ENERGY EVALUATION EUROPE
2020 Conference
Here East, Olympic Park, London
Monday 29 June to Wednesday 1 July 2020
Formerly IEPPEC
Accelerating the energy transition for all: Evaluation's role in effective policy making

Adapting Impact Evaluation Frameworks for Energy Codes and Standards in Emerging Countries

Amandine Gal, Econoler (agal@econoler.com); Marie-Claude Hamelin, Econoler; Stéphanie Nour, Econoler

ABSTRACT

The key objective of evaluating energy efficiency standards and codes is gathering credible information about their benefits to more easily justify their adoption in the market. This supports the argument that energy efficiency (EE) is key to delivering and meeting clean energy, climate change and sustainable development goals in general and in emerging countries specifically. The credibility of evaluation results stems from the quality of the data used and transparency of the methodology used in the evaluation process.

Firstly, this paper explains what constitutes an evaluation framework and discusses the importance establishing practical and solid frameworks for EE policy evaluation.

Secondly, the paper presents schematics of an evaluation framework based on one example, the non-residential building energy standard in Mexico, namely NOM-008-ENER-2001, Eficiencia energética en edificaciones, envolvente de edificios no residenciales. The aim is to highlight the steps of a bottom-up approach to evaluate a standard or code.

Finally, this paper outlines the benefits of evaluation frameworks and provides some recommendations for bridging the data gaps. Developing the capacity of government and technical staff is important, especially in emerging countries, to ensure replicable and comparable evaluation results over time. For example, workshops with main stakeholders help to overcome data gaps identified in evaluation frameworks.

Introduction

Energy consumption in emerging countries is increasing. Brazil, China, India, Indonesia, Mexico and South Africa combined currently use approximately one third of the world's total energy, and this energy consumption is expected to rise to 40% under actual policy trends (IEA, 2018). It is expected that there is potential to save energy by implementing EE policies as emerging countries set EE targets at international and national levels. EE policies are key in complying with national energy targets and strategies and international climate agreements such as the Paris Agreement.

In one of the main energy consuming sectors, the building sector, EE standards and codes[1] are fundamental policies to reduce energy consumption. Evaluation validates the expected energy savings that the policies are intended to provide. Reliable and credible approaches and data are required to ensure the trustworthiness of evaluation results and information to guide governments in improving their processes and policies.

[1] A standard provides a set of technical definitions and guidelines, which serve as instructions for designers, manufacturers, operators, or users of equipment. A code is a model providing a set of rules that knowledgeable people recommend for others to follow; it is not a law but can be adopted into law.

EE evaluation methodologies and modelling undergo constant improvements. We present herein our adaptation of best practices mainly used in North America, where EE standards and codes are based on cutting edge approaches, to emerging countries where data and resources are scarcer. The value of EE policy evaluation frameworks is discussed, followed by an analysis of a specific impact evaluation framework for an EE building standard in Mexico. This example was selected for two main reasons: 1) Mexico is amongst the leaders in emerging economies regarding the development and establishment of EE standards and 2) EE building standards are powerful policies to reduce the energy consumption in buildings in the long term. The framework was developed to support Mexican ministry of Energy, SENER, to improve evaluation of their EE policies. We conclude by presenting possible solutions to overcome difficulties in obtaining reliable data, solutions that could be implemented in emerging countries.

Frameworks for Energy Efficiency Policy Evaluation

What is an Energy Efficiency Policy Evaluation Framework?

An evaluation framework identifies the key steps and data required to help policy and decision makers prioritise the most cost-effective policies and track the progress of existing policies. This document is tailored to a given policy or to a group of policies. An appropriate evaluation framework includes a detailed methodology to evaluate the impacts of a given standard or code and a list of required data to perform the evaluation.

