United Nations Climate Change
Technology Executive Committee

Bureau of energy efficiency, India

Case study

This document is part of a collection of six case studies selected from the work conducted by the Technology Executive Committee (TEC) on "Good practices and lessons learned on the setup and implementation of National Systems of Innovation". It specifically focuses on the Indian Bureau of Energy Efficiency (BEE).

The Summary for Policymakers of the TEC's work presented in June 2023[1] explains that the primary objective of an innovation system is to produce, diffuse, and use innovations. To accomplish this objective, the Summary for Policymakers document identifies specific activities or functions that should be carried out to facilitate the innovation process. Based on empirical evidence, innovation studies identify seven main functions as outlined in Table 1. Evaluating to what extent an innovation system can perform these functions is necessary to identify and assess the innovation system's achievements, failures and gaps or barriers. The functions assessment found that the functions of knowledge development and diffusion (F1), entrepreneurial experimentation (F2), and market formation (F3) are key functions to the Indian BEE study case.

Table 1. Indian case of innovation system

Country	India	Focus	Mitigation
Scope	Energy use sector (demand-side energy management)	Innovation system functions (F)[a]	**Key functions:** F1 Knowledge development and diffusion F2 Entrepreneurial experimentation F3 Market formation **Non-key functions:** F4 Influence on the direction of the search F5 Resource mobilization F6 Legitimation F7 Development of positive externalities
Approach	Top-down	Starting year	2002

[a] See the Summary for Policymakers of "Good practices and lessons learned on the setup and implementation of National Systems of Innovation",[2] and table 2 for the description of functions.

1 TEC, 2023, Summary for Policy makers: Good practices and lessons learned on the setup and implementation of National Systems of Innovation, UNFCCC Technology Executive Commission, Bonn. Available at https://unfccc.int/ttclear/tec/NSI.html.

2 TEC (2023).

This document begins with a general introduction of the case study, followed by a description of the legislative framework and an examination of its context within the national innovation system. This provides a foundation for a more detailed exploration of the case. These sections serve as the basis for assessing the case by analysing its functions. The last sections include additional analysis of the case's role within the national system of innovation, key success factors and lessons learned, and good practices.

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1. Introduction of the case

This case study highlights and evaluates the role of India's Bureau of Energy Efficiency (BEE) in promoting energy conservation and efficiency practices in the Indian economy and shaping the country's innovation landscape. BEE was established by the Indian Government[3] to spearhead the transformation of the Indian energy efficiency market through the use of national-level regulatory and policy instruments.

BEE plays a crucial role in developing and deploying policies and strategies with a focus on self-regulation and market principles. The Bureau works to enhance public and private sector awareness about energy conservation measures and practices that span all economic sectors. One of the primary operating principles of BEE is to achieve the active participation and collaboration of all relevant stakeholders to bring about the swift, sustained implementation of energy efficiency measures. The key initiatives of BEE include energy efficiency standards and labelling of equipment and appliances, energy conservation codes for buildings, energy conservation norms and goals for energy-intensive industries, and awareness-raising and capacity-building.

BEE plays a crucial role in developing and deploying policies and strategies with a focus on self-regulation and market principles.

BEE also plays a crucial role in facilitating reduction and avoidance of India's energy-related greenhouse gas (GHG) emission by promoting energy efficiency. BEE formulates cross-cutting policies and measures at the national level that cover major energy-consuming sectors such as industry, residential and commercial buildings, agriculture and transport. The implementation of energy efficiency schemes steered by BEE is estimated to have resulted in total GHG emission reductions of 178 million tonnes (Mt) in 2019–2020.[4]

3 BEE is a quasi-regulatory authority that implements and promotes energy efficiency initiatives within the regulatory framework of the Energy Conservation Act of 2001. It also functions as an advisory body to the central and state governments on policies for mitigating barriers to market transformation in energy efficiency.

4 BEE. (2021). Impact of Energy Efficiency Measures for the Year 2019-20. https://beeindia.gov.in/sites/default/files/publications/files/BEE_Final%20Report_Website%20version.pdf

2. Legislative framework

Recognizing the relevance of energy optimization in addressing the entwined goals of energy security, energy access and climate change mitigation, the Government of India introduced the Energy Conservation Act in 2001.[5]

The primary objective of the Act is to promote energy efficiency and lower the energy intensity of the Indian economy. To institutionalize the implementation of energy efficiency measures and facilitate the delivery of goals under the Act, BEE was established in 2002 as a central statutory body under the Ministry of Power. The Energy Conservation Act provides the legal mandate, institutional structure and regulatory framework for BEE's policies and strategies at the national and state level. The Act empowers BEE to develop policies and programmes for effective energy utilization, design sectoral energy utilization standards, recommend energy efficiency measures, monitor and verify energy efficiency improvements, and notify and penalize defaulters. In addition, the Act directs relevant state agencies and organizations to coordinate with BEE in undertaking state-level activities that promote energy efficiency. Under the Energy Conservation Act, BEE is also enabled to promote research and development in energy conservation.

Furthermore, BEE spearheads the implementation of energy efficiency activities outlined in India's National Action Plan on Climate Change. Along with organizations such as Energy Efficiency Services Limited (EESL), which is a joint venture of state-run companies, BEE develops and implements flagship schemes and programmes that are part of the Roadmap of Sustainable and Holistic Approach to National Energy Efficiency,[6] which is one of the key missions of the country's National Action Plan on Climate Change.

The Energy Conservation Act provides the legal mandate, institutional structure and regulatory framework for BEE's policies and strategies.

5 Government of India., (2001). Energy Conservation Act 2001. https://beeindia.gov.in/sites/default/files/The%20Energy%20Conservation%20Act%2Cchp1.pdf

6 The Roadmap, which is an update of the National Mission for Enhanced Energy Efficiency, is available at https://beeindia.gov.in/sites/default/files/Roshanee_print%20version%282%29.pdf.

3. The Indian national system of innovation: actors, institutions, drivers and gaps

Energy governance in India is multilayered, reflecting governmental structure, and complex.

Various government actors operate in this area, interacting with an end-user group that is highly diverse in terms of energy needs, income, category (e.g. household or industrial) and other aspects. Actors include central and state ministries for power, petroleum, coal, renewable energy and environment; public agencies, such as the Central Electricity Regulatory Commission, the State Electricity Regulatory Commission, and central and state transmission utilities; and private industrial and other organizations. As such, implementing any policy strategy or programme is challenging.

