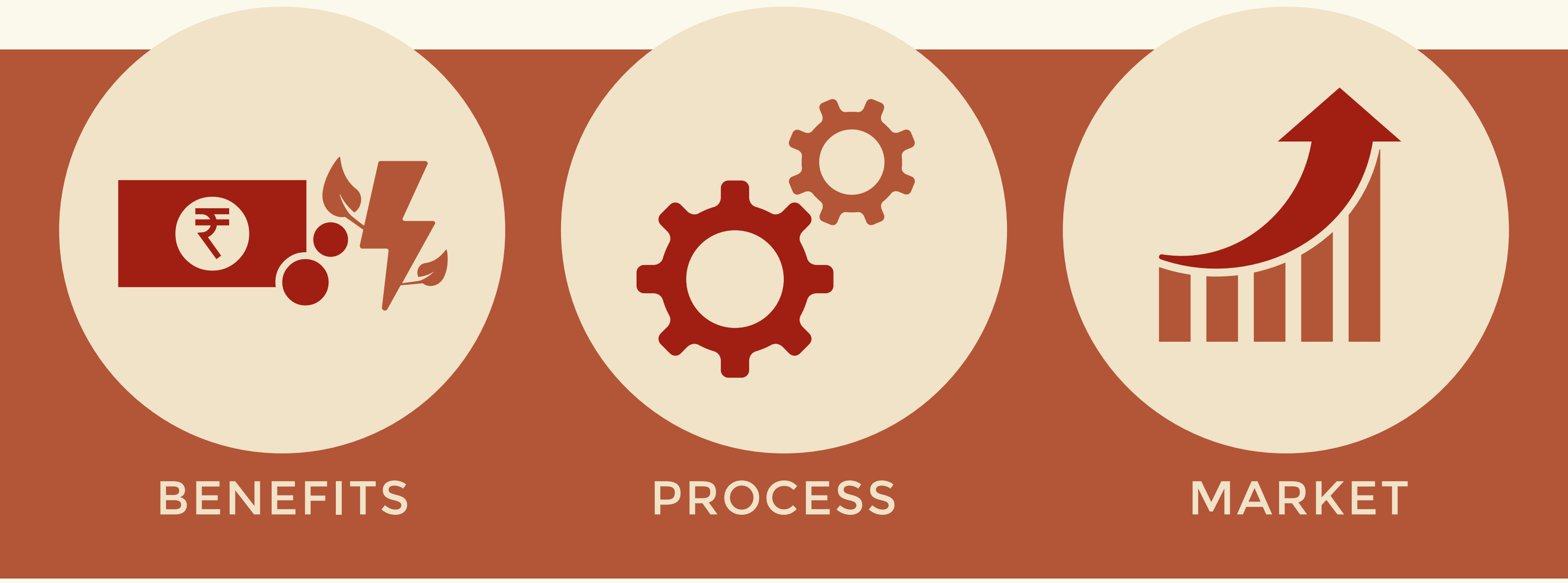
EVALUATING ENERGY EFFICIENCY PROGRAMMES IN INDIA

Prayas (Energy Group)



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Prayas (Energy Group)

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Prayas (Initiatives in Health, Energy, Learning and Parenthood) is a non Governmental, non-profit organization based in Pune, India. Members of Prayas are professionals working to protect and promote the public interest in general, and interests of the disadvantaged sections of the society, in particular. Prayas (Energy Group) works on theoretical, conceptual regulatory and policy issues in the energy and electricity sectors. Our activities cover research and intervention in policy and regulatory areas, as well as training, awareness, and support to civil society groups. Prayas (Energy Group) has contributed in the energy sector policy development as part of several official committees constituted by Ministries and Planning Commission. Prayas is registered as SIRO (Scientific and Industrial Research Organization) with Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India.

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Abbreviations

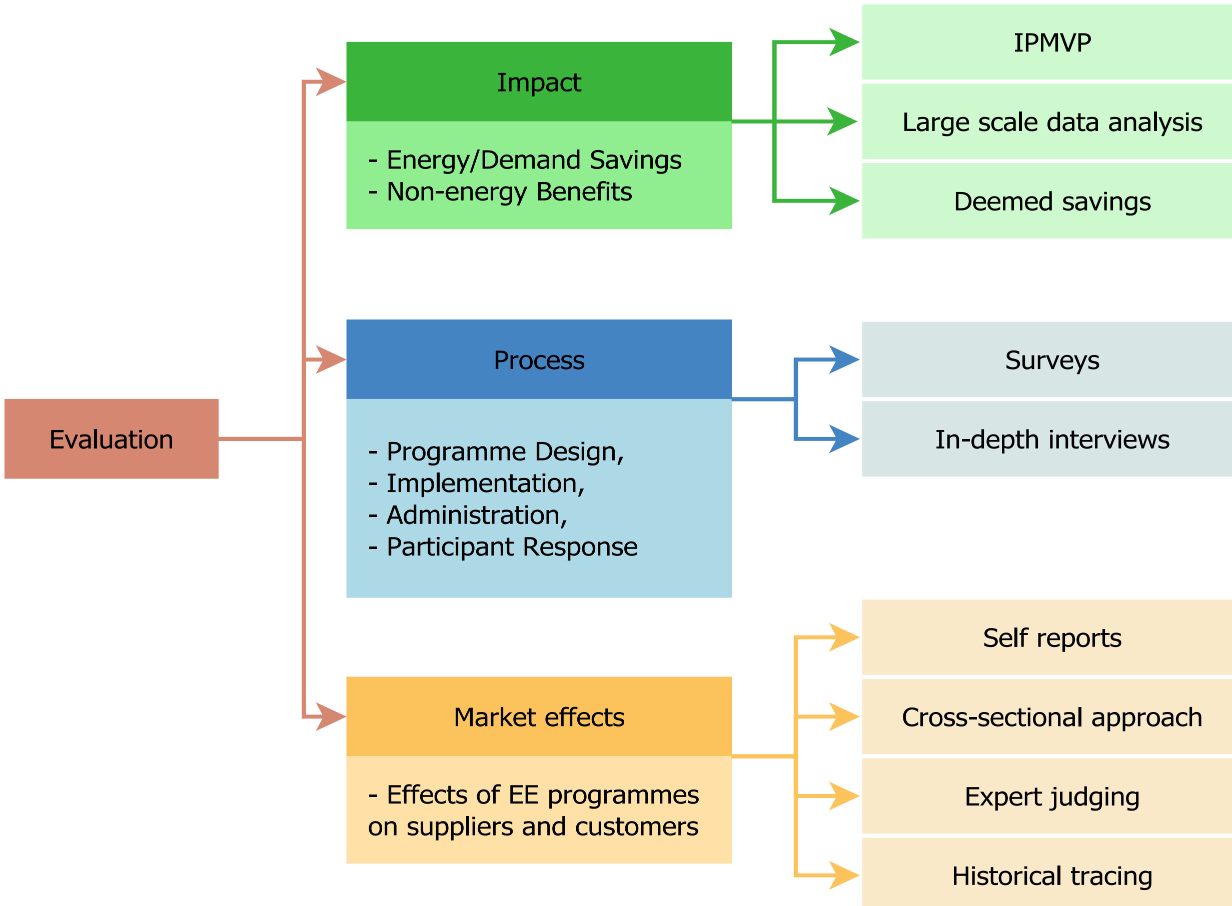
BEE	Bureau of Energy Efficiency
BLY	Bachat Lamp Yojana
CDM	Clean Development Mechanism
CFL	Compact Fluorescent Lamp
DELP	Domestic Efficient Lighting Programme
DISCOM	Distribution Company
DSM	Demand Side Management
EE	Energy Efficiency
EESL	Energy Efficiency Services Ltd
ESCo	Energy Service Company
FoR	Forum of Regulators
IPMVP	International Performance Measurement and Verification
LED	Light Emitting Diode
M&V	Measurement and Verification
MERC	Maharashtra Electricity Regulatory Commission
MSEDCL	Maharashtra State Electricity Distribution Company Ltd.
NEB	Non-energy benefit
NPC	National Productivity Council
NTG	Net-to-gross
PAT	Perform, Achieve, and Trade
QEM	Quasi-experimental method
RCT	Randomized control trials
SERC	State Electricity Regulatory Commission
TRM	Technical Reference Manual
UJALA	Unnat Jyoti by Affordable LEDs for All

EXECUTIVE SUMMARY

Energy efficiency can be crucial to India's goal to provide its people with reliable, affordable, secure, and sustainable access to energy. A number of policies and programmes aimed at conserving energy, improving energy efficiency, and managing energy demand have been implemented in India in recent years. Both the scale and the scope of these programmes are increasing, UJALA (Unnat Jyoti by Affordable LEDs for All), the large-scale programme to offer LED bulbs to households, being one example. However, comprehensive evaluation of these programmes gets limited attention. Such a comprehensive evaluation investigates all the impacts and the effectiveness of these programmes systematically substantially increasing the credibility of the programmes and the estimates of energy saved through them. Secondly, a comprehensive evaluation ensures informed reviews of current programmes and also helps in designing new ones more effectively to realize maximum possible energy savings.

Comprehensive evaluations of energy efficiency programmes in India have been limited because of several systemic barriers. The first barrier is the lack of mandate to any of the institutions involved in implementing energy efficiency programmes to undertake periodic and independent evaluation of the programmes. This lack is evident in the Energy Conservation Act, 2001; the Electricity Act, 2003; National Electricity Policy, 2005 and amendments to it; National Tariff Policy, 2006; and the model demand-side management (DSM) regulations issued by the Forum of Regulators (FoR). The second barrier is the common – and mistaken – perception that evaluation is burdensome, premature, and expensive. This misperception primarily stems from the experience of actually measuring energy savings using data loggers in some of the early programmes implemented in India. Evaluation is also believed to be particularly burdensome for small-scale programmes. Finally, publicly available data on energy efficiency programmes are scarce or lacking altogether, and this lack limits independent evaluations by researchers, academicians, or civil society organizations. These systemic barriers need to be overcome so that more programmes are comprehensively evaluated in India.

A comprehensive evaluation of an energy efficiency programme includes impact evaluation (assessing the reduction in energy and in peak demand), process evaluation (assessing the effectiveness of 'programme delivery'), and market-effects evaluation (assessing changes in the market due to the programme). Evaluations are particularly important at the pilot stage because the lessons learnt during the evaluation can be used to scale up the programme effectively and are also important for on-going programmes because such evaluations can point out what has worked well and what has not. Following figure summarizes different methods of conducting different types of evaluations of energy efficiency programmes.



Categories and methods of evaluating energy efficiency programmes

This report provides broad guidelines on evaluating energy efficiency programmes in India. The guidelines are based on reviews of global best practices and backed by case studies to illustrate the practices. The report is meant for policymakers, managers in distribution companies, and regulators, who can commission comprehensive evaluations of energy efficiency programmes currently being implemented in India but. It will also be useful to energy efficiency institutions in India (the Bureau of Energy Efficiency, Energy Efficiency Services Ltd, and state-designated agencies, for example) in incorporating comprehensive evaluations into the design of programmes. Finally, the report highlights the importance of comprehensive evaluations of energy efficiency programmes to consumers, civil society organizations, and researchers in India. The report is not so much a comprehensive guide to evaluate all energy efficiency programmes in India. Rather this report presents broad guidelines on developing templates or frameworks for regulations aimed at evaluating typical energy efficiency programmes or drawing up the terms of reference for specific programmes.

1 INTRODUCTION

Energy efficiency, which, as used in this report, also includes energy conservation and demand-side management (DSM), is crucial to India's goal to provide people with reliable, affordable, secure, and sustainable access to energy. Potential savings because of energy efficiency have been variously estimated at 15%–30% of the total energy consumption in different sectors such as agriculture, residential, commercial, and industry (Singh, Sant, & Chunekar, 2012). A number of policies and programmes to improve India's energy efficiency have been implemented in recent years. The Bureau of Energy Efficiency (BEE), India's nodal agency for implementing energy efficiency, has long-standing national-level programmes such the Standards and Labelling (S&L) programme for buildings, appliances, and equipment and the Perform, Achieve, and Trade (PAT) programme for industries. A few electricity distribution companies (DISCOMs) have been implementing small-scale DSM programmes in their respective areas. Energy Efficiency Services Ltd (EESL), a public-sector company, has rolled out a national bulk procurement programme for LED bulbs and has expanded it to fluorescent tubes, ceiling fans, air conditioners, and agricultural pumps.

Although energy efficiency programmes in India have been expanding rapidly in terms of both scale and scope, their evaluation has received only limited attention. Evaluation of an energy efficiency programme attempts to answer two basic questions: What were the impacts of the programme and what caused those impacts? Impacts of energy efficiency programmes can be multifarious, including reduced demand, monetary savings, and market transformation. The impacts may vary in scale with the stakeholders (consumers, DISCOMs, manufacturers, and society as a whole, for example). The programme design may incorporate different aspects such as incentives, processes, and the choice of an appliance. External factors including macroeconomic conditions may help or hinder a programme in achieving its objective. A comprehensive evaluation systematically investigates all the impacts and the effectiveness of a programme.

A comprehensive evaluation of energy efficiency programmes is necessary for two main reasons: (1) it gives a realistic estimate of the *actual* impact of a given programme – thereby making the programme and estimated savings from it more credible – as compared to its *potential* impacts, which are typically estimated based on several assumptions; (2) it ensures more informed reviews of current programmes and more effective designs of new ones to realize maximum possible energy savings cost-effectively. The importance of evaluation is perhaps best described by what the economist John Kenneth Galbraith once said: "*Things that are measured tend to improve*". As energy efficiency programmes in India expand in scale and scope, their comprehensive and periodic evaluation becomes even more necessary—and this consideration has been the prime mover of this report.

The report seeks to develop broad guidelines on evaluating energy efficiency programmes being implemented in India and is organized as follows:

A brief review of how energy efficiency policies and programmes are evaluated in India at present, barriers to their periodic evaluation and recommendation to overcome the barriers are presented in Section 2. The global best practices in evaluating energy efficiency programs are covered in section 3 and 4. Annexure 1: Methods of evaluating energy efficiency programmes presents a more detailed overview of different methods used for evaluating energy efficiency programmes and supplements the overview with specific case studies (Annexure 2: Case studies). Annexure 3: End-use-specific measurements and verification provides some examples of monitoring and verification (M&V) methods that can be used for specific end-uses. Finally, Annexure 4: Guidelines for terms of reference for evaluating typical energy efficiency programmes in India outlines broad terms of reference for two typical energy efficiency programmes being implemented in India; bulk procurement programme of appliances and equipment including agricultural pumps, and the Standards and Labeling (S&L) programme.

The report is meant for policymakers, managers in distribution companies, and regulators, who can commission comprehensive evaluations of energy efficiency programmes currently being implemented in India but will also be useful to energy efficiency institutions in India (BEE, EESL, and state-designated agencies, for example) in incorporating comprehensive evaluations into the design of programmes. Finally, the report highlights the importance of comprehensive evaluations of energy efficiency programmes to consumers, civil society organizations, and researchers in India. The report is not so much a comprehensive guide to evaluate all energy efficiency programmes in India. Rather this report presents broad guidelines on developing templates or frameworks for regulations aimed at evaluating typical energy efficiency programmes or drawing up the terms of reference for specific programmes.

2 EVALUATING ENERGY EFFICIENCY IN INDIA

2.1 A BRIEF REVIEW

Literature on evaluation of energy efficiency policies and programmes is scarce in India. Most of the available studies are focused on estimating savings rather than evaluating the programmes as a whole to draw useful lessons for future programmes. Some major studies reported in the literature are briefly reviewed here.

STANDARDS AND LABELLING (S&L)

A flagship programme of the Bureau of Energy Efficiency (BEE), the S&L programme for appliances and equipment was launched in 2006. The programme is currently mandatory for ten appliances and voluntary for eleven. BEE used to estimate annual savings from its various programmes including S&L and publish the results on its website until 2010 (BEE, 2010). The estimates were based on aggregated annual sales figures for rated appliances as provided by manufacturers. An appliance with one star (the least efficient) was taken as the baseline and the number of hours of its use was an assumed number. The National Productivity Council (NPC), while verifying the savings, noted that BEE needs to establish better estimates for various operating factors such as peak coincidence factors, usage hours, and device life. No recent studies are available on BEE's website but data on production of different appliances from 2011 to 2017 are now available on the website along with the estimated energy savings for each year.

A few independent studies were conducted to gauge the extent to which Indian consumers were aware of S&L. One study (Chatterjee & Singh, 2012) surveyed about 20000 households, 550 traders, and 50 manufacturers of different appliances across the country. The survey collected data on the ownership of appliances and their usage to estimate savings from the S&L programme and found that although the level of awareness was increasing, it was yet to reach a critical mass. Energy efficiency mattered far less than other factors such as price and the brand. However, a significant majority were willing to pay only 10% premium for more efficient appliances. Another study (Roy, Roy, Dasgupta, & Chakravarty, 2011) surveyed about 400 households in West Bengal and found that about 40% of the households were aware of the S&L programme. The proportion of star-rated appliances varied from 3% to 24%, depending on the type of appliance. A more recent study (Dhingra, Walia, & Mukherjee, 2016) focused on measuring the impacts of S&L on 5000 consumers, 642 retailers, and 45 manufacturers and found that approximately 63% of the respondents were aware of the S&L programme compared to about 33% in a similar survey in 2010. Most of the consumers understood that the more the number of stars, the more efficient the appliance, but could not understand the values of different technical parameters as given on the label.