The methodology needs to be sufficiently complete, consistent and transparent. Completeness allows the evaluation to consider and quantify all the effects of an EE standard or code. Significant effects should be evaluated based on accurate data obtained from measurements, market studies and surveys. Other less significant effects may be estimated based on solid sources. The evaluation framework should provide enough information to avoid inconsistencies arising from the judgment of the framework's users. Transparency is a key element that enables confidence in future impact calculations.

The data required to follow the evaluation methodology strictly are stated clearly within the framework. At each step of the methodology, data sources are identified as well as the quantity of sources necessary to obtain accurate results.

In summary, the aim of the framework is to provide all needed elements to enable a party to evaluate an EE standard or code.

It is recommended that an evaluation framework be designed at the first stage of EE policy development (Wiel and McMahon 2005). If this recommendation is not implemented, there can be issues in gathering the necessary data.

Ideally, evaluation activities should begin during the first year of EE policy enforcement and impacts should be calculated annually. This approach serves to capture variations in compliance rates and Naturally Occurring Market Adoption (NOMAD).

Evaluation Approach Selection

A broad range of evaluation approaches have been used to evaluate the impacts of EE policies. In Europe, top-down impact evaluation approaches are widely used (Eichhammer, Schlomann and Reuter 2018). These are based on macroeconomic indicators. These approaches help establish comprehensive EE policy impacts by sector. However, they do not enable distinguishing the impacts by policy; consequently, they do not serve to establish the impacts of a specific EE policy.

In North America, where EE policies are supported by both public authorities and private utilities (energy supply companies), bottom-up approaches are most commonly used because they enable identifying or establishing the impacts of a specific policy or program (Cadmus Group, and DNV GL 2015). For example, several policies can tackle energy consumption in the residential sector, including: EE building codes; tax reductions for the purchase of more energy-efficient heating and cooling equipment; and standards and labels for residential heating and cooling equipment.

In North America, evaluation protocols have been developed by public authorities to guide private utilities on how to perform evaluations, starting with the adoption in 2006 of the California Energy Efficiency Evaluation Protocol. This was the first protocol to address the evaluation of codes and standards (Hall, Roth, Best, Barata, Jacobs, Keating, Kromer, Megdal, Peters, Ridge, Trotter, and Vine 2006). It applies bottom-up approaches to evaluate the impacts of codes and standards and it is used as the main reference for the current evaluation protocol for codes and standards programs in California.

Comprehensive ex-post evaluation methodologies for EE policies are generally used in neither developed countries outside North America nor emerging countries. Enforcement issues result in EE building codes dans standards being incorrectly or incompletely implemented in many countries. Emerging countries have higher construction rates, so EE building codes and standards normally have higher impacts than in developed countries. Therefore, evaluating these complex policies is necessary to track results and, if the results are unsatisfactory, it is necessary to take appropriate measures (Mourtada 2016).

Bottom-up approaches are efficient tools to not only evaluate the impacts of policies but also refine policy design, enforcement and monitoring. Based on this analysis, we select a bottom-up approach to develop impact evaluation frameworks for EE building code policies.

Evaluation Impact Indicators

Evaluation frameworks are clear and transparent methodologies that can be replicated and regularly used for codes and standards as they evolve over time and require regular adjustments. The following quantitative evaluation parameters can be included in EE standard and code evaluation frameworks:

- Gross and net energy saved due to an EE policy; the methodology includes baseline definition, potential annual energy savings, compliance rates to evaluate gross savings and the NOMAD approach to evaluate net savings. NOMAD is defined as the proportion of energy-efficient products (meeting the standard compliance level) that are likely to enter and be adopted by at least a proportion of the market throughout the whole value chain, i.e. manufacturers, retailers and customers, even in the absence of a standard.
- Reductions in peak energy demand; peak demand savings correspond to savings that coincide with the electricity peak demand periods based on historical data and projections.
- CO_2 emission reductions; environmental impacts include reduced greenhouse gas (GHG) emissions due to energy consumption savings.
- Financial return on investment at the system level by deferring investments in new electric power plants. A cost value per MW saved is determined according to the latest investments in electric power plants by taking into account the kinds of plants covering the consumption peaks and the transportation and distribution (T&D) losses occurring in the electrical grid.
- Additional costs for the government. The following additional costs of implementing an EE policy are evaluated: design process including cost-benefit analysis, development of required documentation, meetings with relevant stakeholders, etc.; implementation process to ensure compliance with the standard, including testing, on-site visits, etc.; evaluation process including measurement, studies and capacity-building of human resources. To evaluate additional costs, governments must monitor the hours spent by employees to conduct these activities.
- Financial return on investment for EE product suppliers/installers; the additional costs for manufacturers, including developing and producing energy-efficient products with reorganised or new production lines, marketing expenses, and certification processes. Benefits come from the incremental

marginal profits of energy-efficient products compared to old products and increased sales of the energy-efficient products due to enforcement of an EE policy.

The content of an evaluation framework varies depending on data availability within a given country.[2] A generic monitoring and evaluation framework that includes a methodology to determine the baseline of each policy is an acceptable solution when data are not reliable.

Data Gaps Assessment

A data gaps assessment is made during the evaluation framework design phase. This assessment consists of identifying data sources and establishing all data required for calculating quantitative evaluation parameters and their sources. Initial desk research is the first phase of such an assessment. This is followed by research conducted among key market stakeholders; however, private stakeholders such as manufacturers might be reluctant to share sales data with governments.

In some countries, ex-ante impact evaluations of EE standards and codes are conducted before adoption. The aim of ex-ante evaluation is to validate the cost-effectiveness of proposed EE policies and roughly estimate the energy-saving potential. The data used to develop the baselines of ex-ante impact evaluations are, in general, estimations that might lack transparency and credibility. Reliable data for baseline calculations should include surveys and on-site metering. Hence, ex-ante impact evaluation data frequently cannot be used in ex-post impacts evaluation.

Data from other studies can be used to evaluate the baseline of an evaluation framework; however, the methodologies to determine this data need to be transparent and accurate.

Best practices for protocols and evaluation plans

Once a bottom-up approach is selected, the evaluation framework is developed according to the existing protocols to ensure that it uses the most appropriate and up-to-date methodologies. Several protocols are used worldwide as references to evaluate EE programs. Only a few references are available for EE policy evaluation based on a bottom-up approach. The California Energy Efficiency Evaluation Protocol is one reference for the development of evaluation frameworks (Hall, et al 2006)). An evaluation plan for appliance standards based on this reference was developed in 2016 (Cadmus Group 2016). That document can be considered as best practice since the Cadmus Group won an Energy Award for Market Research and Evaluation delivered by the Association of Energy Service Professionals for this evaluation plan.

Additionally, best practices in impact program evaluation can be adapted to standard and code evaluation. The Uniform Methods Project includes a set of protocols for calculating gross energy and demand savings generated by EE programs (Li, Haeri and Reynolds 2017). These protocols are based on the International Performance Measurement and Evaluation Protocol, which is the most used worldwide to determine energy savings because it can be adapted to the vast majority of EE projects thanks to the different options made available therein (International Performance Measurement & Verification Protocol Committee 2016).

The evaluation framework presented below is in line with methodologies based on the above-mentioned best practices for protocols and evaluation plans.

