities that are to be carried out as part of M&V, detailing the energy audit requirements, pre- and post-retrofit activities, reporting requirements, possible energy efficiency measures such as upgrading indoor lighting, roof thermal insulation and renovation, wall thermal insulation, basement thermal insulation, and retrofitting buildings heating, cooling, and domestic hot water system(s).

4 | **The Montenegro Energy Efficiency Project (2008–14)**[15] focused on energy efficiency improvements in public facilities such as schools, hospitals, and government buildings. The energy efficiency improvements were broadly classified as thermal envelope measures and mechanical improvements. The thermal improvement measures consist of insulation of walls, roofs, attics, etc. The mechanical improvements consist of heating, ventilation, and air conditioning (HVAC) improvements and solar thermal water heating systems. M&V activities have been carried out as specified in the project's "Methodology for Technical Monitoring and Evaluation of the Results Achieved." A combined technical monitoring summary report with information on all project sites was prepared consisting of a summary of the monitoring program findings, building retrofit measures, building retrofit costs, monitoring activities, energy savings, financial savings, carbon emission reductions, building comfort, etc. The data measurement periods for each site were taken over 14 days on an average.

The analysis of the aforementioned projects suggests that no single M&V approach is equally suitable in all project situations. The costs of alternative approaches will vary, and the selection of M&V methods will depend on the characteristics and objectives of individual projects (e.g., projects involving monetization of energy savings versus program evaluations). The appropriate M&V approach will depend on its role (e.g., whether it is the basis of payment), type of information that is required, tolerable risk, and the cost involved. Below are some good practices that can be drawn from the review of the aforementioned projects which could be used as guiding principles for designing M&V plans for future energy efficiency projects.

Use of established standard M&V protocol. Established M&V protocols should be considered for developing M&V plans. There is often no need to start from scratch or reinvent the wheel, in the presence of internationally approved robust M&V methodologies, including CDM methodologies. As mentioned above, it is important to also consider the cost associated with using a particular M&V protocol or methodology, as the magnitude of the M&V costs should be commensurate with the value of the benefits (e.g., energy cost savings, emission reduction certificates, etc.) produced by the energy efficiency project.

Reducing uncertainty. Ambiguity of outcome can be avoided through a structured analysis method and use of continuous monitoring, although continuous monitoring may not always be feasible. The

Energy Efficiency Project in Armenia provided detailed engineering calculations for M&V in the bidding document. The Energy Efficiency Project Bosnia and Herzegovina provided a detailed M&V plan in the TOR document as well.

Increase transparency. The requirement to report on the performance of energy efficiency projects helps provide transparency. Using an independent third party for carrying out M&V helps enhance confidence in reported performance, such as with the Energy Efficiency Project in Bosnia and Herzegovina.

Measure the co-benefits of intervention. Measuring the social and ancillary benefits of the energy efficiency intervention will help in an all-encompassing analysis of the project to enable better assessment of a project's overall impact. The Montenegro Energy Efficiency Project included the measurement of the social impact of the initiative through social monitoring and a target evaluation survey. (The multiple benefits of energy efficiency are discussed further later in this report).

2.2.2 External Projects

A review of a number of external projects was carried out to examine the M&V provisions included in energy efficiency project documents of agencies. A summary is provided in Table 2.2. A number of energy efficiency projects implemented by agencies such as Asian Development Bank (ADB), United States Agency for International Development (USAID), KfW Development Bank, Japanese International Cooperation Agency (JICA), public-sector agencies, and Global Environment Facility (GEF) were short listed to select four projects for the review. The criteria for selection of projects were based on the elaboration of the M&V component employed by the projects implemented by other agencies and availability of information for review.

Non-World Bank Energy Efficiency Projects Reviewed

- Bangladesh Energy Efficiency Improvements (ADB)
- Visakhapatnam Street lighting Project, India (EESL)
- Energy Efficient Street Lighting for Tongatapu, Tonga (ADB/GEF)
- Energy Efficient Lighting in Commercial Sector, Samoa (ADB)

1 | **Bangladesh Energy Efficiency Improvements Project (2011–13).**[16] The Bangladesh energy efficiency improvement project for street lighting and water pumping was a technical assistance project funded by ADB. The main objective of this technical assistance was to introduce energy efficiency programs in municipalities by: (a) establishing best practices through pilot demonstration projects in Tongi Pourashava; (b) capacity building of municipal engineers and officials throughout Bangladesh toward the adoption of energy efficiency projects in street lighting and water pumping; and (c) raising awareness among the stakeholders and public representatives with regard to energy efficiency initiatives. The activities under this program consisted of pilot demonstrations and capacity building using various training programs. The declared energy savings from the energy efficiency water pumping program were 0.696 million kWh per year and those from energy efficiency street lighting were 0.26 million kWh per year.[17]

The M&V of the Bangladesh Energy Efficiency Improvements Project consisted of energy audits, baseline development, cost–benefit analysis, ex ante and ex post data collection, etc. The M&V

TABLE 2.2

Key Features Observed in Reviewed Energy Efficiency Projects from Different Agencies

BANGLADESH ENERGY EFFICIENCY IMPROVEMENTS (ADB) (2011–13)	VISAKHAPATNAM STREET LIGHTING PROJECT, INDIA (EESL) (2014–15)	ENERGY EFFICIENT LIGHTING IN COMMERCIAL SECTOR, SAMOA (ADB) (2011–15)	ENERGY EFFICIENT STREET LIGHTING, TONGA (ADB) (2011–15)
Key Features			
1. Detailed energy audits were conducted for each potential site. 2. Pre- and post-retrofit measurements were recorded to estimate the energy savings. 3. CDM potential was also evaluated to take advantage of saleable CDM credits (certified emission reductions, CERs). 4. An evaluation of non-energy component (capacity building) was carried out for this project.	1. A central control and monitoring system is installed, which provides continuous monitoring and control of street lights. This should continue to provide information on the performance of the project.	1. Internationally recognized M&V protocol (IPMVP) was used to develop the M&V plan. 2. The M&V plan details the methods as well as data for baseline, post-retrofit measurements, and results. 3. The M&V plan also provides details and specifications of devices used for M&V. 4. The M&V plan has pictures of equipment procured, on-site installation, measurement equipment, etc.	1. The M&V methodology approved by CDM AMS-II.L is used, which is relevant to street lighting project. 2. The M&V plan details the methods as well as data for baseline, post-retrofit measurements, and results. 3. The M&V plan also provides details and specifications of devices used for M&V. 4. The M&V plan has pictures of equipment procured, on-site installation, measurement equipment, etc.
Opportunities to Strengthen M&V Aspects (based on review of publicly available documents)			
Even though pre- and post-retrofit measurements were recorded, a deemed saving approach was used for the street lighting project as unresolved variations were found in the real-time data. Measurement and verification could have been done on a sample size and then extrapolated to the entire project, which would have saved time and M&V cost. The evaluation of the nonenergy component was qualitative; and could have been strengthened, including with some quantification.	Baseline data were not available, hence the baseline was developed using deemed savings approach. Given the installation of a central control and monitoring system, ex post energy savings calculation could have been considered.	Baseline data were not available, hence the baseline was developed using deemed savings approach. Given the installation of a central control and monitoring system, ex post energy savings calculation could have been considered.	M&V plan could be strengthened with: Inclusion of provisions for baseline adjustment (which might have an effect on future M&V activities). Description of the payment arrangement between the utility and the energy service company (usually a part of the M&V plan). Inclusion of the sample size calculation.

Note | This analysis is based on publicly available project documents. It is possible that there are other documents, which were not publically available at the time of this review, where some of the issues may or may not have been addressed.

process consisted of identification and procurement of required M&V equipment (30 single digital energy meters, 10 voltage controllers, 10 timer controls), setting up of measuring instruments, collection of energy consumption values to establish the baseline energy consumption before the implementation of the pilot projects, collection of energy consumption values to estimate the energy savings after the implementation of the pilot projects, data analysis, and reporting on energy and monetary savings. Further, an assessment was carried out for energy efficiency street lighting and energy efficiency water pumping projects to analyze if these could potentially be registered as official CDM projects and generate CDM credits based on emission reductions resulting from the verified energy savings. The analysis showed that the water pumping project could possibly be developed as a programmatic CDM project, but it would not be worth it for street lighting, largely due to the high transaction costs (for MRV) that would be involved. Subsequently, a project information note was prepared for the water pumping CDM project and submitted to the CDM authority (Designated National Authority) in Bangladesh and ADB.

2 | **Visakhapatnam Street Lighting Project, India (2014–15).**[18] The project was implemented by Energy Efficiency Services Limited (EESL) on behest of Greater Visakhapatnam Municipal Corporation. This was not a typical retrofit project as the street lighting infrastructure had sustained considerable damage as a result of Cyclone Hudhud. Proper baseline data were not available, since only 10,000 streetlights were operational out of the total 90,000 streetlights.

The Vishakhapatnam Street Lighting Project uses an annuity-based deemed-savings approach to quantify the energy savings. Energy savings from the implementation of the project form the basis for arriving at the annuity amount. This methodology is simple to use. The annuity-based methodology is based on savings determined by extrapolation of limited measurements to the entire area of the street lighting project. Payments are determined from these measurements without linking to electricity bills or actual or metered savings. A central control and monitoring system has been installed as part of this project, which will help in the automation of streetlights and continuous monitoring in the reporting period of the project.

3 | **Energy Efficient Lighting in Commercial Sector, Samoa (2011–15).**[19] This project was part of the program on Promoting Energy Efficiency in Pacific initiative, which was co-financed by ADB and Global Environment Facility (GEF). Overall the program covered five Pacific developing member countries—the Cook Islands, Papua New Guinea, Samoa, Tonga, and Vanuatu—with a goal of reducing energy consumption in the residential, commercial, and public sectors through the implementation of energy efficiency measures, and to establish the policy and implementation frameworks to move toward the goals of reducing fossil fuel imports, achieving total energy savings, and reducing GHG emissions. This particular project involved cost-effective energy savings in the commercial sector through the replacement of five-foot T8 fluorescent lamps with magnetic ballasts, which have a rated power consumption of 76.9 W (including ballast power losses) with energy-efficient LED batteries that have a total rated power consumption of 28.8 W (including LED driver). The project was able to achieve energy savings of 145,003 kWh per year, cost savings of $53,702 per year, and GHG emission reduction of 116 tCO_2 per year.

The Energy Efficient Lighting in Commercial Sector, Samoa project had a detailed M&V report, which described the activities undertaken as part of the M&V exercise. The M&V plan followed international protocols such as the International Performance Measurement and Verification Protocol (IPMVP) and CDM rules for lighting retrofits. The activities consisted of pre- and post-retrofit baseline measurement, along with light quality measurement, sample size selection based on IPMVP, etc. The M&V report also provided detailed information on the measurement equipment, equipment procured, and also gave the delivery and installation dates along with photographs.

4 | **Energy Efficient Street Lighting, Tonga (2011–15).**[20] Cofinanced by ADB and GEF, this project was part of the large program on Promoting Energy Efficiency in Pacific (PEEP2). This energy efficiency street lighting project was implemented in the Tongatapu region in Tonga. The project aimed to achieve cost-effective energy savings through the replacement of 100/150/250 W high-pressure sodium (HPS) lamps together with existing luminaires installed in the Tongatapu Island with high-efficiency LED luminaires. The project resulted in energy savings of 67,180 kWh per year, cost savings of $20,342 per year, and GHG emission reductions of 60 tCO_2 per year.

The M&V for Energy Efficient Street Lighting Project, Tonga, complied with both IPMVP Option A and CDM methodology AMS II.L "demand-side activities for efficient outdoor and street lighting technologies." The M&V activities consisted of pre- and post-baseline measurements, light quality measurement, etc. The M&V report provided details in measurement boundary, parameters measured, baseline energy savings calculations, and light quality measurement methodology. The document was supplemented with information on measurement equipment and photographs of the M&V activities.

These projects also suggest some cross-cutting takeaways such as the following:

Using established standard M&V protocol. Established M&V protocols (as provided in Annex 3) are available and can be utilized for developing M&V plans. The Energy Efficient Lighting in Commercial Sector Project, Samoa, and Energy Efficient Street Lighting Project, Tonga, have utilized internationally accepted protocols such as IPMVP and AMS-II to develop M&V plans.

Reducing uncertainty. Ambiguity of outcome should be avoided through a structured analysis method and use of continuous monitoring, particularly when energy savings (and/or associated GHG reductions) generate payment. The M&V plans for Energy Efficient Lighting in Commercial Sector, Samoa, and Energy Efficient Street Lighting, Tonga, provided detailed methods for baseline and post-installation measurements. The Visakhapatnam Street Lighting Project uses a centralized control & monitoring system to continuously monitor streetlights.

Measuring co-benefits of intervention. Measuring the social and ancillary benefits of the energy efficiency intervention will help in an all-encompassing analysis of the project. The Bangladesh Energy Efficiency Improvements Project made an effort to evaluate the capacity-building activity carried out under the project.

2.3 CONCLUSION

Energy efficiency projects should include, from the beginning, the elaboration of an M&V plan that outlines how the performance of the project will be monitored and assessed. The review of a sample of projects indicates that while the energy efficiency projects examined include methods for estimating energy savings ex ante (i.e., during the project preparation phase), very few projects include, from the start, the provisions or methods to systematically measure and assess, ex post, the actual performance of energy efficiency projects and programs. This can lead to:

- Potential under- or overestimation of energy savings;
- Possibility of undermining the credibility of energy efficiency interventions and, thus, their potential replication or scale up;
- Missed opportunities for learning from the actual performance of the energy efficiency interventions; and
- Making it difficult to develop and enable energy performance contracts.

In the case of energy efficiency projects in developing countries, situations of unsatisfied and growing energy demand typically affect the assessment of the performance of energy efficiency projects. Such situations should be taken into account with baseline assumptions reflecting increasing energy consumption in the future. In the advanced economies, an increase in energy consumption following the implementation of energy efficiency measures is typically referenced as the rebound effect or take-back effect (see Section 3.4). However, in developing economies, increases in energy consumption accompanying energy efficiency interventions may be a reflection of suppressed demand, where the "baseline" reflects inadequate or unsatisfied quantity and low quality of energy services, ignoring the multiple benefits of energy efficiency. These issues are further discussed in the following chapters.

ENDNOTES

[9]See for example, Better Buildings Partnership (http://www.betterbuildingspartnership.co.uk/) or Clinton Climate Initiative (https://www.clintonfoundation.org/our-work/clinton-climate-initiative).

[10]http://www.worldbank.org/projects/P116680/electricity-supply-reliability-energy-efficiency-project?lang=en

[11]http://documents.worldbank.org/curated/en/2015/03/24119801/india-street-lighting-energy-efficiency-p107069-implementation-status-results-report-sequence-03

[12]The project consisted of the sale of the first 500,000 emission reductions resulting from improvements in the energy efficiency of street lighting at seven municipalities to the World Bank-managed Spanish Carbon Fund.

[13]The Clean Development Mechanism is a project-based mechanism established under the Kyoto Protocol to the UN Framework Convention on Climate Change. It allows emission reductions achieved through mitigation activities in developing countries to be counted against part of the emissions target taken by the industrialized countries. (https://cdm.unfccc.int)

[14] http://www.worldbank.org/projects/P143580/?lang=en&tab=details

[15] http://www.worldbank.org/projects/P107992/energy-efficiency-public-buildings?lang=en

[16] Bangladesh Energy Efficiency Improvements—ADB/Econoler International Canada.

[17] Ibid.

[18] Energy efficiency Urban Street Lighting Project India—Case Study—AEEE.

[19] Promoting Energy Efficiency in the Pacific (Phase 2)—M&V Report—ADB.

[20] Ibid.

3 UNDERSTANDING THE MEASUREMENT & VERIFICATION PROCESS

3.1 FUNDAMENTAL PRINCIPLES FOR MEASUREMENT & VERIFICATION

Apart from measuring and verifying the energy savings, it is important that the M&V methodology employed should enhance the effectiveness of energy efficiency programs. The M&V approach should not be overbearing on the energy efficiency project. It is important to strike a delicate balance between cost, rigor, and complexity. Some fundamental principles that should be followed with respect to M&V are as follows:

Accuracy. M&V cost is a major consideration with respect to accuracy. The M&V should be as accurate as possible with the available budget. M&V costs should be small relative to the monetary value of the savings being evaluated. M&V expenditures should also be consistent with the financial implications of over- or under-reporting the performance of a project. Accuracy trade-offs should be accompanied by increased conservativeness in any estimates and judgments.

Thoroughness. The reporting of energy savings should consider all effects of a project. M&V activities should be thorough and should be able to use the measurements to quantify all the significant effects while estimating the program benefits.

Conservativeness. In programs where savings are estimated due to poor data availability, conservative values should be adopted to avoid any risks in over- or under-estimation of benefits and impacts.

Measurement/Estimation. Critical performance parameters should be measured, while other less critical or predictable parameters may be estimated.

Transparency. All M&V activities should be clearly defined and disclosed. The M&V plan and M&V reports should reflect the actual savings and the methods used for measuring the savings. Transparency is very important for avoiding any conflict at any stage when it comes to sharing of benefits among stakeholders.

3.2 UNDERSTANDING THE COST OF MONITORING & VERIFICATION

It is difficult to make generalizations on the costs of M&V because of the wide range of energy efficiency projects and different activities associated with M&V. International Performance Measurement and Verification Protocol (IPMVP) suggests that M&V costs are typically less than 10% of the total project cost (EVO 2007).

Factors that can influence the M&V costs are as follows:

- Value of projected savings
- Complexity of efficiency equipment

- Total amount of equipment
- Number of interactive effects among resource-consuming systems
- Level of uncertainty of savings
- Risk allocation for achieved savings between the owner and the energy service company
- Other valuable uses of M&V data (e.g., optimizing O&M, selling carbon credits)
- Availability and capability of an energy management system
- Frequency of M&V activities
- Complexity and size of the project

Based on the type of M&V approach used (Birr 2001), the M&V costs in percentage of total project cost could be as follows:

- Retrofit isolation with measurement of key parameters: 1%–5%
- Retrofit isolation with measurement of all parameters: 3%–10%
- Whole facility measurement: 1%–3% (if meters are already installed)
- Computer simulation costs: 3%–10%

Balancing Cost and Rigor

A challenging aspect of M&V is providing adequate accuracy while ensuring the cost of M&V is reasonable. There is no empirical formula or easy way to define a point where rigor and M&V costs intersect. One must rely on judgment and experience to determine a cost-effective approach. Figure 3.1 represents the incremental value of the information obtained from additional M&V which will at some point be less than the cost to obtain it.

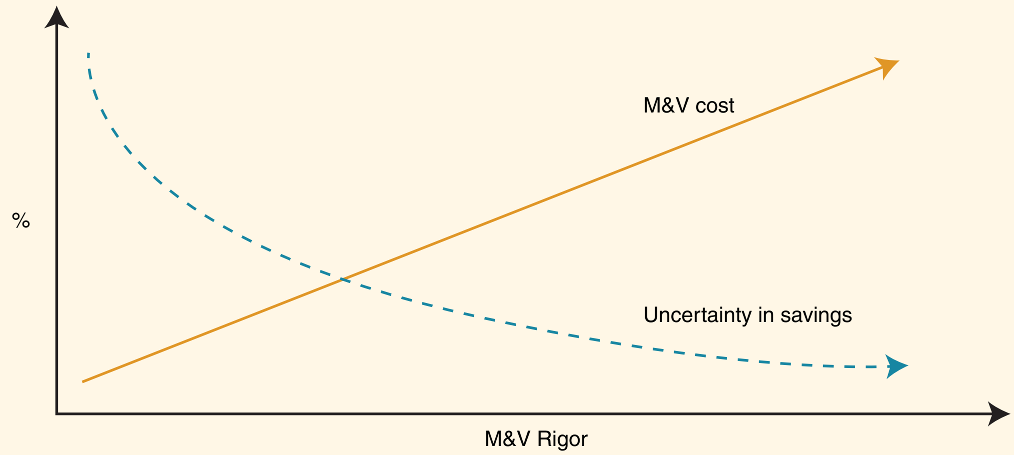
A few strategies for keeping M&V costs low while maintaining the rigor include the following:

- Use extensive metering in the baseline period and stipulate values for parameters which cannot be metered
- Verify key performance items using periodic rather than continuous data collection (should not be confused with continuous M&V) to reduce data collection and management issues
- Rely upon existing instrumentation, energy management systems, and energy management behavioral practices wherever possible
- Engage a third-party M&V expert to assist in the development of the M&V plan to ensure key agency interests are protected and costs are minimized

Ultimately, it is also important to consider in which cases the value/contribution of greater M&V rigor may justify greater M&V efforts and potentially expenses.

FIGURE 3.1

Relation between M&V Cost and M&V Rigor



Source | US DOE 2008.

3.3 RECAP OF ENERGY SAVINGS CALCULATIONS

The standard equation for calculating savings from energy efficiency projects is as follows:

Energy Savings = Adjusted Baseline Energy – Actual Energy

and

Adjusted Baseline Energy = Baseline Energy ± Routine Adjustments ± Non-Routine Adjustments

Where,

Actual Energy = Energy consumption measured during the post-retrofit/post-investment performance period

Baseline Energy = Energy consumption measured during the baseline period

Routine Adjustments = Adjustments due to regular changes in independent variables (e.g., changing weather conditions, varying production levels)

Non-Routine Adjustments = One-off or infrequent changes in energy use or demand that occur due to changes in static factors (e.g., building facade changes, extreme weather events, building extensions, and changes to equipment)

3.3.1 Energy Cost Savings and Price Risk

The success of energy efficiency projects is almost always evaluated based on financial returns and energy saved. A successful energy efficiency project will result in financial benefit due to reduction in energy use, which may be compared to the pre-investment/pre-retrofit level or compared to business-as-usual projected energy levels. This is known as energy cost avoidance or cost savings. Energy efficiency projects often result in other financial benefits that improve the project's payback.

$$\textit{Project Savings} = \textit{Energy Cost Savings} + \textit{Other Financial Benefits}$$

Where,

Energy Cost Savings = Avoided energy cost (or cost saving) resulting from the energy efficiency project

Other Financial Benefits = Other areas of project savings (e.g., maintenance cost, future equipment replacement cost)

Non-financial co-benefits can also be evaluated to determine the overall success of the project. The equation for cost avoidance is:

$$\textit{Energy Cost Savings} = \textit{Pricing Structure} \times (\textit{Energy Use}_{\textit{adjusted baseline}} - \textit{Energy Use}_{\textit{actual}})$$

The energy baseline is adjusted for post-retrofit conditions. The same energy pricing is applied to the adjusted baseline as well as the actual energy usage.