BACHAT LAMP YOJANA

BEE launched the Bachat Lamp Yojana (BLY) in 2009 with a target of replacing 400 million incandescent bulbs with Compact Fluorescent Lamps (CFLs), which were made available at the price of incandescent bulbs, and the difference was met through funds provided by the Clean Development Mechanism (CDM), a carbon-trading scheme established under the Kyoto Protocol. The mechanism required BEE to adopt a well-defined methodology for estimating the savings from the use of CFLs (UNFCCC, 2016). The methodology required actual monitoring of the use of CFLs to establish the basis for the assumptions on operating hours and other parameters that would determine the savings. The methodology was also required to ensure that the CFLs were used for replacing incandescent bulbs at points with high usage. Details of this methodology are given in Section 5.3. The programme sold about 29 million lamps but failed to scale up primarily because of the crash in carbon prices under the CDM. There is no publicly available report evaluating nationwide impacts on the market, actual savings, and the processes of the programme.

Bulk procurement programmes

A large-scale bulk procurement programme for LED bulbs, named called UJALA, is being conducted by the public sector company Energy Efficiency Services Ltd (EESL). More than 25 crore (250 million) LED bulbs have been sold under this programme. The model for LED bulbs is now being replicated for fluorescent tubes, ceiling fans, air conditioners, street lights and agricultural pump sets.

Two reports on the verification, by a third party, of annual energy savings and the number of bulbs from the UJALA programme are available on its website.

- In the first report (Rao, 2015), about 26 000 households were surveyed in two districts of Andhra Pradesh. It was found that the majority of households had replaced incandescent bulbs with LED bulbs and were satisfied with the brightness. Data on points of use and usage hours were also collected to estimate actual savings. Less than 2% of the bulbs were defective but majority of the households did not know whom they should contact to obtain replacements for the defective bulbs.
- The second report surveyed 5 street lighting projects and about 600 households in Andhra Pradesh and Puducherry. Actual measurements were conducted over short durations on a sample of street lights to estimate the savings. In the case of households, the survey questions were limited to the current status of LED bulbs. The report assumed 100% replacement of incandescent bulbs with LED bulbs; for hours of use, the figures were based on an earlier research survey on electrical load. Less than 1% of the LED bulbs were found defective.

Prayas (Energy Group) conducted a study to assess the impacts of UJALA (Chunekar, Mulay, & Kelkar, 2017). The objective was twofold: (1) to learn from the UJALA model by focusing not only on actual savings but also on market impacts and effectiveness of the processes for other current and future programmes based on that model and (2) to highlight the importance of comprehensive evaluation of energy efficiency policies and programmes by demonstrating the value of insights from the evaluation. All three aspects of evaluation, namely savings, market impact, and process effectiveness, were covered.

Demand-side management programmes driven by DISCOMs

A number of small-scale DISCOM-driven DSM programmes have been implemented in India, mostly focusing on lighting and agriculture pumps (see Prayas (Energy Group), 2014), Sarkar, Mukhi, Padmanaban, & PwC, 2016) and (Doolla, Mehta, Singh, & Banerjee, 2002). However, literature on comprehensive evaluation of these programmes is limited.

Prayas Energy Group (Prayas (Energy Group), 2007), on request of the Maharashtra Electricity Regulatory Commission (MERC), comprehensively evaluated a programme of the Maharashtra State Electricity Distribution Company Ltd (MSEDCL) of replacing incandescent bulbs with CFLs. Individual and group consumer surveys, engineering methods, and process analysis were used in evaluating the programme. Consumers were found to be keen on participating in the programme because they considered the distribution company's credibility to be high as a third party selling CFLs. MSEDCL adopted innovative methods for making consumers aware of the programme and for distributing CFLs, such as using women's self-help groups for distribution. However, MSEDCL fell short of its various other responsibilities as an implementing agency. For example, the company did not educate the consumers on the use of CFLs; as a result, a majority of the consumers replaced fluorescent tubes with CFLs or used CFLs at points of low use, nor did it monitor the quality of bulbs, which led to high failure rates (although the manufacturers had offered a one-year warranty, few replacements were made under the warranty). Although the programme had a substantial savings potential, the MERC discontinued it because of several problems related to implementation.

Another comprehensive evaluation was undertaken by the International Institute for Energy Conservation (IIEC), which evaluated the efficient-lighting programme of Bangalore Electricity Supply Company (BESCOM) in March 2006. The programme was conceived as part of the Energy Conservation and Commercialization (ECO II) initiative of USAID. The evaluation considered all the three aspects of the programme: impacts, processes, and market effects. For impact evaluation, the IIEC used standard engineering equations to estimate both pre and post-installation consumption of electricity. Benefits to the customers were assessed through customer surveys – neither actual hours of use nor consumption (in terms of kilowatts) was measured – and overall benefits were assessed using sales data before and after the programme. Customer satisfaction, marketing efforts, and internal procedures and systems of BESCOM were assessed as part of process evaluation through face-to-face interviews of participants and non-participant consumers; participating suppliers, distributors, and retailers; and programme administrators. Programme penetration and a review of the programme's eligibility criteria and incentive levels were the objectives of market-effects evaluation, which was carried out by surveying customers (participating, non-participating, and direct-sales) (International Institute for Energy Conservation, 2006).

2.2 Barriers to evaluating energy efficiency in India

Several systemic barriers have prevented periodic comprehensive evaluations of energy efficiency programmes in India. These barriers are discussed here along with recommendations on how to surmount them.

Lack of mandate for BEE and lack of regulatory oversight

The Energy Conservation Act, 2001 (EC Act, 2001) established the Bureau of Energy Efficiency and set rules and regulations for its working; however, the act made no provisions that mandate independent and periodic evaluation of the policies and programmes implemented by BEE. The Electricity Act, 2003; the National Electricity Policy, 2005 and amendments to it; and the National Tariff Policy, 2006 and amendments to it mention the importance of DISCOMs in implementing DSM programmes but are vague on all the operational aspects including the evaluation of such programmes. Model DSM regulations released by the Forum of Regulators (FoR) in 2010 (Forum of Regulators, 2010) were adopted by a few state electricity regulatory commissions (SERCs). These model regulations require DISCOMs to prepare evaluation plans for the proposed DSM programmes according to the guidelines issued by the respective SERC. The regulations also require the SERC to commission third-party evaluation of programmes implemented by DISCOMs. However, neither has any DISCOM submitted any detailed evaluation plan for its programmes nor has any SERC issued guidelines for such evaluation so far, apart from suggesting periodically in their tariff orders the need for DSM programmes and their evaluation—suggestions that DISCOMs have mostly ignored and the SERCs have not followed up. State-designated agencies were established under Section 15(d) of the EC Act, 2001, for the purpose of coordinating, regulating, and enforcing various provisions of the act at the state level. In most cases, this additional responsibility was given to the existing agencies entrusted with promoting renewable energy. However, even these agencies have no mandate to undertake comprehensive evaluations. Thus a lack of clear mandate for independent evaluation of BEE's policies and programmes, lax implementation of regulations, and poor supervision of programmes conducted by DISCOMs and EESL are the primary reasons for the absence of any comprehensive evaluation reports.

Misconception that evaluation is burdensome, premature, and expensive

In India, evaluation of an energy efficiency programme is generally associated with actual measurements of the energy saved. These measurements are carried out by energy-savings companies (ESCOs) or certified energy managers and auditors by metering a sample of projects, an exercise that is not only costly but sometimes tedious. For instance, time-loggers were installed in selected CFLs distributed under the BLY (*Monitoring Report Form (CMD-MR)*, 2010) and also in selected LEDs distributed under the Domestic Efficient Lighting Programme (DELP) in Puducherry. However, many consumers removed the loggers or often changed the location of bulbs, making it difficult to monitor the use of the bulbs.

These difficulties in conducting evaluations often go together with a general view that evaluations are not really worth the effort. Several arguments are generally put forth for not conducting evaluations: that DSM programmes in India are at a nascent stage, and mandating evaluations will make them more complex; that the scale of programmes in India is too small; and that the impact of these programmes on DISCOMs in terms of energy is minimal. There is also a view that deemed savings approach doesn't need evaluation. On the contrary, it is true if and only if the deemed values that are used are derived from previous rigorous evaluations. Thus the first and most prudent step would be to evaluate all the aspects of energy efficiency programmes and then use those values to evaluate similar programmes in the future. Also, these values should not be termed as constant forever and hence will need on the course corrections as programmes and technologies evolve in the future.

The first argument can be countered by pointing out that a comprehensive evaluation not only investigates the quantum of savings but also their causes, besides assessing the effectiveness of the processes, which is required when pilot programmes are scaled up. Evaluation of the processes in a programme makes it possible to make changes to those processes when it is still manageable and affordable to do so. Thus, pilot programmes require much more rigorous evaluation than established programmes, because the lessons learnt during the evaluation can guide the scaling up. Also, DSM programmes in India are no longer small: for example, EESL is planning to launch a series of large-scale programmes based on the UJALA model which can potentially result in significant savings.

It should also be noted that the massively popular UJALA programme is based on a bulk procurement model to reduce the price of energy efficient appliances and requires no subsidies from the state or from the DISCOMs: the buyer pays for all the benefits achieved from the energy savings and is entirely responsible for them—the benefits to DISCOMs and to the state government are an add-on and free. Because EESL receives no payments based on realized savings, it is argued that it is not necessary to estimate such savings and, consequently, no need for a comprehensive evaluation either.

This argument too can be countered in several ways. First, as discussed earlier, a comprehensive evaluation goes far beyond estimations of savings. Secondly, even with limited focus on savings, the large scale of the programme should prompt DISCOMs to make a reliable forecast of savings. For instance, the UJALA programme claims savings equivalent to approximately 13% of the total electricity consumption of the country's residential sector (www.ujala.gov.in), which is somewhat unrealistic since lighting accounts for approximately 21% of the total electricity consumption of the residential sector. Thirdly, such methods as deemed savings and large-scale data analysis can obviate the need to install meters every time an evaluation is planned and can be used effectively to estimate savings provided all the prerequisites to using these methods, described earlier, are met.

As to evaluations being costly, it has been shown that evaluations do not cost a great deal internationally: roughly 3%–5% of the total programme costs is enough for a basic evaluation (Messenger, Bharvirkar, Golemboski, Goldman, & Schiller, 2010). As programmes expand, mature, and become more sophisticated, more money can be used for rigorous evaluations.

LACK OF PUBLICLY AVAILABLE DATA

Publicly available data can prompt independent evaluations of energy efficiency programmes by academicians, research organizations, and civil society organizations. Such evaluations can complement or, as is the case in India, serve as understudies for, formally commissioned evaluations. However, the data for such independent evaluations are not available in the public domain in India, and regulators do not mandate DISCOMs to make the documents related to programme design available in the public domain; for instance, although EESL published the document on DELP on its website[a] (EESL, 2014), the company did not do the same for UJALA or for any of its other recent programmes. BEE too has limited information in public domain on processes and market effects of its major programmes such as S&L and PAT. Data on end-use and sales can also be useful. For instance, BEE and EESL conducted load research studies in 30 states under a programme to build the DISCOMs' capacity to implement DSM programmes (Prayas (Energy Group), 2016). Data from those studies, if made available to the public, can be used to draw an approximate baseline for evaluating energy savings. Similarly, aggregate data on shipments of star-labelled appliances can be useful in determining trends in the sales of higher-rated appliances

[a] https://www.eeslindia.org/

[b] https://www.beestarlabel.com/Home/EnergySavings

[c] https://energy.gov/eere/analysis/program-evaluation-planning-and-conducting-evaluations

(these data have recently been made available on BEE's website[b]. Lack of relevant data in the public domain restricts independent evaluations.

2.3 The way forward

We recommend the following ways to surmount the systemic barriers to comprehensive evaluation of energy efficiency programmes in India.

Issue model regulations specific to conducting evaluation of demand-side management programmes of DISCOMs. The Forum of Regulators issued model regulations for implementing DSM programmes at the state level, and these regulations were adopted in their entirety by many state regulators (Forum of Regulators, 2010). Similarly, the FoR can issue model regulations for evaluating DSM programmes. These regulations should be comprehensive, covering the evaluation of direct impacts, process impacts, and market impacts. Given the significant impacts of large-scale energy efficiency programmes, the state regulators can develop their own regulations in the absence of any model regulations related to DSM. The more progressive regulatory commissions can take a lead in developing such regulations. However, it is also important to monitor compliance with these regulations. One such mechanism can be a DSM consultative committee (DSM-CC), as has been convened by the MERC, consisting of members from the staff of DISCOMs, academics, technical experts, and civil society organizations. The committee should meet periodically to discuss and approve DSM programmes.

Set aside dedicated funding for evaluations. Expenses related to evaluations should be considered at the design stage of a programme and the required amount set aside for the evaluation. BEE and EESL can conduct evaluation studies as part of the capacity-building exercises for DISCOMs that were part of the load research studies. DISCOMs can also conduct studies on their own given the impact of savings on their annual revenue requirement. Such studies can be part of their DSM activities with the cost being passed on to consumers. EESL's recent investments in DSM programmes have resulted in freeing up DISCOM's funds for DSM activities.

Make data on policies and programmes available to the public. Data related to policies and programmes as appropriate should be made available to the public. Specialized research organizations, academicians, and civil society organizations can be tapped for expertise in social sciences, operations management, and market research required for comprehensive evaluations.

[b] https://www.beestarlabel.com/Home/EnergySavings

3 BEST PRACTICES IN EVALUATING ENERGY EFFICIENCY

The previous section reviewed evaluation practices being followed in India and systemic barriers to comprehensive evaluations of India's energy efficiency programmes. This section provides an overview of global best practices in evaluating energy efficiency programmes and offers broad guidelines on developing an India-specific approach to such evaluations. The various categories and methods of evaluation are explained later in detail in Annexure 1: Methods of evaluating energy efficiency programmes Eight case studies are illustrated for better understanding in Annexure 2: Case studies. Examples of end-use-specific methodologies in Indian and international context are given in Annexure 3: End-use-specific measurements and verification.

Evaluation of an energy efficiency programme involves both real-time and retrospective assessments of the performance and implementation of the programme (Schiller, 2012). These assessments need to be accurate, consistent, and transparent and also need to be part of programme design to ensure a cyclic process of planning, implementation, and evaluation. Evaluating an energy efficiency programme goes beyond M&V. It is generally conducted during or at the end of the programme to a) establish the savings, b) identify the exact causes that result in those savings; and c) measure the process effectiveness and the broader impacts of the programme on the market.

Figure 1 shows the cyclic process of any energy efficiency programme. Programme planning includes identifying the customers to whom the programme will be offered, the funding available for the programme, cost-effectiveness of the programme, the technology to be deployed, major timelines, and the goal in terms of the amount of energy to be saved. Programme implementation includes delivery of the programme to the targeted customers, and programme evaluation includes assessing the performance of the programme in terms of its impacts, the processes followed, and its effect on the market. In an effective energy efficiency programme, each of the three components should provide feedback to the next.

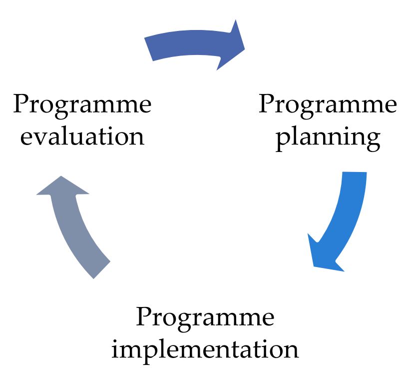


FIGURE 1: CYCLE OF PROGRAMME PLANNING, IMPLEMENTATION AND EVALUATION

Evaluations are of three types (CPUC, 2004; Schiller, 2012).

- **Impact evaluations** are evaluations of the outcome or effects. They measure the changes in energy consumption or in energy demand as a result of the programme implementation. They may also examine co-benefits if any, such as improved health or comfort and avoided emissions. In many cases, the co-benefits are not easily quantifiable and hence are only listed but not measured unless specifically required.

- **Process evaluations** are systemic assessments of a programme and consist of in-depth examination of the design, delivery, and operations of the programmes to obtain higher energy savings and cost-effectiveness and to accomplish programme goals. Process evaluations are usually undertaken in tandem with programme implementation so that mid-course corrections can be made if required.
- **Market-effects evaluations** encompass a broad range of activities that estimate the programme's influence on the market and may include assessments of baselines, current practices, potential studies, effects of the programme on its stakeholders, and consumer satisfaction.

A comprehensive evaluation including all the above three aspects is recommended for programmes that have significant impacts or use new technology or new delivery mechanisms. The scope and rigour with which other programmes are evaluated depend on the type of programme, available funding, vintage of the programme and the technology, and the scale of its impacts. Figure 2 summarizes different methods of conducting different types of evaluations, which are briefly described in the following subsections.