Example of an Evaluation Framework: Non-Residential Building Standard in Mexico

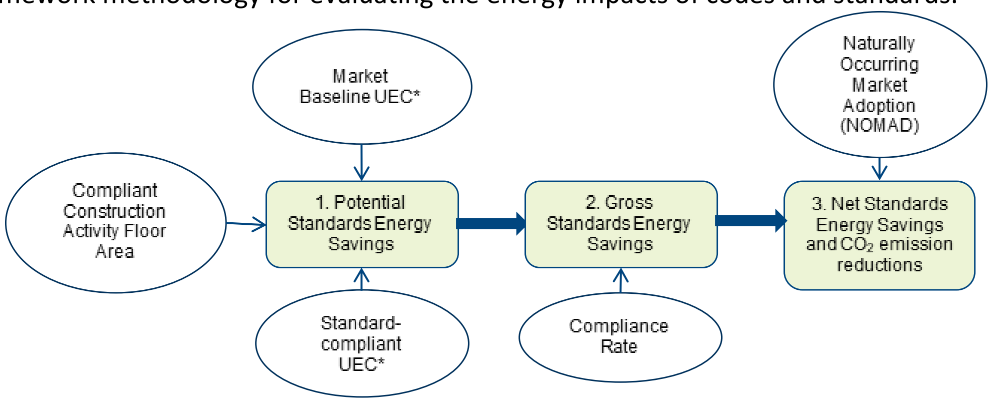
The approach presented here follows the schematic of an evaluation framework based on the non-residential energy building standard in Mexico, namely NOM-008-ENER-2001, Eficiencia energética en

[2] In emerging countries, reliable data to perform standards and code impact evaluation are not always available.

edificaciones, envolvente de edificios no residenciales[3]. The details demonstrate the complexity of EE building related standard evaluation in emerging countries where enforcement is not necessarily applied countrywide.

NOM-008-ENER-2001 (hereafter referred to as NOM-008) limits heat gains through building envelopes (e.g. insulation) to improve occupant comfort, reduces heat losses/gains and reduces cooling energy use. It stipulates that heat gains through as-built building envelopes shall be less than or equal to heat gains from the reference building envelope. NOM-008 sets values for fenestration areas as well as heat gain coefficient and shading coefficient values for opaque and transparent wall and roof elements of the reference building. The standard applies to all new construction and extensions to existing buildings, excluding industrial and residential buildings. NOM-008 is defined at the federal level and is enforced by municipalities through municipal construction regulations. However, only a few municipalities have formally adopted this standard since its promulgation as requirements in local building code. This situation is due to different reasons, mainly political ones. Also, the NOM 008 requires reviewing and updating the procedures for granting building licences in municipalities which need human resources at the municipal level; due to the economic context, many municipalities do not have the capacity to hire personnel for this task.

An overview of the evaluation methodology is presented in Figure 1 below. It outlines the generic evaluation framework methodology for evaluating the energy impacts of codes and standards.



* Unit Energy Consumption

Figure 1: Components of Codes and Standards Program Impact Evaluation. ***Source:*** **Adapted from Cadmus Group and DNV GL 2015.**

Potential Annual Energy Savings

This step consists of calculating annual energy savings attributable to the introduction of the NOM-008 standard using the following equation:

$$Potential\ Annual\ Energy\ Savings \left[\frac{kWh}{year}\right] = Area_{compliant} \left[\frac{m^2}{year}\right] \times UES \left[\frac{kWh}{m^2}\right]$$

Where:

- $Area_{compliant}$ is the construction and retrofit floor area compliant with NOM-008 expressed in m^2 per year;
- UES is the annual unitary energy savings per unit floor area expressed in kWh per m^2.

[3] https://www.gob.mx/cms/uploads/attachment/file/181648/NOM_008_ENER_2001.pdf

The following steps are used to calculate potential annual energy savings.

Define Baseline. The baseline estimation depends on the standard enforcement scenario. There are three possible scenarios:

- First standard scenario. If no standard existed previously, then a market study must be conducted to characterise the buildings available on the market; this, however, requires that the study be planned and conducted before the new standard comes into force. NOM-008 is the first standard that established the minimum thermal heat gain performance levels for non-residential buildings in Mexico. The baseline annual energy consumption estimates of the buildings on the market built before the application of the standard is thus required to calculate the energy impacts of this standard.
- Adopted Scenario: If another EE standard was in force for non-residential buildings prior to evaluating the standard and was widely adopted, then the minimum energy performance required by the previous standard would correspond to the base case.
- Non-Adopted Scenario: The baseline annual energy consumption for a standard that is not widely adopted at the municipal level is estimated through a market study of current construction practices at the time of construction or refurbishment of compliant buildings.