Energy Cost Savings are important as these take into account the changes in factors that determine energy use (e.g., changes in site activities, effects of independent variables such as production or weather, price risks such as changes to energy contracts, structures, or tariff rates, etc.).

3.3.2 Uncertainty

Any measured savings include some degree of uncertainty. Since no instrument can be perfectly accurate, all measurements contain some error or difference between the true and observed value. In addition, energy savings are based on measured values and to some extent on estimates. The goal is to reduce the uncertainty in the reported energy savings values, which can be accomplished by limiting the errors in measurements and analysis conducted.

Calculating the uncertainty in the estimated savings is not required for most projects, but uncertainty is often estimated in order to set the overall level of savings guarantee in performance contract projects. The uncertainty at the project level falls under four types: measurement, sampling, estimation, and modeling. The project often does not contain one or more of the four components. The total project uncertainty is calculated by taking the square root of the sum of the squares of the individual standard errors (SE) of the components, as follows:

$$SE_{Project} = \sqrt{(SE_{Measurement})^2 + (SE_{Sampling})^2 + (SE_{Estimation})^2 + (SE_{Modeling})^2}$$

Measurement. Measurement uncertainty is introduced due to metering equipment inaccuracies. For example, the specifications for a meter may indicate that it is accurate to within ±3%, meaning that any reading taken using the meter may be up to 3% off in either direction. Additional error in measurements may be introduced if the instrument is not properly calibrated or if it is inappropriately used. Data management can also introduce errors. If the accuracy of any instrument is less than suitable, the measurements may introduce unacceptable levels of error into the energy calculations. Instrumentation accuracy requirements should be sufficient to ensure that overall energy and cost estimates are reasonable. Annex 6 provides a note on technologies for M&V.

Sampling. Sampling uncertainty occurs when measurements are taken on a sample and the results are generalized to the entire population of the appliance/equipment. For example, it may not be economical to monitor the hours on every fixture in a building lighting retrofit. So a sample is monitored and the results are applied to the remainder of the lighting population. Sampling uncertainty is calculated from the standard deviation of the sampled results. When the standard deviation is large, the uncertainty is also large.

Estimating. Estimates have to be made when values cannot be measured directly. When engineering estimates are used in place of actual measurements, uncertainty is introduced. This uncertainty needs to be estimated based on the expected accuracy of the estimated values. For example, the efficiency of a motor may be estimated rather than measured directly. The estimate would be based on the type and age of the motor and may result in an estimated stipulation error of ±15% (e.g., 75%, between 60% and 90%). If a building engineer who is familiar with the motor gives additional operational information about the equipment, the uncertainty may be less, such as ±10% (e.g., 75%, between 67.5% and 82.5%).

Modeling. Modeling uncertainty is introduced when savings are estimated using engineering or simulation models. The accuracy of any model is based on the ability of the model to account for all variations in energy use by employing the proper analysis techniques, including all relevant variables and excluding those that are irrelevant.

Calculating the uncertainty in the estimated savings is not always required, but this uncertainty is often estimated in order to set the overall level of savings guarantee for each energy efficiency measure. Including the uncertainty in calculated savings provides a more meaningful statement of savings. Uncertainty is typically proportional to the complexity of the energy efficiency measure.

3.4 THE REBOUND EFFECT

What is called “rebound effect” assumes an improvement in energy efficiency (at technology or policy level) but also a portion of the achieved energy cost savings used toward more/better energy services which constitute a “rebound.” In effect, it is a reduction in expected overall energy savings from an energy efficiency investment because of behavioral responses leading to energy consumption. A rebound effect typically lowers the achieved reduction in energy use compared to the forecasted reduction in energy use that may ignore consumer and/or market responses. Such consumer and market-wide responses can occur because the energy efficiency improvement changes relative prices and income level.

The rebound effect refers to that portion of energy savings that is lost due to consumer and market responses as a result of energy efficiency improvements. It is the difference between the actual reductions in energy consumption and the forecasted reduction in energy consumption, a forecast that may ignore the consumer and market responses. The rebound effect can be induced as a result of energy cost savings being utilized toward more/better energy services to overcome suppressed energy demand or improved product attributes resulting in a market response in the form of increased usage, as noted above. Increasingly, literature emphasizes the importance of linking this rebound effect to developmental benefits in the case of developing countries.

For example, the IEA points out that in the case of developing countries, and in particular emerging economies, improving energy efficiency often comes along with increasing energy consumption (to meet unmet and growing demand for energy services)—something the IEA refers to as **"energy efficient prosperity."** In the case of these countries, the performance of energy efficiency is not so much about "doing more with less [energy]" (which is applicable to industrialized countries), but rather "doing even more [energy services] with more [energy]" and contributing to raising standards of living and promoting prosperity.[21] This shift in how energy efficiency should be considered is reflected in the increased focus on the multiple-benefits generated by energy efficiency investments and policies and will be discussed in the next chapter. While the energy efficiency literature and measurement methods will be evolving to better reflect energy efficiency's multiple productive impacts, the rebound effect is traditionally expressed in the percentage of the forecasted reduction in energy use lost due to consumer and market response.

Example: Consider an appliance that uses 100 kWh per year of electricity. Suppose this appliance is replaced by an efficient appliance that is expected to save 10 kWh per year before consumer and market responses. The consumer and market responses, as a result of energy efficiency, increase energy use by 1 kWh per year, resulting in a rebound effect of 10%, since 1 kWh of the 10 kWh annual energy savings is taken back by the consumer and market responses.

The aforementioned broad definition captures the principle of rebound effect, but it does not dwell on different factors associated with how energy efficiency is improved and other energy- and cost-related attributes. There are two highly generalized scenarios. It is important to pay close attention to consumer behavioral considerations when identifying scenarios applicable to specific projects, as the rebound effect in underserved areas, where baseline service level was very low, could be significantly high. The scenarios presented below are for illustrative purposes only:

Scenario 1 | Energy efficiency improves while all other attributes remain constant. In this case, the rebound effect can be completely credited to energy efficiency. For example, a car manufacturer improves fuel efficiency as a result of an innovation without any increase in product cost and also holding other attributes constant. The subsequent market and consumer responses can be considered (close to) a pure concept of rebound as it captures only the responses induced by energy efficiency.

Scenario 2 | **Energy efficiency improves but other attributes, such as cost of energy services and/or product, change (increase or decrease).** For example, government policy requires car manufacturers to improve fuel efficiency and, in this case, the energy efficiency improvements are costly, resulting in an increase in car cost. This may also induce changes in other attributes such as size and capacity. Subsequently, price and energy services provided change along with energy efficiency. The rebound effect in this case is compounded with energy efficiency and other attributes.

When accounting for rebound effect, it is important to distinguish between the two aforementioned scenarios. Important considerations for the rebound effect include the following:

1 | Energy demand can increase due to many factors. Economic growth and improved technologies are among the important factors. It is crucial to understand the socioeconomic, consumer behavior, and cultural factors and not rush to labelling everything as a "rebound effect."

2 | It would be expected that what is traditionally labelled rebound effect could be higher in developing countries than in developed countries because of large unmet energy demand that may be partly satisfied by using money saved from a particular energy efficiency measure or investment. However, the relative size of the rebound effect is unclear. It is theorized that if energy services and other goods such as food and clothing are substitutes, the rebound effect is high. If they are complements, then the rebound is lower.

3 | As mentioned above, a major misunderstanding associated with rebound is that it is perceived as an undesirable effect. This perception comes from focusing on energy reduction as the sole objective of a project or program, rather than welfare maximization. Rebound is a product of a consumer's response to changes in relative process, so by preference it provides welfare benefits. In fact, while some argue that the rebound effect annuls part of the benefits of energy efficiency activities, others (e.g., Gillingham 2014) argue that including rebound effect in energy efficiency evaluations is most likely to add to the count of benefits and the only increase in costs are due to external costs from additional usage.

4 | In the cases of energy efficiency activities implemented in situations of supressed demand,[22] it is particularly important to consider how the level of the baseline (against which energy savings are assessed) is set.[23] For example, in situations with suppressed demand, it may not be adequate to set the energy use baseline at a constant level over time, but rather recognize that the energy use baseline should be differentiated according to desired and attained level/quality of service. The idea is that energy efficiency activities would avoid future (less efficient) energy use while meeting the demand for improved level/quality of service.

Rebound effect is a complex phenomenon and is difficult to estimate. At the project level, M&V activities can include assessment of rebound effect and try to attribute the rebound to the factors responsible for it (such as productivity, socioeconomic improvement, etc.). Quantifying the rebound will be a challenging task unless it is a direct rebound. The rebound effect induced by a program or on a macroeconomic scale should be part of the energy efficiency program design. It should be incorporated into projections or energy forecasting models during program design stage. Also, determining the level of rebound will require good statistical sampling and follow-on analysis to estimate the scale of rebound. It is also advisable to consider the improved utility for consumers or the improved welfare impact on project beneficiaries, as an economic benefit.

It is also important to document and account for the benefits and development impacts that may come with energy efficiency policies and interventions, so these important impacts of energy efficiency are not simply swept under the "rebound" rug. The next section discusses this in greater detail.

3.5 RECOMMENDATIONS FOR UNDERTAKING AN EFFECTIVE MEASUREMENT & VERIFICATION PLAN

M&V should be a critical aspect of any energy efficiency projects or programs in order to ensure value for money, justify continued or increased funding, and establish the basis of payment mechanisms.

There are a number of M&V protocols and guidebooks available to successfully prepare and implement project-specific M&V plans. The review conducted in this report shows that M&V is an evolving subject and can be adapted to different contexts. It is also important to note that the decision to conform to a particular M&V standard or protocol is determined by many elements such as region, economics, capacity, and project type.

A delicate balance has to be maintained between a robust and reliable M&V that is not only cost effective, but also easy to implement. When using an international M&V protocol/guideline, it is up to the practitioner to decide how rigorously to conform to the guidance document. Often it is advisable to use multiple approaches within the same M&V plan without affecting the overall quality of the M&V. As an example, it would be acceptable to measure only the "key parameters" in a lighting retrofit while measuring "all parameters" for a heating, ventilation, and air conditioning (HVAC) retrofit. This type of strategy would help in reducing the overall cost of the M&V without affecting its quality.

The review of a sample of projects undertaken as part of this report reveals gaps or opportunities for strengthening in the current M&V and impact evaluation of energy efficiency projects. The gaps and omissions in the M&V activities can lead to improper analysis of the outcomes and loss of confidence in the performance of energy efficiency activities. This is especially true in developing countries where the energy service company (ESCO) business and project implementation through the route of energy performance contract (EPC) are still evolving. Project developers and energy service companies should not consider M&V as an extra activity. Instead **M&V should be integrated as a value-adding activity, which can build the confidence of program stakeholders and ensure fair sharing of benefits.**

Inclusion of the multiple benefits of energy efficiency (MBEE) can play a crucial role in enhancing the value of M&V for the stakeholders. In many instances, the nonenergy benefits from an energy efficiency project could be much higher than the energy saved. For example, an energy efficiency street lighting project can enhance lighting quality, reducing road accidents, while increasing the perception of security among pedestrians. The social benefits can be monetized in the form of reduced government spending.

ENDNOTES

[21]Philippe Benoit, IEA (December 2015), presentation at COP21.

[22]"Suppressed demand" typically refers to situations where a minimum service level to meet basic human needs (e.g., basic energy services such as lighting, cooking, drinking water supply, and space heating), was unavailable prior to the implementation of the energy efficiency activity.

[23]The issue of suppressed demand in low-income communities has also been discussed in the context the UNFCCC Clean Development Mechanism, resulting in the inclusion of suppressed demand in baseline and monitoring methodologies. See https://cdm.unfccc.int/Reference/Guidclarif/meth/meth_guid41.pdf

4

METHODS FOR QUANTIFYING MULTIPLE BENEFITS OF ENERGY EFFICIENCY

The multiple benefits of energy efficiency (MBEE) are typically less tangible and more difficult to quantify than energy savings. Moreover, policy decision-making tools require that benefits are monetized to enable comparison with costs of energy efficiency programs. Table 4.1 summarizes some of the methods used to quantify and, in some cases, also monetize MBEE. Monetizing the quantified benefits often requires the extra step of assigning a value to the benefits, for example a carbon price in the case of carbon mitigation benefits or the statistical value of life in the case of health. A detailed list of methodologies is provided in Annex 7.

Collecting primary data may be expensive (e.g., conducting measurement analysis) and take time (e.g., conducting surveys). However, once a reasonable level of evidence has been developed through primary data collection methods for a specific benefit, it is possible to use these examples as references to estimate probable impact at a larger scale or for a similar situation.

TABLE 4.1

Methods of Quantifying the Multiple Benefits of Energy Efficiency

METHODS	DESCRIPTION	EXAMPLES OF BENEFITS
Measurement	The impact of energy savings cannot be directly measured but inferred through the establishment of a baseline which represents what would have occurred in the absence of a program. There are two approaches possible to estimate a baseline (SEEAction, 2012): • **Non-control Group Approaches:** baseline energy use is estimated and compared with post-program energy use measurements or assumptions to estimate savings • **Control Group Approaches:** a comparison group's energy use is compared with the energy use of program participants using, for example, a randomized control trial (RCT).[24]	• O&M cost reductions • Water savings • Utilities reduced • Credit and collection costs • Health impacts • Safety • Environmental impacts (e.g., GHG)
Modeling	Different types of modeling, such as bottom-up cost assessment, input-output tables and macroeconomic, computable general/partial equilibrium, models are used to assess the economic impacts. Modeling of power systems can be used to calculate the benefits of avoided power supply costs attributable to the energy efficiency program.	• Economic activity • Employment • Avoided power supply costs
Surveys	Surveys are powerful tools to gather data and information for estimating MBEE. Questions included in surveys can be quantitative and/or qualitative. For example, a survey about labor productivity may ask employees about sick day counts and also include questions about stress level or comfort level in a specific environment. Surveys can also be used to monetize less-tangible benefits by asking respondents to set a price on benefits through willingness-to-pay or contingent valuation methods. These types of surveys help to determine how much participants value a benefit.[25] Many survey techniques exist and surveys should be designed carefully to maximize the robustness of the information collected.	• Comfort • Productivity • O&M cost reductions • Health impacts • Safety

In fact, many of the current valuations of the MBEE rely on estimates from previous studies that have established some evidence base. Having an established evidence base derived from a rigorous analysis is a key factor to scale up the use of accounting for MBEE.

4.1 DESCRIPTION OF THE MULTIPLE BENEFITS OF ENERGY EFFICIENCY

The topic of MBEE encompasses a wide range of impacts, including economic, health and physical comfort, social, and environmental (both local and global), among others. Identifying all of the direct and indirect benefits of energy efficiency is an evolving field. This section describes some of the benefits commonly cited in the literature, generally employed quantification methods, and examples of their impacts.

4.1.1 Recipient Benefits

Description

Recipient benefits refer to the benefits that accrue to the participants of a program. The range of these benefits are large and depend on the target of the program (residential, commercial, public, and industrial sectors) as well as the energy efficiency measures considered (lighting, heating, cooling, steam, etc.). The importance of these benefits also varies according to recipients' income levels.

> Low-income households tend to receive greater health and comfort benefits from energy efficiency programs because their baseline conditions before improvements are generally lower than those of average-income households.

In a study for the state of Massachusetts, USA, 29 different benefits were identified just for the residential sector, ranging from noise reduction to more durable homes (Tetra Tech and NMR 2011; see Annex 8 for a full list). Table 4.2 describes some of the most common recipient energy efficiency benefits beyond energy cost saving benefits. If demonstrated suitably, these multiple benefits can become the prime motivation for recipients to participate in a program and invest in energy efficiency measures.

Quantification Method

Some benefits are relatively easy to measure, such as water savings or O&M reductions. Others are subjective and less tangible, such as "increased comfort," and others, such as improved health or productivity, are difficult to measure and require rigorous study to show evidence. Table 4.3 lists indicators that can be used for measurement.

O&M cost savings would constitute a notable portion of an energy efficiency project's saving benefits, yet O&M cost savings are rarely calculated rigorously. Measurement consists of collecting data and conducting interviews with facility O&M staff regarding systems operation, occupancy patterns, and problems with equipment reliability before and after implementation of an energy efficiency measure.

TABLE 4.2

Recipient Benefits of Energy Efficiency

BENEFITS	DESCRIPTION	ENERGY EFFICIENCY MEASURES
Operating and Maintenance (O&M) Cost	Measures that both reduce energy use and the cost of operating or maintaining a building, for example, replacing an incandescent lamp (average lifetime 1,000 hours) with an LED lamp (24,000 hours) eliminates multiple lamp replacements, which can save significant O&M costs, especially in the business sector where paid staff change light bulbs.	All (Lighting programs generally have the greatest O&M benefits)
Health Impacts	Improvement in human health as the result of efficiency measures installed in residences and businesses include improvements in indoor air quality, better ventilation, moisture control, building envelope noise protection improvements, etc.	Building measures
Labor Productivity	Improving the energy efficiency of a building can result in gains in worker productivity. Measures such as replacing an older air conditioning or lighting system with a more efficient system can improve air quality, increase comfort, and reduce glare on computer screens, all of which contribute to increasing employee productivity. Since labor costs generally represent the largest share of a commercial entity's costs, even a small percentage gain in productivity can result in significant cost savings.	Insulation retrofit Heating/Cooling system improvements Lighting
Comfort	Energy efficiency measures affect comfort through temperature, indoor air quality, lighting, acoustics, physical space, and humidity.	Building measures
Energy Access	Energy efficiency increases the level of energy services delivered per unit of energy delivered. This is especially relevant for investments in new capacity in developing countries and investment in renewable energy. The amount needed to be invested can be reduced if the energy supplied is used to purchase energy efficient equipment. Energy efficiency maximizes the level of service delivered by energy supply while minimizing its cost and its environmental impacts.	All
Water Savings	Measures that are designed to save energy and that also reduce water and wastewater flows, (e.g., low-flow showerheads).	Water heating Washing machine Dishwasher
Property Value	Investments in energy efficiency increase the value of the property where the measures are installed. People increasingly value a well-insulated energy-efficient home which is perceived as more comfortable, healthier, and cheaper to run.	Building measures
Safety	Energy efficiency can improve visibility and therefore public safety. LED's white color rendering and uniform illumination patterns are considered to improve visibility, which helps reduce criminal activity and can improve safety for drivers, cyclists, and pedestrians.	House retrofit Street lighting
Competitiveness	Energy efficiency is strongly linked in various ways with competitiveness: energy efficiency contributes toward reducing overall company expenses, reduces waste, increases productivity, modernizes production lines, and, in some cases, boosts innovation, all of which contribute to an increase in competiveness for companies. Moreover, by lowering energy costs, energy efficiency also contributes toward reducing the exposure to the risks stemming from volatile energy prices.	Industry programs

TABLE 4.3

Quantification Methods for Recipient Benefits

BENEFITS	INDICATORS
O&M Cost Reductions	Replacement and inspection rate of equipment and monetary value ($, €, etc.)
Health Impacts	Hospitalization and mortality rates, medical costs
Labor Productivity	Days off work, days off school
Comfort	Indoor temperature, humidity level, and monetary value ($, €, etc.)
Energy Access	Energy services provided (lumen-hours in the case of lighting, useful energy in the case of heating or cooling, etc.)
Water Savings	Quantity of water saved (liters) and monetary value ($, €, etc.)
Increased Property Values	Monetary value ($, €, etc.)
Safety	Number of accidents prevented
Competitiveness	Market share, cost per unit of output, energy intensity

O&M cost savings can result from a lower replacement rate of equipment (lamps for example), reduced cooling systems inspection, reduced repair costs, or reduced tenant turnover (Cluett and Amann 2015).

Health impacts are generally difficult to measure. Solid evidence based studies, generally using randomized control trial (RCT) methods, need to be developed to show the benefits of energy efficiency improvements on health. Once evidence is established, modeling can be used to assess impacts from energy efficiency on health in other projects, as it is the case in the United Kingdom, later in this chapter.

Labor productivity gains from energy efficiency improvements in buildings are rarely measured due to the difficulty of quantifying knowledge-based output from service companies (Miller, et al. 2009). However, some studies have shown and quantify the productivity benefits of a more energy efficient building environment by collecting data on absenteeism, hours worked, tardiness, safety rule violations, number of grievances filed, and employee turnover, for example, before and after a program implementation (Building Efficiency Initiative 2013; Munch et al. 2012; ASHRAE 2010; Seppanen et al. 2006; Hedge et al. 2004; Loftness et al. 2003). These data can be complemented by qualitative information collected though surveys that ask employees to report on productivity. Annex 10 provides quantitative and qualitative indicators of labor productivity measures.

Comfort improvements can be measured by the level of satisfaction of building occupants through surveys which ask about the comfort of home or workplace (see Annex 9). Comfort benefits can also be quantified through a willingness-to-pay survey or through the level of energy taken back for increasing thermal comfort (Tetra Tech and NMR 2011; Payne et al. 2015). It is also possible to measure thermal comfort improvements by measuring indoor temperature. Some energy efficiency measures, like the application of cool roofs, can minimize the heat gain of a building and reduce indoor temperature (Garg et al. 2016).

While the benefit of energy efficiency to energy access in developing countries is generally admitted, methods and metrics to quantify this benefit are still evolving. The first step is to move away from the binary definition of energy access (having/not having an electricity connection) and to consider the services that energy enables (lighting, cooling, entertainment, etc.). Greater efficiency increases access to energy services by expanding the amount of services that can be provided by a fixed amount (or cost) of energy. The benefits of energy efficiency on energy access can be measured by an increase in the level of energy services accessed by households, such as lumen hours in the case of lighting, useful energy in the case of heating or cooling, etc. The World Bank is supporting a multitier approach where the definition of energy access[26] is based on the performance of the energy supplied. Through this new approach, the benefits of energy efficiency are defined as increased in the duration of energy services and improvement in the affordability of energy services to households. In this framework, Tier 1 level of energy access includes the amount of lighting in lumen hours per day and phone charging. As the tier level increases, the level of energy services is augmented (ESMAP 2014).