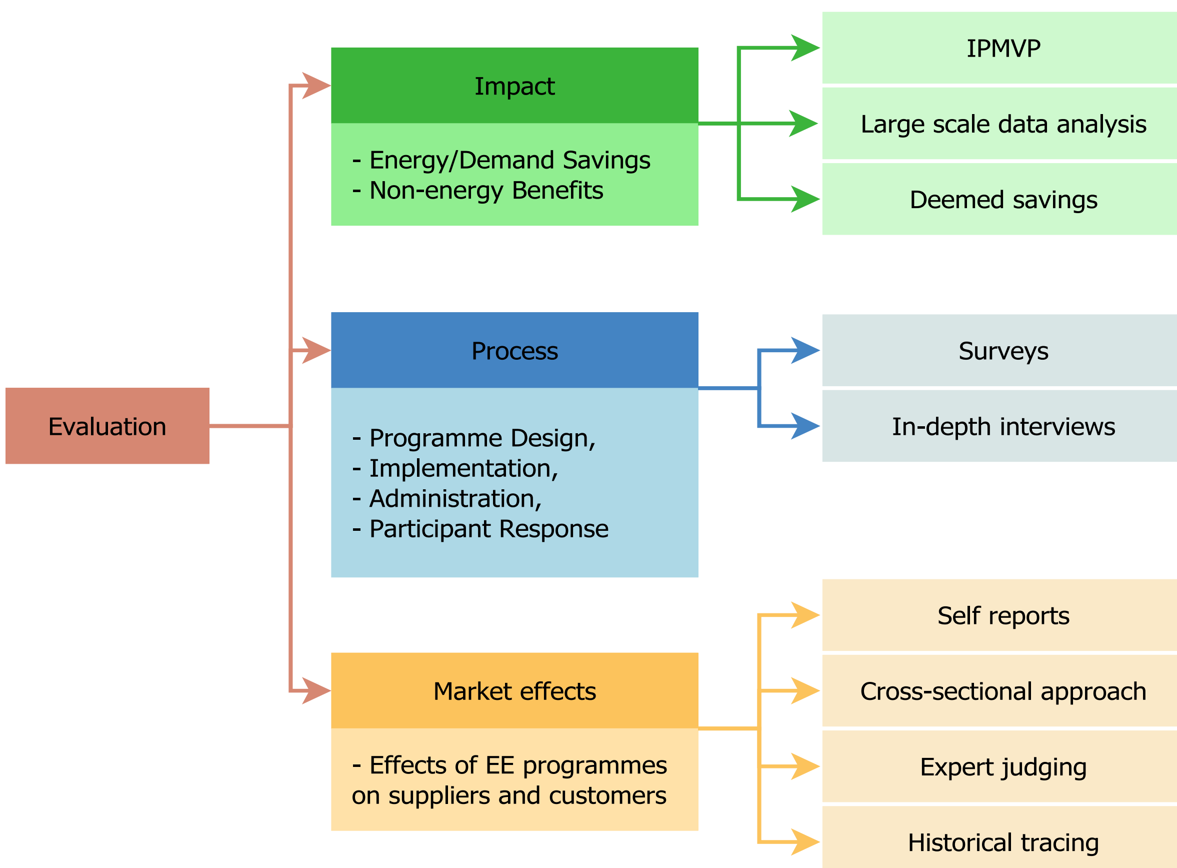


FIGURE 2: CATEGORIES AND METHODS OF EVALUATING EE PROGRAMMES

3.1 Evaluating impacts

Impacts of a programme include both direct impacts, which include savings in gross energy and in energy demand, and co-benefits, which include improved health and comfort and avoided emissions. The metrics, assumptions, approaches – and consequently the budget – of an evaluation exercise are governed by its specific objectives. Some common objectives are listed below.

- Calculating the savings in gross energy (kilowatt-hours) and energy demand (kilowatts)
- Calculating net savings by estimating free ridership and spillover
- Analysing cost effectiveness
- Calculating avoided emissions
- Providing continual feedback to regulators and DISCOMs
- Assessing the need for continuing the programme

Determining the savings in gross energy and energy demand is usually the primary objective of most impact evaluations. If resources permit, programme administrators broaden the scope of the evaluation and determine its net impacts and other co-benefits. Cost-effectiveness is assessed before implementing the programme so that regulators or programme administrators can consider the impacts of programme costs on consumers.

Gross energy savings

Savings in gross energy and in energy demand within the programme's geographic area are the savings that can be attributed to efficiency after accounting for such external factors as weather, occupancy, and macroeconomic conditions. The efficiency achieved and in turn the savings may be attributed to the programme but can also be due to a consumer's own initiative, other efficiency programmes, or changes in the market.

Savings in gross energy and in energy demand can be determined by the following methods.

1 **Measurement and verification:** It involves determining the savings by measuring energy use within an individual facility before and after implementing an energy-saving measure. Four M&V options are available for estimating energy savings, namely Option A, measuring a key parameter; Option B, measuring all parameters; Option C, analysing a whole facility; and Option D, calibrating by simulation. Each option is described in detail in Annexe 1. Table 1 briefly describes the criteria for selecting a suitable option taking into account the measurement boundary, type of measurement and duration, method of analysis, and cost and application criteria.

2 **Large-scale data analysis** involves comparing the energy use of the 'treatment' group (participants in an energy efficiency programme) with that of the 'control' group (non-participants) after ensuring that the two groups are comparable in other respects and that the comparison is carried out at the same time for both groups. The difference in energy use can then be attributed to the programme, because external factors, if any, are the same for both the groups. Such large-scale data analysis uses either randomized control trials (RCTs) or quasi-experimental methods (QEMs). In the former, participants are assigned to the treatment group or the control group at random, whereas in the latter, such assignment is not random.

3 **Deemed savings** method uses a set of predetermined values to calculate the savings: the predetermined values are taken from earlier studies in which actual measurements were made.

As mentioned earlier, the savings need not be determined on the same scale and with the same rigour for every programme. The choice of an approach depends on the objectives, scale, budget, resources available, and other aspects specific to the programme and participants in the programme. Table 2 lists some criteria to facilitate the selection of a suitable approach to estimate savings.

Variable	Option A: measure a key parameter	Option B: measure all parameters	Option C: analyse a whole facility	Option D: calibrate by simulation
Measurement boundary	End-use level such as a single piece of equipment (e.g. replaced motor in a factory)	A system (e.g. an entire pumping system)	Whole facility (e.g. a home, a building, a factory)	Whole facility (e.g. a home, a building, a factory)
Type of measurements and duration	End-use metering, or combination of predetermined values and key parameter measurement for baseline and reporting period, spot measurements or short-term measurements	End- use metering , spot or short-term or continuous measurements for engineering models	Generally require 9–12 months of data before and after the measures were installed, spot, short-term or continuous measurements	Typically hourly or monthly billing data, 9–12 months of pre-installation data for baseline model simulation; for new construction, only reporting period data are used; spot, short-term, or continuous measurements to calibrate computer simulation models
Analysis method and cost	Engineering analysis of baseline and reporting period; cheaper than other three options	Component analysis methods are more difficult and costlier than Option A	Multivariate regression analysis or simple bill data comparisons; cost depends on how the data are collected (metered or bill data)	Calibrated simulation models; cheaper than Option C
Application criteria	Measures with constant loads; magnitude of savings is low; simple project with limited independent variables; interactive effects can be ignored or are predetermined	Replacement of simple equipment where energy savings for each measure are desired; independent variables are not complex; interactive effects can be ignored or are stipulated	Project is complex; predicted savings are large (more than 10% of baseline energy use); energy savings need not be determined for each measure; interactive effects are included; independent variables are simple and easy to monitor	New construction projects; energy savings values per measure are desired; Option C tools are not cost-effective, complex baseline adjustments are likely; baseline measurements do not exist or are very expensive to collect
Examples	A fan retrofit where the demand (kW) before and after is stipulated;, number of hours of operation are measured from short-term measurements	All lights in a home changed or a comprehensive HVAC system retrofit	All home appliances replaced with energy-efficient appliances	Programme affecting many systems in a facility

TABLE 1: OPTIONS FOR MEASUREMENT AND VERIFICATION (ADAPTED FROM SCHILLER, 2012)

Parameter	Measurement and verification	Large-scale data analysis	Deemed savings
Measurement type	• Key parameter • All parameters • Whole building or facility • Calibrated by simulation	Energy billing data of all participants before and after instalment	No actual measurement; values taken from technical reference manuals
Costs	High	Medium	Low
Accuracy	Most accurate	More accurate than deemed-savings method	Least accurate if values of key parameters used are not taken from valid sources such as periodically updated technical reference manuals
Application	• Chosen when other approaches are not feasible, for example when no deemed savings values are available or • when savings do not need to be estimated for each project	• Programmes with many participants with common characteristics • Participation is well defined • At least one year's reporting period and baseline data are available	• Funding resources are limited • Savings do not vary significantly with changes in independent variables • Predetermined values do not increase the uncertainty of evaluation results significantly
Examples	Industrial energy efficiency programmes, performance-contracting programmes	Programmes involving replacement of refrigerators or air conditioners	Lighting and ceiling fan programmes

TABLE 2: CRITERIA FOR SELECTING A SUITABLE APPROACH TO EVALUATE IMPACTS

NET ENERGY SAVINGS

The net energy savings from an energy efficiency programme can be defined as the total change in energy use attributable to the programme. Evaluating net energy savings involves separating the impacts of extraneous factors – such as customer self-motivation or effects of other programmes – from those of the programme being evaluated. Two main factors separate net energy savings from gross energy savings, namely free riders and spillovers. A *free rider* is a programme participant who would have implemented the measure anyway, even in the absence of the programme, and *spillover* refers to additional reductions in energy consumption or energy demand due to programme influences beyond those directly associated with participating in the programme. Spillover accounts for the actions participants take without any financial or technical assistance from the programme.

Some approaches to estimating net energy savings are shown in FIGURE 3.

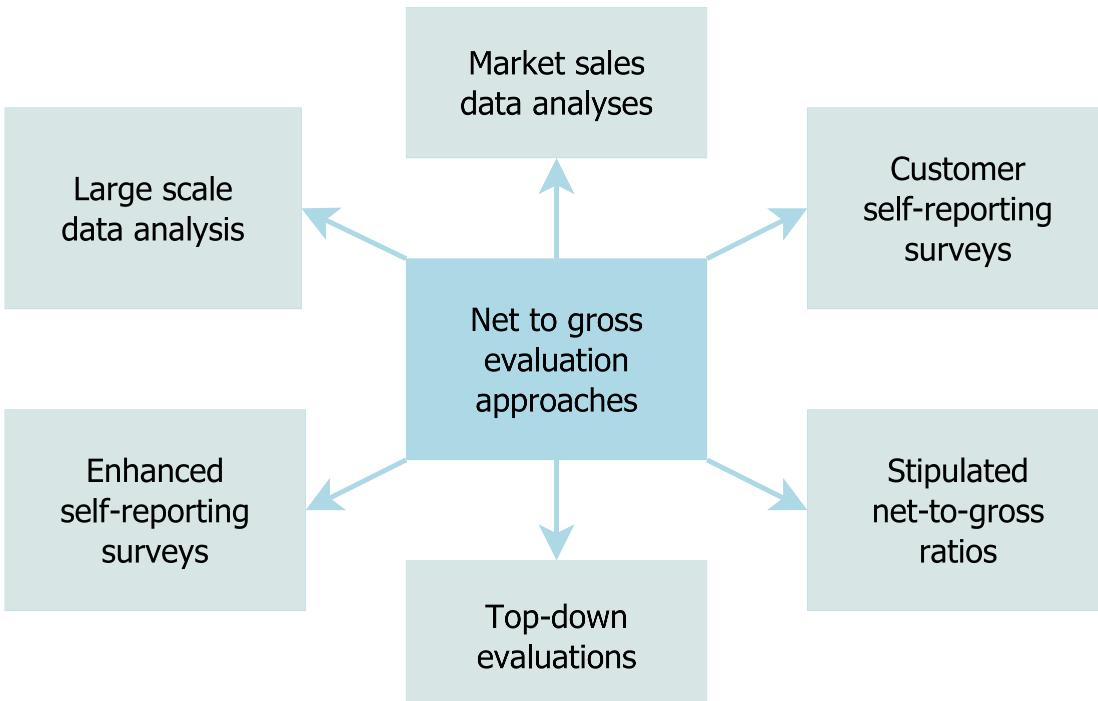


FIGURE 3: NET TO GROSS EVALUATION APPROACHES

The choice of the approach primarily depends on the cost of the net savings analysis along with budget, scale, objectives of the programme, and specific aspects of the measure and on the participants of the programme. The least expensive approach is to use the stipulated net-to-gross ratio, followed, in that order, by self-reporting surveys, enhanced self-reporting surveys, and cross-cutting and modelling. If data are available, the top-down approach can be quite inexpensive. Annexure 2.3 shows how net savings are calculated.

CALCULATING SAVINGS IN ENERGY DEMAND

Savings in the demand for electricity are based on consumption during a specific period. The calculation involves collecting data on consumption and analysing them over specific periods. The first step is to define the metric of interest. Some common metrics are annual average demand savings, peak demand savings, and coincident peak demand savings and are calculated using the following formula:

Demand savings = energy savings ÷ time period of energy savings

Any one of the several approaches to impact evaluation can be used to determine the savings in demand, provided, the required data are available for the required period. The data can be collected through either primary methods or through secondary methods.

- Primary methods involve collecting actual data at hourly or 15-minute intervals or even continuously over the 'window' of interest, for example evening peak hours in summer.
- Secondary methods involve applying load shapes to energy consumption data in the form of daily, monthly, or annual averages or as totals. The shape of the load indicates energy consumption per hour.
    - For example, if a lighting system retrofit in a building saved 3000 kWh in a month, and if the load shape indicated that the hours of use during evenings account for 1% of the monthly total, the reduction in peak demand is assumed to be 30 kW.

Estimating co-benefits

Energy efficiency programmes have a number of co-benefits, some of which are discussed here.

Avoided emissions

Energy efficiency can reduce the emissions of greenhouse gases or pollutants associated with producing electricity from fossil fuels both directly and indirectly. Direct reductions are those that occur at the point where energy is used, e.g. a furnace, whereas indirect emissions are those that occur elsewhere, e.g. in the case of grid-supplied electricity, energy use at one location (the point of use) affects the combustion of fossil fuels at another location (the generating station).

For any energy efficiency programme, avoided emissions are determined by comparing baseline emissions with emissions after the programme is implemented. After net energy savings are calculated, any one of the following approaches can be used to calculate avoided emissions.

- **Emission factor approach** involves multiplying the net energy savings due to a programme by the emission factors. There are several sources of emission factors as well as approaches to calculating these factors. The equation for calculating avoided emissions is as follows.

  Avoided emissions = net energy savings × emission factor
- **Scenario analysis approach** involves comparing emissions from sources without the energy efficiency programme to those from sources operating with reduced energy consumption due to a given efficiency programme. The approach is typically used with large-scale programmes to save electricity. The equation for calculating avoided emissions is as follows.

  Avoided emissions = base case emissions – reporting period emissions

Non-energy benefits

Apart from reduced emissions, energy efficiency programmes often have a wide range of non-energy benefits (NEBs) or co-benefits. These co-benefits are often listed but not quantified because of the lack of standardized and agreed-upon methods for quantifying these benefits or because majority of the benefits can be ascertained from the value of the energy saved.

Non-energy benefits can be categorized as those accruing to utilities, to society as a whole, and to individual participants. Examples of benefits to a utility include avoided capital and operating costs of transmission and distribution, reduced line losses, improved recovery of dues from customers, and service-related savings. Benefits to society include economic development, beneficial effects on energy prices, and greater energy security. Benefits to individual participants include greater comfort, improvements in indoor air quality, lower cost of operation and maintenance of equipment, lower water consumption and smaller volumes of waste water, positive personal perceptions, and avoided capital costs of replacing items of equipment.

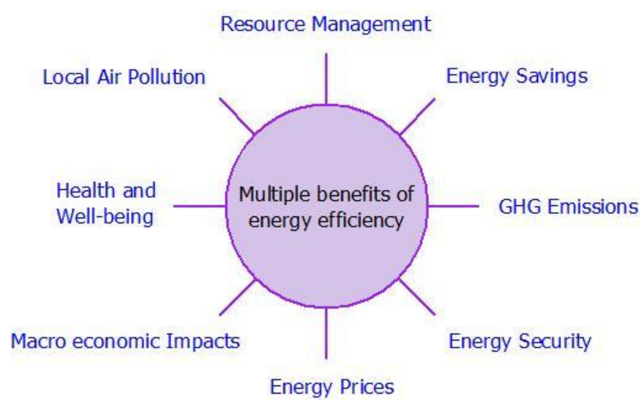


FIGURE 4: NON-ENERGY BENEFITS OF ENERGY EFFICIENCY PROGRAMMES

Source: International Energy Agency, 2014

This list is not exhaustive but represents most prominent benefits of implementing energy efficiency programmes(International Energy Agency, 2014).

Evaluation methods for documenting NEBs fall into following categories.