India's national system of innovation (NSI) is emerging and still fragile; policy frameworks are weak and inconsistent, and actors lack capacity, have limited access to knowledge and finance, and interact inadequately with one another.[7] In recent times, policy framing in the energy sector has been predominantly driven by the twin goals of managing rising energy needs and curtailing GHG emissions from energy generation and consumption. Consequently, the Indian energy sector is undergoing a significant transformation towards increased use of renewables and enhanced energy efficiency.

Despite the merits of doing so, improving energy efficiency in India is quite challenging.[8] As in other developing countries, market failures such as lack of awareness, insufficient access to technology and funds, high transaction costs, limited technical and institutional capacities, and perception of high investment risk make the process difficult.[9] Moreover, factors such as flawed energy pricing and procurement practices, non-internalization of environmental costs, lack of life-cycle analyses, difficulty in assessing costs and benefits of energy efficiency, and lack of consideration of rebound effects make the design of energy efficiency policies complicated. Divergence in energy efficiency performance across Indian states and industrial sectors adds to the complexity.[10]

7 Rajan, Y. S. (2012). Shaping the national innovation system: The Indian perspective. The Global Innovation Index, 131-141.
8 Singh, D., Sant, G., & Chunekar, A. (2012). Improving energy efficiency in India: need for a targeted and tailored strategy. Wiley Interdisciplinary Reviews: Energy and Environment, 1(3), 298-307.
9 Sorrell, S., & O'Malley, E. (2004). The economics of energy efficiency. Books.
10 Ministry of Power, Government of India. (2019). India State Energy Efficiency Index. https://beeindia.gov.in/sites/default/files/State-Efficiency-Index-2019 %281%29.pdf

4. Description of the case

Three leading programmes being implemented by BEE, all of which result in significant energy savings and GHG abatement, are discussed in sections 4.1 – 4.3 below.

4.1 Standards and labelling

BEE launched its Standards and Labelling (S&L) scheme in 2006 to promote energy efficiency in home appliances and provide consumers with information about the energy and cost saving potential of energy-efficient (star-labelled) products to enable them to make an informed choice when purchasing. To materialise the objective of the scheme, the 'star label' was introduced to detail the efficiency of appliances. See figure 1.

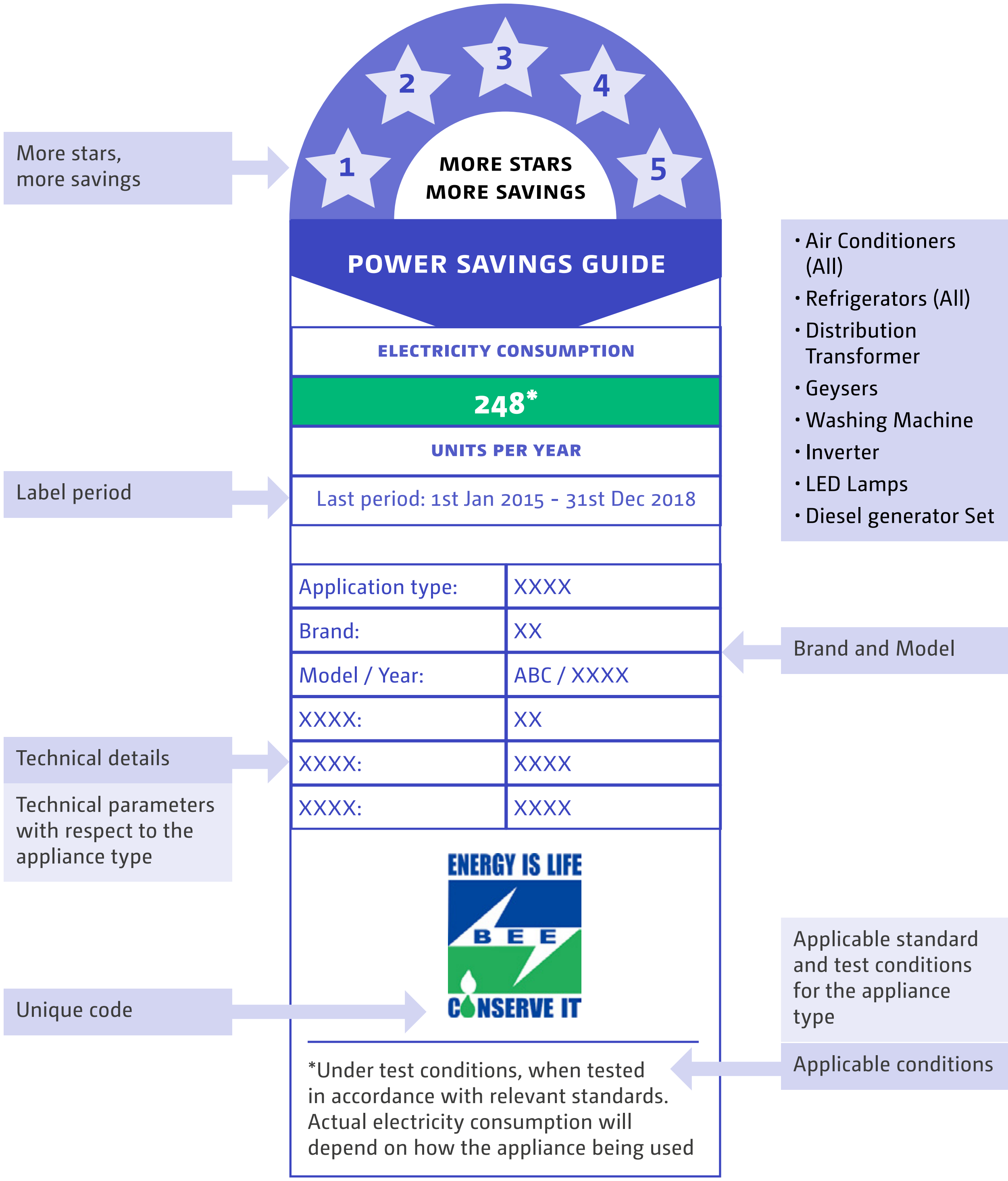
The scheme has been applied to 21 equipment or appliance types to date (e.g. lights, refrigerators, air conditioners). BEE recognizes that to implement performance standards for appliances, three factors are indispensable:

- A definition of performance standards;
- An assured demand and supply;
- A supporting infrastructure for testing and servicing.