Water savings occurring from energy efficiency measures, such as low-flow showerheads, can be estimated by using engineering supplemented by measurement of water use before and after the implementation of a measure.

Increased property value is measured by tracking sales data or interviewing real estate experts. An alternative is to conduct post-upgrade property value appraisal. The Appraisal Institute (2013) provides real estate appraisers with detailed information on how to analyze the effects of energy performance on property value. This contributes to showing the lending opportunity for financial institutions. Increased safety is assessed by measuring the number of accidents before and after a program or by conducting surveys about the perceived safety improvements from users (Frith and Jackett 2013).

Competitiveness is a widely used term and many definitions are associated with this concept. Measurement can be defined in two ways: (i) comparatively to others by using data on market share, or (ii) accordingly to cost indicators, by collecting data on the energy productivity of a company (reverse of energy intensity).

Understanding Impacts

This section includes select examples of studies that have assessed recipient benefit impacts.

United Kingdom. The Health Impact of Domestic Energy Efficiency Measures (HIDEEM) model was developed to estimate and monetize the health impacts associated with energy efficiency measures in houses (UCL 2016). This model is used by the Department of Energy and Climate Change in making program development decisions.

India. Passive technologies that reduce heat gain such as cool roofs, reflective wall coatings, exterior shading, etc., contribute to reduce cooling demand and improve thermal comfort. A case study in Hyderabad showed an average in-room temperature reduction of 2°C and a peak reduction of 4.3°C (Garg et al. 2016).

Massachusetts, United States. Tetra Tech and NMR (2011) quantified health and comfort benefits by surveying 209 energy efficiency program participants and 213 low-income program participants. A willingness-to-pay survey asked participants to value impacts relative to the average bill savings for specific measures, mainly building shell and/or heating, ventilation, and air-conditioning improvements. This study identified recommended values per participant, ranging from $27 to $279, for 56 different benefits that accrued to utilities, occupants, and society. These recommended values are often used as reference estimates to quantify benefits in cost-benefit analyses in other states (Rhode Island, for example). A complete list of the values per type of benefit is given in Annex 8.

Bangladesh. Phadke et al. (2015) show that the use of super-efficient off-grid lighting and appliances can reduce the cost of off-grid energy service by up to 50% and therefore increase access to energy services. The study demonstrates that the use of LED in solar home systems allowed for a reduction in the size of and an increase in the demand for additional energy services in the solar home system. A 20 watt-peak system can deliver the energy services for a household that would have once needed a much more costly 50 watt-peak system by using super-efficient equipment.

Mexico. The Green Mortgage Program was created in 2007 to promote the use of eco-technologies in new housing development and retrofit of existing houses in Mexico. Along with average annual electricity savings of 600 to 1544 kWh (depending on the climatic zone) and 2,890 to 3,115 kWh in gas, the program reduced water consumption by 85 m^3 in water per home per year (Buildings Efficiency Initiative 2013).

United Kingdom. A study from the Department of Energy and Climate Change (2013) reveals that making energy saving improvements increases a property's value by 14% on average and up to 38% in some parts of England.

New Zealand. Grimes et al. (2012) assessed the costs and benefits of the Warm Up New Zealand: Heat Smart Programme. This program offered subsidies for insulating buildings and/or installing clean heating in residences. Detailed evaluation of this program shows that energy benefits alone were insufficient to justify program expenditures, but the benefit-to-cost ratio exceeded 4:1 when health benefits were included.

United States Weatherization Assistance Program. According to a retrospective evaluation of the 2008 WAP, the program's benefit-cost ratio was 1:4 when only energy savings costs and benefits are accounted for, but improves when health and safety benefits and costs are included (US DOE 2015). The result is in part because a small share of program costs were invested to address health and safety issues found in homes (typically around 15% of the funds invested in a weatherized unit) (ORNL 2014). For example, while WAP technicians were in homes installing energy-savings measures, they fixed broken windows and installed working smoke detectors.

Mexico. The 2016 Implementation Completion and Results Report for the World Bank Efficient Lighting and Appliances project assesses the project's performance. The project was implemented over the 2011–15 period and replaced over 45 million incandescent bulbs with compact fluorescent lamps (CFL), including a portion distributed to households in low-income communities (including indigenous communities) and appliances (refrigerators and air conditioners). The project resulted in energy savings of over 10,000 GWh and mitigated over 5 Million tCO_{2e}. The report notes, but does not quantify, other economic benefits, including: (i) delaying or avoiding new power generation infrastructure; (ii) reduction in consumers' electricity bills; (iii) mitigation of the burden of the electricity subsidies; and (iv) enhanced energy security.

4.1.2 Energy Supply Benefits

Description

Benefits to electricity supply are numerous. They include deferring the need to build new infrastructure to meet growing demand and increasing grid reliability. IEA (2014) identifies 21 multiple benefits that accrue to energy providers. Table 4.4 describes some of the most-referenced MBEEs related to grid infrastructure and reliability.

Quantification Methods

In the United States, the typical approach for quantifying MBEE programs is to calculate "avoided costs," defined as costs that would have been incurred if the energy efficiency measures had not been put in place. Different methods, using modeling approaches, are used to calculate energy- and

TABLE 4.4

Power Supply Benefits of Energy Efficiency

BENEFITS	DESCRIPTION	INDICATORS
Avoided capacity costs	Demand reductions from energy efficiency measures reduce the need for additional generation capacity to meet demand.	Avoided capacity (KW) and saved monetary value ($, €, etc.)
Avoided T&D costs	Implementing energy efficiency measures can avoid the need for T&D expansion and associated costs.	Avoided kWh losses and saved monetary value ($, €, etc.)
Reduce peak load	Energy efficiency reduces costly investments needed to meet demand during peak hours.	Avoided peak capacity (KW) and saved monetary value ($, €, etc.)
Reduced credit and collection costs	In the case of low-income energy efficiency programs, utilities can realize financial savings from reduced costs associated with arrearages and late payments, uncollectible bills and bad debt write-offs, service terminations and reconnections, bill-related customer calls, and the bill collections process.	$ savings
Increased reliability	By reducing electricity demand, energy efficiency programs increase electricity system reliability and help prevent demand from exceeding maximum capacity when it otherwise would have, thereby preventing blackouts. Benefits include the value added from avoiding blackouts.	$ of value added produced Number of avoided power outages
Energy security	By reducing energy demand, energy efficiency contributes to reducing a country's dependence on imported energy and increases its energy security.	Avoided energy imports (tj, etc.) and saved monetary value ($, €, etc.)

T&D—Transmission and Distribution

capacity-related avoided costs, as explained by Elefant (n.d.). Energy efficiency measures can avoid costs such as those associated with line losses and reserve margins. See a description in Lazar and Colburn (2013).

For impacts of reduced credit and collection costs from low-income energy efficiency programs, the quantification method often includes pre- and post-program billing data from a treatment and a comparison group. However, as mentioned earlier, collecting primary data may be expensive and many of the current valuations of this benefit in utility programs in the United States now rely on estimates from previous studies.

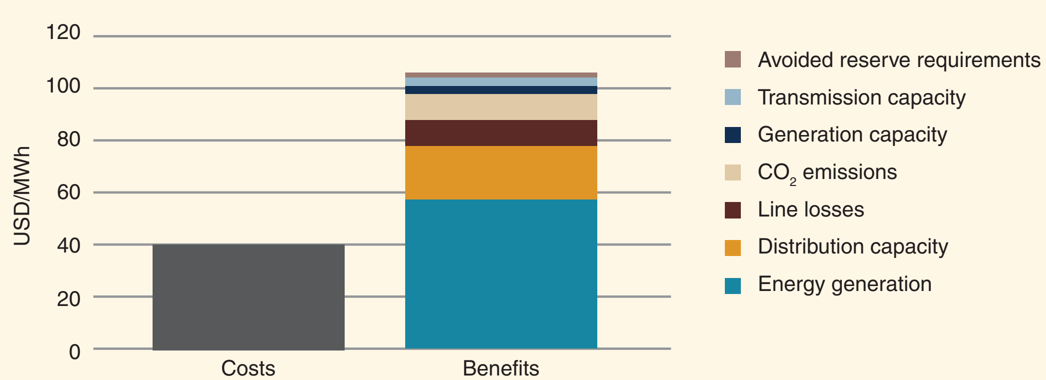
Increased reliability benefits can be assessed by first determining how an energy efficiency project affects the number and length of customer outages and then multiplying that expected change by the estimated cost of an outage. The estimated cost of an outage is determined based on customers' economic activities.

Understanding Impacts

2010 Vermont energy efficiency program portfolio assessment. Figure 4.1 reports the costs and benefits of Vermont energy efficiency programs portfolio in 2010, taken from the IEA (2014) publication on MBEE. The levelized cost of energy efficiency measures is $39 per megawatt hour compared to benefits to energy providers estimated at $104.8 per megawatt hour, which results in an overall benefit-cost ratio of 2.3 to 1. Avoided distribution capacity costs are the largest nonenergy benefits, equal to 35% of the energy benefits. Avoided line losses represent 18%, avoided generation capacity costs represent 16%, avoided transmission capacity costs 6%, and avoided reserve requirements 1% of energy benefits.

FIGURE 4.1

Multiple Benefits of Energy Efficiency Accrued to Vermont Energy Providers in 2010



Note | Values are expressed as levelized USD/MWh.

Source | IEA 2014. (Original: Efficiency Vermont 2012: Annual Report 2010, Efficiency Vermont)

TABLE 4.5

Utility MBEE Resulting from Low-income Energy Efficiency Programs (in USD/year/participant)

CARRYING COST ON ARREARAGES	BAD DEBT WRITE-OFFS	TERMINATIONS AND RECONNECTIONS	CUSTOMER CALLS	NOTICES	SAFETY-RELATED EMERGENCY CALLS
1.37 to 4.00	0.48 to 6.09	0.07 to 7.00	0.07 to 1.58	0.04 to 1.49	0.07 to 15.58

Source | *Tetra Tech and NMR report 2011.*

United States. Table 4.5 reports a range of estimated values for utility financial savings from reduced credit and collection costs (in USD/year/participant) for eight low-income programs in the United States. As specified in Tetra Tech and NMR (2011), there are several reasons for the variability in the magnitude of impacts reported in the literature, including differences in program structure and utility cost structures and policies.

Kyrgyzstan. Using a RCT method and measuring household's electricity consumption at the transformer substation level, Carranza and Meeks (2015) provide evidence on the benefits of increased reliability of electricity services from a CFL program. Results show that households that were recipients of the program experienced approximately two fewer electricity outages per month on average.

Uganda. One of the primary objectives of the World Bank Power Sector Development Operation project, started in 2007, was to reduce power shortages by implementing energy efficiency measures and adding new capacity in Uganda. At project closure, the evaluation report found that monthly energy unmet demand was reduced by about 95% due to an estimated 55 GWh of energy savings per year through a number of energy efficiency initiatives related to energy use efficiency and load management (World Bank 2012).

South Africa. Serious electricity shortages experienced in 2008 triggered the implementation of energy efficiency policies in South Africa. The government decided to include an environmental levy in electricity tariff to fund the implementation of energy efficiency demand-side management programs targeting various energy efficiency measures/technologies (e.g., energy efficient indoor and street lighting, heat pumps, energy management systems, etc.). During the energy crisis, the utility company Eskom used energy efficiency actively to reduce the gap between supply and demand of electricity. Energy efficiency is now included as a resource of choice in planning for future energy resources (de la Rue du Can et al. 2013).

India. Sathaye and Gupta (2010) evaluated the aggregate economic benefits from reducing the gap between supply and demand of electricity through the implementation of energy efficiency programs in India. They estimated that the resulting cumulative production increase would contribute $505 billion to GDP between 2009 and 2017, which can be compared with India's 2007–08 GDP of $911 billion.

Sri Lanka, Thailand, and Vietnam. Selvakkumaran and Limmeechokchai (2013) focus on the effect of energy efficiency measures on energy security in three developing countries: Sri Lanka, Thailand, and Vietnam. Results show that energy efficiency in Sri Lanka significantly increases the energy security whilst also accruing co-benefits of CO_2 mitigation and mitigation of local air pollution. In the case of Thailand and Vietnam, energy security is enhanced in the short term.

4.1.3 Public Budget Benefits

Description

Important benefits of energy efficiency programs accrue in the public budget when governments are the beneficiaries of the program, such as public buildings or street lighting energy efficiency retrofits. This is part of the recipient energy savings benefits which is covered in Section 4.1.1.

Additional benefits to the public budget exist. In economies that subsidize end-use energy tariffs, energy efficiency programs reduce fiscal expenditures on energy subsidies, which enable governments to lower deficits or increase spending in other priority areas, such as health and education. Public budget increases can also result from increased spending effects (increased tax revenue and reduced payout for unemployment benefits). However, indirect benefits should be balanced with decreases in fuel/energy tax revenues resulting from decreases in energy consumption. In some countries, fuels are taxed at a higher rate than other goods (excise duties), so shifting consumption from fuel to other goods will lead to lower tax revenues. Table 4.6 lists public budget MBEE programs.

Quantification Methods

While indirect impacts are difficult to quantify and depend on macroeconomic activity impacts, reduction of energy subsidies that result from reductions in energy use can be estimated based on the cost of energy subsidy per kilowatt hour consumed. However, the level of energy subsidy per kilowatt hour or terajoule of energy sold is not always directly available. The IEA and International Monetary Fund (IMF) use similar methodologies to estimate energy subsidies, comparing average end-user

TABLE 4.6
Public Budget Benefits of Energy Efficiency

BENEFITS	DESCRIPTION
Reduced energy subsidies budget	Reducing energy consumption reduces public funds spent on energy subsidies.
Indirect public budget effect	Energy efficiency programs result in consumers paying less in energy bills. Consumers may spend the saved funds for goods and services, which, in turn, can create jobs and thus reduce payout for unemployment benefits. Energy efficiency programs can also improve occupant health, which reduces health care costs. Energy efficiency measures increase property values and thus property tax revenues. Reduced energy demand also reduces the need for public investment in energy infrastructure.

prices with the full cost of supply. The difference represents the amount by which an end-use price falls short of the full cost of supply (IEA 2013; IMF 2013).

Understanding Impacts

Mexico. In Mexico where the presence of subsidies on the price of electricity distorts resource allocation by encouraging excessive energy consumption and reducing incentives for investment in energy efficiency, Leventis et al. (2013) found that avoided subsidy payments alone could finance incentive programs that cover the full incremental cost of refrigerators that are 27% more efficient and televisions that are 32% more efficient than baseline models.

European Union. Copenhagen Economics (2012) estimates that annual investment of $56 billion in the energy efficiency renovations of buildings through 2020 in the European Union would result in permanent public revenue gains and €5 to €6 billion of reduced need for energy-consumption subsidies, as well as €9 to €12 billion from reduced public spending on energy bills (e.g., in public buildings and institutions). The study also estimates permanent revenue losses of €4 to €5 billion from reduced fuel consumption taxes. In total, annual permanent net public revenue gains could reach €30–40 billion in 2020, if health-related benefits (e.g., fewer hospitalizations) from energy efficiency renovations are included. In addition, the study estimates approximately 760,000 to 1,480,000 jobs will be created annually as a result of energy efficiency programs, which would lead to an additional annual reduction of cost in public budgets.

Germany. The Residential Energy Efficiency Buildings Program of KfW between 2006 and 2014 benefitted 50% of all newly built residential and 33% of all refurbished buildings, as well as 2,000 public buildings. The energy efficiency program created approximately 440,000 jobs, additional tax revenue, social security contributions, and reduced costs for unemployment amounting to reduction in the public budget of about €4 to €5 for each Euro spent (Schüring 2014).

4.1.4 Air Emissions Benefits

Description

Air emissions resulting from energy consumption are the major cause of global warming. Some of these emissions have strong warming effects, but are short lived, classified as short-lived climate pollutants (SLCPs). Air emissions are also a source of indoor and outdoor pollution and a cause of ozone depletion. A study from the World Health Organization (WHO 2014a) estimates that 3.7 million and 4.3 million premature deaths could be attributed to ambient (outdoor) air pollution and household (indoor) air pollution in 2012, respectively. Outdoor air pollution, notably in concentration of human settlements like cities, causes a spectrum of health effects, ranging from eye irritation to death. Additionally, methane emissions are a source of diminished agriculture production. Table 4.7 below lists air emissions MBEE. **Reduced air emissions that result from energy efficiency can contribute to decreased global warming impacts, improved human health, and reduced ozone depletion.**

TABLE 4.7

Air Emissions Benefits of Energy Efficiency

EMISSIONS	SOURCE	DAMAGE
Carbon dioxide (CO_2)	Energy combustion Industrial processes	Global warming
Sulfur dioxide (SO_2)	Energy combustion Industrial processes	Respiratory diseases Acidification of forests and waterways
Methane (CH_4)	Animal waste Landfills Fuel	Global warming (SLCP) Respiratory diseases Diminished agriculture productivity
Nitrogen oxides (NOx)	Energy combustion Fertilizer use	Respiratory diseases Crop yield impacts Global warming (SLCP)
Black carbon (BC)	Energy combustion	Global warming (SLCP) Increase in premature deaths
Hydrocholorofluorocarbons (HCFCs) Chlorofluorocarbons (CFCs)	Refrigerant	Global warming Ozone depletion
Hydrofluorocarbons (HFCs)	Refrigerant	Global warming (SLCP)

SLCP—short-lived climate pollutants

Quantification Method

Methods for assessing benefits of air emissions reductions entail first estimating the quantities of emissions reduced and then determining the value of these quantities.

GHG emissions are estimated by applying emissions factors to the quantity of energy saved. For fuel savings, default values[27] are available in the Intergovernmental Panel on Climate Change 2006 Guidelines. For electricity savings, emissions factors need to be based on the fuel mix of the electricity saved (including the transmission and distribution saved). For energy measures that reduce peak electricity, marginal emissions factors can be calculated to reflect emissions variations during peak periods. Methodologies have been developed to calculate grid emissions factors (e.g., through the UNFCCC Clean Development Mechanism). GHG emissions have different global warming potential which represents the ability of each GHG to trap heat in the atmosphere relative to carbon dioxide (CO_2) over a specified time horizon (see IPCC 2007, 2014 and GHG Protocol for more detail).

Estimating the cost of avoided damages due to GHG emissions reduction can be done by using the social cost of carbon. The social cost of carbon is an estimate of the direct effects of carbon emissions on the economy—it estimates how much damage climate change will cause by considering net agricultural productivity loss, human health effects, property damages from increased flood risk, and the value of ecosystem services due to climate change. In the United Kingdom, the social cost carbon value has been used in policy analysis and regulatory impact assessment since 2002 and was revised in 2007 and 2010 (IPCC 2014). In the United States, the government also estimates the social cost of carbon to be used by all agencies in their regulatory emissions-reduction impacts analysis. The four social cost of carbon estimates are: $14, $46, $68, and $138 per metric ton of CO_2 emissions in the year 2025

(2007 dollars), based on 5%, 3%, and 2.5% average discount rates and 95th percentile, respectively (USG 2010; US EPA 2015). The IMF (2014) uses an illustrative damage value of $35 per $MtCO_2$ based on a study that estimates taxes on coal, natural gas, gasoline, and diesel needed to reflect environmental costs.

For air pollutants, different tools exist to estimate the pollutant concentrations and their effect on human health (mortalities, years of life lost) and crop yield. Quantitative estimates of air pollution health impacts have become an increasingly critical input to policy decisions, and many governments have invested in tools that best represent localized impacts and provide timely information. Internationally, organizations such as the World Health Organization (WHO) and the World Bank have invested in similar tools to quantify air pollution-related health impacts for a variety of purposes. Global Model of Ambient Particulates (GMAPS) is an econometric model developed by the World Bank to predict ambient PM10 levels for world cities larger than 100,000. Another tool used in the World Bank and Climate Works Foundation study (2014) is the Fast Scenario Screening Tool (TM5-FASST).

Researchers can then place a monetary value on the damages caused by air pollution and assess the monetary damages associated with emitting a given type of pollutant. These cost assessments help optimize policies with respect to their health benefits and costs. Jaramilloa and Muller (2016) estimate the monetary damages due to air pollution exposure (PM2.5, SO_2, NOx, NH_3, and VOC) from electric power generation, oil and gas extraction, coal mining, and oil refineries in the United States. They point out the importance of considering spatial distribution of population in the impacts of air emissions when estimating the benefits of policies. The WHO organized a workshop in 2014 to discuss the evidence for air pollution health effects and propose expert advice on the best options and methods to estimate health risks from air pollution and its sources. A document reviews available air pollution analysis methods and tools globally (WHO 2014b).

Understanding Impacts

Global Impacts of Short-Lived Climate Pollutants. The United Nations Environment Program (UNEP 2016) estimates that, by 2030, using technologies and strategies available today, reduced SLCP emissions could avoid an estimated 2.4 million premature deaths from outdoor air pollution annually and about 32 million tons of crop losses per year.

Maryland, United States. Itron (2015) estimated the benefit from reduced air emissions (CO_2, NO_x, SO_2) from State of Maryland energy efficiency programs at $79 million over the lives of the program, equivalent to $0.011 per kilowatt hour saved by the programs in 2013, using an assumed CO_2 damage cost of $45 per ton. The study estimated that counting air emissions benefits increases the statewide benefit-cost ratio to 2:1, a 16% increase over the ratio of 1:8 without air emissions benefits.

United States, the European Union, China, India, Mexico, and Brazil. The World Bank and Climate Works Foundation study (WB-CWF 2014) examined the benefits from policies that stimulate a shift to clean transport, improved industrial energy efficiency, and more energy-efficient buildings and appliances through regulations, taxes, and incentives in six major economies—United States, the

European Union, China, India, Mexico, and Brazil. The study found that those policies would prevent 94,000 premature pollution-related deaths and 8.5 gigatons of CO_2-equivalent emissions in 2030.

Global. In a study analyzing more than 150 countries, the IMF (2014) explored how to align fuel taxes with environmental damages that reflect global warming, air pollution, road congestion, and other adverse environmental impacts of energy use. The study develops a practical methodology, and associated tools, to show how the major environmental damages from energy can be quantified for different countries and used to design corrective fuel taxes that reflect environmental costs.