- **Measurement of benefits**, used when benefits can be measured or calculated, such as reduction in water consumption. Control groups and M&V methods can be used to measure these benefits.
- **Modelling** includes macroeconomic modelling and analytical tools that look at broader societal impacts such as greater employment opportunities or reduced emissions.
- **Surveys** are used for documenting many different types of co-benefits, particularly those that are difficult or expensive to quantify. Different types of survey techniques include the following.
  - *Contingent valuation* directly asks the respondents how much they would be willing to pay for a particular appliance.
  - *Direct querying* involves asking respondents to value the NEBs relative to a given parameter such as energy savings due to a given project.
  - *Conjoint analysis* involves providing respondents with descriptions of different scenarios or levels of NEBs and asking them to rank the NEBs or to choose between different options; econometric techniques are then applied to calculate the relative value of each attribute.

Section 2.4 illustrates the use of contingent valuation and direct querying to evaluate NEBs.

3.2 EVALUATING THE PROCESS

The goal of process evaluation is to develop better and cost-effective programmes. Process evaluations supplement the impact evaluations by exploring:

- Why savings were achieved?
- Examine how efficient and effective the procedures and systems of implementing the programme were?
- Recommend changes if any in the programme's structure, implementation, and goals.

Process evaluations usually consist of asking questions to those involved in the programme, analysing their answers, and comparing the results with established best practices. Process evaluations of energy efficiency programmes are particularly valuable in the following circumstances (Peters & Mcrae, 2009).

- Programme benefits are higher or lower and/or being achieved more quickly or slowly than expected.
- Participation in the programme is limited.
- Participants report problems with the programme.
- Programme does not appear cost-effective.
- Programme is built on a new concept that could be replicated for other populations, technologies, etc.

The four areas that make up process evaluation (FIGURE 5) are briefly described below (Hall, Roth, & Best, 2006).

- **Programme design** assesses the design of the programme, its characteristics, mission, vision, and goal-setting process, and whether the programme uses new practices or best practices.
- **Programme implementation** assesses the implementation of the programme and delivery process, quality control methods and issues, marketing and outreach efforts, goal attainment, timing, timelines, and time-sensitive accomplishments.
- **Programme administration** assesses supervision of the programme, the process to improve it, staffing allocation and requirements, management, skills and training needs of staff, information systems, tracking, and management.
- **Participant response** assesses customer interaction and satisfaction, their needs to reduce energy consumption and the extent to which the programme fulfils those needs, level and rate of participation, and intended or unexpected market effects.

Methods of process evaluation

The primary methods used for process evaluation are surveys and in-depth interviews. The sources of data and of interviewees include programme administrators and related personnel, third-party programme implementation staff, stakeholders, participants in the programme and comparable non-participants, and participating market actors and comparable non-participating market actors.

Some process evaluation methods are briefly described below.

- **Primary survey techniques** consists of interviews of programme staff and contractors conducted in person, analysis of systems that track the progress of the programme, study of relevant documents, telephone, mail or onsite surveys, gathering specific information by posing, incognito, as a participant (the 'mystery shopper' method), and focus-group interviews. Such surveys help in obtaining information on various processes of the programme. Personal interviews are flexible but expensive, telephone surveys are quick and can work if responses are kept simple and sorted into clear categories, and mail surveys are inexpensive but have low response rates.
- **Direct observation and measurement** as a method has the advantage that the results are not affected by the respondents' ability and willingness to answer, but lacks the means to find out what the target group likes or is thinking. Also, the method can be expensive. Direct observations are often combined with surveys.
- **In-depth and focus-group interviews** help to find out why people behave in certain ways. This technique is mostly qualitative. In an in-depth interview, respondents are free to raise relevant topics that are not part of an interview schedule. A group interview is the same kind of interview with a group of respondents. These methods are suitable for preliminary studies and are generally inexpensive.

The choice of a suitable method for process evaluation depends upon the scope, data required and ways of collecting the required data, and the effort required. It is advisable to draw up a schedule for process evaluation and budget for it at the project planning stage itself.

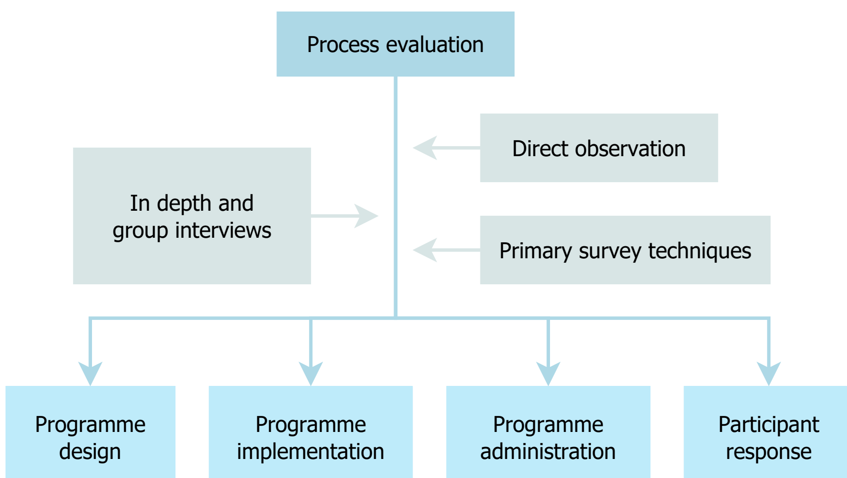


FIGURE 5: PROCESS EVALUATION AREAS AND METHODS

Process evaluation is described in detail in annexure 2.1.

3.3 EVALUATING MARKET EFFECTS

The goal of evaluating market effects is to identify and quantify the effects of an energy efficiency programme on the relevant suppliers and customers. Market-effect evaluations have typically been conducted for programmes that target market change and often require a significant effort because they require data from a wide range of market actors. Some questions that a market-effects evaluation may answer are listed below.

- Are customers undertaking additional installations other than those offered by the programme?
- Are customers adopting concepts and technologies promoted by the programme?
- Are manufacturers, suppliers, and retailers changing the ways in which they offer energy-efficient appliances (e.g. ways of stocking, pricing, or marketing the appliances)?

A typical market for energy-efficient appliances evolves in three stages:

- the first stage is the early-acceptance stage in which the newer and energy-efficient models are bought by enthusiasts
- the second stage is the take-off stage marked by customer awareness and the visibility of appliances in shops
- the third stage is the maturity stage; by that time, all major competitors offer the appliances, and codes and standards are developed for them.

Energy savings depend on how fast these stages are completed in the market for a particular appliance, and tracking the performance of a programme through each of the above stages provides valuable feedback to those who are implementing and administering the programme. Therefore market-effects evaluations are spread over many years. Market effects can be assessed by some of the following approaches (Rosenberg & Hoefgen, 2009).

- **Self-reports of net programme effects** involve asking customers and supply-side market actors about how the programme influenced their adoption of energy efficiency measures. Data are collected through telephone or in-person interviews. As the method relies on customer recall, the interviews should be carried out soon after implementing the programme.
- **Cross-sectional approaches** involve study designs in which the number of units of the product or appliance sold, its market share, or some other indicator of adoption in a market in which the programme is not active is used as a baseline against which the levels of adoption in markets served by the programme are compared. The differences between the markets served by the programme and those not served by it can be attributed to the programme. The data required are primarily in the form of sales data from retailers and distributors; survey data from supply-side actors or customers could be the second choice.
- **Structured expert judging** consists of asking panels of experts to forecast two trajectories of market acceptance for the product or service in question: one that takes into account the effects of the programme and one that does not, with the latter representing the baseline. The difference between the baseline and cumulative sales shows the net effects of the programme. The selection of panel in this method is particularly critical, especially when products are new to the market.
- **Historical tracing**, or the case study method, is a qualitative approach. The researchers examine the cause-and-effect relationship to explain the outcomes. The data for historic tracing studies are obtained through in-depth interviews with programme principals, staff of other programmes operating in the market, market actors, and documents of various kinds.

Annexure 2.7 shows an example of assessing market effects of California's upstream lighting programmes.

The next section briefly describes how to plan and conduct evaluations of energy efficiency programmes, how to select an evaluator, and typical elements of an evaluation report.

3.4 Planning and conducting evaluations

The most efficient approach to effective evaluation planning is to consider "what the evaluation needs and incorporate those needs in programme design". This allows evaluators to work with programme planners to identify the data required, estimate the likely expenses, and offer feedback on the programme's performance and also ensures a serious commitment to rigorous and transparent evaluation (NYSDPS and EAG, 2013). The general steps in planning an evaluation are as follows[c]:

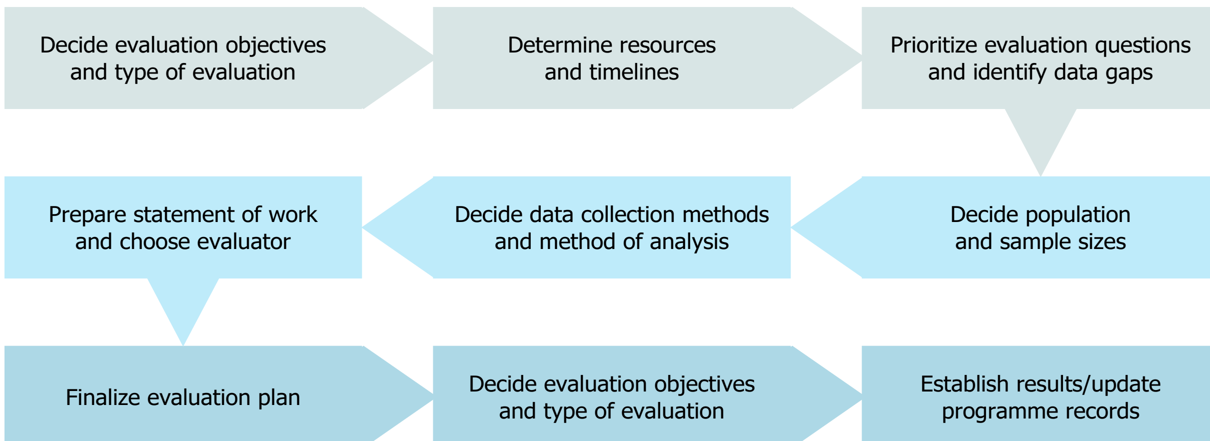


FIGURE 6: PROCESS OF EVALUATION PLANNING

Decide evaluation objectives based on the decision to be taken once the evaluation is complete (continue, expand, cut back, or terminate the programme) and then decide the type(s) of evaluation (impact or process or market) to be conducted. The steps involved in evaluation planning are briefly described below:

1. Determine the cost and resources available based on the importance of information obtained from the evaluation. Evaluations in USA are funded by setting a percentage of the annual programme costs as the budget for evaluations; the percentage ranges from 1% to 8% (Schiller, 2012).
2. Determine the timeline for completing the evaluation based on the time by which information from the evaluation is required. Allow time for various mandatory approvals and processes such as approvals from a regulator or a government department and the bidding process.
3. Select questions that the evaluations must answer and prioritize them based on what information is most needed and when, and then identify data gaps if any.
4. Decide the size of the population and of the sample from which these data gaps will be filled and identify the methods for data collection (e.g. surveys and interviews).
5. Decide the method of analysing the collected data (e.g. engineering equations and statistical tools).

[c] https://energy.gov/eere/analysis/program-evaluation-planning-and-conducting-evaluations

6 Prepare the statement of work and choose an evaluation contractor. The evaluation contractor must be familiar with techniques of data collection and analysis.
7 Work with the evaluation contractor to get the evaluation plan finalized.
8 Conduct the evaluations and monitor the performance of the programme.
9 Lastly, use the results to establish or update programme records for future evaluations.

Funding the evaluations: It is recommended that a certain percentage of the total programme costs be set aside for funding the evaluations. In the case of programmes funded by DISCOMs in India, the amount can be recovered through the annual revenue requirements submitted to the SERCs by the DISCOMs. For government (both national and state) programmes such as S&L and PAT or programmes implemented by EESL, evaluations could be funded by the Ministry of Power or from the energy conservation fund that each state is supposed to build.

Selecting an evaluator: Defining the role and ensuring the independence of the evaluator for all the programmes is important. An independent evaluator should be able to give a true and clear picture of the status of the programme being evaluated to the regulators, implementers, and consumers and to provide ongoing and early feedback. Third-party independent evaluators may be selected by inviting a request for proposal, and the typical selection criteria should include qualifications, experience, resources available to the evaluator, availability of key staff, labour rates, overall budget expectation, schedule, and deliverables.

4 CONCLUSIONS

The number and scale of energy efficiency programmes implemented in India have been rising in recent years but rigorous evaluations of these programmes have been lacking. Evaluating energy efficiency policies and programmes is crucial to increase their credibility and to design better programmes in the future. A comprehensive evaluation includes impact evaluation (assessing the reductions in energy demand and peak demand), process evaluation (assessing the effectiveness of programme delivery), and market-effects evaluation (assessing changes in the market due to the programme). Evaluations are far more important at the pilot stage because lessons offered by an evaluation can help in effectively scaling up a programme. Evaluations are also important for on-going programmes because evaluations can show what has worked well and what has not.

In India, evaluation of energy efficiency programmes has been limited to evaluating the impacts. Programmes are evaluated only to estimate the quantum of energy saved. One primary reason for lack of comprehensive evaluations is that they are not mandated by the relevant acts and regulation. This is exacerbated by the common misperception among stakeholders that evaluations are complex and expensive. Finally, lack of publicly available data on programmes and policies precludes any independent evaluations by academics or civil society organizations.

We recommend that the FoR issue model regulations on conducting comprehensive evaluations of DSM programmes similar to the regulations on DSM implementation framework issued in 2010. This can lead to faster adoption of these regulations by SERCs. The general guidelines developed in this report based on global best practices can inform the model regulations. As EESL is implementing large-scale DSM programmes, BEE can commission independent evaluations of these programmes to examine their impact and assess their effectiveness. State regulatory commissions can ensure that evaluations plans and funding requirements are taken into account when programmes are designed. The case studies and terms of reference developed in this report (and given in the annexes to follow) can inform these evaluation plans. Finally, we recommend that all relevant data on policies and programmes be made public to increase transparency and facilitate independent evaluations.

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Annexure 1: Methods of evaluating energy efficiency programmes

IMPACT EVALUATION

MEASUREMENT AND VERIFICATION

The measurement and verification method involves determining the savings in energy or in energy demand by measuring energy use within an individual facility and comparing energy use before and after implementing energy-efficiency measures. The basic equation used for determining energy savings is as follows.

Energy savings = baseline energy use − reporting period energy use ± baseline adjustments

Baseline energy use is the energy consumption before or without implementing energy efficiency measures; reporting period energy use is the energy consumption after implementation; and baseline adjustments are factors (the weather, occupancy levels and hours, and production levels, for example) that modify energy use but cannot be controlled by the programme implementer.

The International Performance Measurement and Verification Protocol (IPMVP) provides an overview of current best practices for verifying the results of energy efficiency projects. The protocol describes common practices in measuring, computing, and reporting the savings achieved because of energy- or water-efficiency projects at end-user facilities and prescribes the following four options for M&V [d]:

- Option A: measure a key parameter
- Option B: measure all parameters
- Option C: analyse a whole facility
- Option D: calibrate by simulation

In using any of these options, it is necessary to understand two concepts: measurement boundary and interactive effects. Measurement boundary is the area or portion of the facility or system for which the savings are to be determined; it may be a single piece of equipment such as a fan, a motor, or a pump; a system such as the lighting system or pumping system; or an entire building or facility. Any effects on energy beyond the measurement boundary are interactive effects: for example, if an incandescent bulb in a room is replaced with an LED bulb or a CFL, less heat is emitted, and the air-conditioning requirement of that room will be lower. If such effects are large enough, they should be taken into account while calculating energy use and a suitable method of estimating them should be decided.

OPTION A: MEASURE A KEY PARAMETER

Option A determines energy savings by actually measuring a 'key' performance parameter (such as hours of use or power drawn) during the baseline and during the reporting period. Such parameters may be measured continuously or for short periods. A predetermined set of values based on historical data or on data provided by manufacturers may be used for parameters that are not measured. However, it should be ensured that the impact of these predetermined values on the overall reported savings is not

[d] more information is available at http://emanz.org.nz/energy-management-audits/measurement-verification and https://energy.gov/sites/prod/files/2016/01/f28/mv_guide_4_0.pdf

significant and that their sources are fully documented. Apart from the measurement of key parameters, re-inspection of whether the equipment is still being used and its proper operation and maintenance are also necessary at defined intervals to ensure that the predicted or expected potential of a given efficiency measure to save energy is realized and to validate assumptions and prior estimates of savings. Annexure 2.1 illustrates the use of Option A.

Option B: measure all parameters

Option B determines energy savings by measuring, either for a short term or continuously, all the parameters affected by the energy efficiency measures. No predetermined values are allowed in this option, which also requires additional and often longer-term measurements as compared to those used in Option A. The difficulty and the cost of Option B increase as the measurements become more complex and the savings more variable. However, the estimates of savings are more reliable than those determined with Option A: the validity of options A or B is inversely proportional to the complexity of measurements and the variability of savings (Jayaweera, Stern, Violette, & Baumgartner, 2013) .