Regardless of the entry of the multinationals Hitachi, LG, Philips and Whirlpool, as well as other big names, into the Indian market, the consumer appliance product category hardly had any energy-efficient products.[11] Moreover, the absence of performance benchmarking (and standardization) and the prevalence of small and medium units in the appliance manufacturing ecosystem resulted in wide variation in the operational features[12] of appliances.[13] End users were unaware of potential climate gains and cost savings of energy-efficient appliances. However, in the light of the growing appliance market in the country, BEE saw the immense potential for energy savings and GHG emission reductions from energy-efficient appliances. To tap into this opportunity, BEE recognized that it was crucial to focus on four actor groups: end users, retailers, manufacturers, and testing and servicing professionals.

11 Chaudhary, A., Sagar, A. D., & Mathur, A. (2017). Innovating for energy efficiency: a perspective from India. In Sustainability-oriented Innovation Systems in China and India (pp. 57-58). Routledge.
12 For instance, voltage settings, wattage, run time, idle time, and energy usage patterns.
13 Chaudhary et al., 2017.

Figure 1. Standards and Labelling programme star label[14]



14 Adapted from Central Electricity Regulatory Commission, 2018, Stars and their Wonders! Star Labeling and its Energy Efficiency, 2018, Consumer Education and Research Centre, Ahmedabad, India, http://cercenvis.nic.in/PDF/BEE%20Star%20Labelling.pdf

One of the first important task was to **create a demand for energy-efficient products**. To achieve this, intensive awareness-raising efforts were conducted through, for example, publications and promotional materials (newspapers, magazines, books, corporate brochures, leaflets, etc.), electronic media,[15] social media,[16] radio[17] and television. Awareness-raising workshops, seminars, outreach programmes and capacity-building initiatives were undertaken. BEE also conducted training programmes for retailers to disseminate information on the merits of star-labelled products so that the retailers could persuasively motivate consumers into opting for these energy-efficient products. To begin with, performance standards were defined for refrigerators and air conditioners, as these were the most energy-consuming appliances in the Indian context.

After gaining buy-in from end users, it was important to effectively engage with manufacturers and establish an adequate testing and servicing infrastructure for energy-efficient equipment and appliances.[18] The creation of market demand and the definition of performance standards **instilled confidence in manufacturers and spurred innovation**, eventually leading to market transformation. The 'technology-neutral' nature of the S&L programme afforded manufacturers the flexibility to innovate in technologies and processes. To develop a complementary infrastructure for testing, actors and resources were created using a multi-pronged strategy. Government research organizations such as the Central Power Research Institute, private actors, academic institutions (Indian Institutes of Technology Delhi and Bombay) and other actors were consulted in setting up testing facilities and defining protocols. Sectoral experts, manufacturers, accreditation authorities (e.g. National Accreditation Board for Testing and Calibration Laboratories), testing laboratories, standards bodies, consumer groups and others were also consulted before and during the firming up of the standards.

The creation of market demand and the definition of performance standards instilled confidence in manufacturers and spurred innovation, eventually leading to market transformation.

The scheme design also drew on **international experience and resources** using the technical expertise of the Collaborative Labelling and Appliance Standards Program (CLASP) and funding opportunities provided by it (with the United States Agency for International Development (USAID), United States Environmental Protection Agency (USEPA) and United Nations Foundation (UNF)).[19]

The S&L programme followed a phased approach. It started as a voluntary programme for selected products, and became a mandatory programme for several product categories once market preparedness, consumer receptivity and market penetration of energy-efficient appliances increased.[20] The **design and focus areas of the S&L programme were strategically planned.** Specific gaps in the NSI were recognized early on. Efforts were focused on engaging the missing actors and institutions and finding the missing resources and capabilities. In this process, all significant elements and stakeholders of the NSI were brought into the loop so as to enable effective implementation of the S&L programme.

15 For example, messaging by SMS and online content to raise awareness of National Energy Conservation Day.
16 Facebook, Twitter, YouTube, etc.
17 Spots on FM radio; for example, 156 episodes of "BachatKeSitare", a radio programme on energy conservation, were broadcast on AIR FM Gold.
18 Malhotra, A., Mathur, A., Diddi, S., & Sagar, A. D. (2021). Building institutional capacity for addressing climate and sustainable development goals: achieving energy efficiency in India. Climate Policy, 1-19.
19 Malhotra et al., 2021
20 CUTS CCIER. (2017). BEE energy star labelling program: Brief overview on implementation & success factors. CUTS Centre for Competition, Investment & Economic Regulation (CUTS CCIER).

4.2 Energy-efficient lighting

Two energy-efficient lighting programmes are covered in this section: Bachat Lamp Yojana (BLY) and Unnat Jyoti by Affordable LEDs for All (UJALA).[21]

The BLY programme was launched in 2009 under the Market Transformation for Energy Efficiency programme to promote the large-scale deployment of energy-efficient compact fluorescent lamps (CFLs) to replace incandescent bulbs. BEE recognized that the high price of CFLs could prove to be a significant deterrent to end users and, accordingly, developed an innovative business model. The BLY programme was developed as a programme of activities under the clean development mechanism,[22] and the revenue from the certified emission reductions issued was leveraged to eliminate the price difference between CFLs and incandescent bulbs. The BLY programme distributed CFLs at about 15 Indian rupees to households in exchange for incandescent bulbs. Participation by households in the programme was voluntary. To make the market transformation smooth and effective, BEE facilitated public–private partnerships (PPPs) between the Government of India, private CFL manufacturers and state-level electricity distribution companies. Thus, the BLY programme was designed as a win–win proposal for all.

The BLY programme was replaced by the Unnat Jyoti by Affordable LEDs for All (UJALA) programme in 2014[23]. Despite the lower operating costs of light-emitting diodes (LEDs) compared with conventional lighting and their GHG emission reduction potential, large-scale LED deployment was challenging because of the higher upfront costs of LEDs, limited awareness of them among potential users, the absence of policies incentivizing LED implementation and apprehensions of some key actors (e.g. electricity distribution companies).[24] Moreover, the lack of technical standards for LED lamps and their components posed a crucial gap that needed to be addressed before their market implementation.[25]