4.1.5 Economic Benefits

Description

Energy efficiency improvements deliver benefits across the whole economy, with direct and indirect impacts on economic activity, employment, trade balance, and energy prices.

- Direct impacts include the additional economic activity associated with local commercial services and industries in response to energy efficiency program investments. Energy efficiency programs lead to purchases of goods and services in the economy (e.g., labor for energy audits, increased sales of energy efficient equipment, labor for training energy auditors, etc.).
- Indirect impacts include economic activity associated with increased disposable income or higher profits from the cost reductions associated with energy saved.

Together, these financial flows have multiplier effects locally and regionally on the economic activity and job creation. The positive economic multipliers associated with these expenditures are generally larger than the impacts from the energy sector.

Energy efficiency improvements also help alleviate household poverty and are often considered a more long-term solution to alleviate poverty than energy subsidies and direct financial support, leading many countries to implement energy efficiency programs targeting low-income households. A recent publication from the World Bank analyzed the benefits that energy efficiency has on diminishing the distributional affordability impact of raising energy tariffs to cost recovery levels (Ruggeri Laderchi et al. 2013). Raising energy tariffs to cost recovery levels can result in very high increases and energy efficiency can help cushion this impact. The term “energy poverty” (or “fuel poverty”) has been developed to refer to situations where households are unable to afford their basic energy needs. Three factors influence energy poverty: household income, energy prices, and energy efficiency of equipment and buildings.

When energy efficiency is improved, households can decide to either expand the energy services provided from a fixed amount (or cost) of energy or reduce their energy demand and keep the same level of service as before the measure, or a combination of both. In all cases, household wealth increases. As mentioned in previous sections, when a consumer decides to expand the energy services, this reduces the energy savings potential and is often referred to as a direct rebound effect or take-back effect in the literature (see de la Rue du Can 2015, for a brief information note on this

TABLE 4.8
Economic Benefits of Energy Efficiency

BENEFITS	INDICATORS	METHODS
GDP Growth	Monetary value ($, €, etc.)	Macroeconomic modeling
Job Creation	Net number of jobs created	Macroeconomic modeling
Energy Poverty	Number of households	Survey
Price	$/kWh reduction	Macroeconomic modeling
Trade Balance	Monetary value ($, €, etc.)	Macroeconomic modeling

topic). However, this can also be considered as an economic benefit of expanding the amount of energy services that can be provided by a fixed amount (or cost) of energy (IEA 2014). Indeed, the United Kingdom's treasury guidance document on project appraisal recommends considering comfort take-back as a welfare benefit to the consumer (see "United Kingdom" section below). In developing countries, energy poverty is generally defined in terms of inadequate and unreliable access to energy services and reliance on traditional biomass. Energy poverty is recognized as a major barrier to economic growth and to health and well being (UN 2010; IEA 2010). In fact, ensuring access to affordable, reliable, sustainable and modern energy is recognized as one of the United Nations Sustainable Development Goals adopted in 2015 (UN SDG 7).

Energy efficiency also contributes to reduction in energy prices, as it reduces the demand for energy. In competitive markets, the marginal unit price of energy increases with the amount required. Therefore, a decrease in supply due to a reduction of demand results in price reduction. This phenomenon is referred as Demand Reduction Induced Price Effect (DRIPE) in the United States' utility industry (Chernick and Plunkett 2014). Price suppression has been accepted as an energy efficiency benefit by regulators in Massachusetts, Delaware, Connecticut, the District of Columbia, and Rhode Island.

Quantification Methods

To assess the economic impact of energy efficiency programs, a combination of modeling approaches is generally needed. First, the total investment necessary from public and private funds is estimated using technology-based bottom-up models that gather information on the cost of energy efficiency measures. The total estimated investment is then introduced into economic models to determine impact on economic activity and job creation. Economic models, such as computable general equilibrium, are generally used because they cover the whole economy of a country and integrate input-output tables to estimate the impacts of additional investment in a sector of the economy. How energy efficiency measures influence economic sectors (i.e., positively or negatively) depends on a country's economic structure and on the design and scale of the underlying policies.

There is no consensus on which method to use internationally to define the energy poverty line below which households are considered to be in fuel poverty. Eurostat, the statistical office of the European

Union, surveys household income and living conditions annually. Information that relate to energy poverty is collected through three indicators:

- the percentage of households experiencing an inability to keep their home adequately warm
- the percentage of homes that are damp, rotting, or leaking
- the percentage of homes that are behind on utility bill payments

Atanasiu et al. (2014) used a combination of these indicators to describe the current fuel poverty situation in Europe. This study estimates that between 50 and 125 million people in Europe currently suffer from fuel poverty and are unable to afford proper indoor thermal comfort. Bulgaria and Lithuania have the highest rates in Europe of residents unable to keep their homes adequately warm.

In developing countries, the term energy affordability is often used, notably in the context of tariff reforms which require moving from subsidized tariffs to cost reflective tariffs. These transitions have a large impact on the energy affordability of households, as the increase can be very steep. Ruggeri Laderchi et al. (2013) recommend implementing energy efficiency programs to lower the impact of higher tariffs on the affordability of energy services. The multitier approach currently being developed by the World Bank's Energy Sector Management Assistance Program (ESMAP) and described above, also helps to demonstrate the impact of energy efficiency interventions as a contributor to a higher level of affordability of energy services (ESMAP 2014). The affordability of energy is considered as an attribute of achieving energy access.

Examples

Global. The IEA (2014) reports that GDP changes from large-scale energy efficiency policies are positive, with economic growth ranging from 0.25% to 1.1% per year. According to the IEA, the potential for job creation ranges from 8 to 27 job years per €1 million invested in energy efficiency measures.

Eastern Europe and Central Asia. Ruggeri Laderchi et al. (2013) show that energy efficiency programs reduce the negative impact of raising energy tariffs to cost recovery levels measures on households and the economy. The report assessed, at the micro level for the whole region, the distributional impact of raising energy tariffs to cost recovery levels and simulating policy options to cushion these impacts. They estimate that most countries in the region could save 0.5 to 1% of GDP by improving the effectiveness of social assistance systems and increasing energy efficiency.

United States. United States Department of Energy (US DOE) employment impact analysis estimates the aggregate indirect national job impacts from the implementation of minimum energy performance standards, using a model called ImSET 3.1.12 (Impact of Sector Energy Technologies). This is a customized version of the national input-output model for building energy technologies.

European Union. In Europe, many studies have recently been published on energy poverty and the need to scale up energy efficiency programs to help alleviate it (Atanasiu et al. 2014; Pye et al. 2015;

Schumacher et al. 2015; Mzavanadze et al. 2015). However, most studies report the effectiveness of measures to alleviate poverty as the number of households participating in the programs. No quantification of the impact of energy efficiency programs on energy poverty was found.

4.2 SUMMARY OF INTERNATIONAL EXPERIENCE

This section gives a brief overview of the experience in integrating the quantification on MBEE in energy efficiency investment programs and select international initiatives.

United States

In the United States, MBEE are generally referred to as **non-energy benefits** (NEB). However, more recently the term non-energy impacts (NEI) has become more common, to encompass both the positive and negative effects of energy efficiency programs. Non-energy impacts are grouped into three classes based on "beneficiary" or "perspective." These classes are utilities, program participants, and society.

Assessment of non-energy impacts has generally focused on low-income programs where non-energy benefits are part of the program goals. However, recognizing the additional value that these benefits bring, an increasing number of state regulators are now working to include them in cost-effectiveness tests, program design and marketing strategies (Skumatz 2009; Malmgren and Skumatz 2014). In the United States, energy efficiency programs are funded through utility rates, and each state regulatory agency has its own mandate regarding the specific test(s) and requirements for demonstrating program cost effectiveness (Cluett and Amann 2015).

Malmgren and Skumatz (2014) identified four different ways that state regulators include non-energy benefits in energy efficiency program assessments and cost-effectiveness tests:

1 | **Adders.** Incorporating an adjustment factor to reflect subsets of non-energy benefits contributions to all benefits:

- Iowa, Colorado, Oregon, Washington, Vermont, New York, Washington DC, and other states include simple adders (between 7.5% and 25%) (Skumatz 2014)

2 | **"Readily measured" non-energy benefits.** Incorporating "easy-to-measure" benefits:

- Massachusetts, Vermont, Colorado, New Hampshire, Oregon, Connecticut, Rhode Island, Maine, Washington DC, and others such as BC Hydro (Canadian electric utility) include subsets of "readily measured" non-energy benefits (Skumatz 2014)
- These benefits generally include:
  - O&M expenditure reductions
  - Water and sewer usage reductions

3 | **Measuring non-energy benefits.** Direct measurement of most non-energy benefits

4 | **Hybrid approach.** Using an adder and measuring easy-to-measure benefits

The National Efficiency Screening Project (2014) recommends using alternative screening tests or setting a lower cost-benefit screening threshold for programs that have many hard-to-quantify benefits.

United Kingdom

The United Kingdom Treasury publishes a guidance document called the *Green Book* on how to appraise proposals before committing funds to a policy, program or project. The *Green Book* is supplemented by additional guidance documents giving more information on particular issues and on applying the *Green Book* in specific contexts. For example, the United Kingdom Treasury provides additional guidance for valuation of energy use and GHG emissions for appraisal, as well as an excel-based calculation toolkit and data tables containing the carbon values, energy prices, long-run variable energy supply costs, emissions factors, and air quality damage costs over the 2010–2100 period (UK Treasury 2015a; UK Treasury 2015b).

The background document explains the theory and rationale behind the methodology applied to valuing changes to energy efficiency. Direct rebound effect[28] is considered as a welfare benefit (comfort take-back) to the consumer and is valued using the retail price of energy which is higher than the long-run variable costs used for valuing energy savings.

Payne et al. (2015) describe how the *Green Book* and its related documents have been applied in recent impact assessments of energy efficiency programs in the United Kingdom. (See Annex 11 for a summary table showing the value of the different benefits and costs identified which result in the benefit cost ratio.)

European Union

Horizon 2020—the biggest European Union Research and Innovation program—is funding a three-year project entitled Calculating and Operationalizing the Multiple Benefits of Energy Efficiency in Europe (COMBI). COMBI aims to quantify the multiple nonenergy benefits of energy efficiency in the EU-28 area and was developed because existing research on the MBEE is incomplete and dispersed. The overall objective is to provide a comprehensive overview of the existing benefits in Europe for policy makers, evaluators, and the interested public and to make research findings accessible. One of COMBI's goals is to develop a graphical online tool to visualize the multiple energy efficiency impacts and their aggregation.

The project is organized around five main working group research topics:

- Air pollution
- Resources
- Social welfare
- Macroeconomy
- Energy system

The project is coordinated by the Wuppertal Institute with the University of Antwerp, University of Manchester, Copenhagen Economics, and Advanced Buildings and Urban Design as research partners.

International

The IEA has conducted several workshops on MBEE at which key international experts have shared their work. This led to the frequently cited 2014 IEA publication describing MBEE in five areas: macroeconomic development, public budgets, health and well-being, industrial productivity, and energy delivery. The IEA has also put forward the concept of "energy efficient prosperity" that considers the social and economic benefits of enhancing energy efficiency, which is especially relevant for developing countries.[29]

UNEP (2015) published a report entitled "The Multiple Benefits of Measures to Improve Energy Efficiency," which summarizes the results of four detailed studies. The report's objective is to illustrate how MBEE can be used to promote efficiency in the Energy Efficiency Accelerators Initiative, which is part of Sustainable Energy for All. The report estimates energy-savings potential using two different models, compares the results, assesses the economic impact of realizing the energy efficiency potential estimated in the G20 countries, and provides case studies of 25 programs in 8 thematic areas. The survey provides qualitative insights into the economic, social, and environmental benefits attributable to increased energy efficiency, which macroeconomic models cannot capture.

4.3 SECTOR-SPECIFIC EXPERIENCE

4.3.1 Street Lighting Energy Efficiency Measures

Large energy savings are possible with technology advancements in LED street lighting and controls. The main benefit of this advanced technology is reduction of energy consumption (often reaching 50% or more) without compromising the level of lighting. This reduces municipalities' electricity costs,[30] which translates into a reduced budgetary burden. **Energy efficient LED streetlights bring additional benefits such as reduced carbon emissions, improved visibility and public safety, and reduced light pollution.**

Potential MBEE:

- **Maintenance cost savings.** LEDs have a longer life than the incumbent units they generally replace (10–15 years versus 4–6 years), which decreases maintenance requirements. In addition, remote monitoring is often installed with LEDs, which helps to identify system problems in real time.
- **Air emissions reductions.** As in many other energy efficiency projects, saved energy can reduce emissions, depending on the mix of fuels used to generate power.

- **Improved public safety.** LEDs' white color rendering and uniform illumination patterns[31] are considered to improve visibility, which helps reduce criminal activity and can improve safety for drivers, cyclists, and pedestrians. The New Zealand Transport Agency Economic Evaluation Manual cites a 35% reduction in crashes resulting from upgrading or improving poor lighting (Frith and Jackett 2013).
- **Reduced light pollution.** LEDs are designed to be directional, so their light flow is controllable, which can reduce the amount of light directed into the night sky. This feature helps to reduce light pollution and sky glow (unnecessary illumination of night sky by artificial lighting). However, the greater content of blue wavelength light in LEDs produce more glare, which contributes to light pollution (IDA 2016).
- **Reduced waste.** Most conventional fluorescent, high-intensity discharge, or high-pressure sodium lamps contain a range of materials, including mercury that can be damaging to the environment if not disposed of correctly. Because LEDs contain no toxic materials and are completely recyclable, they can greatly contribute to sustainability goals. Additionally, their long operational life span means that replacement lamps no longer need to be manufactured, which saves materials, labor, and energy.

4.3.2 Multifamily Buildings

In countries with cold climates, buildings generally represent the largest source of energy consumption. In countries with warm climates, the soaring penetration of air conditioning is contributing to increase the share of buildings in energy consumption, notably when the indirect energy used for the production of electricity used in building is accounted for. Buildings are also considered part of the solution, as a large source of untapped energy efficiency potential exists in this sector with investment costs that are lower than the cost of the supply of energy. Moreover, energy efficiency in buildings has numerous benefits that are directly tangible to households.

Potential MBEE:

- **Lower energy bills.** Energy savings allow reducing the cost of energy to the building occupants.
- **Increased comfort.** Measures like improved insulation of buildings or more efficient air conditioners contribute in increasing the comfort of the building occupants.
- **Reduced operation and maintenance.** Energy efficiency can reduce O&M costs by reducing the frequency or intensity of work needed for addressing equipment, lighting, and building durability issues. For example, Cluett and Amann (2015) report a 17% decrease in O&M costs from air sealing, roof cavity insulation, and furnace replacement measures in a study of multifamily building program MBEE in the United States.
- **Reduced air emissions.** Some energy efficiency projects targeting biomass cookstoves can reduce drastically the level of harmful indoor emissions. Moreover, because the main source of

energy in buildings is generally electricity, some energy efficiency projects targeting appliances and lighting can mitigate GHG emissions and air pollution significantly, depending on the mix of fuels used directly and to generate power in the country considered.

- **Economic impacts.** The implementation of energy efficiency measures in the building sector often results in increases in job creation from local companies that have to implement the measures. In some cases, trainings on energy efficiency improvement and energy efficiency assessment are also necessary, increasing the labor impact.

4.4 RECOMMENDATIONS FOR INCLUSION OF MULTIPLE BENEFITS OF ENERGY EFFICIENCY IN MEASUREMENT & VERIFICATION

MBEE are often omitted from assessments of the benefit of energy efficiency programs for three main reasons: lack of data, lack of consensus for quantifying their impact and monetary values, and lack of resources to conduct the analysis. However, **MBEE contribute significantly to economic growth, social welfare, and environmental health, justifying efforts by policy makers and program administrators in overcoming these barriers and for including MBEE in evaluations of energy efficiency programs so that the social benefit of these programs can be optimized. In some cases, evidence has shown that when MBEE are accounted for, program's benefit-cost ratio is increased fourfold** (see examples in section 4.1.1, Recipient Benefits). Not accounting for MBEE may lead to suboptimized allocation of funds.

This recognition has led many national government agencies to increasingly integrate MBEE to inform energy efficiency policies and program investment decisions. Cost-benefit and appraisal methodologies are being updated to increase the number of MBEE being considered, quantified, and assessed. However, many gaps remain in practice and current scientific evidence is largely derived from studies in North America, Western Europe, and Oceania (mostly Australia and New Zealand).

Although the multitude of energy efficiency benefits makes clear the broad value of energy efficiency programs, it also creates challenges. A large number of benefits exist. A first selection must be applied to identify the benefits most relevant to a country's stakeholders and beneficiaries which correspond to the overarching goal(s) of the program. Information about benefits can also be used in different ways; how the information is used determines whether the benefits can simply be quantified in physical terms or must be expressed in monetary terms.

Once the most valuable or relevant benefit categories are selected for a given purpose, decisions must be made about how to measure the benefits and how to generate results that are robust enough to inform energy efficiency policy making. Continued research on the topic of MBEE has resulted in new modeling tools that can provide comprehensive benefits calculations and streamline the process. However, tools have typically been developed and used in the United States and the European Union, and rarely cover developing or emerging economies.

Based on this analysis, the following steps are recommended for incorporation of MBEE in analysis of energy efficiency projects:

1 | Identify the benefits most relevant to the overarching program's goals and to the counterparts

2 | Determine the goal of quantifying the benefits (advertising, stakeholder engagement, program decision, impact evaluation)

3 | Consider MBEE at the beginning of a program design and planning

4 | Determine the form in which benefits will be quantified (monetized or not)

5 | Develop the evidence base and establish reference studies, most likely based on randomized control trial (RCT) methods or willingness-to-pay surveys

6 | Streamline the quantification process by developing appropriate model and tools

Quantification of benefits require selecting a method. Less tangible benefits are sometimes quantified differently across countries (e.g., comfort level is estimated differently in the United States and United Kingdom). Comparison of methods and discussion about which method to apply in the context of developing countries can help to build a consensus around the method finally selected.

Although an increasing number of research projects and publications have recently studied MBEE, the focus had tended to be either on developed economies or global macroeconomic impacts. **Researchers and practitioners commonly agree that accounting for MBEE is especially essential for assessing low-income household energy efficiency results. The quantification of MBEE in developing countries could also have significant impacts for policy and investment decisions.**

Public sector interest in energy efficiency is expected to encompass multiple benefits, including social and economic. MBEE can help identify appropriate incentives to encourage assessment of energy efficiency projects. More research is in fact needed to explore MBEE for developing countries, to deepen understanding of the opportunities that MBEE offer society, to develop evidence and quantify MBEE in their context, to determine transferability of methods used in developed countries to developing countries context, and to develop models and tools to provide a robust base for rapid decision making.

ENDNOTES

[24]RCT studies randomly assign individuals to an intervention group or to a control group, in order to measure the effects of the intervention by comparing the results from both groups.

[25]The reliability of survey methods to monetize the value of benefits is the subject of much debate. Wobus et al. (2007) examine the range of methods for valuing nonenergy impacts and assess the benefits and constraints of each approach in the context of U.S. utility energy efficiency program assessments.

[26]"Access to energy is the ability to avail energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy & safe, for all required energy services across household, productive and community uses" (ESMAP 2014).

[27]Many countries have developed specific emissions factors.

[28]Estimates of rebound effects appear to vary widely depending on the type of equipment or energy use targeted, the magnitude of the efficiency improvements considered, and the class of consumers affected (see de la Rue du Can et al. 2015).

[29]See https://www.iea.org/topics/energyefficiency/beyondenergyefficiency/energyefficientprosperity/

[30]In municipalities, spending on public lighting can account between 10–40% of their overall energy bills.

[31]http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_whitepaper_nov2010.pdf


Parque
METROPOLITANO SIMÓN BOLIVAR
¡Peligro!
Lago profundo.
Prohibido entrar al agua

STEP-BY-STEP MEASUREMENT & VERIFICATION

Based on industry experience, literature review, the M&V protocols summarized earlier, and the review of projects, the following steps have been outlined. The following steps provide generic guidance on how to plan and implement M&V for energy efficiency projects and programs.

1 | **Role of Stakeholders.** Define the roles of different stakeholders with respect to M&V. This is particularly important to identify the energy efficiency benefits most relevant to each of the stakeholders. There are typically three main stakeholders: (a) energy efficiency project beneficiary, (b) energy efficiency project implementer, and (c) project/program administrator. With respect to M&V, measurement can be done by the project implementer or project beneficiary or by a third party. The verification has to be done by the project administrator or a third party engaged by the program administrator. The overall program evaluation should be done by a third party independent of the project proponent or program administrators.

2 | **Identify the relevant MBEE.** Energy savings is the primary goal of most energy efficiency interventions. Once the key stakeholders have been identified, identify the MBEE that may be most relevant and attractive to the stakeholders (using Table 1.1). The selection of M&V methods will depend on the MBEE, including energy savings, identified for the project.

3 | **M&V Methodologies.** Discuss and develop the M&V plan in close consultation with the project proponents (implementer and beneficiary) based on the particular features of the energy efficiency project and considering standard M&V protocols, namely, IPMVP or CDM methodologies for energy efficiency projects, such as AMS-II.C (demand-side energy efficiency for specific technologies) and AMS-II.L (demand-side activities for efficient outdoor and street lighting technologies). These are recommended as they are the most comprehensive, transparent, and flexible M&V methodologies. CDM-approved M&V methodologies for energy efficiency projects can be used for non-CDM projects, focusing the baseline and monitoring aspects of the methodologies (while other CDM-specific requirements can be ignored).

In general, it is still not common practice in developing countries for project implementing agencies to use internationally approved M&V protocols, as they tend to lead to additional project costs, and the implementing agencies are often not technically equipped to use the international protocols. However, particularly where energy savings or other benefits are to be monetized or form the basis of payment, these protocols can help strengthen energy efficiency projects. When feasible, it is also useful to consider building the capacity of the project stakeholders in understanding M&V.

The M&V plans come in all shapes and sizes and reflect upon the complexity and size of the project and the budget of M&V. For example, the retrofit isolation method involves narrowing of the measurement boundary to wrap tightly around the system, area, or equipment affected by an energy efficiency measure. The purpose is to reduce the effort required to understand and incorporate independent variables and static factors that affect site energy use but are unrelated to the energy efficiency measure. Though more accurate results may be obtained by avoiding complexity, tightening a boundary typically requires additional metering at the boundary edge, which may lead to increased M&V cost.