Option C: analyse a whole facility

Option C involves using meters that monitor the electricity consumption of an entire building or sub-meters that do the same for different parts of a facility to assess the energy performance of a whole building or facility. The metered data are analysed using multivariate regression. All the independent variables that affect energy consumption need to be monitored during the performance period for the regression analysis—option C requires at least 9–12 months of pre- and post-installation data and is used where the savings are large enough (typically greater than 10% of the total consumption) and are not affected by random or unexplained variations in energy consumption, which are normally observed at the whole-facility level. Option C is the most common option for retrofits involving multiple measures to increase building-energy efficiency in industries that make use of performance contracting.

Option D: calibrate by simulation

Option D involves calculating savings by simulating the energy use of components or of the whole facility. The simulations are calibrated using hourly or monthly billing data or metering. Linking the inputs and outputs of the simulation to baseline data or the data for the reporting period calibrates the result to actual billing or metered data. Data from manufacturers, spot measurements, or short-term measurements may be collected to characterize the baseline and reporting period conditions and operating schedules. The collected data link the simulation inputs to actual operating conditions. Savings determined with option D are based on one or more complex estimates of energy use, which is why the reliability of the estimates depends on how well the models are calibrated and how well they reflect actual performance.

Examples of each of the above options are given in volume I of the IPMVP (IPMVP, 2002).

Large-scale data analysis

Large-scale data analysis involves comparing the energy use of a ‘treatment’ group (participants in an energy efficiency programme) with that of a ‘control’ group (non-participants, but comparable in other ways to the participants during the same period of time). The difference in energy usage can then be attributed primarily to the impact of the programme, because external factors, if any, are common to both the groups. Two generic types of large-scale data analysis are randomized control trials (RCTs) and quasi-experimental methods (QEMs).

In RCTs, members of the study population are randomly assigned to either the treatment group or the control group. Data on energy use (typically metered data or billing data) are collected for all facilities for both the groups to estimate energy savings, which are calculated in two ways: either from the difference between the measured energy use of the two groups during the evaluation period or from the extent of decrease in energy use by each group after installation. The key to the method is random assignment, which eliminates the effects of pre-existing differences, both observable and unobservable. This also means that the two groups are statistically identical and that the selection bias is eliminated. The ability to account for free riders and spillover is built in and hence the trials deliver net energy savings (discussed in the next section).

In QEMs, members of the study population are not assigned randomly, which is why the methods may carry a selection bias and thus lead to biased estimates of savings. Amongst the different QEMs, the before-and-after method is the most common. The method compares energy use of participants before the programme to that after the programme. Another method is the matched control group, which entails constructing a non-random control group of participants that are similar to those in the treatment group, and savings are determined by comparing the energy use of the two groups after the programme. One drawback of the method is that although the groups can be matched for observable characteristics (e.g. level of energy use, use of air conditioners, and residence in the same locality), they cannot be matched for such unobservable characteristics as attitudes and willingness to participate in the programme. The third method, namely variation in adoption, compares energy use of participants with that of future participants, i.e. those who are expected to enrol in the programme at a later date. This method thus accounts for both observable and unobservable characteristics.

Annexure 2.2 illustrates how large-scale data analysis was used to assess energy savings for the 'cash for coolers' programme.

Deemed savings

The deemed savings method uses predetermined values to estimate savings in energy and in energy demand due to a programme. These values are obtained by looking at historical data on actual measurement related to the proposed measure (from such sources as TRMs, or technical reference manuals, prior metering studies, manufacturers' specifications, occupancy levels of buildings, and standard tables from recognized sources). Care must be taken to ensure that such data are applicable to the project being evaluated. Since no measurement is involved, only the installation and operation of the equipment is verified.

Projects with well-known and documented savings values use the deemed-savings method for evaluation. Examples are programmes for such energy-efficient appliances as fans and refrigerators and for lighting retrofits, with reasonably reliable data on the hours of operation. The method is popular particularly because it is inexpensive and gives reliable estimates of savings. In this method, it is common to hold the predetermined values constant regardless of the actual values during the time of evaluation. If such requirements as verification of installation and performance, satisfactory commissioning, and proper maintenance are met, the savings from the project are confirmed.

In USA, TRMs are used when a programme is evaluated using the deemed-savings method. These manuals – printed or electronic – are a database of standardized state- or region-specific calculations of deemed savings and associated deemed savings from well-documented energy efficiency measures and include items of information useful in programme planning, such as kilowatt-hours saved per year by a 12 W LED bulb), engineering algorithms to calculate savings such as kilowatt-hours saved per year = annual operating hours × (kW_{before} − kW_{after}), impact factors to be applied to calculated savings (e.g. net-to-gross values), source documentation, specified assumptions, and other relevant material to help in calculating the savings from a measure or a programme.

Net energy savings

Free riders, or programme participant who would have implemented the measure anyway, on their own, even without the programme. Free riders can be partial, total, or deferred: a 'total' free rider is a participant who would have installed the same measure as offered by the programme at the exact same time and at the same price even if the programme were not to exist; a 'partial' free rider is a participant who would have replicated the programme's measures in part, and a 'deferred' free rider is a participant who would have replicated the programme's action completely or in part but at a time in future beyond the programme's time frame.

Spillover, or additional reductions in energy consumption or in energy demand due to the influences of the programme beyond those due to direct participation in it, accounts for actions participants take without any financial or technical assistance from the programme and can be of two types, participant spillover and non-participant spillover. Participant spillover refers to additional energy savings from a programme participant independently installing incremental energy efficiency measures as a result of the programme's influence, whereas non-participant spillover refers to similar savings from a non-participant doing the same and for the same reasons.

Some approaches to estimating net savings are listed below.

- **Stipulated net-to-gross ratios** are established based on historical studies of similar programmes and multiplied by gross savings to estimate net savings.
- **Customer self-reporting surveys** offer information reported by participants and non-participants without independent review. Participants are asked whether they would have implemented a given measure supported by the programme on their own without an incentive (free riders) and whether they implemented additional efficiency measures as an effect of the programme (participant spillover). Non-participants are also asked the same questions to assess non-participant spillover.
- **Analyses of market sales** (cross-sectional studies) can capture the net savings from a programme including those from both free riders and spillover. The most common approach is the cross-sectional comparison area method, which compares post-programme data with data from a similar non-programme area over the same time. Thus evaluators can compare pre-programme and post-

programme sales data from the two areas over the same period. This method is suitable for programmes that promote a large number of homogenous measures.

- **Large-scale data analysis** (RCTs and QEMs) employs statistical models to compare energy and energy-demand patterns of a group of participants and those of a control group. If a control group of non-participants is used, the savings are net savings, free of those from free riders and spillover.
- **Enhanced self-reporting surveys** supplement the surveys with interviews, documentation reviews, and analysis.
- **Top-down evaluations** use the data for the appropriate sector at the level of a state, a region, or a country to assess the extent to which markets for energy-efficient products are affected by the programmes.

OTHER CONSIDERATIONS IN EVALUATING IMPACTS

Such matters as selecting baselines, persistence of savings, and methods to deal with uncertainty while evaluating energy efficiency programmes are briefly touched upon in this section.

SELECTING BASELINES

Baselines represent a counterfactual scenario in which we estimate energy consumption and energy demand in the absence of an energy efficiency programme. Such baselines also define non-energy metrics such as emissions and employment opportunities that can be measured. Hence assessing the baselines is a major decision and should be taken at the planning stage. The goal is to avoid reaching a stage of an evaluation only to realize that some critical items of baseline information were not collected. Baseline research can be used for

- making informed decisions about the end-uses of energy
- Identifying items of equipment that are the most effective targets for energy efficiency programmes
- characterizing the type and efficiency levels of the installed equipment
- confirming the assumptions to be made in programme planning
- evaluating the impacts of energy savings once a programme is established.

In methods involving large-scale data analysis, the baseline is defined by the characteristics and energy use of the control group(s). However, in methods such as deemed savings and M&V that use non-control groups, the baseline is defined by the type of project being implemented, site-specific issues, and broader, policy-oriented considerations. These considerations usually result in one of the three types of baseline: existing conditions, common practice, and codes and standards. The choice of appropriate baselines for deemed savings and M&V methods is discussed below.

Existing-condition baselines can be defined on the basis of what is in place (equipment, tools, procedures, etc.) at the project site before the proposed energy efficiency measures are implemented. The common means of determining such baselines are an inventory of pre-retrofit equipment, site-specific characteristics including name-plate ratings, and energy consumption of selected equipment based on measurements or historical data. In the deemed-savings method, the existing conditions are determined at the time of programme design or taken from TRM. For M&V, existing conditions are typically determined at the time of installing the proposed energy efficiency measures.

Common practice baselines are estimates of what typical consumers would have done at the time of project implementation. For example, if a programme involves incentives to consumers to buy high-efficiency refrigerators, the common practice baseline would be non-rated refrigerators or those with low ratings. The relevant common practice is determined by surveying the participants and non-participants or by analysing market data.

Codes and standards baselines consist of official figures of energy consumption of buildings or by specific items of equipment as published by the appropriate and recognized agency. Codes and standards tend to change, and these baselines need to be regularly updated. Annexure 2.5 shows how baselines are calculated for programmes aimed at residential buildings.

Persistence of savings

Other important item in an evaluation is how long the energy savings are expected to last following an energy efficiency activity. A persistence study measures changes in net impacts over time. Such a study can be expensive and needs to be carried out for long periods. Two important terms in persistence studies are measure persistence and effective useful life. Measure persistence is the duration for which an energy-consuming measure is in place and operable, and effective useful life is an estimate of the median number of years that the measures installed under a programme are expected to be in place and operable. The next important term is savings persistence, which can be defined as the percentage change in expected savings due to changed operating hours, changed process operations, or the decline in performance of an item of efficiency equipment relative to the baseline efficiency.

The methods of measuring persistence include the use of historical and documented data on persistence from such sources as studies by manufacturers or by industry organizations, laboratory or field testing of energy efficiency and baseline equipment, field inspections over several years of energy efficiency programmes, telephone surveys and interviews, and analysis of consumption data. Annexure 2.6 illustrates how the life of CFLs is estimated.

Uncertainty

An energy efficiency programmes is evaluated in terms of the 'estimated' difference between actual energy consumption and energy consumption in the absence of the energy efficiency measures. This difference is an overall indicator of how well a calculated or measured value represents the true value—a measure of 'goodness' of an estimate. Such estimates can be questioned if the sources and level of uncertainty or reported savings estimates are not clearly understood and described. However, before removing or reducing uncertainty, one has to judge whether the increase in evaluation costs to reduce uncertainty and to improve accuracy is justified. Uncertainty may be due to (1) systematic errors that are subject to decisions and procedures developed by the evaluator and are not subject to chance and are hard to estimate and (2) random errors or sampling errors that are subject to chance and arise because of sampling instead of collecting data from the entire population.

In most circumstances, systematic errors can be prevented whereas random errors can only be estimated and their impact mitigated by using statistical tools. Laws of probability and sampling distributions can be used to identify sampling errors.

Systematic errors

Systematic errors are problematic because the savings estimates become biased, i.e. the figures are systematically underestimated or overestimated. These errors potentially occur because of

- measurement errors due to inaccurate meters and errors in recording observations
- non-coverage errors due to a part of population being excluded from the sampling frame
- non-response errors due to refusal on part of some participants to give the required data
- modelling errors due to the selection of an inappropriate model.

Random errors

A change in energy use by a participant may be due to many reasons, and impact evaluation tries to analyse the reasons that can be attributed to the programme. However, some factors that influence energy use may be unobservable. Random errors occur because

- whenever a population is sampled, some degree of random sampling error is inevitable
- what is sampled and when—decisions that introduce some uncertainty
- random measurement errors due to faulty recall by respondents with reference to dates and expenses or due to differences in mood or circumstances.

The common factors for reporting uncertainty associated with random errors are confidence and precision: precision provides the interval believed to contain the actual value (for example, a statement such as 'the values ranges from X to Y') and confidence is the probability of that value lying in that range or interval.

Other terms in considering uncertainty are external validity and internal validity. An evaluation is considered externally valid if the observed outcomes can be generalized and applied to the entire population from which the sample was drawn and can also be applied to new populations, circumstances, and future years. An evaluation is considered internally valid is if the observed results can be shown as due to the programme; in other words, the estimated savings are reliable and unbiased. The evaluation of uncertainty takes time and resources, and the need to reduce uncertainty should be justified by the value of the improved information.

Annexure 2: Case studies

2.1 Efficiency Maine's retail lighting programme

The impact of Efficiency Maine's retail lighting programme[e] was evaluated in terms of gross energy savings using Option A of the IPMVP protocol, and the process was evaluated using surveys and interviews with manufacturers, programme staff, and managers of retail stores.

Programme

Efficiency Maine's retail lighting programme distributes efficient lighting options to its consumers. The primary distribution channels are manufacturers and retailers of energy-star appliances (similar to BEE's programme of awarding stars to appliances in India to reflect their energy efficiency). Efficiency Maine collaborates with manufacturers and retailers to lower the price of appliances sold at retail stores. The programme began in 2002 and has evolved over the years. In 2014, the appliances were distributed through three channels: stores of manufacturers and retailers at 289 locations, rebate programmes to make packs of CFLs available to programme participants, and an NGO, which gave away CFLs free of charge to low-income residential consumers.

Evaluation

The impact and process effectiveness of the retail lighting programme have been evaluated periodically (Maine, 2007). The evaluation for this year aimed at assessing the impacts, namely reduction in electricity consumption through the sales of these bulbs, to ascertain whether the programme was cost-effective and whether it needed any modifications. In FY 2014 (October 2013 to September 2014), 2.1 million bulbs were sold through manufacturers and retailers and about 0.4 million through the other two channels.

The energy savings were measured using Option A of the IPMVP protocol. Hours of use were measured by installing lighting loggers in selected households after verifying that the bulbs had been installed in those households. The data were captured for eight months, and gross energy savings were calculated based on those data. Net energy savings were calculated using price-elasticity modelling to isolate the effect of free riders: sales of bulbs without the discount were estimated, and energy savings due to those estimated sales were calculated next.

Process evaluation was conducted to assess how well the programme was executed, the experiences of programme partners and customers, and also to understand market trends to make the programme more effective in the next phase. Programme staff were interviewed in depth to understand how the programme works and how it could be improved. Interviews with manufacturers and managers of retail stores were helpful in understanding customer demands, trends in technologies and products, and the effectiveness of advertising the programme and marketing it. Telephone interviews with residential customers helped in assessing their awareness of the programme and the discounts it offered, familiarity with LED bulbs to assess future trends, judgements about energy use, and purchase points

[e] https://www.efficiencymaine.com/at-home/retail-lighting-program

(e.g. retail stores); in finding out the status of the bulbs (whether they were used or stored or had been replaced or were to be replaced or had been removed and no longer in use); and in assessing customer satisfaction and reasons if any for dissatisfaction with the programme or the bulbs.

Key findings and recommendations

- LEDs were still not affordable to many consumers coupled with lack of education and confusion regarding use of LEDs.
- Because inefficient and cheap lighting options continued to be available in the market, the manufacturers said that consumers should be offered some incentives to buy CFLs and LED bulbs and educated on different options for efficient lighting.
- It was recommended that the share of sales be extended to stores where net-to-gross ratio was more.
- Update the TRM with values of hours of use and watts obtained from this impact evaluation.

2.2 'Cash for Coolers' programme

Direct impacts were quantified in terms of net energy savings using large-scale data analysis.

Programme

The 'Cash for Coolers' programme was a national programme launched in Mexico in 2009 by the Mexican Federal Electricity Commission, Mexico's sole electricity supplier. The programme's objective was to reduce electricity consumption and carbon dioxide emissions. Under the programme, over 1.9 million customers replaced their old and inefficient refrigerators and air conditioners with new and energy-efficient variants using either a cash subsidy on upfront payment or subsidized financing to do so. To be eligible to participate in the programme, the following conditions were stipulated: (1) the existing appliance should be at least 10 years old and in working condition; (2) the capacity of the new refrigerator should be the same as the old one; and (3) those seeking to replace their air conditioners should be living in warm climates. These criteria were intended to ensure that people do not use bigger appliances for more time just because they are efficient. Refrigerators accounted for about 90% of the total replacements under the programme, because replacing air conditioners carried geographical restrictions.

Evaluation

Two professors from the University of California, Berkeley, evaluated the programme independently using large-scale data analysis (Davis, Fuchs, & Gertler, 2014). The Mexican Federal Electricity Commission provided the researchers with billing records of over 26 million Mexican residential consumers for two years. The commission also provided data on the 1.9 million participants in the programme. The researchers cleaned the two data sets and merged them to analyse the impact of the programme on the participants' electricity bills.

The researchers employed an approach referred to as 'difference-in-differences', which compares the difference in electricity consumption of participants before and after the programme to the difference in electricity consumption of non-participants over the same period. This approach makes it possible to isolate the impact of the programme on the participants' electricity consumption. A general regression equation was developed with a household's monthly electricity consumption as a variable dependent on the purchase of an appliance under the programme and accounting for the effects of seasons and characteristics of the household.