Define Archetype. An archetype building is defined by (1) building type (e.g. hotel, office) and (2) building size range (floor area). The baseline annual energy consumption for NOM-008 is estimated using the annual energy consumption of archetype buildings. Archetype buildings are designed to best represent the Mexico non-residential building stock before the application of the standard (adopted scenario) or at the time of construction or refurbishment (non-adopted scenario). Each archetype has its own properties: (1) building envelope parameters (e.g. windows, walls, roofs); (2) architectural characteristics (e.g. shape, window-to-wall ratio, shading devices, orientation); and (3) building loads (e.g. occupancy, air conditioning, lighting). These characteristics of archetype buildings are established through field studies or audit reports resulting from a market characterisation study. To continuously enhance the accuracy of energy savings calculations, verifying and improving archetype building models on a regular basis is recommended (Goel, Athalye, Wang, Zhang, Rosenberg, Xie, Hart and Mendon, 2014). For evaluation purposes, the models must be updated every year.

Characterise the Market.

Characterising the market means proceeding with the estimates of (1) annual construction activity[4] and (2) annual baseline construction practices (e.g. architectural characteristics, building envelope parameters and building loads). The construction activity estimate is needed to calculate potential countrywide energy savings and gross energy savings. The characterisation of common construction practices must be broken down by building archetype and climate zone to accurately estimate the energy consumption of the building stock across Mexico. Common construction practices to be documented include (1) technical characteristics of commonly used energy intensive equipment in buildings (air conditioning, lighting, ventilation, plug loads): capacity, efficiency, wattage, controls, technology, schedules, etc.; (2) occupancy load profiles: levels, schedules, etc.; (3) technical properties of commonly used building envelope elements (windows, exterior walls, roofs, foundations, shading devices): thermal conductivity, thickness, assembly, shading coefficient, solar heat-gain factor, emittance, etc.; and (4) architectural characteristics of commonly constructed buildings: wall, roof, window, door and floor areas, exposure orientations, external shading features, etc. Market characterisation must be undertaken in parallel with the calculation of unitary savings to ensure that the level of detail obtained by the market characterisation corresponds to that required by the approach selected for establishing unitary savings.

[4] Construction activity is the total floor area of new construction and retrofit buildings.

Estimate Unitary Energy Savings.

Usually, evaluating potential unitary energy savings associated with a building code is based on estimated as-built energy consumption data obtained through energy modelling using approved software. However, such data was not available for the purposes of evaluating NOM-008. The software used to calculate building performance under the standard establishes as-built heat gain (in watts) rather than as-built energy consumption (in watt-hours). Hence, the energy impact analysis of NOM-008 has to be carried out using building energy modelling to determine both the baseline and standard-compliant annual energy consumption.

NOM-008 is aimed at reducing heat losses/gains of the building and improving occupant comfort. Overall, space cooling is the main energy end use evaluated under this standard since heating-related energy needs in Mexico are very low. Although some regions could be cold and would benefit from a reduction of heat losses through the use of the NOM-008. Cooling energy consumption is estimated through whole facility modelling with the use of a building energy simulation program. Climatic differences across Mexico are accounted for through parametric simulations using weather files.

In the case of NOM-008, savings are determined using both archetype building and certified building energy consumption. More specifically, the steps to be followed to determine potential unitary energy savings are presented in Figure 2 below.