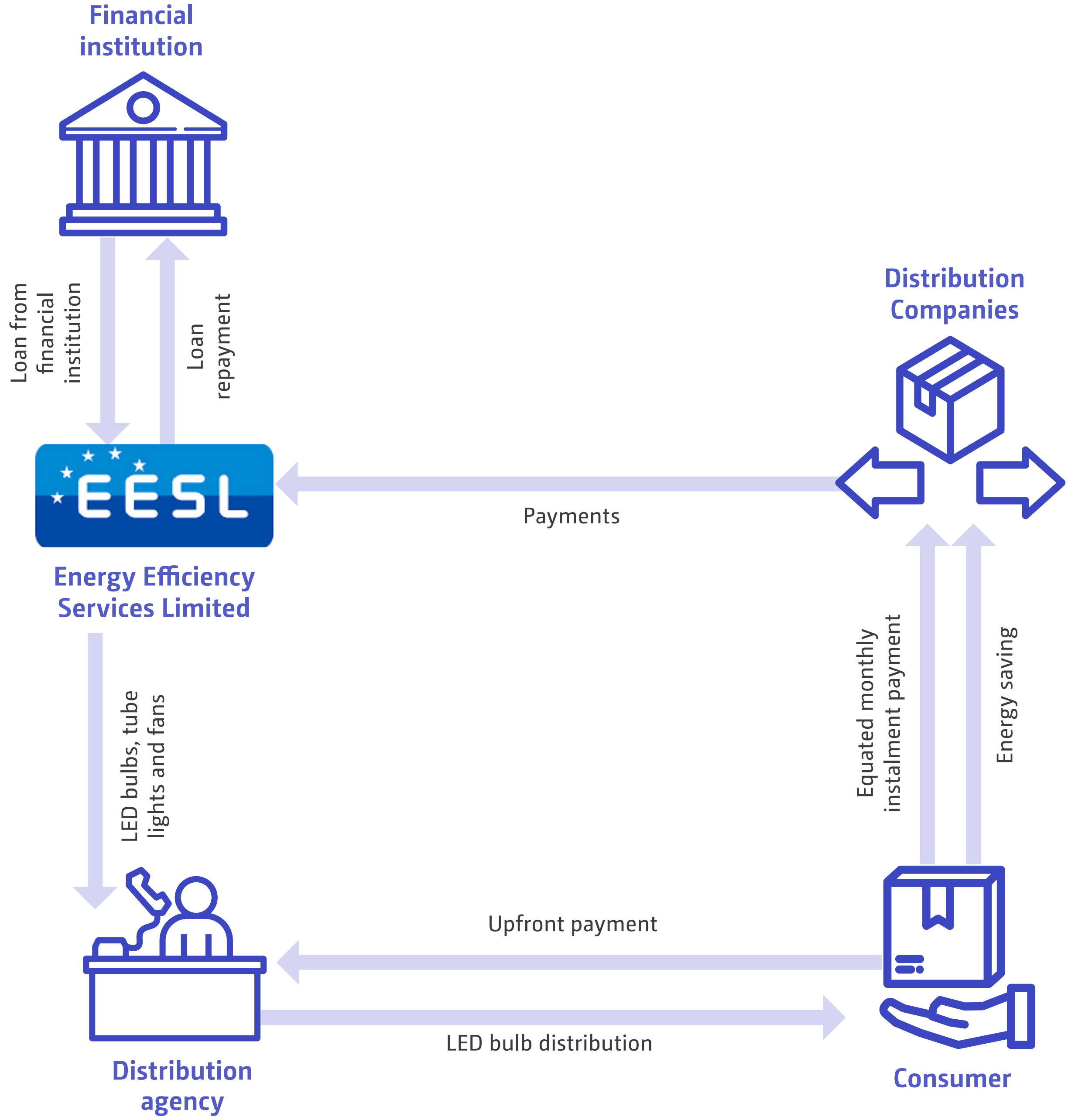
EESL, the organization that spearheaded the UJALA programme under the guidance of BEE, developed a 'demand aggregation–price crash model' to partially close this gap.[26] This **business model involved lowering costs by employing economies of scale through demand aggregation and bulk procurement** of LEDs.[27] Consequently, LEDs were distributed to end users at 40 per cent discounted prices, without subsidies.[28] Furthermore, consumers could choose between paying the total cost up front or utilizing a pay as you wish/on-bill financing programme, under which the cost was included as monthly instalments in their electricity bills.[29] Government networks and infrastructure were utilized for distributing the LEDs under the UJALA programme.[30]

To define energy efficiency standards for LED lamps and their components, BEE tapped into the experience of the S&L programme. An international expert group developed the standards, which were adopted by the Bureau of Indian Standards. See figure 2 with the operating model of the Unnat Jyoti by Affordable LEDs for All programme.

Despite the lower operating costs of LEDs compared with conventional lighting and their GHG emission reduction potential, large-scale LED deployment was challenging.

21 The UJALA programme is also known as the LED-based Domestic Efficient Lighting Programme.
22 The programme of activities was registered with the UNFCCC in 2010.
23 A factor in the discontinuation of the BLY programme was the fall in certified emission reduction prices following the weakening of the clean development mechanism after 2012.
24 The distribution companies feared that energy-efficient lighting could lead to losses in profit. However, the reduction in peak load demands due to energy-efficient lighting in situations of energy deficit helped them better manage energy demand.
25 Malhotra et al., 2021
26 IBEF. UJALA. YOJANA. https://www.ibef.org/government-schemes/ujala-yojna. (accessed on May 15, 2022)
27 EESL procured LED bulbs over successive rounds of competitive bidding. Manufacturers submitted technical and price bids according to criteria specified by EESL.
28 IEA. 2017. "India's UJALA Story." International Energy Agency (IEA). https://eeslindia.org/img/uajala/pdf/UJALA_Case_Studies_1.pdf
29 IBEF. UJALA. YOJANA (2022)
30 Chunekar, A., Mulay, S., & Kelkar, M. (2017). *Understanding the Impacts of India's LED Bulb Programme," Ujala"*. Prayas (Energy Group). https://www.researchgate.net/profile/Sanjana-Mulay/publication/349924839_Impact_of_India's_large-scale_LED_bulb_program/links/604789f492851c077f297fcb/Impact-of-Indias-large-scale-LED-bulb-program.pdf

Figure 2. Operating model of the Unnat Jyoti by Affordable LEDs for All programme[31]



Furthermore, under the UJALA programme, all relevant actors across the value chain (manufacturers, state utilities, local vendors, distributors, etc.) were given responsibilities, depending on their capabilities, and were directed to work according to **standard templates and processes** developed by EESL.[32] To create early markets and build the confidence of the actors engaged in the deployment of LEDs, BEE funded pilot installations of street lighting applications in selected regions. The choice of street lighting for a pilot project had strategic relevance: similarly to the S&L programme, BEE wanted to **kick-start the programme with the 'low-hanging fruit'**, that is, with the maximum energy savings potential from the investment or effort. The resulting cost and energy savings encouraged stakeholders, including state government regulators, to buy into the programme and to scale it up further. Beyond cost optimization and large-scale deployment, the UJALA programme also managed to create a local ecosystem for LED manufacturing in the country.[33,34]

31 Adapted from Nitin Bhatt, 2017, Success Story "Scaling Up Energy Efficiency" An Indian experience, presentation to Asia Clean Energy Forum 2017, https://www.asiacleanenergyforum.org/wp-content/uploads/2017/06/3_SUCCESS-STORY-SCALING-UP-ENERGY-EFFICIENCY-AN-INDIAN-EXPERIENCE.pdf.
32 Malhotra et al., 2021
33 Chunekar et al., 2017
34 Mir, D. A., Doll, C. N., Lindner, R., & Parray, M. T. (2020). Explaining the diffusion of energy-efficient lighting in India: A technology innovation systems approach. Energies, 13(21), 5821.