Ultimately, the project proponent should make a decision on how to conduct the M&V of the energy efficiency project at the design stage of the project and clearly lay out the M&V plan—along with the identification of factors which may trigger adjustments—for the life of the project.

4 | **M&V Plan Templates.** The M&V planning process and standard M&V templates are publicly available and can be useful references for developing project-specific M&V plans. There are useful M&V guidelines in the public domain: Measurement and Verification for Federal Energy Projects of the Federal Energy Management Program and Measurement and Verification Operational Guide of New South Wales Government have detailed M&V templates, which are easy to use (refer to Annexes 3 to 5 for further details.)

5 | **Activities before and after Implementation.** It is often recommended to carry out an energy audit—or a detailed investment grade energy audit (IGEA) where appropriate—before the implementation of energy efficiency measures and commissioning process (rather than after implementation). In fact, this is typically the case where energy savings performance contracts are involved. IGEAs help get a better perspective on the feasibility of the measures, thus helping in the decision-making process with respect to implementing energy efficiency retrofits. The IGEA cost should not exceed 10% of the annual utility bill (US DOE 2011). Commissioning is the quality assurance procedure upon implementation of the project. It is a systematic, documented, and collaborative process, which includes inspection, testing, and training to confirm that the energy efficiency project components meet their requirement. As a general rule, the commission cost represents approximately between 0.6% and 1.8% of the project cost (PECI 2002).

In case an IGEA is not possible, it is recommended to undertake a less intensive energy audit (or at a minimum, a walk-through energy audit). For some of the MBEE, additional information may have to be collected through qualitative surveys, focus group discussions, and other techniques.

6 | **Third-Party Verification.** It is typically recommended that the M&V activities should be carried out by an independent third party to ensure transparency in the M&V process. M&V by a third party gives unbiased and specialized evaluation of the system and energy performance of an energy efficiency project. At the same time, M&V services through the use of a third-party provider need to be weighed carefully between budget constraints and quality assurance.

7 | **Deemed Savings Approach.** The deemed savings approach consists of multiplying the number of installed measures by an estimated (or deemed) savings per measure, which is derived from historical evaluations. This approach is attractive because of its simplicity and lower associated costs. The Public Utility Commission of Texas used a deemed savings approach to estimate the savings generated from its residential lighting program, which involved retrofitting incandescent

lamps with CFLs.[32] However, the deemed savings approach typically has less precision (by definition) and thus may increase the level of uncertainty of the actual achieved energy savings. A deemed savings approach may nonetheless be appropriate if actual measurement is not possible for baseline development and energy savings calculations. **A deemed savings approach is often considered suitable in the case of projects where the key parameters are fairly constant.**

In order to address the higher uncertainty levels associated with deemed savings, it is typically recommended to use a conservative approach to address any risk of overestimation of impact. A slightly more complex approach to estimating savings—but more robust—is to use simplified, predefined calculations that employ a combination of deemed or "default" input assumptions with some site-specific inputs and/or sample measurements.

The deemed savings approach requires no further evaluation, M&V, engineering analysis, or market research provided that there is a mechanism to ensure that energy efficiency measures are indeed installed and operated in accordance with the measure description and technical requirements.

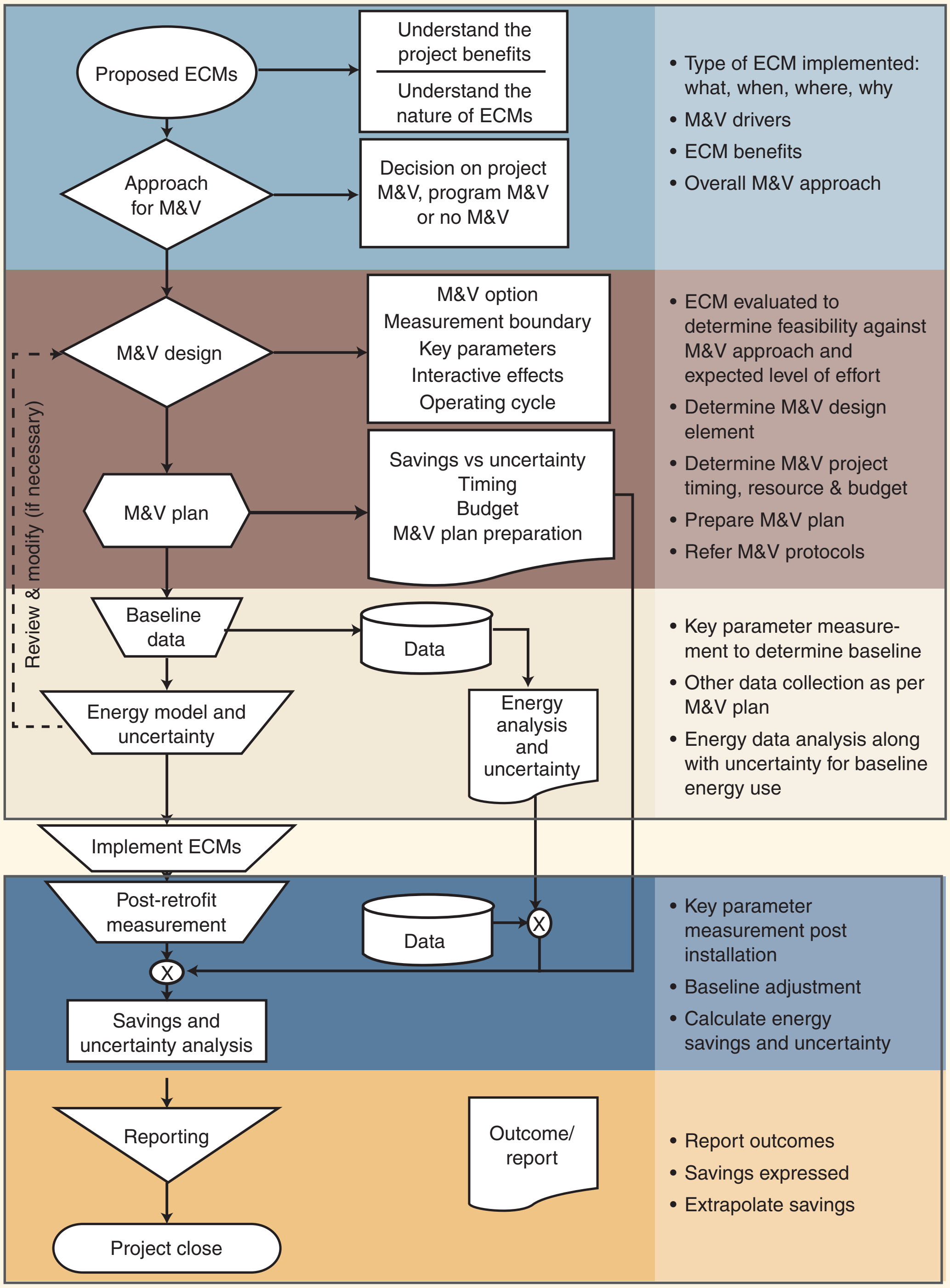
8 | **M&V Process.** At the beginning of the project, it is important to outline the M&V process. The process should be made as simple as possible. An illustrative flow chart is provided in Figure 5.1. The schematic highlights the logical process flow, main activities, their output, and quick reference notes. For example, once the decision on performing M&V is taken, the next logical step is M&V design. M&V design is the main activity. The outputs of M&V design are decisions on M&V option, measurement boundary, etc. The quick reference notes draw attention to important factors like the feasibility, level of effort, and so on.

9 | **Baseline Development.** A baseline study should be conducted before the onset of energy efficiency activities in order to establish the pre-installation exposure conditions of the outcome level indicators. This means determining ex ante the data to be collected and conducting relevant measurements and data/information gathering on the pre-energy efficiency project situation and energy use. (Although it is not uncommon—yet more challenging—for baseline studies to be conducted after the retrofit activities have already begun.) It is important to consider that in some cases there may be a need to make adjustments to the baseline (e.g., colder weather may involve changing assumptions for the energy needed to provide heating services). It is important to consider the possibility of such potential adjustments from the outset.

- **Baseline data/inventory:** A baseline study should mention all the categories and subcategories of parameters for which data are collected. An inventory of all equipment should be prepared to conduct the verification in the future. The source of the data should be recorded properly.
- **Identification of static factors:** Identify the static factors that will affect energy use in the measurement boundary but are not included in the routine adjustment. For example, for a lighting project, this could be a substantial change that might occur in the operating hours, or lux levels.

FIGURE 5.1

Measurement & Verification Flow Chart



Note | The term energy conservation measure (ECM) in this figure is equivalent to the term "energy efficiency measure" used throughout this report.

Source | NSW OEH 2012.

- **Measurement techniques:** It is recommended that a decision be made about the measurement techniques well in advance, and the barriers and challenges that might be faced should be listed.
- **Linkage with planned activities:** The baseline study should be closely linked with the critical aspects of the monitoring plan so that the data collected can be replicated, if necessary, during the ongoing activity monitoring and any subsequent evaluations. Baseline data should provide the minimum information required to assess the quality of the activity implementation and to measure the development results.
- **Clear goals and objectives:** It is recommended that the project's logical framework be reviewed to ensure that it is clear and well structured. Logical and precisely expressed outputs, component level objectives, purpose, and goal for an activity will assist data collection, making clear what needs to be measured.
- **Data management system:** Planning should include adequate provision for data collation and analysis, including appropriate staff, materials such as computer software and recording forms, data storage facilities, and a clear picture of who will need to access data and in what form.
- **Reconstructing baseline data:** In the event no baseline study was carried out prior to installation and completion of the project and no baseline data are available, reconstructing the baseline data is necessary, using secondary data, project records, and interviews.

10 | **Post-Implementation.** Post-implementation data must be collected using the same principles/techniques defined ex ante and as applied to baseline data collection so as to maintain uniformity in the data collection process and decrease the associated uncertainties. For example, in an energy efficiency street lighting project, it is advisable to use the same energy meter and sampling system to record baseline energy consumption and post retrofit energy consumption.

11 | **M&V Report.** Define the expected final M&V report outline at the beginning of the project.

- Use the details within the M&V plan to shape the report, including goals, expected outcomes, and measures for success.
- Use both words and diagrams to demonstrate the savings.
- Add pictures that demonstrate the energy efficiency measures on-site and the process for conducting measurements.
- Describe step-by-step data analysis and savings calculations. Add equations with explanations if they are unfamiliar to the audience.
- Report savings figures using an appropriate number of significant digits.
- Note that "actual" savings can only be stated for the post-implementation measurement period. Any extrapolation beyond this is considered an estimate.

12 | **Risk and Responsibility Matrix.** A risk and responsibility matrix should be included clearly highlighting the risk and responsibilities associated with M&V along with an approach to complete the responsibilities.

13 | **Continuous M&V.** Instead of a onetime M&V approach, it is preferable to use continuous monitoring with the help of technologies such as energy management systems (EMS) and central control and monitoring systems where appropriate and feasible. Verification activities can be performed at regular intervals. This approach will help the beneficiary in sustainable energy efficiency. However, continuous M&V comes at a cost. It is important to perform a proper cost–benefit analysis before committing to invest in it. In most projects where such sophisticated equipment is installed, it is considered an energy efficiency measure in its own right with a specific payback and, thus, is not included in the cost of M&V. Annex 6 provides a short note on the recent advancements in technologies that could be useful in conducting M&V.

14 | **Impact Evaluation.** Apart from project-specific M&V, it is recommended to undertake overall program impact evaluation for multiple projects within the same portfolio. The impact evaluation will estimate the net change in electricity usage, demand, and also the behavioral impacts that are expected to produce change in the energy use. This means the impact evaluation will estimate the direct impact (i.e., energy savings), and the indirect impact in the form of behavioral changes that will lead to energy savings, as well as other potential associated impacts.

15 | **Rebound Effect (and MBEE).** A rebound effect is frequently observed in energy efficiency projects, although the magnitude is often not so large and does not overwhelm the savings from the project. It is often advisable to focus on the economic efficiency of the project in a broader sense rather than focusing on the rebound. Instead of considering the rebound effect as a deterrent or negative aspect of energy efficiency projects, efforts should be made, as mentioned above, to include the social and economic MBEE associated with energy efficiency interventions in the impact evaluation. Particularly, in the context of developing countries, consideration of energy efficient prosperity, as suggested by the IEA, may be relevant.

ENDNOTE

[32]Details of the methodology can be found in *Texas Technical Reference Manual Volume 2: Residential Measures Guide for PY2015 Implementation.*

ANNEX 1 | LEXICON

Actual Peak Reduction: The actual peak reduction in the annual peak load (measured in kilowatts) achieved by customers that participate in a utility demand-side management (DSM) program. It reflects the changes in the demand for electricity resulting from a utility DSM program that is in effect at the same time the utility experiences its annual peak load, as opposed to the installed peak load reduction capability (i.e., potential peak reduction).

Adjusted Gross Savings: Gross energy savings that are adjusted to include what can be physically counted and reliably measured, such as installation/in-service rates, breakage of equipment, data errors, hours of use, measure persistence rates, and so on. Adjusted gross savings can also be calculated by applying a realization rate to gross savings estimates. Most regions determine adjusted gross savings through M&V activities, although the M&V methods vary substantially.

Baseline: Baseline is the starting condition or metric against which the result of an intervention is evaluated. For energy efficiency projects, it can be defined as the level of energy consumption that occurs prior to implementation of energy efficiency measures. This can also be referred to as "business-as-usual," if the baseline demonstrates independent change in the level of energy consumption, prior to or during, implementation of energy efficiency projects or programs. The baseline condition takes into account whether the measure is replacing equipment at burnout versus retrofitting or changing the performance of existing equipment that has substantial remaining service life. The baseline can also represent typical business-as-usual conditions for greenfield energy efficiency interventions.

Baseline Adjustment: The nonroutine adjustments arising during the post-retrofit (or post commissioning) period that could not be anticipated (and may require custom engineering analysis).

Base Year: The period serving as the reference point to assess the impact/performance of implementation of an energy efficiency measure or action. The "base year" may be limited to a single season if the measure's impacts are not observable in multiple seasons.

Benchmarking: It is a method for measuring the energy performance of a building, process (e.g., industrial process) or a program through the tracking of the energy use of a building, process or a program and then comparing it to the average for a similar building, process or program. Benchmarking allows direct comparisons of the energy use by accounting for variables such as local climate, area, patterns of use, operating hours and behavioral changes.

Deemed Savings: A predetermined, validated estimate of energy and peak demand energy savings attributable to an energy efficiency measure in a particular type of application that may be used in lieu of direct measurement and verification activities. Also called "stipulated" energy savings.

Demand-Side Management: Demand-side management (DSM) typically involves utility-sponsored activities designed to save electricity or gas through shaving the peaks during different times of the day. The ultimate goal of DSM for most utilities is to avoid the need to invest in new power plants or other equipment.

Energy Audit: An energy audit is an assessment of current energy performance of an industry, building, process, equipment, or entity, which is conducted to determine and prioritize energy-saving improvements.

Energy Conservation: Conservation is the process of preserving or using wisely. With respect to energy, conservation is reduction in energy-using behavior leading to using less energy services and to energy savings. It differs from energy efficiency in the sense that energy efficiency refers to energy reduction without sacrificing services.

Energy Conservation Measure: An energy conservation measure (ECM) is a project conducted or technology implemented that reduces the consumption of energy in a facility, industry, equipment, process or entity.

Energy Efficiency: Energy efficiency is the ratio of the energy service provided by a system to the energy put into it. Services provided can include building-sector end uses such as lighting, refrigeration, and heating; industrial processes; or vehicle transportation. Unlike conservation, which involves some reduction of service, energy efficiency provides energy reductions compared to a baseline without sacrifice of service.

Energy Efficiency Program: Energy efficiency programs are a collection of similar projects that are intended to motivate customers in a specific market segment to implement more energy-efficient technologies and measures.

Energy Efficiency Projects: An energy efficiency project is an activity or course of action involving one or multiple energy efficiency measures at a single facility, industry, site or program.

Energy Efficiency Certificate: An energy efficiency certificate is a document or a seal certifying the authenticity of an electric appliance or a system for being energy efficient. Examples of such certificates are the "Energy Star" on appliances and Leadership in Energy and Environmental Design (LEED) certificates (silver, gold, platinum, etc.) for buildings. "White certificates," a type of energy efficiency certificates, are tradable instruments giving proof of the achievement of end-use energy savings through energy efficiency improvement initiatives and projects.

Energy Management System: An energy management system (EMS) is the mechanism to monitor, control, and optimize the performance of any energy system.

Energy Performance Contract: A contract between two or more parties where payment is based on achieving specified results, typically, guaranteed reductions in energy consumption and/or operating costs. Also known as energy savings performance contract (ESPC).

Energy Savings Performance Contract: An energy savings performance contract (ESPC) is a form of "creative financing" for capital improvement, which allows funding energy upgrades from energy cost reductions. Under an ESPC arrangement, an energy service company (ESCO) typically implements a project to deliver energy efficiency, or a renewable energy project, and uses the stream of income from the cost savings, or the renewable energy produced, to repay the costs of the project, including the costs of the investment.

Energy Service Company: An energy service company (ESCO) is an organization that provides energy efficiency and DSM-related services to facilities, utilities, industries, and other energy-consuming establishments.

Free Ridership or Freeriders: The impact of customers targeted by a program who are tracked and measured by the program, but who would have adopted the recommended practice or measure in the absence of the program. Freeriders, if present and measured, will decrease a program's overall impacts and cost effectiveness.

Free Drivers: Customers that install the energy efficiency measure as a result of the indirect effects of the energy efficiency program but never collect a rebate or incentive.

Gross Energy Savings: The change in energy consumption and/or demand that results directly from program-related actions taken by participants in an efficiency program, regardless of why they participated. This is the physical change in energy use after taking into account factors not caused by the program (e.g., changes in weather or building occupancy).

Impact Evaluation: The process of measuring the effects and predicted longevity of an energy efficiency, water efficiency, or renewable energy program with sufficient confidence and precision upon which to evaluate cost effectiveness and to validate investment decisions.

Investment Grade Energy Audit: An investment grade energy audit is a comprehensive analysis of potentially priced energy efficiency improvements with a distinct focus on financial concerns and return on investment.

Key Performance Indicators: Key performance indicators (KPI) are metrics that are used to evaluate factors that are crucial to the success of a program/project. The KPIs differ for different programs. As an example for energy efficiency, the KPIs may be energy saved, payback period, etc., or they can also be social development and improved access to energy.

Market Evaluation: Market evaluations are assessments of the structure or functioning of a market, the behavior of market participants, and/or market changes that result from one or more energy efficiency programs. Market evaluations indicate how the overall supply chain and market for energy efficiency products work and how they have been affected by a program.

Measurement and Verification: Measurement and verification (M&V) is the process for quantifying energy savings from individual sites or projects (through data collection, monitoring, and analysis) and ensuring that the energy savings are being generated with a certain degree of confidence. Since savings cannot be directly measured, the M&V methodology is based on developing a plan to gather measurements on variables that are affected by the implementation of the energy efficiency project or measure. M&V can be a subset of program evaluation.

Measurement Boundary: (i) The virtual contour of a device or system separating a set of processes considered to be relevant, in terms of an energy efficiency improvement action, from those that are not relevant. All the energy consumed by the equipment or system(s) within the measurement boundary must be measured or estimated. (ii) A notional boundary that defines the physical scope of an M&V project. The effects of an ECM are determined at this boundary.

Metering: Collection of energy and water consumption data over time at a facility through the use of measurement devices.

Multiple Benefits (of Energy Efficiency): The term multiple benefits aims to capture the many different benefits to different stakeholders as a result of investment in energy efficiency, apart from the energy saved and monitory benefits, which are often overlooked. Multiple benefits are also referred to as "co-benefits," "ancillary benefits," and "non-energy benefits."

Net Energy Savings: Net energy or demand savings are the change in energy consumption and/or demand that is attributable to a particular energy efficiency program. Estimating the net energy savings typically involves assessing free ridership and spillover.

Net-to-Gross: An adjustment to overall program impacts that corrects for free drivers and freeridership effects.

Payback Period: A payback period, in the energy efficiency industry, is the ratio of the estimated total cost of an efficiency measure divided by its annual financial savings. This figure is one way to determine whether an energy efficiency measure is cost effective. More sophisticated versions of this calculation may take interest rates and discount rates into account.

Protocols: Protocols are sets of rules or guidance documents that aim to standardize procedures across different economies. In the energy efficiency sector, the term most commonly refers to measurement and verification protocols that are used to evaluate energy efficiency projects/programs.

Rebound Effect (Take-Back Effect): Rebound effect is the term used to describe the effect that the lower costs of energy services, due to increased energy efficiency, has on consumer behavior both individually and nationally. It is essentially the extent of the energy saving produced by an energy efficiency investment that is taken back by consumers in the form of higher consumption, typically in the form of more hours of use. It may also take the form of a higher quality of energy service.

Satisfied Energy Demand: Satisfied energy demand is the level of energy services that would be reached with access to better quality and more affordable services, and that would be adequate and reasonable for households (usually rural) to meet their basic needs (i.e., satisfied demand is seen when the income effect and energy cost effect are overcome).

Spillover: Additional energy efficiency measures implemented by an energy customer that were induced due to participation in an efficiency incentive program. Nonparticipant spillover comprises action influenced by an energy program but not linked to participation.

Suppressed Energy Demand: Suppressed energy demand is the situation where energy services provided are insufficient for necessary human development (due to poverty or lack of access to modern energy infrastructure) or only available to an inadequate level.