Regression analysis was then conducted on different comparison groups selected either at random or carefully matched. The first group was an equal-sized random sample of non-participating households; the second group was a sample of participating households in which the participants who had not yet replaced the appliances served as the comparison group; the third group was a sample matched purely for location (non-participants along the same route taken by meter readers to read the participants' metres) to ensure that the comparison households experienced approximately the same weather as that experienced by the treatment households); and the fourth group was a sample matched for both location *and* pre-replacement electricity consumption (each participating household was matched with ten non-participating households with account numbers closest to that of the participating household and among these ten non-participating households, the one with average monthly pre-treatment consumption closest to that of the participating household was selected).

Regression estimates based on the above comparison groups showed that electricity consumption of households that had replaced their air conditioners was considerably higher and their consumption pattern was distinctly seasonal. In case of air conditioners, matched comparison groups were found to be a better indicator than non-matched groups (i.e. matched only for being non-participants). Electricity consumption of all groups was seasonal and increased substantially during summer. In the households that had replaced their refrigerators, the consumption patterns of all comparison groups were similar to the consumption pattern of the participating households.

Key findings and recommendations

- Replacing the refrigerators lowered electricity consumption by 7% and accounted for about a quarter of the savings predicted by pre-programme techno-economic studies.
- Replacing the air conditioners actually increased electricity consumption by 2%.
- The cost of the programme per unit of reduced electricity consumption and reduction in carbon dioxide emissions was significantly higher than estimated.

One reason for the less-than-predicted savings from the programme was the inability of the programme administrators to enforce the criteria for exchanging the old appliances. It was found that a number of exchanged appliances were of recent vintage or not in working condition. The new appliances were larger and also included such new features as ice-makers and side by side doors, which consumed more electricity. The programme also set the technical specifications of efficient appliances based on 2002 efficiency standards, thereby losing out on technological advancements achieved since.

2.3 Massachusetts residential retrofit and low-income programme

The evaluation used the net-to-gross method (assessing free riders and spillover) based on customer self-reports and modelling of market shares.

Programme

The Home Energy Services programme has been in place since 1980s, helping low-income households to improve their energy efficiency by providing energy audits and suggesting different options of saving energy. The primary goal was to improve the energy efficiency of the entire house through incentives, financing, and education. Several visits were made to the households for their selection, installation of efficient appliances, and quality assurance.

Evaluation

The purpose of the evaluation was to analyse net savings using two methods (The Cadmus Group, 2012). Given the lack of consensus on the right method to estimate the values of free ridership and spillover, the team used two methods. The first method involved customer self-reporting: customers were asked to estimate the influence of the programme on their decision-making process. Based on the responses, the evaluators determined the possibility of the measures being installed even without the programme, i.e. free riders. The second method estimated the spillover by asking participants as well as non-participants to assess the influence of the programme in terms of the customers' taking additional measures to save energy. Some questions used for assessing free riders are listed below.

- Did the participants have plans to install any energy-saving measure prior to learning about the programme?
- Would the participant have installed the same quantity of measures without the programme?
- In the programme's absence, when would the participant have installed a given measure?

Some questions to assess the spillover are listed below.

- Since participating in the programme, has the participant installed additional energy efficient equipment not offered through the programme?
- What additional items of energy efficient equipment were installed? How many?
- How influential was the programme in the participant's decision to install additional energy-efficient equipment at home?

Statistical modelling – specifically, discrete choice modelling – was also used along with customer self-reports to determine free riders and spillover for select measures in the programme. The model identifies the factors that influence the customers' decisions to install a given energy efficiency measure. These factors include age of the customer, type of house owned, amount of incentive, and awareness of the programme. These factors, or independent variables, were fitted to the data to estimate the probability of a customer choosing to participate in the programme. An error term was included in the model to account for unknown or random factors that may also influence the customers' decisions.

Key findings and recommendations

- As the design of the programme changes and the knowledge and practices of market actors evolve, so do the results from the net-to-gross method. Therefore any application of the net-to-gross method for planning purposes should consider these changes.

- Net-to-gross values change according to the type of programme and area served and hence the values for one particular programme cannot be used for other programmes.
- Net-to-gross ratios using two methods can be combined to form composite net-to-gross ratios for different measures.

2.4 'Energy Smart New York' programme

Non-energy impacts were evaluated using the direct-query approach and the conjoint method.

Programme

The energy-star products and marketing programme in New York helped in increasing the sale of such energy-star products as lighting, home electronics, and HVAC equipment. The programme works on the supply, midstream, and demand sides of the market. Incentives are given to manufacturers, distributors, and retailers to increase the supply of energy-star products. These incentives are passed down to consumers through a discounted purchase price. The programme is marketed through consumer awareness campaigns throughout the state.

Evaluation

The programme was evaluated in 2005/06 primarily to quantify its non-energy impacts to help in making better investment decisions (Summit Blue Consulting, 2006) and to market it more effectively. A few research questions were also tested to develop new and innovative approaches to estimate non-energy impacts for future evaluations.

The evaluation consultants used two approaches to quantify non-energy impacts, namely direct query and conjoint analysis. In the direct-query approach, consumers were asked to assign a hypothetical monetary value to the non-energy benefits of a given measure. In conjoint analysis, consumers were asked to choose between different sets of options, each consisting of one or more non-monetary benefits and a hypothetical price of the energy efficiency measure in question. It was assumed that the consumers would make their choice based on the value of non-energy benefit vis-à-vis its price.

For the direct-query approach, the following attributes were selected: bulb lifetime, lighting quality, delay in turning on, warm-up period, heat generated, general sense of doing good to the environment, and overall impacts; for conjoint analysis, the attributes were bulb lifetime, warm-up period, delay in turning on, and heat generated.

A couple of examples on how the questions were asked are given below.

In the first set (comparison 1, Table A1), light bulb A had a considerably higher price, a longer lifetime, attained its full light output without any delay (no warm-up time), and stayed cool, but had the same turn-on time as that of bulb B. The respondent had to choose between bulb A and B. If A was chosen, it meant that the customer would be willing to pay $5.65 more for the three positive impacts.

Table A1: Price and some non-monetary attributes of two kinds of light bulb

Attribute	Bulb A	Bulb B	Difference
Purchase price	$6.00	$0.35	B far cheaper
Turn-on time	Comes on instantly	Comes on instantly	No difference
Lifetime	8 years	6 months	A lasts longer than B
Warm-up period	Full light output immediately	Takes 90 seconds to reach full light output	A has no warm-up time
Heat generated	Stays cool, therefore little impact on heating or cooling costs	Gets very hot; therefore, lowers heating costs in winter but raises cooling costs in summer	A stays cooler than B

In the second set (comparison 2, Table A2) light bulb A had a higher price but no warm-up time. If B was chosen, it meant that the customer did not consider the attribute (no warm up required) worth the extra cost.

Table A2: Light bulbs that differ in price and in only one non-monetary attribute

Attribute	Bulb A	Light Bulb B	Difference
Purchase price	$6.00	$0.35	B is far cheaper
Turn-on time	1 second	1 second	No difference
Lifetime	6 months	6 months	No difference
Warm-up period	No warm-up	90 seconds to reach full light output	B takes 90 seconds longer to give full light output
Heat generated	Gets very hot; therefore, lowers heating costs in winter but raises cooling costs in summer	Gets very hot; therefore, lowers heating costs in winter but raises cooling costs in summer	No difference

Responses from a series of such comparisons were analysed using regression analysis. The most valued attribute was lifetime and the least valued was warm-up period. The values derived from conjoint analysis were converted into annual dollar values that respondents would be willing to pay for the different attributes by dividing the total lifetime dollar value of each attribute by the lifetime of the bulb (here four years).

Key findings and recommendations

- Non-energy impacts continue to be important to respondents, who do assign a supplementary positive value to such impacts in addition to savings in energy.
- The information obtained from this evaluation can be used to market the programme more effectively.

2.5 Assessing market baselines

The baselines were assessed using home visits and a telephone survey.

Programme

The Department of Natural Resources and Environmental Control, Dover, Delaware, conducted a residential end-use and saturation study for the state of Delaware to document the types of energy-consuming equipment in Delaware homes and consumer awareness on energy efficiency and energy conservation. The study evaluated the characteristics of energy equipment and equipment stock in the residential sector to integrate the information with resource planning for the future and with energy-efficiency activities in Delaware (Opinion Dynamics Corporation, 2012).

Methodology

The study consisted of home visits and a quantitative telephone survey to determine the penetration and saturation of key end-use appliances. The telephone survey focused on lighting, particularly to establish a baseline for the degree of awareness of CFLs, penetration and saturation, central heating and air conditioning, consumer electronics, and appliances. Energy-consuming appliances for the following end-uses were surveyed: lighting, space heating and cooling, water heating, laundry, cooking and food storage, and entertainment (consumer electronics). The survey also collected information on attitudes towards, and knowledge of, energy efficiency and key demographics.

The sample design ensured that both urban and rural households were adequately represented and had a precision level of ± 4%–10% and confidence intervals between 90% and 95% for telephone surveys and in-home assessments. Each zip code was tagged either as rural or urban depending on the population of the area served by the zip code. For the telephone survey and the in-home assessment, the population was stratified using such as characteristics as rural or urban, retired or non-retired, and landline users or cellphone users, and quotas were set to ensure a representative mix of residents from all important subgroups. Telephone survey participants residing in single-family homes (similar to bungalows in India) were selected for in-home assessments. The response rate (number of completed interviews divided by total eligible respondents) and the cooperation rate (completed interviews divided by households actually contacted) were also calculated using the formulae given by the American Association for Public Opinion. Since the stratification for telephone survey and in-home assessments matched that of the entire population, weighting was not required. In addition to the telephone survey and in-home assessment, highly qualitative surveys of HVAC contractors were also undertaken to assess the sales of energy-efficient HVAC equipment in Delaware.

The results from both the surveys were analysed to determine whether the differences between comparison groups were statistically significant: proportions were compared using the independent z-test[f] and percentages and means were compared using the two-tailed independent *t*-test[g].

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[f] http://www.statisticshowto.com/z-test/, http://stattrek.com/hypothesis-test/difference-in-proportions.aspx

Key findings and recommendations

- Incentives and consumer education have the potential to increase energy savings. If programmes are to be cost effective in a constantly changing lighting environment, they need to be flexible and have the ability to change the programme approach (consumer education, upstream incentives, etc.), product mixes, and incentive levels throughout the year as necessary.
- Refrigerators have fairly high saturation levels, and many homes have a second operating unit as ancillary storage. Programmes aimed at recycling refrigerators and freezers can achieve significant energy savings if the number of refrigerators in participants' homes can be lowered.
- Upstream or market-lift programmes that provide upstream incentives to manufacturers, retailers, and wholesalers may prove more effective for consumer electronics in Delaware than the traditional rebate programmes.

Apart from the above findings, the team believed that whole-house improvements with energy-star products and educational programmes to encourage appropriate behaviour also have a potential in Delaware.

2.6 Measuring the life of lighting products and energy efficiency measures

The life of CFLs was measured using parametric regression.

Purpose

The purpose of this study was to estimate the life of lighting products distributed, or measures deployed, through energy efficiency programmes in New England (England, Lighting, & Sponsors, 2008). The items measured include life of equipment (number of years the equipment will operate until failure) and the persistence of energy efficiency measures (business turnover, early retirement of installed equipment, and other reasons for which measures might be removed or discontinued) but not that of energy savings.

Methodology

The sample design was based on the number of energy-efficient light bulbs distributed through energy efficiency programmes. If the participant had bought at least one bulb during 2002–2006 and if information on model number, manufacturer and wattage, location of installation, and the customer's contact number was available, the programme qualified for being included in the study. Of the eligible programmes, a random sample of participants was drawn based on the type and number of products they obtained. A total of 285 homes were visited.

This type of sampling introduced some bias.

- Due to lack of data, only a few programmes could be selected (coupon programmes, direct install), which resulted in other sponsor-administered lighting programmes such as markdown programmes being excluded.

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[g] http://vassarstats.net/textbook/ch11pt1.html

- To make the study cost-effective, the site visits aimed at homes with a higher number of fixtures, which resulted in unintended inclusion of electricians, contractors, and landlords. Further, these respondents had many more products and hence could not recall information on at least some of them.
- Recall was also affected because of the delay between the time of purchase and the survey and led to majority of the products being excluded because of poor recall.
- Because respondents were contacted by telephoning them, only those were included in the survey who had neither moved nor changed their telephone number from the time they had bought a CFL; this mostly excluded tenants, low-income households, and young adults.

The products were categorized into 'survived', 'failed', or 'excluded': survived, if the auditor visually confirmed that the product had been installed and was in working order; failed, if the product was burnt out, broken, permanently removed from service, or returned to the store; and excluded if the product was not found, reported installed but not in place, installed outside the surveyed area, was being stored for future use, had been returned to the store before it had failed, or had been given away.

Although the life of the measure was analysed using three methods, the team chose parametric regression for survival analysis and estimated the lifetime of CFLs, which turned out to be 5½ to 7 years. The data also pointed to a longer life for the CFLs as a result of improved product quality. Most of the CFLs were found installed in the living room, bedroom, kitchen, dining room, and basement. Respondents generally replaced burnt out or broken CFLs with new CFLs (59%) but replaced broken energy-efficient fixtures only with regular fixtures. The study also estimated the spillover at 81%–128% for the selected programmes.

Recommendations

- Adopt the estimated lives of energy efficiency products for future programmes.
- Wherever the programme type allows, collect all possible information such as product type, manufacturer, model number, fixture type, wattage, room or location of installation, date of installation, and any other information on the product or customer such as name, address, and telephone number.
- Conduct such 'life of a measure' study at a point in the life cycle that is not too early.

2.7 California's upstream lighting programmes

Market effects were evaluated using surveys, interviews, and home audits.

Programme

The upstream lighting programmes of California have been running since 1992 and are the largest and the longest programmes in USA. In 2006–2008, utilities offered rebates for over 95 million CFLs through the programmes, which have worked through existing market channels; increased the availability, diversity, and promotion of CFLs through supplier programmes; and increased awareness, knowledge, acceptance, and purchases of CFLs through supplier markets and consumer marketing. These programmes may have changed the market, changes that would not have occurred otherwise. The programmes were evaluated to understand their cumulative effects on CFL markets, quantify energy and peak savings, and ascertain whether savings from potential market effects can be quantified and treated as resources (The Cadmus Group, 2010).

Evaluation

The evaluation team had understood three aspects from the beginning: the evolution of the CFL market in California and in the country, current CFL programmes offered in California, and CFL markets in other states. This knowledge helped the team in identifying key research questions and in deciding how to evaluate the programmes. Two methods were used for arriving at a baseline for the CFL programmes. In the first method, California was compared with other states that do not offer CFL programmes but were comparable to California in terms of income and education levels. The second method consisted of multi-state regression analysis. Data were collected from 16 states to identify the factors responsible for CFL purchases in 2008.

Primary data were collected through surveys, interviews, and home audits. Programme managers, policymakers, and evaluation consultants were interviewed to gather qualitative information about factors that have influenced California's CFL market over time. Users of CFLs were interviewed on telephone to gather information on their awareness of and familiarity with CFLs, past and recent purchases, use and storage, satisfaction, disposal of CFLs, environmental attitudes, and demographics. In-home lighting audits were conducted to determine penetration and saturation of CFLs in California and in other comparable areas. Product stocks on shelves were surveyed to gather information on such attributes of CFLs as bulb type, shape, wattage, lumens, and package size and counts). Manufacturers and retailers were interviewed to understand the characteristics of programme participants, motivation, recent trends in programme, assessment of free ridership and spillover, market share, global sales and policies, and stocking and pricing practices. Store-level retailers were telephonically interviewed to understand stocking patterns and get insights into the markets for lighting products.

As part of the analyses, the team analysed the effects of the CFL programmes on retail prices based on information from interviews of manufacturers and retailers, point-of-sale data, and pricing information from the shelf-stocks surveys. The pricing model used in the evaluation helped to identify the internal and external factors that affected the retail prices of CFLs. The parameters analysed included geographic location of sale, wattage, lumens, package size, retail channel, discounts offered, and time of the year.

Key findings and recommendations

- The programmes had a small but positive effect in terms of consumer awareness, availability of CFLs, floor space for CLFs in retail stores, lower price of CFLs, and greater saturation. The programmes were also instrumental in enactment of lighting efficacy regulations in California.
- Consumers should be educated about the variety of CFLs, appropriate applications of CFLs, and their proper disposal in future programmes, because even now CFLs account for only 21% of all sockets.
- Proper recording of baseline data before programme implementation as well as throughout the programme is extremely important for correct assessment of market effects.

2.8 Pilot CFL programme of MSEDCL in Nashik

The evaluation used engineering methods, and the required values were obtained from sample surveys of consumers.

Programme

Recognizing that lighting is a major contributor to peak load, MSEDCL decided to distribute over 3 lakh (0.3 million) CFLs in Nashik to its residential and commercial consumers. The programme sought to reduce peak demand and improve the load factor, power quality, and customer relations. The price of the CFLs was brought down through tenders, and consumers bought CFLs at that price. Three suppliers provided the bulbs under the programme, who were selected based on product quality, price, warranty, and retail network.

The consumers could buy a maximum of five bulbs (15 W or 20 W) and pay upfront or in instalments (the amount was added to the monthly bill for electricity). The CFLs were available at bill collection centres, through door-to-door sales organized by 'Bachat Gut' (self-help groups), at retail shops, and at stalls set up by suppliers at MSEDCL meetings to publicize energy efficiency.