4.3 Perform Achieve and Trade (PAT) Mechanism

The Perform, Achieve and Trade (PAT) mechanism was launched in 2012 under the National Mission for Enhanced Energy Efficiency as a market-based strategy to promote energy efficiency in industrial sectors. BEE is the overall regulator of the programme, while EESL is the implementing and monitoring agency. Despite the availability of appropriate technologies and the potential for energy conservation and cost savings in the medium to long term, energy efficiency strategies have not been very popular in Indian industries. The reasons for this include lack of information, poor access to funds for initial investments, long payback periods and the absence of incentive.[35] The national energy management ecosystem also lacked qualified personnel to monitor and verify energy consumption in industrial units at a large scale. The PAT mechanism was introduced to address some of these barriers and establish a methodology-driven, robust, transparent and flexible mechanism to **incentivize the implementation of industrial energy efficiency measures** in a cost-effective manner.[36]

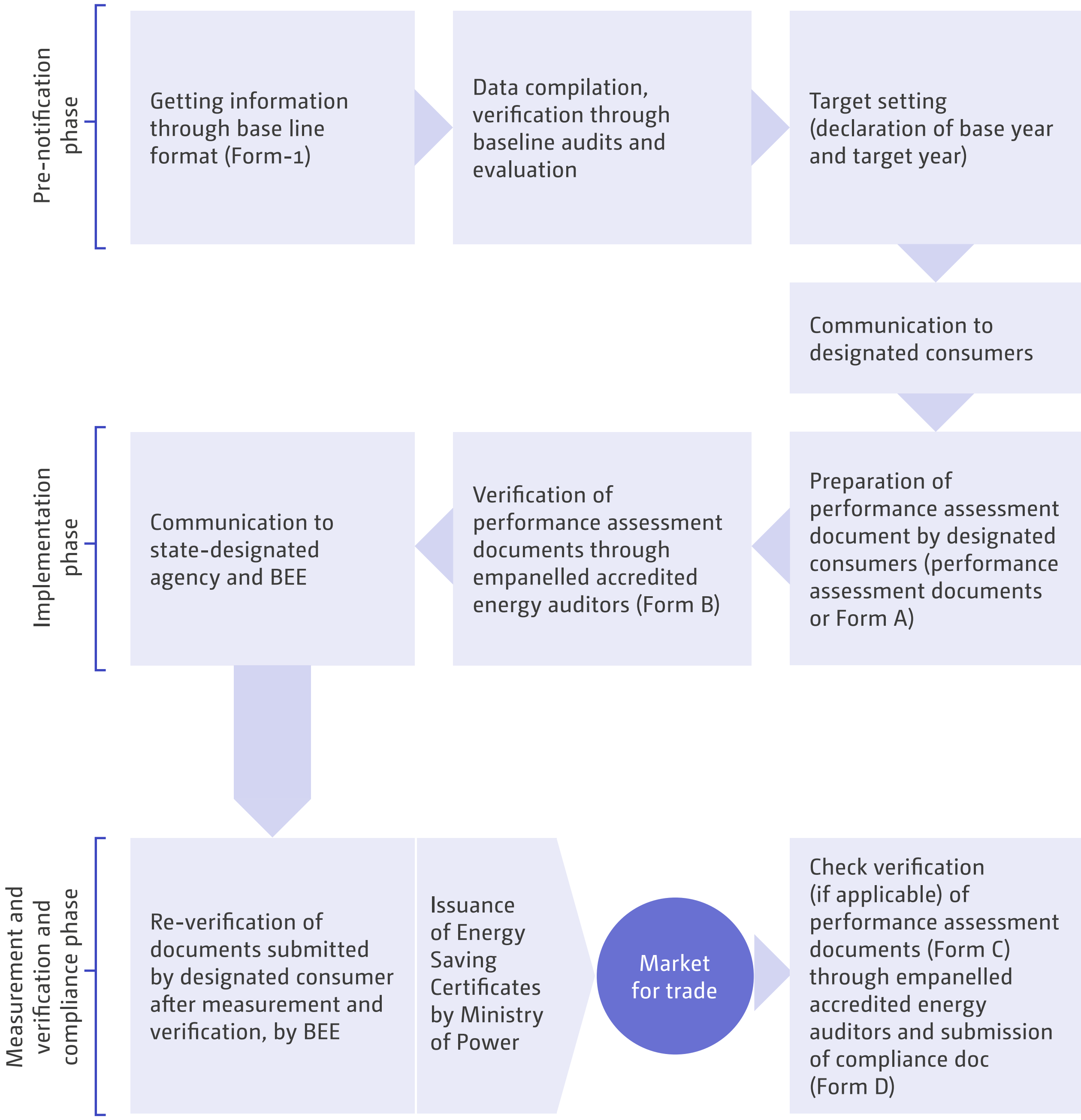
Under the PAT mechanism, industrial units from energy-intensive sectors are selected for inclusion in the scheme, and unit-specific baselines and mandatory energy saving targets are defined. Sectoral baselines or similar approaches are considered problematic as the industrial units within a sector display a wide range of efficiency levels.[37] Also, setting energy standards that are too strict could lead to units shutting down, whereas setting standards that are too lenient could facilitate the continuation of underperformance. Penalties are levied for non-compliance, while tradable energy saving certificates are issued for over-performance, that is, being more efficient than required under the standard. The market determines the prices of energy saving certificates, and over-performers can sell their certificates to those who do not comply with the standard. The 'technology-neutral' approach of BEE provides facilities with the required flexibility to choose a pathway for energy conservation that is most suitable for them.[38]

This 'technology-neutral' approach meant that BEE required plant-level energy data inventories to define baselines and energy saving targets. To obtain the inventories and achieve this task, BEE engaged third-party energy auditors, most of whom were already working for BEE, and **conducted rigorous consultations with industry stakeholders**. The industry consultations also helped fine-tune the details of the PAT mechanism's implementation. BEE created a knowledge exchange platform to facilitate interaction among industry actors and, in turn, peer-to-peer learning about best practices and technologies.[39] Furthermore, the PAT mechanism needed technically trained and accredited energy auditors, verifiers and managers; BEE, along with EESL and other energy service companies, delivered an extensive training and accre¬ditation programme to **create a pool of energy specialists**.[40]

The PAT mechanism has been designed as a **dynamic, evolving scheme**, with each implementation cycle redefining the designated sectors and units and the energy consumption norms.[41] Over the course of the PAT cycles, the industrial units have matured and have become incentivized to upgrade their capacity and infrastructure to achieve maximum energy savings. While PAT implementation had some flaws,[42] it has helped steer industrial sectors towards efficient operations and created a technically trained human resources base for measuring and monitoring energy consumption by industry.[43] See figure 3 with the activity flowchart of the PAT mechanism.