ANNEX 2 | COMPARISON M&V—EM&V—MRV

TYPES	MEASUREMENT AND VERIFICATION (M&V)	EVALUATION, MEASUREMENT, AND VERIFICATION (EM&V)	MEASUREMENT, REPORTING, AND VERIFICATION (MRV)
Origin	In a reaction to the lower-than-expected investments in energy efficiency in the 1990s related to high uncertainty associated with future energy savings, the US Department of Energy and Lawrence Berkeley National Laboratory initiated an effort in 1994 to establish an international consensus on methods to determine energy/water efficiency and promote third-party investment in energy efficiency projects. The effort also sought to help create a secondary market for energy efficiency investments (EVO website). This led to the publication of the North American Energy Measurement and Verification Protocol (NEMVP) in 1996. The 1997 updated version was renamed the International Performance and Verification Protocol.	EM&V evolved to carry out impact evaluation of the energy efficiency program portfolios implemented by the investor-owned utilities (IOUs) in the United States. The earliest such efforts involved project-based measurement and verification (PB-MV) of individual projects; this was followed by an evolution and improvement in practices for a broad range of energy efficiency program strategies and delivery mechanisms across sectors.	The term MRV has its origin in the international climate change negotiations. It was coined in the 2007 Bali Action Plan (Para. 1b), bringing together all aspects pertaining to transparency in the climate regime, including, but not only, the implementation of GHG mitigation activities.
Definition	M&V activities comprise the documentation of energy or demand savings at individual sites or projects using options that involve measurement, engineering calculations, analysis, simulation modeling, etc.	EM&V is the collection of methods and processes used to assess the performance of energy efficiency programs to measure the energy or demand savings, and to determine if the program is generating the expected level of savings (US DOE website). The addition of "evaluation" refers to an independent process to determine the success and cost effectiveness and to capture lessons.	In the context of the UNFCCC, MRV is a term used to describe all measures that states take to collect data on emissions, mitigation actions, and support, to compile this information in reports and inventories, and to subject these to some form of independent review or analysis. It cover countries' quantitative estimates of GHG emissions (which may be associated with several measures, including EE) (measuring), communication of progress in achieving objectives, and implementing climate change-related activities (i.e., reporting), and procedures to ensure that the reported information is prepared in accordance with agreed methodologies (verification), which often involves some form of third-party (international) review or analysis.

TYPES	MEASUREMENT AND VERIFICATION (M&V)	EVALUATION, MEASUREMENT, AND VERIFICATION (EM&V)	MEASUREMENT, REPORTING, AND VERIFICATION (MRV)
Scope	M&V typically applies to energy efficiency projects. It can cover all types of energy efficiency activities (e.g., in residential as well as industrial sectors).	While EM&V can be used for both projects and programs, it is a process typically adopted in the context of programs. It covers all types of programs seeking to enhance energy efficiency (e.g., incentive schemes, DSM programs).	MRV is associated with the transparency and accountability of GHG mitigation actions (including energy efficiency as well as all other mitigation and sequestration activities) and financial and technical support for mitigation. In the specific case of mitigation actions through EE, MRV can apply to projects and programs.
Stakeholders	Project owner, project implementer, project funder	Government bodies, project administrators, utilities	International community, governments, stakeholders of market-based mechanism, project implementer, project owner

ANNEX 3 | LIST OF MONITORING & VERIFICATION PROTOCOLS

UTILIZATION	EXAMPLES OF M&V PROTOCOLS OR GUIDELINES	DESCRIPTION
Individual Energy Efficiency Project M&V	IPMVP ASHRAE Guideline 14 Federal Energy Management Program (FEMP) Australia's BPG M&V Fide's Mexico M&V Guide ClubS2E (France—energy efficiency stakeholders) Measurement & Verification Process for Calculating and Reporting on Energy and Demand Performance (CEM)	Protocols or guidelines for evaluating energy savings for a single energy efficiency project implemented in an industrial enterprise or building (e.g., a project implemented by an ESCO). This could be based on a measure-isolation approach or a whole-facility approach.
Energy Efficiency Program Evaluation	The California Evaluation Framework, 2004 California Energy Efficiency Evaluation Protocol, 2006 National Energy Efficiency Evaluation, M&V Standard, USA LBL Model Energy Efficiency Program Impact Evaluation Guide, US EPA Evaluation and Monitoring for the EU directive on Energy End-Use Efficiency and Energy Service, Intelligent Energy Europe, 2009 prEN 15900 Energy Efficiency Services (Europe) Energy Efficiency Program Impact Evaluation Guide, US Department of Energy (US DOE), SEE Action program, 2012 Arkansas EM&V protocol Common State-wide Energy Efficiency Reporting Guidelines (not M&V per se but an integration of different states' savings; may be of interest to such a large country as China, India) There are many other protocols and guidelines that, though they share similar basic concepts and principles, are adapted to specific contexts of individual jurisdictions.	Protocols or guidelines for evaluating real energy savings generated by energy efficiency programs. The program evaluation includes several components, one of them being the energy savings impact evaluation. Different evaluation techniques may be used to demonstrate the savings achieved. Performing M&V on a sample of or all the projects included in the program is one of them.
Nationwide/Region-wide Tracking of Trends in Energy Use Indices or Energy Intensity	CIPEC program, the Canadian government (voluntary) Dutch Long-term Agreements (LTAs) (voluntary) Since many countries track these indicators, there are many more examples.	Procedures for calculating energy intensity performed by government ministries, statistical agencies, or research institutions. Could be voluntary initiatives or government regulation to collect energy consumption information.

UTILIZATION	EXAMPLES OF M&V PROTOCOLS OR GUIDELINES	DESCRIPTION
Emergency Management Systems for Organizations	ISO 50001 Energy Management System (Global) EN16001—Energy Management Standard (Europe)	Energy management processes and procedures implemented in an organization to monitor energy performance. The energy performance indicators (EnPIs) can be based on energy units or on other units (e.g., COP for chillers). The energy measurement system is only one component of a larger long-term initiative in a facility or organization. In some organizations, the data collected and organized within the framework of the EMS can be used to conduct M&V of energy savings.
Climate Change—Emission Trading Scheme; Monitoring, Reporting, Verification (MRV)	World Resource Institute (WRI), Greenhouse Gas Protocol, World Business Council for Sustainable Development European Union Méthodologies (EU ETS) Western Climate Initiative (WCI) New Zealand ETS US Northeast and Mid-Atlantic State Regional Greenhouse Initiative (RGGI) California ETS (Cal ETS) Australia "Clean Energy Future" Carbon Pricing Mechanism Tokyo Cap-and-Trade Program (Tokyo C&T) Perform, Trade, Achieve (PAT) India Climate Action Reserve ODS Project Protocol VCS Recovery and Destruction of ODS from Products	Protocols for measuring emission reductions. Often included as part of an emissions trading scheme (ETS). For energy efficiency projects submitted as part of the ETS scheme, there is always an M&V component to calculate energy savings. These savings are then converted into emission reductions.
Energy Efficiency Certificate Exchange/Trading Schemes (White Certificates)	Italian White Certificate Scheme French White Certificate Scheme UK Energy Efficiency Commitment Scheme	Protocol for measuring energy efficiency achieved by individual projects or programs. They are used in the context of white certificate schemes.

Source | *World Bank 2013.*

ANNEX 4 | SUMMARY OF MONITORING & VERIFICATION PROTOCOLS

International Performance Measurement and Verification Protocol (IPMVP): IPMVP Volume I is an international measurement and verification (M&V) protocol describing different methods to determine water and energy savings of energy efficiency projects. IPMVP was first published in 1996 under the name of North American Energy Measurement and verification protocol (NEMVP).

It was first developed by a volunteer committee under the United States Department of Energy (US DOE). Since 2001, the committee in charge of IPMVP has developed into Efficiency Valuation Organization (EVO), a not-for-profit organization to improve the protocol's content and promote its use.

IPMVP is in its fourth version of publication and is translated into more than 11 languages, describing the common practices of savings measurement, calculations, and follow-up of energy or water efficiency projects. IPMVP presents four M&V options to evaluate a project's savings and the activities include on-site studies, energy or water flow measurements, and follow-up of independent variables, calculations, and reports. It also presents the M&V principles, the structure of an M&V plan, and explanations on measurement boundaries, adjustment bases, measurement period, and reporting (EVO 2012).

M&V methods prescribed in IPMVP are presented in Table A4.1.

IPMVP presents a framework for transparent, reliable, and consistent reporting on the project's savings, which can be used to develop M&V plans for projects. IPMVP Volume 1 is a support document describing common practices in measurement, calculation, and monitoring of savings achieved by energy efficiency or water projects at end-user facilities (which are generally buildings, plants, or factories, but can also be public lighting systems and municipal water distribution networks). M&V activities include studies of energy efficiency measures implemented at sites, measurement of the flow of energy or water, identification of independent variables that affect energy usage, baseline modeling, and savings calculation and reporting. M&V activities carried out by adhering to the IPMVP can help ensure establishing conservative, transparent, and verifiable savings.

IPMVP consists of three parts as follows:

- Volume 1 describes the current practices in terms of measuring, calculating, and monitoring the savings generated by Energy Efficiency Improvement Actions. It defines the terminology to be used in the M&V Plan, as well as the procedures allowing an economically viable determination of the energy efficiency savings.
- Volume 2 is devoted to the internal environmental quality of buildings, in particular the quality of indoor air, insofar as their appearance may be influenced by the S2E project.
- Volume 3 describes the concepts and practices for the determination of energy savings in new buildings and gives further implementation examples.

TABLE A4.1
IPMVP M&V Guideline Approaches

APPROACH	DESCRIPTION
Option A: Retrofit isolation—key parameter measurement	Key performance parameters are measured that define the energy use of the ECMs and contribute to the project. The measurements can be for a short duration or continuous in nature depending on the expected variations in the measured parameter and length of the reporting period. Parameters that are not measured are estimated, and these estimates may be based on historical data or on the manufacturer's specifications along with the source.
Option B: Retrofit isolation—measurement of all parameters	This option is more detailed than Option A in the sense that all the parameters required to calculate energy savings of the ECMs have to be measured. This usually means measuring energy consumption and operating hours.
Option C: Whole facility	In this approach, energy savings are determined by measuring the energy consumption for an entire facility or sub-facility. Electric, gas meter, and utility billing data are used to determine the baseline for energy savings calculations. The measurement is continuous for the entire length of reporting period.
Option D: Calibrated simulation	Computer simulations of energy consumption of the entire facility or sub-facility aided by software are used to determine the energy savings. Usually used when multiple systems affect the facility energy use and no meters exist in the baseline period. Baseline energy use, determined using the calibrated simulation, is compared to a simulation of reporting period energy use.

Source | *EVO 2012; World Bank 2013.*

Comment: IPMVP provides a comprehensive framework for M&V and has become the de facto M&V standard in many countries, including the United States. IPMVP helps develop transparent and robust M&V plans, though the level of emphasis varies from region to region.

Federal Energy Management Program (FEMP): FEMP M&V Guidelines were launched in the United States to help the federal government agencies measure and verify energy savings achieved in federal buildings. FEMP provides guidelines and methods for measuring and verifying energy, water, and cost savings obtained from a performance contract targeting federal buildings. The United States Energy Policy requires federal buildings to reduce their energy intensity. Hence, to assist federal agencies in reducing energy and cost of their building, FEMP was developed. FEMP is basically an application of IPMVP for federal buildings. It contains procedures and guidelines for quantifying the savings resulting from cogeneration, renewable energy, water conservation, and energy efficiency equipment projects.

Version 2.2 of the FEMP M&V Guidelines was developed to provide methods and specific guidelines for the M&V of energy savings achieved through an energy performance contract targeting a federal building. Version 3 of the FEMP M&V Guidelines was published in 2008. It contains procedures and guidelines for quantifying savings achieved by projects in cogeneration, renewable energy, water conservation, and energy-efficient equipment.

Currently (as on June 2015) in the draft stage, Version 4.0 includes revised definitions of the four main M&V options and provides a tighter overall presentation by moving much of the auxiliary material to

TABLE A4.2
FEMP M&V Guideline Approaches

APPROACH	DESCRIPTION
Option A: Retrofit isolation—key parameter measurement	Key performance parameters are measured that define the energy use of the ECMs and contribute to the project. The measurements can be for a short duration or continuous in nature depending on the expected variations in the measured parameter and length of the reporting period. Parameters that are not measured are estimated, and these estimates may be based on historical data or on the manufacturer's specifications along with the source.
Option B: Retrofit isolation—measurement of all parameters	This option is more detailed than Option A in the sense that all the parameters required to calculate energy savings of the ECMs have to be measured. This usually means measuring energy consumption and operating hours.
Option C: Whole facility	In this approach, energy savings are determined by measuring the energy consumption for an entire facility or sub-facility. Electric, gas meter, and utility billing data are used to determine the baseline for energy savings calculations. The measurement is continuous for the entire length of the reporting period.
Option D: Calibrated simulation	Computer simulations of energy consumption of the entire facility or sub-facility aided by software are used to determine the energy savings. Usually used when multiple systems affect the facility energy use and no meters exist in the baseline period. Baseline energy use, determined using the calibrated simulation, is compared to a simulation of reporting period energy use.

stand-alone documents. It also includes a new section that provides general M&V guidance for the majority of the standard energy conservation measures and water conservation measures typically implemented in federal energy savings performance contracts (ESPC) (US DOE 2008).

M&V methods prescribed in the FEMP are presented in Table A4.2.

FEMP is an application of IPMVP for federal buildings with detailed guidelines and examples on the approaches applicable to certain energy conservation measures normally found in federal buildings. Unlike other protocols that only present a general framework, FEMP provides specific measurement plans adapted to most common measures implemented in buildings.

Comment: FEMP is limited to the United States and is exclusively used for measuring and verifying energy savings achieved in federal buildings through energy efficiency activities. FEMP and IPMVP are complementary documents. FEMP M&V Guide is an application document based on the 1997 version of IPMVP specifically prepared for the federal building sector in the United States. FEMP M&V Guide also provides a more detailed guidance on the application of different M&V options for specific energy conservation measures common in federal buildings.

ASHRAE Guideline 14: The ASHRAE Guideline 14 was published in April 2000 with the aim to standardize the energy savings calculation procedures. This guideline can be considered a more technical version of IPMVP. The guideline provides three approaches to energy savings as presented in Table A4.3.

TABLE A4.3
ASHRAE Guideline 14 M&V Options

APPROACH	DESCRIPTION
Option A: Whole building approach	This approach uses the main energy meter normally installed by the electricity, gas, oil, or hot water utility. Measures of energy conservation can address one or more subsystems in the building. It is often necessary to use billing history to define the baseline.
Option B: Retrofit isolation approach	This approach uses measuring devices to isolate the energy consumed by sub-systems affected by the extent of energy conservation. The baseline is determined from the observed measurements before installing the ECM. All parameters must be measured.
Option C: Whole building calibrated simulation approach	This method applies to an entire building; computer software is used to create a simulation model of consumption and energy demand for the building. Parameters affected by ECM are changed in the model to increase the accuracy level of energy savings results.

Source | *NRCan's CanmetENERGY (2008).*

The ASHRAE Guideline requires measurement of all parameters; estimation is not permitted. It requires that an uncertainty analysis be introduced and discussed for each measurement plan as well. The guideline is well developed, detailed, and exhaustive, hence less flexible and can be difficult to use for someone who is not an M&V expert. Also due to it exhaustive nature, the M&V cost will tend to be high and hence not very suitable for simple projects (ASHRAE 2002).

Comment: The ASHRAE Guideline 14 is comprehensive and provides thorough technical description of M&V. Though detailed and well developed, Guideline 14 is not extensively used by energy service companies (ESCO) or M&V practitioners for the following reasons:

- The AHSHRAE Guideline 14 has to be purchased, as opposed to other protocols that can be downloaded for free.
- Being a highly technical document, it is considered too academic and hence not practical for everyday M&V activities.
- It is considered less flexible as there is no room for stipulation or limited metering (World Bank 2013).

CDM Methodology—AMS-II.C (Demand-side energy efficiency activities for specific technologies) and AMS-II.L (Demand-side activities for efficient outdoor and street lighting technologies): The Clean Development Mechanism (CDM) requires the application of a baseline and monitoring methodology in order to determine the amount of certified emission reductions (CER) generated by a mitigation CDM project activity in a host country (UNFCCC 2016). "Methodologies for small-scale CDM project activities" is relevant to DSM activities in the public sector. AMS-II.C is for demand-side energy efficiency activities for specific technologies such as lamps, ballasts, refrigerators, motors, fans, air conditioners, pumping systems, and chillers. AMS-II.L is meant for demand-side activities for efficient outdoor and street lighting technologies. The CDM methodology document provides the user with necessary guidelines to develop and implement an M&V plan per the CDM criteria so as to qualify for emission reduction certificates. The main contents of the guideline documents are scope and applicability, normative references, definitions, baseline methodologies, and monitoring methodologies.

Comment: AMS.II.C and AMS.II.L are very comprehensive documents. The documents provide definitions and calculation methodologies for baseline development along with monitoring techniques. The project proponents need to follow these guidelines in carrying out the M&V of energy efficiency projects to qualify for emission reduction certificates.

Australia's Best Practice Guide to Measurement and Verification of Energy Savings: This best practice guide was developed by the Australian Energy Performance Contracting Association (AEPCA) with the support of the Innovation Access Program (IAccP) in 2004. This guide is almost similar to IPMVP with respect to M&V options. It also uses ASHRAE and FEMP guidelines for uncertainty and cost evaluation of M&V benefits (NRCan's CanmetENERGY 2008). The guide aims to encourage development of energy efficiency projects in Australia with primary focus on energy savings performance contract.

Comment: The Best Practices Guide is mostly used in the Australian continent.

TABLE A4.4

GSEP M&V Methodologies

METHODOLOGY	DESCRIPTION
Stipulated	This methodology employs highly probable assumption (preferably a known fact) that has been agreed on in writing by all stakeholders as part of the M&V plan. (For example, the time period in which lighting systems will be operational can be stipulated due to it being controlled with timers or building management systems.)
Measurement	This methodology implies that the parameter in question will be physically measured using approved, calibrated measurement instruments and appropriate measurement periods. The measurement period should be long enough to capture the major energy-governing factors within the facility/boundary, i.e., the measurement period should fairly represent all operating conditions of a normal operating cycle. The length of the reporting period should be determined with due consideration of the life of the EE measure and the likelihood of degradation of originally achieved savings over time.
Inference	In this methodology, a suitable parameter is inferred when its value is determined by relating this (unknown) parameter to some other (known) parameter or parameters. There are two circumstances under which this method (inference) can be used: • When the fundamental relationship(s) is/are known. • When a relationship may be extracted from a data set.
Simulation	This method is a detailed computer simulation of the system (or components of the system) using commercially available simulation packages. Simulation can be particularly useful in cases where the interaction between variables is present and required.

Measurement & Verification Process for Calculating and Reporting on Energy and Demand Performance—General Guidance: The Global Superior Energy Performance (GSEP) Energy Management Working Group published this guide in September 2014 with the aim to help organizations around the world assess the impacts of energy efficiency projects. The guide provides a framework to develop consistent project-specific M&V plans. The guide defines three standard parameters (i.e., operating hours, load, and system efficiencies) essential from an energy saving's point of view and presents four methodologies to obtain these parameters.

Section II of the guide provides a framework for developing a project-specific M&V plan along with templates and flowcharts walking the user through the process.

Measurement and Verification CLUBS2E: This guide is created by CLUBS2E (France) with the aim to make it easier to adopt and implement IPMVP protocol. The intention of this guide is to integrate the broad scope of IPMVP into a documentary context for the purposes of presentation and assistance with implementation.

The California Evaluation Framework: This framework was published in June 2004 by the California Public Utilities Commission (CPUC). The framework provides an approach for planning and conducting evaluation of California's energy efficiency programs.

The framework provides a systematic approach to conduct evaluation so that all programs are able to document their effects and compare to other programs and supply options.

The framework covers key concepts and considerations required for planning and conducting evaluation of energy efficiency programs. The framework details the following nine components required for performing program evaluation:

- Impact evaluation, and M&V approaches
- Process evaluation
- Information and education program and evaluation
- Market transformation program evaluation
- Nonenergy effects evaluation
- Uncertainty
- Sampling
- Evaluation and cost effectiveness
- The use of evaluation roadmap

Comment: The California Evaluation Framework forms the backbone of the California Energy Efficiency Evaluation Protocols.

California Energy Efficiency Evaluation Protocols (Evaluators Protocols): Published in April 2006, the protocols are the primary guiding tools for policy makers to plan and structure evaluation efforts for energy efficiency programs. The protocols are significantly grounded in the California Evaluation Framework of June 2004 presented on the previous page.

The evaluation types covered include the following: direct and indirect impact (including the associated M&V approaches), market effects, emerging technology, codes and standards, and process evaluations. This document includes a separate protocol for each of the following categories:

- Impact evaluation—direct and indirect effects
- M&V (IPMVP)
- Process evaluation
- Market effects evaluation
- Codes and standards program evaluation
- Emerging technology program evaluation
- Sampling and uncertainty protocol (for use in determining evaluation sampling approaches), reporting protocol (to guide evaluation data collection and reporting)
- Effective useful life protocol (used to establish the period over which energy savings can be relied upon)

Comment: The protocol is used by program evaluators to conduct evaluations of California's energy efficiency programs and program portfolios. It is also used by policy makers to plan and structure evaluation efforts.

National Energy Efficiency Evaluation, Measurement and Verification (EM&V) Standard: Scoping Study of Issues and Implementation Requirements: Prepared and published in April 2011 by the Ernest Orlando Lawrence Berkeley National Laboratory (LBNL) and prepared for the United States Government, this document presents a study on the scope of developing national-level EM&V standards. The document provides the following:

- A set of definitions applicable to an EM&V Standard
- A literature review of existing standards guidelines related to EM&V and evaluation of bottom-up versus top-down evaluation approaches
- A summary of EM&V-related provisions of the federal legislative proposal that includes national (US) efficiency resource requirement
- An annotated list of issues that are likely to be central to and need to be considered as part of developing a national EM&V standard for energy efficiency

The document identifies four high-level issues associated with developing national EM&V standards and proceeds to nine issue topic categories that, if addressed and resolved, would take care of the high-level issues.

The document also provides brief summaries of a few selected EM&V guidelines, protocols, and standards and concludes with a draft outline for EM&V national standards.

Model Energy Efficiency Program Impact Evaluation Guide: The guide was published in November 2007 as part of the National Action Plan for Energy Efficiency (US). The guide provides guidance on model approaches for calculating energy, demand, and emissions savings resulting from energy efficiency programs.

It aims to assist utilities, utility regulators, and others in the implementation of the National Action Plan for Energy Efficiency and the pursuit of its long-term goals.

The guide describes a structure and several model approaches for calculating energy, demand, and emissions savings from facility energy efficiency programs that are implemented by cities, states, utilities, companies, and similar entities.