Evaluation

The programme was evaluated for its impacts, processes used, and the tracking and monitoring system by Prayas (Prayas (Energy Group), 2007). Two methods were used, namely surveying a sample of participants and conducting in-depth interviews of stakeholders. The survey was used for obtaining information on the number of CFLs bought, the points at which they were installed, the lighting option they replaced, power consumption, and hours and time of use. Apart from this, the survey also captured data on bulb failures and replacements and consumer opinions of the programme. Urban consumers were surveyed using stratified random sampling, the strata differentiated by tariff slabs, whereas rural consumers were surveyed using the snowballing method. The reduction in peak demand and in energy consumption was calculated using standard engineering equations

The in-depth interviews of stakeholders, including participants and non-participants, suppliers, retailers, members of all-women self-help groups, and MSEDCL staff, provided the data required for evaluating data-tracking and monitoring systems and different processes of the programme. The stakeholders were interviewed to assess their satisfaction level, effects of marketing and advertising, concerns related to the programme, the need to improve programme design, and effectiveness of the processes of the programme.

Key findings and recommendations

- High failure rates and very low power factor of CFLs wiped off the benefits of energy savings. Any large-scale programme should ensure the appropriate power factor and quality bulbs.
- Bulk purchases and instalment schemes can lower the costs of efficient technologies. However, the repayment period for further programmes could be longer to make them more affordable to small consumers.

- To achieve estimated energy savings, consumers should be educated on the hours of use of bulbs and where they should be fitted.
- The substantial backlog in entering data could be avoided by incorporating data requirements at the time of designing future programmes.

ANNEXURE 3: END-USE-SPECIFIC MEASUREMENTS AND VERIFICATION

Various measurement and verification methods adopted in different end-use-specific DSM projects such as lighting and agricultural pump sets are discussed in this section. The idea is to have all M&V methods pertaining to a particular end-use or DSM project in one place so that M&V standards and procedures can be assessed effectively for developing an India-specific M&V framework for a portfolio of DSM programmes.

ESKOM NATIONAL EFFICIENT LIGHTING PROGRAMME, SOUTH AFRICA

Description: Energy-efficient light bulbs, in the form of CFLs, are distributed to replace incandescent lamps (ICLs) in households (60 W ICLs are replaced with 15 W CFLs and 100 W ICLs with 20 W CFLs). By providing CFLs free of charge to each household either by installing them at all points in the household or by exchanging them for ICLs (up to 6 CFLs per household), the programme aims to lower the emissions of greenhouse gases, reduce the national electricity demand significantly, promote energy infrastructure, and help individual households to lower their electricity bills.

Timeline: 2007–2010 (historic roll-out projects through voluntary emissions reduction), 2011 (small-scale greenfields projects through CDM), and 2011–2016 (sustainability projects through CDM)

Method[h]: Measurement and verification were conducted in two phases. The objective of the first phase was to estimate the hours of use. This required installation of loggers that monitored the light's on/off status to build a profile of lighting use. The logger has a light-sensitive sensor, which is triggered the moment a light is switched on or off. The loggers are mounted close to or onto the light source using a magnet or double-sided tape. The light sensitivity of the logger is so adjusted that the sensors are triggered only by the light of the installed lamp. Apparently, the loggers give inaccurate readings in well-lit areas. This problem was minimized by installing the loggers in rooms with small windows or in rooms that did not receive much natural light. The loggers were also mounted with the sensor facing away from windows. Every time the light is switched on, the meter sends an alert, using SMS, that gives information on the preceding 12 switching events. Simple random sampling was used for selecting households for installation of these GSM-based light status loggers.

The second phase of the M&V was conducted to obtain reliable estimates of failure rates of the CFLs and the proportion of CFLs in use. Stratified multi-stage random sampling was used for surveying the following subgroups of the population:

- low-income urban areas
- low-income rural areas
- middle-to-high-income urban areas
- exchange programmes.

[h] Sustainability CFL Replacement Programme of Activities in South Africa. POA design document. Page no. 46 to 70.
https://cdm.unfccc.int/ProgrammeOfActivities/poa_db/3V9RNQGOC51T7Y2BUDMWZ64XK0ILFA/view

Questionnaires were used for recording typical lighting replacements for a given type of room or area during the roll-out of CFLs and information on typical operating hours for the CFLs. The first round of the survey was conducted within one year of installation to find the number of CFLs in service and operating as part of project activity. Subsequent surveys were carried out at regular intervals (e.g. a minimum of 3 years or 30% of the CFL's lifetime) during the project tenure to estimate failure rates.

Benefits:

Project tenure	Number of CFLs distributed (millions)	Estimated tonnes of CO_2 emissions avoided
Historic roll-out projects (2007–2010)	30.0	More than 7 million
Greenfields projects (2010–2011)	1.5	More than 300 000
Sustainability projects (2011 –)	32.5	29 518 a year

Bachat Lamp Yojana

Description: Energy Management Centre (EMC), Thiruvananthapuram, in collaboration with Kerala State Electricity Board (KSEB), distributed about 12.7 million CFLs under Bachat Lamp Yojana (BLY). The project was registered with the UNFCCC under the CDM in 2010. Every household in Kerala – 23 electrical circles of the KSEB in all – was given two CFLs in exchange for two ICLs (60 W ICLs replaced with 14 W CFLs).

Timeline: 2010–2011

Replacement mechanism: 2 working ICLs replaced with 2 CFLs (for each residential connection) at a cost of Rs 15 per CFL.

Distribution phases:

Area (no. of project circles)	No. of CFLs distributed	Coverage (%)
South (6)	35,28,478	82.56
Central (7)	40,71,566	79.55
North (10)	50,13,976	83.19
Total (23)	1,26,14,020	81.81

Funding: The total project cost was Rs 95 crore (Rs 950 million). The Government of Kerala extended an interest-free loan of Rs 40 crore (Rs 400 million) to the EMC, to be repaid through the amount received by selling certified emission reductions (CERs). The EMC also received a loan of Rs 55 crore (Rs 550 million) at 13.5% interest from KSEB.

Method: The proposal to use GSM-based meters to monitor the hours of use was abandoned because of its high costs; instead, a conservative estimate of 3.5 hours of daily use was assumed. A sample of

1250 domestic consumers was selected from each of the 20 project areas of KSEB and details of the project participants were collected from these households using a structured questionnaire[i].

Benefits: The project was reported to have saved 300 MW during the peak season (March and April) in 2010.

Recovery of project cost: The project investor can claim the carbon credits earned by replacing 60 W ICLs with 14 W CFLs. These carbon credits are called certified emission reductions and are issued by the CDM executive board for emission reductions achieved by CDM projects (1 CER is issued for a verified reduction in emissions of 1 tonne of carbon dioxide). These CERs can be traded in international markets – the most active ones include European countries, Japan, Canada, and New Zealand – and buyers buy these credits to meet their targets of limiting emissions. Most sellers are from developing countries such as India and Brazil. When BLY was registered under the CDM, the cost of 1 CER was about 10 euro, and the money spent on the project was expected to be recovered by selling these CERs.

Closure: The project was curtailed in Kerala and was unsuccessful in getting vendors because the price of 1 CER fell considerably, to 2–3 euro (and currently stands at 0.5 euro). The investment is no longer profitable and discourages investor from investing in BLY and other schemes under the CDM. At present, EMC has about 8 million CERs. The present cost of CER in the market is too low for EMC to recover the project cost; EMC has therefore decided to sell these CERs in the voluntary carbon market.

DSM-BASED EFFICIENT LIGHTING PROGRAMME

Description: The first DSM-based efficient lighting programme (DELP) in India was launched by EESL in collaboration with Puducherry Electricity Department (PED) on 7 February 2014 as a standard offer programme in Puducherry. Under the scheme, each household was allowed to replace a maximum of 3 ICLs of wattage 60 W each with LED bulbs of 7 W each by paying Rs 10 apiece. The scheme was meant for domestic customers, and 2.45 lakh (0.245 million) households were enrolled in the project.

Method: A web-based monitoring system was put in place to capture the operational hours for a sample of LED bulbs. The sample included 200 LED bulbs installed in Muthailpet, Puducherry, in a housing colony for government employees. Each bulb in the sample was fitted an RFID tags, and 5 RF transmitters were installed in the colony (Figure A1). However, most of these bulbs were lost, and a conservative estimate of 3.5 hours of use a day over 300 days in a year was assumed to estimate the savings.

Before implementing the programme, baseline ICL use was estimated based on the pattern of use of ICLs in the DISCOM area through a baseline sample survey conducted by the DISCOM. The survey objectives as mentioned in DELP toolkit[j] were as follows.

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[i] A detailed M&V report of the BLY project prepared by Datamation Consultants Pvt. Ltd, New Delhi is available with EMC, Kerala

[j] DELP Toolkit- Energy Efficiency Services Limited.
http://www.eeslindia.org/writereaddata/DELP%20Toolkit%20final.pdf

- To determine the number of ICLs in the project area
- To determine the number of hours the ICLs are used by households
- To estimate the total numbers of ICLs to be replaced

A template was used for sampling the households and model questionnaires and for the method itself.

RF Antennas and transmitters installed in government quarters

Benefits:

Power savings for each ICL replaced with one LED bulb: 53 W (60 W − 7 W)
Total number of bulbs to be distributed: 7,35,000
Operating days in a year: 300
Operating hours in a day: 3.5
Total energy saved (million units)per year: (53 × 735000 × 300 × 3.5) / (10^6) = 40.90
Transmission and distribution (T&D) losses: 12.85%
Energy requirement at periphery (million units): 40.90 / (1 − 0.125) = 46.74
Pool losses: 4.37%
Deemed energy supplied per year (MU): 46.74 / (1 − 0.0437) = 48.88

Funding:

Cost of an LED bulb including transport, insurance, storage, and distribution: Rs 310 + 10 = 320
Total number of bulbs to be distributed under the scheme: 7,35,000
Cost recovered from customers: Rs 10 per bulb
Project cost (net investment by EESL): Rs (320 − 10) × 735000 = Rs 22.785 crore (Rs 227.8 million)
Debt (70% of project cost): Rs 15.9495 crore (about 160 million) (to be arranged by EESL)

Equity (30% of project cost): Rs 6.8355 crore (68.4 million) (to be arranged by EESL)										
Interest on loan: 12.5%										
Return on equity: 15.5%										
Annual maintenance cost: 3% of project cost (including replacement warranty cost for 2 years by EESL)										
Financial savings deemed to have been accrued to PED by saving energy sold at a subsidized rate of Rs 4.40 − 2.55 = 1.85 per unit Annual energy saving: 40.90 million units Savings over 10 years: Rs (1.85 × 4.09 × 10 = 75.665 crore (756.65 million)										
DELP Standard offer programme price (in Rs/kWh) from year 1 to year 10	1	2	3	4	5	6	7	8	9	10
	1.23	1.17	1.11	1.04	0.98	0.92	0.86	0.79	0.73	0.67
Total payment by PED to EESL over 10 years excluding taxes (in Rs crore) from year 1 to year 10	Rs 46.41 crore (464.1 million)									
	1	2	3	4	5	6	7	8	9	10
	6.02	5.71	5.40	5.10	4.79	4.49	4.18	3.88	3.57	3.27
The Puducherry Electricity Department had planned to recover the annual payout to be made to EESL through annual revenue requirement for the respective year.										

Project status: The project was made part of a national initiative, namely UJALA, and re-launched on 1 May 2015. The programme has sold more than 290 million LED bulbs in India so date. The current status of the programme is shown on the website www.ujala.gov.in.

AGRICULTURE DSM PROGRAMME

Description: The first agriculture-DSM (Ag-DSM) project was implemented in Solapur in Maharashtra in 2010, in which BEE replaced 3530 old pump sets with BEE star-rated pump sets. This project had a payback period of 4 years in terms of energy savings and reduction in the subsidy achieved by the state utility. In 2015, EESL, in coordination with Bengaluru Electricity Supply Company, a utility, planned an ambitious project to replace one lakh (0.1 million) pump sets.

Method: The salient features of the M&V process used for the Ag-DSM projects by EESL are detailed in its toolkit[k] and are enumerated below.

- Baseline energy consumption is calculated based on initial testing of old pump sets and actual annual operating hours of such old pump sets or 1800 hours, whichever is higher. From the second year of contract, the annual number of hours of operation of the old pump sets and of the energy-efficient pumping system (EEPS) for calculating energy saving are actual hours of operation (as verified from information received from the substation) or 6 hours per day, whichever is higher. The pump sets are taken to operate 6 hours a day for calculating energy savings, irrespective of any power shutdown or load shedding.
- Power consumption (in kW) of EEPS will be measured at the time of installation of such EEPS by a joint team of EESL and the DISCOM.

[k] EESL toolkit for Ag-DSM projects. http://www.eeslindia.org/writereaddata/EESL%20Toolkit%20for%20AgDSM%20Projects.pdf

- For each feeder, a maximum of 5% of the EEPS connected to the feeder are selected by a joint team of EESL and DISCOM for M&V and the measured energy savings are extrapolated for the total number of EEPS connected to the feeder.
- Annual energy savings for the contract year are calculated based on actual hours of operation or a minimum of 1800 hours a year or 6 hours a day, whichever is higher.
- Criteria for selection of sample EEPS for measurement include the type and the rating of the pump sets, input power, the flow and the head for the EEPS, and the operating efficiency of the EEPS.
- Energy saving = (Total power (in kW) consumed by the old pump sets connected to a single feeder to be replaced by EEPS – total power (in kW) consumed by the replaced EEPS) x 6 hours.
- Energy savings are calculated at the prevailing tariff or at Rs 4.50/kWh, whichever is higher.
- If any pumps are added or removed after the feeder completion date, pre- and post-measurement (kW) data are adjusted accordingly.
- At the time of replacement of the old pump sets, a joint team of EESL and DISCOM will check the power consumption (in kW) of the old pump set (baseline power consumption) and of the EEPS after installation.

Benefits and costs: The benefits and costs of the project are given in Table A3.

Table A3: Benefits and costs of the agriculture DSM programme

Project	Number of pump sets replaced	Date of completion	Energy saved per year (lakh units)	Investment (crores of rupees)
Hubli Electricity Supply Company Ltd, Byadgi and Nippani circles	590	30 Dec. 2013	30.00	2.60
Chamundeshwari Electricity Supply Corporation Ltd, Mandya district	1337	18 Mar. 2015	56.68	5.03
Eastern Power Distribution Company of Andhra Pradesh Ltd, Rajanagaram Mandal	2496	In progress	213.17 (estimated)	19.66

Poland efficient lighting programme

Description: The Poland efficient lighting programme (PELP)[l] was implemented by the International Finance Corporation (IFC) and funded by the World Bank's Global Environment Facility (GEF) in Poland from 1995 to 1998. The Netherlands Energy Company was the local executing agency to administer the project. The project sought to reduce the emissions of greenhouse gases by replacing conventional ICLs with energy-efficient CFLs in households.

[l] Poland Efficient Lighting Project, World Bank GEF, Post Implementation Impact Assessment. http://siteresources.worldbank.org/GLOBALENVIRONMENTFACILITYGEFOPERATIONS/Resources/Publications-Presentations/Poland.pdf

The project aimed at transforming the market for energy efficiency products in Poland. Five Polish lighting manufacturing companies were selected on a competitive basis and given a subsidy of $2.6 million to reduce the cost of 1.2 million screw-base CFLs. A part subsidy totalling $82,000 was also given to customers, who bought nearly 57 000 CFLs. The project was promoted through television and print advertising, school education programmes, press conferences and interviews, and energy efficiency awareness programmes.

Three cities, Chelmno, Elk, and Zywiec, were selected to participate in a pilot programme under the PELP because they had pockets that suffered because of inadequate grid capacity. Several target areas within the three cities were identified for electric load analysis.

Method: Synergic Resources Corporation and Navigant Consulting carried out the M&V for the project, which involved surveying manufacturers and consumers, direct internal information generated by the subsidy system, and statistical and contextual analysis carried out by third parties. Energy savings (Figure A2) and the amount of decrease in the emissions of CO_2 were used as performance indicators for the project.

Benefits and costs: PELP was a $5-million project, which led to an estimated energy savings of 3034 GWh, reductions in the emissions of CO_2 totalling 3.6 million tonnes (Figure A4), and a boost to Polish economy through domestic manufacturing of CFLs. Apart from demonstrating the value of DSM, the project helped in building the capacity of government and non-government entities to develop their own DSM programmes in future.