35 Bhandari, D., & Shrimali, G. (2018). The perform, achieve and trade scheme in India: An effectiveness analysis. Renewable and Sustainable Energy Reviews, 81, 1286-1295.
36 Chaudhary et al., 2017; Bhandari and Shrimali, 2018
37 Chaudhary et al., 2017
38 Chaudhary et al., 2017
39 Bhandari and Shrimali, 2018
40 Chaudhary et al., 2017; Malhotra et al., 2021
41 Sarangi, G. K., & Taghizadeh-Hesary, F. (2020). Unleashing market-based approaches to drive energy efficiency interventions in India: An analysis of the Perform, Achieve, Trade (PAT) Scheme (No. 1177). ADBI Working Paper Series
42 For example, in defining targets, setting baselines, and ensuring clarity and consistency in methodologies.
43 Bhandari and Shrimali, 2018; Sarangi and Taghizadeh-Hesary, 2020

Figure 3. Activity flowchart of the Perform, Achieve and Trade mechanism[44]



44 Adapted from N. Kumar Yadav, S. Kannappan, S. Ramanathan and S. Arora, 2021, Perform, Achieve and Trade (PAT) Scheme in Thermal Power Plants: A Critical Analysis, Centre for Science and Environment, New Delhi, see: file: https://www.cseindia.org/content/downloadreports/11070.

5. Assessment of the case functions

The assessment of the BEE case consists of a structure–function coupled assessment that was conducted for the programmes discussed in sections 4.1–4.3 above to underscore how they have facilitated the delivery of systemic functions by enhancing the structural elements of the NSI in the energy efficiency domain and eventually strengthened the NSI with respect to the overall energy use sector.

The BEE is well aware of the strengths and weaknesses of the Indian energy innovation space. So, although the programmes were designed to focus on enhancing the strengths and closing the gaps in line with the objectives and context of each intervention, the BEE used some strategies across its interventions. These common strategies were essentially some of the systemic functions (particularly in the Indian context) that support the crucial stages or structural elements of the innovation process.

The following points discuss the vital systemic functions performed by the BEE, which have strengthened the Indian innovation system's structural elements. For better reference, the table 2 describes the systemic functions of systems of innovation.[45] Key and no-key functions have been included in the analysis.

Table 2 Functions of systems of innovation[a]

Number	Function	Description
F1	Knowledge development and diffusion	Expansion and intensification of the knowledge base of the innovation system, dissemination of knowledge among actors in the system, creation of new combinations of knowledge
F2	Entrepreneurial experimentation	Designing business models for emergent technologies and knowledge, practices of uncertainty reduction through experimentation with new technologies, applications and strategies
F3	Market formation	Creation of a space or an arena in which goods and services can be exchanged between suppliers and buyers. Includes processes related to definition of demand and choices, positioning (pricing, segmentation) of products, regulation of standards and the rules of exchange
F4	Influence on the direction of search	Processes that influence the direction of research of firms and other actors; that is, which technologies they explore, which problems or solutions they choose to invest in, where they channelize their resources from, etc.
F5	Resource mobilization	Processes by which the system acquires the resources required for innovation, which could be financial and human resources (workforce and capabilities), complementary assets such as infrastructure, etc.
F6	Legitimation	Mechanisms by which an emergent technology, its developers and the TIS in question attain regulative, normative and cognitive legitimacy as viewed by the stakeholders concerned
F7	Development of positive externalities	Creation of system-level utilities (or resources), such as pooled labour markets, complementary technologies and specialized suppliers, which are also available to system actors that did not contribute to building them up

[a] Adapted from Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research policy, 37(3), 407-429.

Knowledge development and diffusion, and network impacts: All BEE programmes have a significant impact on knowledge generation and diffusion, as well as on capacity-building. Depending on the design and focus of the initiatives and the prevailing deficiencies in the innovation system, BEE ensures that relevant actors' technical, institutional, political and financial capacity-building (including the creation of new or newly trained actor groups) is at the core of the implementation plan.

BEE recognizes that innovation is a systemic affair, and that pockets of capable actors and institutions are interspersed with actors or institutions lacking adequate capacity – this is a common feature in the developing country context and could undermine the overall effort. BEE also acknowledges that capacities are distributed across a range of actors

45 TEC (2023).

and networks comprising the innovation system. It is therefore critically important that effective interaction and exchange among the various components of the system[46] take place during the innovation cycle. BEE makes a strong effort to engage relevant research organizations and academic institutions in order to leverage their domain expertise alongside providing a sound scientific basis and backing to its interventions. The creation of the knowledge exchange platform under the PAT mechanism and the PPPs under the BLY programme are other examples of interactions among components during the innovation cycle.

Most of the BEE initiatives have built-in procedures for monitoring and verifying outcomes, which supports the sustained delivery of goals in addition to helping pinpoint missing links or gaps in the innovation system. BEE acknowledges the cumulative nature of knowledge creation and capacity-building and ensures that all relevant actors and networks have ownership of the BEE initiatives. The BEE initiatives have a forward-looking and flexible outlook and adapt to changes in the policy, market and technology domains in the country and beyond.

Entrepreneurial experimentation and market formation: To improve negative risk perceptions that affect the willingness of actors to buy into a programme, BEE has developed innovative governance and market models based on no regrets and win–win approaches.[47] For instance, the design of the BLY and UJALA programmes was such that every actor engaged in the programme felt incentivized to participate – end users and manufacturers alike could see the energy savings and financial gains to be made. Under the UJALA programme, a 'demand aggregation–price crash model' was successful to bridge the price gap between LEDs and conventional lighting. End users, over and above the savings in their electricity bills, purchased the LEDs at a 40 per cent discounted price, and had the option to make their payment in one go or over time. A street lighting pilot project was run to instil confidence in stakeholders about the feasibility of the programme. BEE generally followed a 'technology-neutral' approach in situations that demanded product- or process-level innovation by manufacturers. This provided manufacturers with the flexibility to opt for the energy conservation pathways most suitable to them. Such innovations in governance or market structure alleviated stakeholders' concerns about risk and facilitated the formation of early markets and, eventually, market transformation.