It provides direction on evaluation process and key issues related to documenting, energy and demand savings, avoided emissions, and comparing demand- and supply-side resources. The guide also discusses the evaluation planning issues as well as presents some evaluation plan outlines.

Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services (EMEEES): The EU Directive on Energy End-Use Efficiency and Energy Services, also known as Energy Service Directive (ESD), requires the member states to achieve the annual energy savings targets of 9% or more. EMEEES assists the European Commission in developing methods to evaluate the measures implemented to achieve the energy savings targets set out by the ESD.

EMEEES has prepared a general method for bottom-up and top-down calculation methods plus guidelines for ensuring consistency between the results of bottom-up and top-down calculations. The bottom-up method starts from data at the level of a specific energy efficiency improvement measure (e.g., energy savings per participant and number of participants) and then aggregates results from all the measures. The top-down method starts from the global data (e.g., national statistics for energy consumption or equipment sales), then going down to more disaggregated data when necessary (e.g., energy efficiency indicators already corrected for some structural or weather effects).

EMEEES developed 20 bottom-up case applications and 14 top-down cases of these general methods, which already cover the largest part of potential ESD energy savings from the energy efficiency improvement measures the member states have pledged to implement in their national energy efficiency action plans.

ISO 50001 Energy Management Standard (EnMS): ISO 50001 is a voluntary international standard developed by the International Organization for Standardization (ISO) to manage and improve energy performance.

ISO 50001 EnMS is a framework developed for industrial facilities, commercial facilities, and organizations to manage energy, which includes energy procurement and use. The EnMS institutes a structure and discipline to implement technical and managerial strategies to cut energy consumption and GHG emissions. The standard addresses the following:

- Energy use and consumption
- Measurement, documentation, and reporting of energy use and consumption
- Design and procurement practices for energy-using equipment, systems, and processes
- All variables affecting energy performance that can be monitored and influenced by the organization

ISO 50001 requires continuous energy performance improvement, but it does not include prescriptive energy performance improvement goals. It provides a framework through which each organization can set and pursue its own goals for improving energy performance.

Certification by an independent auditor of conformity of the user's energy management system to ISO 50001 is not a requirement of the standard itself. To certify or not is a decision to be taken by the ISO 50001 user, unless imposed by regulation. Alternatives to independent (third-party) certification include inviting an organization's customers to verify its implementation of ISO 50001 in conformity with the standard (second-party verification) or self-declaring its conformity.

EN16001-Energy Management Standard (Europe): The EN16001-Energy Management Standard is the European standard on energy management, similar to ISO 50001.

EN16001 offers a systematic approach to monitor and reduce the energy consumption in all kinds of organizations. Like ISO 50001, it is based on plan-do-check-act cycle, with requirements for establishing an energy policy with solid objectives, putting in place activities to reduce and monitor energy use, verifying energy savings, and planning improvements. It offers a comprehensive set of guidelines to meet carbon emission reduction requirements.

The Greenhouse Gas Protocol—A Corporate Accounting and Reporting Standard: The Greenhouse Gas Protocol is a multi-stakeholder partnership of businesses, nongovernmental organizations, governments, and others, spearheaded by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The protocol sets global standards for how to measure, manage, and report GHG emissions. It serves as the basis for nearly every GHG standard and program in the world—from the ISO to The Climate Registry—as well as hundreds of GHG inventories prepared by individual companies.

The protocol also offers developing countries an internationally accepted management tool to help their businesses to compete in the global marketplace and their governments to make informed decisions about climate change.

The protocol sets out standard and/or guidance on the following: GHG accounting and reporting principle, business goals and inventory design, setting organizational boundaries, setting operational boundaries, tracking emissions, calculating GHG emissions, managing inventory quality, accounting GHG reduction, reporting GHG emissions, verifying GHG emissions, and setting GHG targets.

EU Emissions Trading System (EU ETS): EU ETS is the foundation of the EU's policy to fight against climate change and a key tool to reduce GHG emissions costs effectively. It is the first, and still the biggest, international system for trading GHG emissions allowance, covering more than 11,000 power stations and industrial plants in 31 countries (28 EU countries plus Iceland, Liechtenstein, and Norway).

The system works on the cap-and-trade principle. A cap is set on the total amount of emissions that can be emitted by installations covered by the system. Within the cap, companies receive or buy emission allowances, which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world.

EU ETS focuses on emissions that can be measured, reported, and verified with a high level of accuracy. The system covers emissions of carbon dioxide (CO_2) from power plants, a wide range of energy-intensive industry sectors, and commercial airlines. It also covers nitrous oxide emissions from the production of certain acids and emissions of perfluorocarbons from aluminum production.

Businesses must monitor and report their emissions each year and have their emission reports audited by an accredited professional. Accounting and reporting can be done following protocols such as "The GHG Protocols" summarized above. After each year a company must surrender enough allowances to cover all its emissions, otherwise heavy fines are imposed. These allowances are then cancelled so that they cannot be used again. The accurate accounting of all allowances issued is assured by a single EU registry with strong security measures. A company is penalized if it does not surrender enough allowances to cover its emissions. It has to buy allowances to make up the shortfall, is "named and shamed" by having its name published, and must pay a dissuasive fine for each excess tonne of GHG emitted. The fine in 2013 was €100 per tonne of CO_2 (or the equivalent amount of N_2O or PFCs). The penalty rises annually in line with the annual rate of inflation in the Eurozone.

Similar to the EU and its EU ETS, several countries and jurisdictions have implemented multi-sector market-based cap-and-trade programs. (See World Bank 2016b).

White Certificate Scheme: White Certificates are obligations imposed on electric and gas utilities to attain certain reduction in energy consumption among medium and large energy end users. These are coupled with tradable energy savings certificates. The scheme has been developed to promote implementation of energy efficiency in industry.

White Certificate obligations impose energy savings targets on energy companies; if the mandated targets are not met, they have to pay a penalty. The White Certificates are given to the utilities; whenever an amount of energy is saved, the utility can use the certificate for its target compliance or can sell the certificate to parties who cannot meet their targets, similar to emissions trading. They can be seen as a means of internalizing energy-use externalities and addressing energy efficiency market failures (Giraudet and Finon 2014).

In Europe, the White Certificate Scheme is implemented in Italy, France, and the UK. The savings verification approaches used in the three countries are explained in the following paragraphs:

The Italian White Certificate Scheme uses three M&V approaches: deemed savings approach with default factors for free riding; an engineering approach (delivery mechanism and persistence); and a third approach based on monitoring plans whereby energy savings are quantified via a comparison of measured or calculated consumptions before and after the project. All monitoring plans must be submitted for preapproval to the Regulatory Authority for Electricity and Gas (AEEG) and must conform to predetermined criteria (Bertoldi and Rezessy 2008).

The French White Certificate Scheme uses a list of standardized actions with the saving evaluation method. Currently, a number of standard actions are employed in different sectors: 31 in the residential sector, 22 in the commercial sector, 3 in the industrial sector, and 3 in the transport sector (Bertoldi and Rezessy 2008).

In the UK Energy Efficiency Commitment Scheme, the savings of a project are calculated and agreed based on a standard estimate taking into account the technology used, weighted for fuel type, and discounted over the lifetime of the measure. There is limited ex post verification of the energy savings carried out by the government in order to inform the design of standardized estimates in future periods (Bertoldi and Rezessy 2008).

ANNEX 5 | COMPARISON OF MONITORING & VERIFICATION PROTOCOLS

PROTOCOL	APPLICATION	KEY FEATURES	GEOGRAPHICAL COVERAGE	COMMENTS
International Performance Measurement and Verification Protocol (IPMVP) Volume I.	IPMVP is an international M&V protocol describing different methods to determine water and energy savings of energy efficiency projects. It presents a framework for transparent, reliable, and consistent reporting a project's saving, which can be used to develop M&V plan for projects.	IPMVP presents four M&V options to evaluate a project's savings: Option A: Retrofit isolation—key parameter measurement Option B: Retrofit isolation—measurement of all parameters Option C: Whole facility Option D: Calibrated simulation IPMVP is available in more than 11 languages.	Global	IPMVP is one of the most comprehensive frameworks for M&V. It is used extensively and has become the de facto M&V standard in many countries.
Federal Energy Management Program (FEMP)	FEMP M&V guidelines were launched in the United States to help the federal government agencies measure and verify energy savings achieved in federal buildings. FEMP provides guidelines and methods for measuring and verifying energy, water, and cost savings obtained from a performance contract targeting federal building.	Similar to IPMVP, FEMP presents four M&V options: Option A: Retrofit isolation with measurement of key parameters Option B: Retrofit isolation with measurement of all parameters Option C: Whole facility measurement Option D: Calibrated computer simulation	USA	FEMP is an application of IPMVP for federal buildings with detailed guidelines and examples on the approaches applicable to certain energy conservation measures normally found in federal buildings. FEMP provides specific measurement plans adapted to most common measures implemented in buildings.
ASHRAE Guideline 14	The ASHRAE guideline 14 is a highly technical M&V protocol.	The guideline provides three approaches to measure and verify energy savings: Whole building approach Retrofit isolation approach Whole building calibrated simulation approach The protocol requires measurement of all parameters, and estimation is not permitted.	USA	Though detailed and well developed, Guideline 14 is not extensively used because of its highly technical nature. It is considered too academic and hence not practical for everyday M&V activities.

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PROTOCOL	APPLICATION	KEY FEATURES	GEOGRAPHICAL COVERAGE	COMMENTS
CDM Methodology-AMS-II.C and AMS-II.L	The AMS-II.C methodology is for demand-side energy efficiency activities for specific technologies such as lamps, ballasts, refrigerators, motors, fans, air conditioners, pumping systems, and chillers. The AMS-II.L methodology is for demand-side energy efficiency activities for efficient outdoor and street lighting technologies.	These documents provide the user with necessary instructions to develop and implement M&V plan as per the CDM criteria so as to qualify for emission reduction certificates. The main contents of the methodology documents are scope and applicability, normative references, definitions, baseline methodologies, and monitoring methodologies.	Global	The methodologies AMS.II.C and AMS.II.L are very comprehensive documents. They provide definitions and calculation methods for baseline development along with monitoring techniques. Project proponents need to follow these guidelines in carrying out the M&V of energy efficiency projects to qualify for emission reduction certificates under the CDM.
Australia's Best Practice Guide to Measurement and Verification of Energy Savings	The guide aims to encourage development of energy efficiency projects in Australia with primary focus on energy savings through performance contracting.	This guide is almost similar to IPMVP with respect to M&V options, and it also uses ASHRAE and FEMP guidelines for uncertainty and cost evaluation of M&V benefits (NRCan's CanmetENERGY, 2008).	Australia, Asia Pacific	This best practice guide was developed by the Australian Energy Performance Contracting Association (AEPCA) with the support of the Innovation Access Program (IAccP) in 2004.
Measurement and Verification Process for Calculating and Reporting on Energy and Demand Performance: General Guidance	The guide provides a framework to develop consistent project-specific M&V plans.	The guide defines three standard parameters (i.e., operating hours, load and system efficiencies) essential from the point of view of energy savings and presents four methodologies to obtain these parameters: Stipulated Measurement Inference Simulation	—	The guide provides framework for developing project-specific M&V plan along with templates and flowcharts walking the user through the process.
Measurement and Verification CLUBS2E	This guide is created by CLUBS2E (France) with an aim to make it easier to adopt and implement IPMVP protocol.	This guide integrates the broad scope of IPMVP into a documentary context for the purpose of presentation and assistance with implementation.	France	—

The California Evaluation Framework	The framework provides an approach for planning and conducting evaluation of California's energy efficiency programs.	The framework covers key concepts and consideration required for planning and conducting evaluation of energy efficiency programs. The framework details nine components required for performing program evaluation: 1. Impact evaluation and M&V approaches 2. Process evaluation 3. Information and education program and evaluation 4. Market transformation program evaluation 5. Nonenergy effects evaluation 6. Uncertainty 7. Sampling 8. Evaluation and cost effectiveness 9. Use of evaluation roadmap	California, USA	The framework provides a systematic approach to conduct evaluation so that all programs are able to document their effects and compare to other programs and supply options.
California Energy Efficiency Evaluation Protocols (Evaluators Protocols)	This is a primary guiding tool for policy makers to plan and structure evaluation efforts for energy efficiency programs.	This document includes a separate protocol for each of the following categories: Impact evaluation—direct and indirect effects Measurement and verification (IPMVP) Process evaluation Market effects evaluation Codes and standards program evaluation Emerging technology program evaluation Sampling and uncertainty protocol (for use in determining evaluation sampling approaches); reporting protocol (to guide evaluation data collection and reporting) Effective useful life protocol (used to establish the period over which energy savings can be relied upon)	California, USA	The protocol is used by program evaluators to evaluate California's energy efficiency programs and program portfolios. It is also used by policy makers to plan and structure evaluation efforts.

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PROTOCOL	APPLICATION	KEY FEATURES	GEOGRAPHICAL COVERAGE	COMMENTS
National Energy Efficiency Evaluation, Measurement and Verification (EM&V) Standard: Scoping Study of Issues and Implementation Requirements	This document presents a study on the scope of developing national-level EM&V standards.	The document provides: A set of definitions applicable to an EM&V Standard A literature review of existing standards guidelines related to EM&V and evaluation of bottom-up versus top-down evaluation approaches A summary of EM&V-related provisions of the federal legislative proposal that includes national (USA) efficiency resource requirements An annotated list of issues that are likely to be central to and need to be considered part of developing a national EM&V standard for EE	USA	The document identifies four high-level issues associated with developing national EM&V standards and proceeds to nine issue topic categories that, if addressed and resolved, would take care of the high-level issues. The document also provides brief summaries of a few selected EM&V guidelines, protocols, and standards, and concludes with a draft outline for EM&V national standards.
Model Energy Efficiency Program Impact Evaluation Guide	The guide aims to assist utilities, utility regulators, and others in the implementation of the National Action Plan for Energy Efficiency and the pursuit of its long-term goals.	The guide describes a structure and several model approaches for calculating energy, demand, and emissions savings from facility energy efficiency programs that are implemented by cities, states, utilities, companies, and similar entities.	USA	—
Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services (EMEEES)	EMEEES assists the European Commission in developing methods to evaluate the measures implemented to achieve the energy saving targets set out by the Energy Service Directive (ESD).	EMEEES has general method for bottom-up and top-down calculation methods plus guidelines for ensuring consistency between the results of bottom-up and top-down calculations.	Europe	—

ISO 50001 Energy Management Standard (EnMS)	ISO 50001 EnMS is a framework developed for industrial facilities, commercial facilities, and organizations to manage energy, which includes energy procurement and use. The EnMS institutes a structure and discipline to implement technical and managerial strategies to cut energy consumption and GHG emissions.	The standard addresses: Energy use and consumption Measurement, documentation, and reporting of energy use and consumption Design and procurement practices for energy-using equipment, systems, and processes All variables affecting energy performance that can be monitored and influenced by the organization	Global	ISO 50001 is a voluntary international standard developed by the International Organization for Standardization (ISO) to manage and improve energy performance. Certification by an independent auditor of conformity of the user's energy management system to ISO 50001 is not a requirement of the standard itself. To certify or not is a decision to be taken by the ISO 50001 user, unless imposed by regulation. Alternatives to independent (third-party) certification are to invite the organization's customers to verify its implementation of ISO 50001 in conformity with the standard (second-party verification), or to self-declare its conformity.
EN16001- Energy Management Standard (Europe)	The EN16001-Energy Management Standard is the European standard on energy management similar to ISO 50001.	EN16001 offers a systematic approach to monitor and reduce the energy consumption in all kinds of organizations.	Europe	—
The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard	The protocol sets global standards for how to measure, manage, and report GHG emissions.	The protocol sets out standard and/or guidance on the following: GHG accounting and reporting principle, business goals and inventory design, setting organizational boundaries, setting operational boundaries, tracking emissions, calculating GHG emissions, managing inventory quality, accounting GHG reduction, reporting GHG emissions, verifying GHG emissions, setting GHG targets.	Global	It serves as the basis for nearly every GHG standard and program in the world—from the International Standards Organization to The Climate Registry—as well as hundreds of GHG inventories prepared by individual companies.

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PROTOCOL	APPLICATION	KEY FEATURES	GEOGRAPHICAL COVERAGE	COMMENTS
EU Emissions Trading System (EU ETS)	EU ETS is the first and still the biggest international system for trading GHG emissions allowance. It is a critical element of the European Union's policy to fight against climate change and a key tool to reduce GHG emissions cost effectively.	The system works on the cap-and-trade principle. A cap is set at the EU level on the total amount of emissions that can be emitted by the covered installations. Within the cap, companies receive or buy emission allowances, which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. At the end of each year each company must surrender enough allowances to cover all its emissions, otherwise fines are imposed.	Europe	Similar to the European Union and its EU ETS, several countries and jurisdictions have implemented multi-sector market-based cap-and-trade programs. (See World Bank's State and Trends of Carbon Pricing 2016).
White Certificate Scheme	The scheme has been developed to promote implementation of energy efficiency in industry. It is an accounting tool and a tradable commodity.	White certificate obligations impose energy-saving targets on energy companies. If the mandated targets are not met, they have to pay a penalty. The white certificates are given to the utilities. Whenever an amount of energy is saved, the utility can use the certificate for its target compliance or can sell it to parties who cannot meet their targets, similar to emissions trading. They can be seen as a means of internalizing energy-use externalities and addressing energy efficiency market failures.	Italy, France, Great Britain, Flanders, Denmark	—

ANNEX 6 | ADVANCEMENTS IN MONITORING & VERIFICATION TECHNOLOGIES

Advancements in information technology have had a big impact on the monitoring of energy efficiency programs. An important aspect is continuous M&V. Continuous M&V will help enhance transparency and confidence in achieved savings from energy efficiency projects by ensuring that the systems designed into a facility actually work as anticipated during operation, and that the facility does not overuse energy.

Some of the new and upcoming technologies that have gained popularity and steady market growth in buildings, street lighting, and other public energy efficiency programs are energy management systems, central control and monitoring systems (CCMS), and advanced metering infrastructure (AMI). All of these technologies have similar modus operandi, in the sense that they have the capability to communicate with equipment and at the same time control and monitor them.

Energy management systems (EMS): EMS are computer-aided mechanisms to monitor, control, and optimize the performance of any energy project. When used in reference to building management, they are referred to as building management systems (BMS) or building automation systems (BAS). Efficient use of EMS can save 10%–40% on electric bills. An EMS can enhance existing operations by allowing control of various aspects of energy use, including lighting, and HVAC from a central point, reducing error intensity caused by manual operation of these services.

The Clean Energy Ministerial defines an Energy Management System (EnMS) as a suite of procedures and practices that ensure systematic tracking, analysis, and planning of energy use through a Plan-Do-Check-Act framework of continual improvement. (www.cleanenergyministerial.org)

Central control and monitoring systems (CCMS): A CCMS can be regarded as a variation of EMS. The CCMS can be used in commercial/public buildings or public infrastructure projects such as street lighting and water pumping. There are three basic tasks that should be performed to qualify as a CCMS: monitor, control, and schedule. The basic system should be able to monitor the energy consumption, voltage, and other parameters. The system should be able to control the energy-consuming equipment, and the system should be able to schedule the operating hours of the equipment. The ability to remotely manage these three tasks makes the CCMS a vital tool in energy efficiency initiatives.

In the context of street lighting, the CCMS operates either through wires or wirelessly, enabling individual lights to be switched on or off, dimmed, and monitored independently. Dimming and trimming strategies can then be developed, which contribute to energy savings and allow for lights to be independently monitored, reducing the need for scouting. CCMS has excellent monitoring capacity by virtue of two-way communication, which makes operation and maintenance easy. Though it increases the initial capital costs and requires some lifetime operating costs, CCMS can generate up to 20% more energy savings.

Advanced metering infrastructure (AMI): AMI is a combination of smart meters, communication networks, and data management systems that allows two-way communication between utilities and customers. Customer systems include advanced meters, visual home displays, home communication networks, energy management systems, and other equipment that enable smart grid functions in residential, commercial, and industrial facilities (SMARTGRID.GOV 2015). The customers can use AMI to remotely monitor and control their energy systems using computers and smart phones.

The objectives of AMI are remote meter reading, error-free data, network problem identification, load profiling, energy audit and partial load curtailment, demand response, etc.

The AMI consists of various hardware and software components essential for monitoring and recording data, transmitting information, and controlling usage. The components used in AMI include the following:

- **Smart meter:** An advanced meter capable of collecting and recording information about energy, water, etc., and transmitting it to the utility at fixed intervals through communication networks. It can also receive information from the utility on pricing, demand response, and faults and convey it to the consumer.
- **Communication network:** Two-way communication from a smart meter to the utility and vice versa as well as with the consumer. Networks such as phone lines, cellular 2G/3G, radio frequency, Wi-Fi, etc.
- **Meter data acquisition system:** Software applications in the control center hardware and the DCUs (data concentrator units) used to acquire data from meters via communication networks and send them to the MDMS (ISGF 2015).
- **Meter data management system:** Host system that receives, stores, and analyses the metering information (ISGF 2015).
- **Home area network:** It can be an extension of AMI deployed at consumer premises to facilitate the communication of home appliances with AMI and hence enable a better control of loads by both utility and consumer (ISGF 2015).

With these advances in communication technologies, it is possible to monitor and control the energy consumption of appliances and equipment and to record and maintain historical data of every last kWh used with more precision. However, these advanced technologies come with a cost, which is likely to go down over time with greater use. Nonetheless, in many cases (especially where energy costs are high), these technologies can already be justified as they can ensure higher energy savings, reduced O&M costs, reduced downtime, quick restoration, improved monitoring capacities, and reduced power thefts.