	With PELP			Counter-factual Scenario							
	Annual Sales of CFLs (000)	Annual Sales Growth Rate	Total Stock of CFLs Installed (000)	Annual Sales of CFLs (000)	Annual Sales Growth Rate	Total Stock of CFLs Installed (000)	Added CFLs from PELP (000)	Energy Saving Factor per CFL Installed in kWh/bulb	Estimated Energy Saving (GWh)	CO_2 Reduction Index (kg CO_2/KWh)	CO_2 Reduction (000 tons)
1996	2938	103.3%	6 216	1621	30.0%	4701	1515	56.7	86	1.27	109.1
1997	3465	17.9%	9 681	2107	30.0%	6809	2872	56.7	163	1.24	201.9
1998	3964	14.4%	13 645	2411	14.4%	9219	4426	53.3	236	1.23	290.4
1999	4543	14.6%	18 188	2763	14.6%	11982	6205	53.3	331	1.21	400.6
2000	5208	15.9%	22 152	3202	15.9%	14062	8090	40.0	324	1.20	388.4
2001	5971	16.0%	25 615	3715	16.0%	16318	9298	40.0	372	1.19	442.7
2002	6846	17.1%	29 649	4350	17.1%	18771	10878	40.0	435	1.18	513.6
2003	7849	12.2%	34 104	4880	12.2%	21481	12623	40.0	505	1.18	596.0
2004	9000	12.2%	39 015	5474	12.2%	24468	14548	40.0	582	1.17	681.0
Total									3034.0		3623.7

Figure A3: Energy savings due to Poland efficient lighting programme

PROMOTING ELECTRICAL ENERGY EFFICIENCY IN THAILAND

Description: The Thailand Promotion of Electricity Energy Efficiency Project (TPEEE)[m] was approved in 1993 and completed in 2000. The project was co-financed by the GEF to the tune of $9.5 million and by the Government of Australia to the tune of $5.4 million. A loan of up to $25 million from the Overseas Economic Cooperation Fund of Japan / Japan Bank for International Cooperation, and funds from the state-owned public electricity utility, the Electricity Generating Authority of Thailand (EGAT), were also instrumental in designing and implementing the project.

The project had many components ranging from developing and implementing technological and market-intervention strategies in residential, commercial, and industrial sectors to residential appliance labelling programme and establishing testing laboratories. The project aimed at developing project evaluation and monitoring systems and protocols and training ESCOs and DSM programme contractors. The project objectives revolved around integrating supply-side and demand-side planning in electricity planning and also helped in developing a direct utility load control programme for Thailand.

Method: Three subjective scenarios were used for evaluating the impact of TPEEE, of which two counterfactual scenarios ('No TPEEE, high baseline' and 'No TPEEE, low baseline') were based on educated best guesses.

- The factual 'With TPEEE' scenario incorporated all the available data on product sales and extrapolated these data to provide a complete time series of sales from the start of TPEEE until 2010 (this year was chosen because it provides a reasonable period of time to allow the differences between the scenarios to become evident).
- The 'No TPEEE, high baseline' scenario sets a high boundary for the range of estimates of sales that would have happened in the absence of TPEEE and hence represents the lower boundary of the range Impact Assessment Framework and Approach 17 of estimates of the incremental impact of TPEEE
- The 'No TPEEE, low baseline' scenario sets a low boundary for the range of estimates of sales that would have happened in the absence of TPEEE and hence represents the higher boundary for the range of estimates of the incremental impact of TPEEE.

These scenarios were defined on the basis of interviews and some key assumptions (Table A4).

Table A4: Key assumptions in the high baseline and low baseline scenarios

Programme components	High-baseline scenario: low impact	Low-baseline scenario: high impact
T8 lamps	Sales delayed by 5 years, then rising by 500 000 units per year until 2010, when sales are nearly the same as those in the TPEEE scenario.	Sales delayed by 8 years, then rising by 500 000 units per year until 2010.

[m] Thailand Promotion of Electrical Energy Efficiency Project, World Bank GEF, Post Implementation Impact Assessment. http://siteresources.worldbank.org/GLOBALENVIRONMENTFACILITYGEFOPERATIONS/Resources/Publications-Presentations/Thailand.pdf

CFLs	CFLs not introduced until 2004, when a 'second push' occurs (sales of CFLs under TPEEE not significant until 2004)	CFLs not introduced until 2004, when a 'second push' occurs (at that point, modest sales start at 1 million units per year, rising by 500 000 units per year up to 2010)
Energy-efficient ballasts	Few ballasts sold in 1998, slowly rising to TPEEE scenario levels by 2010	Ballasts not sold until 2000, then slowly rising by 50 000 units per year
Refrigerators	All refrigerators remain at 3-star level until 1996, after which half the sales shift to 4-star units; by 2000, no 3-star units sold; by 2003, shift to 5-star units until 2010, when majority is 5-star units	All refrigerators remain at 3-star level until 2000, after which half the sales shifted over to 4-star units; by 2003, a slight shift to 5-star units, but sales continue to be dominated by 4-star units until 2010
Air conditioners	All units sold up to 2000 are 4-star units; after that, sales split between 4- and 5-star units.	All units sold up to 2000 split equally between 3-start units and 4-star units; after that, sales split between 4-star and 5-star units

Outcomes and benefits: TPEEE was designed to cover various aspects of DSM holistically. The outcomes of various components of TPEEE are mentioned in Table A5.

Table A5: Outcomes of different components of the Thailand Promotion of Electricity Energy Efficiency Project

Programme component	**Outcomes**
Fluorescent tubes T12 to T8	All manufacturers switched production to T8; market transformation complete.
Refrigerators	100% of indigenous production and 82% of all units sold are rated 5 stars in energy efficiency
Air conditioners	Units rated 5 stars account for nearly 40% of units sold
Compact fluorescent lamps	Large volume (900 000 units) sold at subsidized prices (40% below prevailing market price)
Street lighting (high-pressure sodium bulbs)	Lamps procured (275 000) and installed; high cost of local HPS bulbs halts promotion.
Green (designated commercial) buildings	More than 250 commercial and industrial buildings audited; installed more than 120 control systems; four demo project sites completed
Green Leaf buildings hotel certification	More than 85 audits completed; just under 60 hotels rated; 5 were at highest level; results disseminated widely
High-efficiency motors	More than 60 demonstration/test motors procured, but only four HEM motors

	purchased; laboratory set up
Low-loss ballasts	Distributed more than 545,000 5-star units to 11 manufacturers; no promotion; on hold
Load management	Interest among more than 190 customers; programme put on hold because of large power capacity surpluses
Thermal storage	Financial viability deemed marginal; put on hold

The impact of the outcomes mentioned in Table A5 can be observed from the values of following performances indices evaluated for the project.

- Energy savings: 3140 GWh a year
- Peak reduction: 566 MW
- Reduction in emissions of greenhouse gases: 2.32 million tonnes a year

Annexure 4: Guidelines for terms of reference for evaluating typical energy efficiency programmes in India

Appliances- or equipment-based programmes

Bulk procurement programmes to sell energy-efficient appliances or to replace them can be comprehensively evaluated using the methods described in Section 2. Depending on the scale of the programme and the objectives of the evaluations, different aspects of programmes can be evaluated. For instance, if a DISCOM is interested in evaluating a programme in its territory, it can focus on direct savings in energy and in energy demand and effectiveness of local processes. If the objective is to understand only the market impacts of a national-level programme, that aspect can be focused on. This section describes how all the three aspects of programme evaluation, namely direct impacts, process effectiveness, and market impacts, can be conducted in India.

Direct impacts

Directs impacts of a programme can be evaluated using the most relevant of the following methods.

- If a programme is new or has never been evaluated, metering of a sample of consumers should be used for estimating savings. Meters can be used to measure consumption before and after the installation of energy efficiency measures. The measurements should account for different typical operating conditions including seasonal variations. These measurements can be used as predetermined values to establish savings in further evaluations. Care should be taken to establish proper baselines and to address uncertainties while choosing the sample.
- Consumer surveys can be conducted as an alternative to estimating energy savings. A statistically adequate sample of consumers can be surveyed to verify the installation, the old replaced appliances, and also hours of use, which, ideally, should have been measured for a smaller set of consumers because recall of relevant details by consumers in household surveys may be poor.
- Large-scale data analysis can also be employed to measure the impact of the programme in quantitative terms by examining electricity bills. This approach requires proper collection of purchase-related data on energy-efficient appliances sold or distributed under the programme such as the consumer number given by the DISCOM, date of purchase, and quantity of purchase. Sample of consumers can be chosen from different strata of the population and one of the methods described in Section 2 can be employed. As a general rule of thumb, it is recommended that the energy savings by an appliance be more than at least 10% to use this method effectively.
- Impact on consumer awareness can be found out from surveys of consumers as well as retailers.

Market impacts

- One set of indicators of the market impact of a programme includes sales figures for the appliance and reduction in prices at national as well as local level. These data can be obtained through the database of relevant manufacturing associations, market research reports, or through such government agencies as BEE. The current price can be found from retailer surveys or a survey of e-commerce websites. However, it is difficult to find data on historical trends in prices.

- Impact on the market can also be assessed using other indicators such as investments on manufacturing units or assembly lines, establishment of new testing infrastructure, and development of standards for the appliance.
- It is also particularly important to establish the causality and the sustainability of impacts. This can be established through in-depth interviews of manufacturers, industry experts, retailers, and other stakeholders. International trends in prices of appliances or its components can also be studied to identify the causes of impacts. The sustainability of impacts can also be probed using interviews of stakeholders as well as of consumers. The willingness of consumers to buy the energy-efficient appliance in question even in the absence of the programme should be confirmed.

Process evaluation

Some questions to probe the four main aspects of the process evaluation are given below.

- Programme design
    - Is a programme design document with all the relevant information available?
    - What was the basis for selecting the particular appliance? Was it based on load studies? How were the technical specifications decided?
    - What was the process adopted for designing the programme? Were all stakeholders involved?

  Answers to these questions can be found by interviewing the staff of DISCOMs, implementing agencies, and other stakeholders.

- Programme implementation
    - Was the bidding process for selecting manufacturers and distributors transparent and simple?
    - Were the procedures laid out for implementation followed by people manning the distribution centres? Were the following items documented: payment of incentives if any, information on the product in terms of performance, application and warranty, disposal of old appliances, and replacement of faulty appliances?
    - Was product quality ensured? If not, what was the procedure to return defective products? Were the reports of tests available publicly?
    - What was the effectiveness of the mechanisms used for marketing?

  Answers to these questions can be obtained through interviews with participating and non-participating bidders, EESL, DISCOM staff, and consumer surveys.

- Programme administration
    - Was there enough personnel to distribute the appliances? Were the laid-down procedures of distribution adhered to? Were the personnel skilled enough to handle the processes?
    - What kind of reporting was recommended during implementation of the programme and how frequently was it done?
    - Were the various records and databases maintained systematically and regularly?

  Answers to these questions can be collected by interviewing programme staff and surveying consumers.

- Participant response
    - Were the consumers satisfied with the programme? How were problems handled?
    - Were the manufacturers and distributors satisfied with the way the programme was implemented?

  Answers to these questions can be collected by interviewing the manufacturers and distributors, whether in person or telephonically, and through consumer surveys.

In case of programmes involving replacement of agricultural pumps, the following additional points can be considered while preparing a plan of evaluation.

Impact evaluation

- Baseline surveys on farming and irrigation systems are necessary before installing energy-efficient pumps at sample locations and need to be conducted at least a year before new pumps are installed. The surveys should include information on name of the farmer, area cultivated, type of irrigation, crop(s) cultivated, pump details (capacity of pump, make, year, depth of pump installation, and bore depth).
- Energy consumption after installation of pump sets at the selected sample sites should be monitored over time: short-duration measurements of energy consumption at a given point of time are not accurate representations of total energy consumed.
- Option B of the IPMVP protocol should be used for the first evaluation and, once the number of hours of use, energy consumption, and maximum power drawn are established, Option A should be used for further evaluations.
- Additionally, feeder-level data should be used to measure the effectiveness of a programme. This is applicable to states in which feeders for agricultural use have been separated from those for other uses. If a majority of the pumps on a feeder are replaced, feeder-level consumption data before and after the installation of pumps can be a good indicator of the impact of energy-efficient pumps.
- Impact on farmers could be assessed by surveying the participating farmers.

Process evaluation

- The selection of pump is the most important factor in evaluating the programme. Interviews with pump manufacturers, farmers, and implementing staff will provide information on how the pumps were selected.
- Programme implementation process, delivery of energy-efficient pumps, and disposal of old pumps can be evaluated by interviewing farmers and the staff engaged in implementing the programme.
- Maintenance and repairs and warranty on replaced pumps should be evaluated at suitable intervals by surveying the participating farmers.

STANDARDS AND LABELLING

The Bureau of Energy Efficiency's S&L programme can be comprehensively evaluated on three aspects, namely market effects, direct impacts, and process effectiveness, as described in Section 2.

Market effects

- Increase in sales of star-labelled appliances and increase in their stocks with retailers is a good indicator of a positive market impact. These figures can be obtained from sales and shipment data from manufacturers, government departments or industry organizations, companies, manufacturers, and from product catalogues and stocking surveys of retailers before and after implementation of S&L for a given appliance.
- Prices of star-labelled appliances can be compared with those of non-star-labelled appliances to understand the impact of S&L on prices through surveys of retailers and manufacturers.
- Market penetration and segmentation can be studied to understand the availability of star-labelled appliances in urban, semi-urban, and rural areas, and also by ascertaining whether inefficient appliances are phased out of the market, using surveys of participants, non-participants, and suppliers and in-depth interviews of industry experts.
- Global trends in technology development and prices can be examined to compare the existing standards and their cost-effectiveness.
- The frequency of inclusion of new appliances in the S&L programme, upgrading of existing products, and tightening of standards can be examined to understand how the market is responding to S&L by surveying S&L programme staff and manufacturers and comparing with international benchmarks and how strictly they are enforced.

Direct impacts

- Energy use before and after installation can be found out by metering a sample of households; large-scale data analysis can be used for such energy-intensive appliances as air conditioners and refrigerators; and deemed savings can be used for lights and fans to estimate savings.
- Reduction in emissions can be calculated by using emission factors after calculating net energy savings.
- Impact on consumers can be ascertained by surveying them to find out the extent to which they are aware of labels and to understand their decision-making process in buying star-rated appliances. Some pointers to such impacts are as follows.
    - Level of awareness among buyers and potential buyers, level of importance given to energy labels, understanding of the label and of the energy label, related product material, and advertising
    - Customers' perceptions of the usefulness of the label, related product material, and advertising
    - Changes suggested by consumers to the labels, related product material, and advertising to make them more effective
    - Weighting given to energy efficiency in choosing an appliance
    - Relation to priorities for other purchases
    - Customers' use of the appliance
- Impact on manufacturers could be assessed by asking them the following questions.
    - How did they change the processes to produce energy-efficient appliances?
    - What were the cost implications of such changes?

- What is the market size of energy-efficient appliances?
- How do they comply with standards and labels?
- How do the standards compare with international benchmarks?

Process effectiveness

Following questions can be asked to evaluate the effectiveness of S&L processes.

- How were appliances chosen for S&L? This information can be found through all the relevant documents, requests for proposals related to the selection of an appliance, reports of meetings, interactions with manufacturers, industry associations, and the staff of Bureau of Indian Standards (BIS) and of BEE.
- What is the method for setting standards? What is the percentage of appliances not adhering to the standards? Are there enough testing laboratories? Answers to such questions can be found in documents related to the process of setting the standards, reviews of international standards, strictness of action for non-compliance, testing protocols, methods and frequency of upgrading the standards, classification of mandatory and voluntary standards, and surveys of manufacturers, staff of the BIS and BEE, consumer organizations, and testing laboratories.
- How does the labelling work in practice? The question can be answered by examining all the processes related to the fixing of labels, action for non-compliance, and comprehensibility of labels and by surveying the manufacturers, BEE staff, distributors, retailers, and consumers.
- What are the methods used for marketing and advertising and are they effective? The answer can be found by interviewing programme staff (BEE) and surveying consumers, distributors, retailers, and manufacturers.
- Are the resources (human and financial) used for implementing the programme adequate? Interviewing programme staff can tell evaluators whether the resources are adequate.
- How is the administrative efficiency? The time taken for registering, verifying manufacturers' claims on energy efficiency of appliances, certifying, and checking and the actions taken against non-compliance are good indicators of administrative efficiency.

Related publications of Prayas (Energy Group)

1. Plugging in: A collection of insights on electricity use in Indian homes (2018)
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Energy efficiency can play a crucial role in India's goal to provide reliable and affordable access to energy in a sustainable and secure manner. A number of policies and programmes aimed at conserving energy, improving efficiency, and managing demand have been implemented in India in recent years. The scale and scope of these programmes is increasing as evidenced in the large scale LED bulb programme, UJALA. However, limited attention is given to comprehensively evaluate these programmes. A comprehensive evaluation systematically investigates all the impacts and the effectiveness of a programme in achieving them. This increases the credibility of energy efficiency programmes and consequent use of the savings estimates in the planning process. Secondly, a comprehensive evaluation provides lessons for reviewing the current programmes and effectively designing new ones to realize maximum possible energy savings cost-effectively.

This report provides broad guidelines to evaluate energy efficiency programmes in India. Towards, this objective, we first identify the barriers precluding periodic evaluations in India along with some recommendations to overcome them. We then review the best practices adopted globally and provide case studies to illustrate them. The report is targeted at the policy-makers, distribution companies, and regulators who can commission comprehensive evaluations of the energy efficiency programmes currently being implemented in India. It can also be used by the energy efficiency institutions in India (BEE, EESL, and the state designated agencies) to incorporate comprehensive evaluations in their programme designs. Finally, the report also aims to highlight the importance of comprehensive evaluations of energy efficiency programmes among consumers, civil society organizations, and researchers in India.

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