46 Primarily policymakers, technology developers, manufacturers, industrial and household end users, financial institutions and knowledge institutions.
47 These approaches are cost-effective or low in cost and generate climate gains and other co-benefits without having any hard trade-offs with the objectives of other policies.

Resource mobilization and development of positive externalities: For each of its initiatives, a crucial element of BEE's strategy was to identify the factors that could determine the effectiveness or the scale of the intervention and ensure that a complementary, system-level infrastructure[48] was developed. For instance, the development of energy auditors and managers (under the PAT mechanism), performance standards for LEDs and appliances (under the UJALA and S&L programmes respectively) and testing facilities under the S&L programme were unambiguously aimed at ensuring that an enabling, complementary infrastructure was generated to implement the programme in a robust, sustained and effective manner. Furthermore, BEE ensured that each energy efficiency programme was backed by an effective institutional framework in the form of policies and regulations that provided direction in terms of developing systems and procedures to measure, monitor and verify energy efficiency; coordinating different policies and governance structures; and leveraging multilateral and bilateral policy frameworks and collaborations.

BEE also taps into international expertise, experience and resources (technical and financial) to enhance the effectiveness and reach of its initiatives. International experience in areas such as implementation schemes, market models and regulatory structures has been used not to copy what is being done in other contexts but to adapt these schemes, models and structures to suit realities on the ground in India.

Legitimation: BEE followed two fundamental strategies to develop credibility and legitimacy for its programmes: moving from the voluntary to the mandatory, and minimizing risk while maximizing gain. Regarding the first strategy, most of the BEE programmes started as voluntary initiatives. After achieving a certain degree of positive consumer reception and market preparedness, voluntary standards were made mandatory, with a broadened scope. Regarding the second strategy, BEE's choice of a specific sector or area and appliance or equipment type early on (when the programmes were being designed), was not incidental but the result of strategic thinking on minimizing risks and maximizing gains with limited effort. BEE recognized the need for a nuanced understanding of energy consumption patterns in the country and the energy efficiency improvement potential in different sectors and for various applications.

Accordingly, given limited resources and capabilities, BEE prioritized its efforts and assets towards interventions that could accrue maximum energy savings and GHG emission reductions ('biggest bang for the buck'). Focus areas were determined, for instance, on the basis of analyses of the largest energy-consuming sectors and activities (both industrial and household), as well as of those with the highest growth rates (e.g. electrical home appliances such as air conditioners and fans). As a result of BEE's strategic prioritization and design of energy efficiency interventions (along with other factors), between 2011 and 2019, the country's energy intensity decreased from 65.5 to 55.5 tonnes of oil equivalent/Indian rupee crore,[49] and emissions were reduced by 178 Mt carbon dioxide per year in the same period.[50]

Table 3 presents a summary of the findings of the structure–function coupled assessment for the BEE programmes.

48 Knowledge infrastructure including ensuring human resources, financial infrastructure and physical infrastructure.
49 Crore is a unit of value equal to ten million rupees or 100 lakhs.
50 AEEE. 2021. https://aeee.in/wp-content/uploads/2021/05/India's-Energy-Efficiency-Landscape-Report.pdf

Table 3. Structure–function coupled assessment of the Indian Bureau of Energy Efficiency

Function[a]		Structural element	BEE interventions
F1	Knowledge development and diffusion	Actors	• Raising awareness of energy efficiency to create an informed user base • Applying a 'technology-neutral' approach to provide flexibility to and promote innovation by manufacturers
		Institutions[b]	• Setting energy saving targets and performance standards for appliances (including LEDs) to create much-needed institutional backing for promoting energy efficiency and healthy competition in the market • Designing institutions in an iterative manner, meaning that standards are periodically revised or upgraded from voluntary to mandatory
		Interactions	• Building trust among actors to facilitate their interaction and peer-to-peer learning across the value chain, leading to network impacts • Utilizing the respective capabilities of different actors (e.g. academic and research institutes were engaged in the definition of standards for the S&L programme; distribution companies' infrastructure was used facilitate the distribution of LEDs in the UJALA programme; energy auditors were engaged in preparing energy data inventories in the PAT mechanism; CLASP experience was utilized in the S&L programme to define standards and mobilize international funding) • Facilitating actor interactions to promote knowledge diffusion, peer-to-peer learning and the application of best practices • Creating specific knowledge exchange platforms for shared learning • Bringing into the loop foreign expertise and resources (e.g. CLASP, USEPA, USAID) • Forming PPPs to minimize risk and capitalize on the respective capabilities of different actors (e.g. UJALA programme)
		Infrastructure	• Creating complementary infrastructure, both human resource and physical (e.g. testing and servicing infrastructure, as well as retailer training programmes, for the S&L programme; energy auditors pool for the PAT mechanism) • Preparing energy data inventories (e.g. PAT mechanism) so that future interventions are designed in an informed, scientific manner
F2	Entrepreneurial experimentation	Actors	• Applying a 'technology-neutral' approach to provide flexibility to manufacturers
		Institutions[b]	• Applying a phased and evolutionary approach to promote experimentation
		Interactions	• Tapping into the respective capabilities of stakeholders to create rigorous, sustainable and attractive business models (e.g. for the UJALA programme, various stakeholders engaged) • Bringing into the loop foreign expertise and resources (e.g. CLASP, USAID, USEPA, United Nations Foundation)
		Infrastructure	• Not applicable

[a] See the Table 2 for the description of functions.
[b] References to institutions as a structural element in this table are to systems of formal and informal rules governing organizational and individual patterns of behaviour

Table 3. (continued) Structure–function coupled assessment of the Indian Bureau of Energy Efficiency