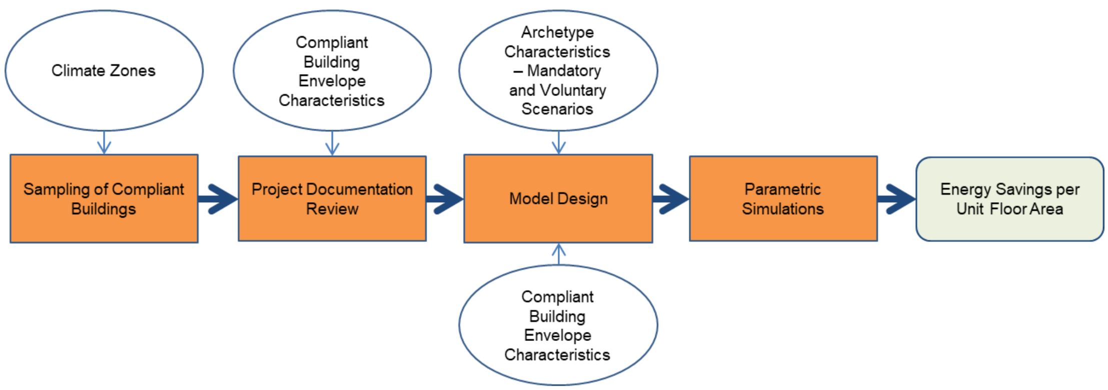


Figure 2: Steps to Establish Unitary Energy Savings for Each Archetype.

These steps must be followed for each archetype building defined:

- Sampling of Compliant Buildings: Samples only target newly built or retrofit buildings compliant with NOM-008. It is recommended that the sampling methodology should be based on the following criteria to properly represent the standard compliant building stock (population of standard compliant buildings): buildings from various climate zones in Mexico; buildings from each archetype; recently built or refurbished buildings.
- Project Documentation Review: To determine the building envelope parameters of standard compliant buildings, the project documentation of a selection of buildings must be consulted. Project documentation should include architectural drawings and technical specifications, NOM-008 software output, third-party certifications and NOM-008 labelling information.
- Model Design: Each archetype is modelled using the baseline parameters obtained during the market characterisation study. The building envelope parameters obtained through the project documentation review of selected buildings are used to model the compliant archetype. Other building characteristics (e.g. loads, architecture) remain unchanged to isolate the impacts of NOM-008.
- Parametric Simulations: Parametric simulations of both baseline and standard compliant models are run for all seven Mexico climate zones with the use of weather files. The baseline and standard compliant annual energy consumption per unit floor area are thereby obtained, as well as the energy savings per unit floor area for each archetype building in each climate zone.

To calculate potential countrywide energy savings, the unitary energy savings values are multiplied by the total construction and retrofit floor area of compliant buildings for each archetype building in each climate zone.

Gross Energy Savings

Gross energy savings are defined as the potential energy savings multiplied by the compliance rate (expressed in %). The compliance rate means the percentage (%) of buildings that meet the requirements of the standard.

$$Gross\ Energy\ Savings\ \left[\frac{kWh}{year}\right] = Potential\ Energy\ Savings\ \left[\frac{kWh}{year}\right] \times \%Compliance$$

Compliance Rate.

The compliance of each sampled building can be assessed through either a prescriptive or a performance-based method. Under the prescriptive method, the compliance rate is established by determining whether or not a building is standard compliant. Under the performance-based method, the compliance rate is established by comparing the energy consumption of a standard compliant building to the energy consumption of an as-built building. Since NOM-008 limits heat transfer through the building envelope without limiting energy consumption, the prescriptive method is suggested.

Where NOM-008 is enforced at the municipal level, the compliance rate is defined as the ratio between the annual floor area compliant under the standard and the annual new building stock.

Measurement of Compliance Rate.

The suggested sampling strategy is a proportional-to-size[5] multiple sampling stage strategy based on the following steps: (1) Select sample sites proportionally distributed among climate zones. Allocate sample sites according to documented total recent construction or retrofit area for each zone; (2) Select municipalities in each climate zone based on a proportional-to-size method; (3) Develop a list of permits recently issued for sites compliant with NOM-008. Randomly select sites for sampling.