ANNEX 7 | LIST OF METHODOLOGIES FOR ASSESSING CO-BENEFITS/MULTIPLE BENEFITS

CO-BENEFITS	COUNTRY/ REGION	METHODOLOGY	IMPACT OF CO_2 EMISSION REDUCTION: PHYSICAL INDICATOR	IMPACT OF CO_2 EMISSION REDUCTION: MONETARY INDICATOR	REFERENCES
Quantifiable Health Effects					
Morbidity reduction	USA, New Zealand, Denmark	A double-blind, multiple crossover intervention Initial self-completed background questionnaires; then shorter weekly questionnaires assessing the outcomes Environmental measurements Statistical analysis Cost–benefit analysis Literature review Authors' adjustment/estimates	USA: A drop of concentration of the smallest airborne particles by 94% resulted in a decrease in confusion scale by 3.7%, fatigue scale by 2.5%, the feeling of "stuffy" air 5.3%, of "too humid" by 7.0%, of "too cold" by 5.5%, and "too warm" by 3.5%. USA: Cooler temperatures within the recommended comfort range resulted in a decrease in the chest tightness by 23.4% per each 1°C decrease. Denmark: Better thermal air quality led to better concentration of 15% of respondents and a 34% decrease in "sick building syndrome*" cases.	USA: Improved ventilation may result in net savings of €302/employee-year that on a national scale represents productivity gain of €17 billion/year. USA: NPV** over the lifetime of improved ventilation can reach as high as €1652/hh. USA: Better ventilation and indoor air quality reduce influenza and cold by 9%–20% (ca 16–37 million cases) that translates into savings of €4.5–10.6 billion/year. New Zealand: Health benefits due to a weatherization program amount to €35/hh-year or 18.5% of the total annual energy savings of a household.	Mendell et al., 2002; Milton et al., 2000; Schweitzer and Tonn, 2002; Wyon, 1994; Stoecklein and Scumatz, 2007; Fisk, 1999; Fisk, 2000a
Mortality reduction	Hungary; USA, Ireland, Norway	Bottom-up study (with Monte Carlo simulation) Statistic time-series analysis: semi-parametric log-linear model, a weighted two-stage regression Analysis of mortality statistics with a population of a similar country as the control group	USA: Every 10 g/m³ increase in ambient particulate matter (the day before deaths occur) brings a 0.5% increase in the overall mortality. Ireland, Norway: The share of excess winter mortality attributable to poor thermal housing standards is 50% for cardiovascular disease and 57% for respiratory disease.	Hungary: Energy-saving program resulted in the total health benefit of €489 million/year due to a decrease in chronic respiratory diseases and premature mortality. Ireland, Norway: The total mortality benefit of a hypothetical thermal-improving program is €1.5 billion (undiscounted) for a study in the left column.	Aunan, et al. 2000; Samet et al., 2000; Clinch and Healy, 1999
Environmental (ecological) Co-Benefits					
General environmental benefits	New Zealand	Direct computation Willingness to pay/accept, contingent valuation, other survey-based methods	New Zealand: Benefits to the environment gained after the weatherization program amount to €44/hh-year in 2007, which accounts for around 18.7% of the total annual energy expenditures saved.		Stoecklein and Scumatz, 2007

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CO-BENEFITS	COUNTRY/ REGION	METHODOLOGY	IMPACT OF CO_2 EMISSION REDUCTION: PHYSICAL INDICATOR	IMPACT OF CO_2 EMISSION REDUCTION: MONETARY INDICATOR	REFERENCES
Cleaner indoor air	USA	Literature review Data analysis	USA: A sample considered a reduction of concentration of the smallest airborne particles by 94%. USA: The reduction in emissions per year of a green school as compared to the average practice: • 1200 pounds of NO_x—a principal component of smog • 1300 pounds of SO_2—a principal cause of acid rain • 585,000 pounds of CO_2—GHG and the principal product of combustion • 150 pounds of coarse particulate matter (PM10)—a principal cause of respiratory illness and an important contributor to smog		Mendell et al., 2002; Kats, 2005
Fish impingement	USA	Literature review Authors' adjustment/estimates	USA: NPV of reduction in fish impingement over the lifetime of weatherization measures is €17.6/hh.		Schweitzer and Tonn, 2002
Wastewater and sewage	USA	Literature review Authors' adjustment/estimates	USA: NPV of reduction in wastewater and sewage over the lifetime of weatherization measures is €2.6–495.3/hh.		Schweitzer and Tonn, 2002
Construction and demolition waste benefits	USA	Statistical analysis NPV analysis with a 7% DR over 20 years	USA: Construction and demolition diversion rates are 50%–75% lower in green buildings (with the maximum of 99% in some projects) as compared to an average practice. USA: A sample of 21 green buildings submitted for certification, 81% of such buildings reduced construction waste by at least 50%, 38% of such buildings reduced construction waste by 75% or more.		SBTF, 2001; Kats, 2005
Reduction in air pollution (indoor + outdoor)	USA	Literature review Authors' adjustment/estimates Statistical analysis	USA: A green school emits 544 kg of NO_x, 590 kg of SO_2, 265 tonnes of CO_2, 68 kg of coarse particulate matter (PM10) less in comparison with the average practice.	USA: The study in the left column results in NPV €0.4/ft² (~€0.037/m²) over 20 years. USA: NPV of air emission reduction (CO_2, SO_x, NO_x, CO, CH_4, PM) over lifetime of the measures is (all in thousand euro/hh): (a) from natural gas burning 30.2–37.7; (b) from electricity consumption €118–185; (c) air emissions of heavy metals is 0.75–12.8.	Schweitzer and Tonn, 2002; Kats, 2005; Kats, 2006
Economic Co-Benefits and Ancillary Financial Impacts					
Indirect secondary impact from reduced overall market demand and resulting lower energy prices market wide	USA	NPV analysis with a 7% DR over 20 years Literature review Simplified quantification of the effect of renewable energy/energy efficiency on gas prices and bills Using a range of plausible inverse elasticity estimates	USA: Efficiency-driven reductions in demand result in a long-term energy price decrease equal to 100%–200% of direct energy savings; assuming the indirect price impact of 50% over 20 years from an efficient school design, the impact of indirect energy cost reduction for new and retrofitted schools has NPV €0.21/m². USA: 1% decrease in the national natural gas demand through energy efficiency and renewable energy measures leads to a long-term wellhead price reduction of 0.8%–2%; the indirect monetary savings from this price decrease amounted to 90% of the direct monetary savings, that is, €14.6 million for all customers (cumulative 5-year impact, 1998–2002, over June–September peak hours). USA: 1% reduction in natural gas demand resulted in a 0.75%–2.5% reduction in the long-term wellhead prices.		Kats, 2006; Wiser et al., 2005; O'Connor, 2004; Platts Research & Consulting, 2004

Enhanced learning in "greened" buildings	USA	Review of the financial benefits of education	Better environmental condition leads to enhanced learning abilities; a 3%–5% improvement in learning and test scores is equivalent to a 1.4% lifetime annual earnings increase; an increase in test scores from 50% to 84% is associated with a 12% increase in annual earnings.		Hanushek, 2005
Employees' retention: avoided reduced-activity days	USA, Washington State, Ireland	Statistical analysis Literature review Bottom-up model NPV analysis with a 7% DR over 20 years A walk-through assessment of schools Survey	USA: The improved quality of schools increases teacher retention by 3%. USA/The State of Washington: "Greening" schools could bring 5% per year of improvement in teacher retention.	USA: If the cost of teacher loss is 50% of salary, the left column tops study equals to a saving of €0.28/m² if ~214 m²/teacher is assumed. USA/The State of Washington (left column): Savings of $160,000/year during 20 years (not discounted). Ireland: The annual value of the morbidity benefits of the energy efficiency program is €58 million excluding reduced-activity days and €66.6 million including them.	Buckley, et al. 2005; Kats, 2005; Paladino & Company, 2005; Clinch and Healy, 2001
Improved productivity	USA	Case studies on documented productivity gains Empirical measurements Computer-based literature searches, reviews of conference proceedings, and discussions with researchers Multivariate linear regression analysis of student performance data Log-linear regression model Statistical analysis Questionnaire NPV analysis with a 7% DR over 20 years	USA: In well day-lighted buildings, labor productivity rises by about 6%–16%, students' test scores show ~20%–26% faster learning, and retail sales rise 40%. USA: Students with the most day lighting show 20%–26% better results than those with the least day lighting. USA: Ventilation rates less than 100% outdoor air and temperature higher than 25.4°C result in lower work performance. Canada: A new ventilation system improved the productivity of co-workers by 11% versus reduced productivity by 4% in a control group. USA: After building retrofitting, absenteeism rates dropped by 40% and productivity increased by more than 5%; after moving to a retrofitted facility, two business units monitored 83% and 57% reductions in voluntary terminations versus a control group with 11% reduction in voluntary termination of employment.	USA: The productivity can improve by 7.1%, 1.8%, and 1.2% with lighting, ventilation, and thermal control by a tenant; an average workforce productivity increase is 0.5%–34% each control type. A 1% increase in productivity (~ca 5 min/day) is equal to €452–528/employee-year or €0.21/m²-year; a 1.5% increase in productivity (~ca 7 min/day) is equal to ~€754/employee-year or €0.35/m²-year. USA: More comfortable temperature and lighting result in productivity increase by 0.5%–5%; considering only United States office workers, such a change translates into an annual productivity increase of roughly €15–121 billion.	Lovins, 2005; Fisk, 2000a; Fisk, 2000b; Heschong Mahone Group, 1999; Federspiel, 2002; Menzies, 1997; Kats, 2003; Pape, 1998; Shades of Green, 2002

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CO-BENEFITS	COUNTRY/ REGION	METHODOLOGY	IMPACT OF CO_2 EMISSION REDUCTION		REFERENCES
			PHYSICAL INDICATOR	MONETARY INDICATOR	
Avoided unemployment	USA	Literature review Authors' adjustment and calculations	NPV of avoided unemployment over the lifetime of weatherization measures is €0–137.9/hh.		Schweitzer and Tonn, 2002
Lower bad debt write-off	USA	Literature review Authors' adjustment/estimates	NPV of lower bad debt write-off over the lifetime of weatherization measures is €11.3–2610/hh.		Schweitzer and Tonn, 2002
Employment creation	USA	NPV analysis with a 7% DR over 20 years Literature review Authors' adjustment/estimates Statistical assessment of the 5-year energy efficiency programs	USA: Green schools create more jobs than conventional schools; the long-term employment impact of increased energy efficiency may provide €0.21/m^2 of benefits. USA: NPV of direct and indirect employment creation over the lifetime of the measures is €86.7–3200/hh. (Note: This benefit occurs only once in the year in which weatherization is performed.) USA: Energy efficiency investment of €85.2 million in the Massachusetts economy in 2002 created 1780 new short-term jobs; in addition, lowered energy bills for participants and for Massachusetts resulted in additional spending, creating 315 new long-term jobs; energy efficiency jobs added €104.8 million to the gross state product, including €48.2 million in disposable income (in 2002 in Massachusetts).		Kats, 2005; Schweitzer and Tonn, 2002; O'Connor, 2004; Kats, 2005
Rate subsidies avoided	USA	Literature review Authors' adjustment/estimates	NPV of avoided rate subsidies over the lifetime of weatherization measures is €4.5–52.8/hh.		Schweitzer and Tonn, 2002
National energy security	USA	Literature review Authors' adjustment/estimates	NPV of enhanced national energy security over the lifetime of weatherization measures is €56.5–2488/hh.		Schweitzer and Tonn, 2002
Service provision benefits					
Transmission and distribution loss reduction	USA	Literature review Authors' adjustment/estimates	USA: NPV over the lifetime of weatherization measures installed is €24.9–60.3/hh.		Schweitzer and Tonn, 2002
Fewer emergency gas service calls	USA	Literature review Authors' adjustment/estimates	USA: NPV of fewer emergency gas service calls over the lifetime of weatherization measures is €29.4–151.5/hh.		Schweitzer and Tonn, 2002
Utilities' insurance savings	USA	Literature review Authors' adjustment/estimates	USA: NPV of utilities insurance cost reduction over the lifetime of weatherization measures is €0–1.5/hh.		Schweitzer and Tonn, 2002
Decreased number of bill-related calls	New Zealand	Direct computation Willingness to pay, willingness to accept, contingent valuation, and other survey-based methods	Bill-related calls became less frequent after the implementation of weatherization program, which resulted in savings of NZ$ 30 (~€15.9/hh-year), i.e., 7% of the total saved energy costs.		Stoecklein and Scumatz, 2007
Social co-benefits					
Improved social welfare and poverty alleviation	UK	Survey monitoring the impact of energy company schemes that were set up to fuel poverty	UK: Energy efficiency schemes applied to 6 million households in January–December 2003 resulted in the average benefit of €12.7/hh-year.		DEFRA, 2005

Safety increase, fewer fires	USA	Literature review Authors' adjustment/estimates	USA: NPV over the lifetime of the measures installed is €0–418/hh.		Schweitzer and Tonn, 2002
Increased comfort	Ireland, New Zealand	A computer-simulation energy assessment model Direct computation Willingness to pay, willingness to accept, contingent valuation, and other survey-based methods	Ireland: Household temperature increased from 14°C to 17.7°C once the energy efficiency program was completed. The analysis showed that comfort benefits peak at year 7 and then decline gradually until year 20.	Ireland: The total comfort benefits of the program for households (described in the left column) amount to €473 million discounted at 5% over 20 years. New Zealand: Comfort (including noise reduction) benefits after the weatherization program were estimated as €103/hh-year, i.e., 43% of the saved energy costs.	Clinch and Healy, 2003; Stoecklein and Scumatz, 2007

Source | *Diana Ürge-Vorsatz 2009.*

ANNEX 8 | MASSACHUSETTS RECOMMENDED VALUES FOR NON-ENERGY IMPACTS

NON-ENERGY IMPACTS	QUANTITY (YES/NO)	METHOD OF QUANTIFICATION	RECOMMENDED VALUE	DURATION
Utility Perspective				
Arrearages	Yes	Literature	$2.61	Annual
Bad debt write-offs	Yes	Literature	$3.74	Annual
Terminations and reconnections	Yes	Literature	$0.43	Annual
Rate discounts	Yes	Algorithm & PA data	Algorithm	Annual
Complaints and payment plans	No	None for now	None	—
Customer calls	Yes	Literature	$0.58	Annual
Collections notices	Yes	Literature	$0.34	Annual
Safety-related emergency calls	Yes	Literature	$8.43	Annual
Increased electricity system reliability	No	Quantified Elsewhere	None	—
Transmission and distribution savings	No	Quantified Elsewhere	None	—
Insurance savings	Yes	Literature	National WAP Evaluation (2011)	—
Participant Perspective (occupant)				
Higher comfort levels	Yes	Survey	$125 (NLI retrofits); $77 (NLI new construction)/ $101 (L1)	Annual
Improved sense of environmental responsibility	No	Quantified Elsewhere	None	Annual
Quieter interior environment	Yes	Survey	$31 (NLI retrofits); $40 (NLI new construction)/ $30 (L1)	Annual
Reduced noise (dishwashers)	No	None for now	None	Annual
Lighting quality & lifetime	Yes	TRM Report	$3.50/CFL fixture; $3.00 per CFL bulb	One time
Increased housing property value	Yes	Survey	$1,998 (NLI retrofits); $72 (NLI RNC/$949 (L1)	Onetime (Annual for NLI RNC)
Buffers energy price increase	No	Quantified Elsewhere	None	—

NON-ENERGY IMPACTS	QUANTITY (YES/NO)	METHOD OF QUANTIFICATION	RECOMMENDED VALUE	DURATION
Reducing energy expenses, making more money available for other uses, such as health care	No	Quantified Elsewhere	None	—
Reduced need to move and costs of moving, including homelessness	No	Quantified Elsewhere	None	—
Reduced detergent usage (dishwashers)	No	None	None	Annual
Reduced water usage and sewer costs (dishwashers)	Yes	Algorithm from literature	$3.70	Annual
Reduced water usage and sewer costs (tankless water heaters)	No	None	—	—
Reduced water usage and sewer costs (faucet aerators)	Yes	Algorithm from literature	Algorithm	Annual
Reduced water usage and sewer costs (low-flow showerheads)	Yes	Algorithm from literature	Algorithm	Annual
More durable home and less maintenance	Yes	Survey	$149 (NLI retrofits)/$35 (LI)	Annual
Equipment and appliance maintenance requirements	Yes	Survey	$124 (NLI retrofits)/$54 (LI)	Annual
Health related NEIs	Yes	Survey	$4 (NLI retrofits)/$19 (LI)	Annual
Improved safety (heating system, ventilation, carbon monoxide, fires)	Yes	Algorithm & PA data	$37.40 (avoided fire deaths); $0.03 (avoided fire injuries); $1.24 (avoided fire property damage); $6.38 (avoided CO poisonings; all LI	Annual
Improved safety (lighting)	No	None for now	None	—
Heat (or lack thereof) generated	No	None	None	—
Warm up delay	No	None for now	None	—
Product lifetime	No	None	None	—
Availability of hot water	No	None for now	None	—
Product performance	No	None for now	None	—
Window AC NEIs	Yes	Literature	$49.50	Annual
Bill-related calls	No	Quantified Elsewhere	None	—
Termination and reconnection	No	Quantified Elsewhere	None	—
Reduced transaction costs	No	None	None	—
Education	No	None	None	—

(*continued*)

NON-ENERGY IMPACTS	QUANTITY (YES/NO)	METHOD OF QUANTIFICATION	RECOMMENDED VALUE	DURATION
Societal Perspective				
Weatherization by utility programs saves costs of inspections and upgrades by other agencies	No	None for now	None	—
Equity and Hardship	No	None	None	—
Improved Health	No	None for now	None	—
Improved Safety	No	None for now	None	—
Water	No	None for now	None	—
National Security	Yes	Algorithm from literature	Algorithm	Annual
Participant Perspective (owners of low-income rental housing), per Housing Unit				
Marketability/ease of finding renters	Yes	Survey	$0.96	Annual
Reduced tenant turnover	Yes	Survey	$0	Annual
Property value	Yes	Survey	$17.03	One time
Equipment maintenance (heating and cooling systems)	Yes	Survey	$3.91	Annual
Reduced maintenance (lighting)	Yes	Survey	$66.73	Annual
Durability of property	Yes	Survey	$36.85	Annual
Tenant complaints	Yes	Survey	$19.61	Annual
Non-Resource Benefits				
Appliance Recycling—Avoided landfill space	Yes	Algorithm from literature	$1.06	One time
Appliance Recycling—Reduced emissions due to recycling plastic and glass, reduced emissions	Yes	Algorithm from literature	$1.25	One time
Appliance Recycling—Reduced emissions due to incineration of insulating foam	Yes	Algorithm from literature	$170.22	One time

Source | Tetra Tech, Inc. and NMR 2011.

ANNEX 9 | THERMAL COMFORT SURVEY

FACTOR	DESCRIPTION	YES
Air temperature	Does the air feel warm or hot?	
	Does the temperature in the workplace fluctuate during a normal working day?	
	Does the temperature in the workplace change a lot during hot or cold seasonal variations?	
Radiant temperature	is there a heat source in the environment?	
	Is there any equipment that produces steam?	
	Is the workplace affected by external weather conditions?	
Humidity	Are your employees wearing PPE that is vapour impermeable?	
	Do your employees complain that the air is too dry?	
	Do your employees complain that the air is humid?	
Air movement	Is cold or warm air blowing directly into the workspace?	
	Are employees complaining of draught?	
Metabolic rate	Is work rate moderate to intensive in warm or hot conditions?	
	Are employees sedentary in cool or cold environments?	
PPE	Is PPE being worn that protects against harmful toxins, chemicals, asbestos, flames, extreme heat, etc?	
	Can employees make individual alterations to their clothing in response to the thermal environment?	
	Is respiratory protection being worn?	
What your employees think	Do your employees think that there is a thermal comfort problem?	

Source | *http://www.hse.gov.uk/temperature/assets/docs/thermal-comfort-checklist.pdf*

ANNEX 10 | MEASURE OF LABOR PRODUCTIVITY

MEASURES OF PRODUCTIVITY	METHODS OF MEASUREMENT
Speed	Quantative: Data collection
Accuracy	
Absenteeism	
Incidence of complaints	
Cycle time of a process	
Billable hours	
Ability to work more hours	Qualitative: Questionnaires, observation, structured interviews, focus groups, self assessment
More creative	
Learn better	
Sustain stress better	
More harmonious	
Feel healthier	
Respond more positively to requests	

Source: Building Efficiency Initiative 2013.

ANNEX 11 | IMPACTS IDENTIFIED IN RECENT UK ENERGY EFFICIENCY POLICY INITIATIVES

	AREA OF IMPACT[1]	GREEN DEAL/ECO JUNE 2012	PART L BUILDING REGULATIONS AUGUST 2013	PRS MINIMUM EE STANDARDS[2] JULY 2014
BENEFITS	Energy savings	€21,331 million	€1,661 million	€582 million
	Increased comfort	€4,910 million	mention	€155 million
	Carbon reductions[3]	€8,173 million	€455 million	€125 million
	Air quality	€2,041 million		€10 million
	Energy security	mention	mention	mention
	Sustainability	mention	no mention	no mention
	Fuel poverty	*125,000–250,000 households*	*no mention*	*mention*
	Economic growth	mention	no mention	mention
	Employment	38–60,000 jobs	no mention	8,400 jobs
	Asset values	no mention	mention	mention
	Tax revenues	no mention	mention	no mention
	Welfare spending	no mention	no mention	mention
	Physical health	mention	mention	€36 million[4]
	Mental well-being[5]	mention	no mention	
COSTS[8, 9]	Installation	€14,404 million	€1,571 million[6]	€329 million
	Additional[7]	€4,936 million	—	€33 million
	Assessment	€1,728 million	—	€16 million
	Finance	€2,166 million	—	€205 million
	Business cost	€1,345 million	—	—
	Administration	€57 million	mention	—
	Transition	—	€7 million	—
	Understanding regs	—	—	€23 million
	Unintended health	mention	mention	mention
	Net Present Value	€11 ,820 million	€539 million	€269 million
	Benefit-Cost Ratio	1.5:1	1.3:1	1.5:1

[1]Quantified values are central estimates.

[2]These estimates are for the preferred Option 1 proposal, domestic CBA.

[3]Lifetime non-traded carbon savings, and lifetime EU allowance savings.

[4]A UK policy objective that encompasses a range of other impacts described elsewhere.

[5]There is no quantification of this since comfort take is not assumed relevant in the new homes model.

[6]An estimate of health impacts from HIDEEM was included as an indication of impact, but was not counted in headline total quantification of benefits from the policy, see main body for further discussion.

[7]The additional capital costs of compliance with regulations.

[8]These hidden and overlooked costs to participants; sometimes termed "hassle" costs.

[9]The classification of costs varies between each assessment.

Source: Payne, et al. 2015.

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