Data collection consists of gathering all information needed to verify the compliance of sampled buildings, such as architectural drawings, calculation notes and software program documentation used to determine heat gains/losses through building envelopes. On-site visits can also be conducted to verify the installation and characteristics of building envelope measures covered by NOM-008. Certain methods are used to verify the key construction characteristics of sampled buildings. These verification methods include on-site measurements, use of thermal cameras, professional judgment and architectural drawings.

Verifying standard compliance is achieved by comparing building envelope parameters outlined in the compliance documentation (calculation notes or software) and building envelope parameters obtained through project documentation reviews and/or on-site verifications. If differences are observed, adjustments are made, adjusted heat gain transfer is calculated and results are then compared to the reference heat gain transfer. The number of buildings meeting standard requirements is thereby obtained.

[5] The probability of a site being selected is set proportionally to size. Size is defined as the total construction or retrofit floor area compliant under the standard.

Net Energy Savings and CO_2 Emission Reduction

To obtain net energy savings, a deduction is made from gross savings to account for NOMAD expressed as a percentage.

$$Net\ Savings = Gross\ Savings\ (1 - \%NOMAD)$$

Deductions to account for NOMAD are only applicable once the standard is adopted in municipal construction regulations. In cases where the standard is not adopted at the municipal level, the baseline already takes into account the NOMAD effect.

Also, further adjustments are included to take into account the impacts of previous EE programs on NOMAD since they might have had a significant impact on the adoption of more efficient building envelope measures. Indeed, they might have already been included in the NOMAD estimate. This is why data from programs that affected the measures regulated by the building code are requested. A NOMAD deduction is then applied to account for the number of building envelope measures that were installed as part of the programs.

Greenhouse gas (GHG) emission reduction due to electricity consumption savings are calculated by using the net savings of each standard multiplied by the emission factor of the Mexican electricity grid.

Evaluation Framework Benefits

Developing an evaluation framework prior to evaluation has two main benefits, notably building capacity at the governmental level as well as identifying ways to bridge data gaps. This section describes the benefits of these activities and how they are used for the next step of the impact evaluation process.

Building Capacity

Key stakeholders should embrace the evaluation framework, and developing their capacities helps the deployment of the evaluation framework. A capacity-building programme should be designed from the beginning to ensure all key stakeholders' involvement. The programme should be structured with an initial assessment survey conducted among a specific representative sample of the intended audience to verify their level of knowledge. Consequently, capacity-building workshops as well as communication and outreach campaigns should be conducted.

The public authorities in charge of EE policies are the first audience of an evaluation framework. Direct capacity building improves ownership of the evaluation framework. Building the capacity of government and technical staff is important, especially in emerging countries, to ensure replicable and comparable evaluation results over time. For example, workshops with main stakeholders help to overcome data gaps identified in a framework.

Also, workshops help identify several sources of information and secure commitments from various stakeholders to support public authorities in the data-gathering and evaluation process. It is important to prioritise good quality data that can be provided on a regular basis. The tasks of data gathering and analysis require a certain amount of effort from the various stakeholders. Government support is key to ensuring the mobilisation of all parties.

Bridging Data Gaps

Based on experience, the following solutions can be adapted to facilitate data gathering.

- Create a sharing information platform or a committee. This method serves to collect and share data and knowledge from various projects, programs, studies, databases and initiatives led by various management and operation divisions. The committee should coordinate efforts and explore collaboration with public authorities that may support data-collection efforts and be willing to share information. If possible, one person should be put in charge of leading this platform or committee.

- Characterise the market. Multiple sources should be used to characterise the market, including: industry statistics published by product manufacturing trade organisations; publicly available market characterisation reports including audit reports; data purchased from market research firms; data obtained through other evaluation activities; and interviews with relevant stakeholders.
- Involve experts in the evaluation process. A Delphi approach is recommended to determine NOMAD (Cadmus Group and DNV GL 2014). This approach consists of an interactive technique to obtain inputs from experts. It is recommended that input from a minimum of five expert panellists be required for each high-priority standard. The minimum number of five panellists for lower impact standards is not a requirement; however, the panel must be formed by multiple panellists.
- Adapt the number of sources in accordance with the expected impacts of a given EE policy. Using multiple sources allows triangulation and improves the accuracy of results. It is suggested that a minimum of two sources be used for the lowest priority standards (standards that are assumed to have a lesser impact on energy consumption) and up to five sources for the highest priority standards.
- Sign agreements with private stakeholders. Public authorities in charge of EE policy should enter into agreements with associations and manufacturers to ensure data provision.

Conclusion

Evaluation frameworks are tools to ensure that EE policies produce expected energy savings. This example has shown that best practices from developed countries used in program evaluation can be easily adapted to EE policy evaluation in emerging countries.

A clear and transparent methodology to evaluate gross and net energy savings as well as the economic and financial impacts of EE policies is the core of any evaluation framework.

By describing a concrete example of an evaluation framework using a bottom-up approach, we demonstrate herein the level of detail necessary to ensure a transparent and complete impact evaluation methodology. From this example, the main issue is found to be the data gaps between available and required data. All stakeholders in EE policy have a role to play in the evaluation process, including public authorities, utilities, retailers, product associations, manufacturers, non-governmental organisations, universities, laboratories and certifiers. Many data exist in the market; however, collection and validation efforts are important.

The main recommendation is developing an evaluation framework prior to conducting an evaluation. This has two main benefits, building capacity at the governmental level and identifying ways to bridge data gaps.

References

Cadmus Group Inc., and DNV GL Inc. 2014. *Statewide Codes and Standards Program Impact Evaluation Report for Program Years 2010-2012.* California, CA: Consultant Report prepared for the California Public Utilities Commission.

Cadmus Group Inc., and DNV GL Inc. 2015. *California Statewide Codes and Standards Program Impact Evaluation Plan: Phase One*. California, CA: Consultant Report prepared for the California Public Utilities Commission.

Cadmus Group Inc. 2016. *California Statewide Codes and Standards Program Impact Evaluation Report: Phase One Appliances.* California, CA: Consultant Report prepared for the California Public Utilities Commission.

Eichhammer N., Schlomann B., and Reuter M. 2018. "A comparison of impact evaluations ideally to be used for energy efficiency measures and evaluations used in practice: how can we close the gap?" Vienna, Austria: 2018 International Energy Policy & Programme Evaluation Conference.

Hall N., Roth J., Best C., Barata S., Jacobs P., Keating K., Kromer S., Megdal L., Peters J. S., Ridge R., Trotter F., and Vine E.L. 2006. *California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals*, prepared for the California Public Utilities Commission.

Goel S., Athalye R., Wang W., Zhang J., Rosenberg M., Xie Y., Hart R., and Mendon V.. 2014. *Enhancements to ASHRAE Standard 90.1 Prototype Building Models*. Washington, DC: PNNL Report prepared for the U.S. Department of Energy.

IEA. 2018. *Energy Efficiency 2018*.

International Performance Measurement & Verification Protocol Committee, 2016. "Core concepts International Measurement and Verification Protocol 2016". Efficiency Valuation Organization.

Li M., Haeri H. and Reynolds A. 2017. "Chapter 1: Introduction: The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures".

Mourtada. A. 2016. Case study on evaluation of energy building codes in emerging countries: Relevant issues and argumentations aiming at facilitating the discussion and exchange information among countries. Online publication: Agence de l'environnement et de la maîtrise de l'énergie (ADEME) and World Energy Council (WEC).

Wiel S., and McMahon J. E. 2005. *Energy-efficiency labels and standards: A guidebook for appliances, equipment, and lighting 2nd edition*. Washington, DC: Collaborative Labelling and Appliance Standards Program (CLASP)