Function[a]		Structural element	BEE interventions
F3	Market formation	Actors	• Raising awareness to create market demand • Developing innovative business models to sustain supply-and-demand dynamics (e.g. programme of activities under the BLY programme; demand aggregation under the UJALA programme) • Designing business models such that risks (or the perception of risks) are mitigated, gaps are bridged and each actor feels incentivized (e.g. BLY programme and UJALA programme distribution models)
		Institutions[b]	• Applying a phased approach (with the first phase comprising voluntary standards with limited coverage, and mandatory standards with broader coverage being introduced over time) to help market transformation
		Interactions	• Establishing networks among all relevant actors (e.g. under the UJALA programme, networks of standards bodies, manufacturers, state utilities, local vendors and distributors) to enable effective implementation • Forming PPPs between government agencies, private manufacturers and state electricity distribution companies (e.g. UJALA programme) to promote effective market transformation • Promoting actor interaction and knowledge exchange to induce peer-to-peer learning and healthy competition in the market
		Infrastructure	• Using carbon markets (e.g. BLY programme), demand aggregation (e.g. UJALA programme), innovative payment generation mechanisms (e.g. BLY and UJALA programmes) and auction mechanisms for manufacturers (e.g. UJALA programme) to help create supporting market infrastructure • Creating complementary capabilities, systems and infrastructure to help market formation (e.g. training energy managers and auditors under the PAT mechanism; creating testing infrastructure under the S&L programme; creating a local LED manufacturing industry under the UJALA programme) • Defining protocols and standards for manufacturers and other actors participating in the value chain (e.g. UJALA programme) to provide the basis for more systematic and monitorable interventions in the future • Using pilot programmes to develop early markets (e.g. UJALA street lighting pilot project)
F4	Influence on direction of search	Actors	• Applying a 'technology-neutral' approach to provide flexibility to manufacturers to innovate (in processes and products) according to their preference
		Institutions[b]	• Defining energy saving targets, performance standards, etc. to promote innovation and research and development
		Interactions	• Promoting interaction among industry actors to disseminate information on best practices and steer innovation and research and development
		Infrastructure	• Not applicable

[a] See the Table 2 for the description of functions.
[b] References to institutions as a structural element in this table are to systems of formal and informal rules governing organizational and individual patterns of behaviour.

Table 3. (continued) Structure–function coupled assessment of the Indian Bureau of Energy Efficiency

Function[a]		Structural element	BEE interventions
F5	Resource mobilization	Actors	• Building the capacity of human resources and infrastructure to support the programme (e.g. energy specialists for the PAT mechanism, testing and servicing infrastructure for the S&L programme, PPPs for the UJALA programme) • Building the capacity of retailers to support the promotion of energy-efficient equipment and appliances • Providing assurance of market gains and demand to encourage manufactures to invest
		Institutions[b]	• Defining energy saving targets, performance standards, etc. to make investments by industry and manufacturers obligatory
		Interactions	• Promoting interaction among national and international stakeholders to help pool human expertise and finances
		Infrastructure	• Developing complementary testing and servicing infrastructure • Using carbon markets (e.g. BLY programme), demand aggregation (e.g. UJALA programme), innovative payment generation mechanisms (e.g. BLY and UJALA programmes) and auction mechanisms for manufacturers (e.g. UJALA programme) to help mobilize resources
F6	Legitimation	Actors	• Applying an evolutionary nature to and gradual tightening of programmes (voluntary to mandatory) to help build credibility and legitimacy among actors
		Institutions[b]	• Gaining legal and political backing to legitimize interventions and for rigorous design (e.g. for energy saving targets and energy saving certificates under the PAT mechanism) • Applying a phased approach and a gradual broadening of the coverage of a programme to promote cumulative learning and error correction in the institutional domain and maximize climate change mitigation (e.g. S&L programme, PAT mechanism) • Selecting focus sector or area and equipment or appliance type in a strategic manner, particularly in the initial phase of a programme, to make it easy to implement, monitor and verify the programme and achieve maximum climate gains (e.g. focus on home appliances in the S&L programme, lighting in the UJALA programme and large industries under the PAT mechanism)
		Interactions	• Promoting interaction among actors to help spread the word on the merits of energy-efficient appliances
		Infrastructure	• Creating complementary infrastructure (human resource and physical) to enhance the credibility of BEE and its programmes (e.g. PAT mechanism, S&L programme)
F7	Development of positive externalities	Actors	• Creating market demand to encourage the engagement of manufacturers • Applying a 'technology-neutral' approach to provide flexibility to manufacturers
		Institutions[b]	• Defining standards, benchmarks and targets to create institutional infrastructure that enables effective and ambitious implementation
		Interactions	• Promoting interaction among technology providers, financiers, manufacturers, retailers, users and policymakers to create trust and an enabling environment for implementing and scaling up interventions
		Infrastructure	• Creating complementary infrastructure, both human resource (including pools of skilled personnel such as energy specialists) and physical (a testing and servicing ecosystem) • Creating demand and supply to promote the financial infrastructure • Helping develop local manufacturing ecosystems (e.g. LED manufacturing under the UJALA programme; energy-efficient appliance manufacturing under the S&L programme) • Providing institutional and policy incentives to motivate actors

[a] See the Table 2 for the description of functions.
[b] References to institutions as a structural element in this table are to systems of formal and informal rules governing organizational and individual patterns of behaviour.

6. Role of the BEE programmes in India's nationally determined contribution

The Government of India, in its effort to align and consolidate BEE's initiatives with the nationally determined contribution (NDC), launched the Roadmap of Sustainable and Holistic Approach to National Energy Efficiency in 2019.

The Roadmap includes all the current and potential interventions related to energy efficiency in various economic domains. BEE developed the strategic plan Unlocking National Energy Efficiency Potential to meet India's target under its NDC by 2030. The plan includes a framework and implementation strategy for the short, medium and long term which shows the linkage between energy demand scenarios and energy efficiency opportunities within the framework of overall energy efficiency targets for the country. The implementation strategy identifies potential opportunities alongside focusing on the ongoing BEE programmes.

The NSI, reinforced by BEE, can act as a stepping stone to broadening and deepening energy efficiency interventions. Actors already engaged in programmes such as the PAT mechanism or the Energy Conservation Building Code[51] can align their activities with the NDC targets in a straightforward manner. With its current programmes, BEE has made considerable progress in strengthening the NSI, creating a favourable regulatory and policy regime, and developing innovative market and business models to improve energy efficiency in the country. Moreover, in sectors engaged in BEE programmes, the building of human resource, technological, industrial and complementary infrastructure capacities and the pooling of resources and expertise (including international collaborations) is already at a significant level. Streamlining these processes further with an ambitious outlook to cover more sectoral GHG abatement opportunities could contribute extensively to achieving the NDC.

BEE has made considerable progress in strengthening the NSI, creating a favourable regulatory and policy regime, and developing innovative market and business models to improve energy efficiency in the country.

51 The Energy Conservation Building Code is an initiative being undertaken by BEE (under the Energy Conservation Act of 2001) to promote energy efficiency standards in commercial and residential buildings. The initiative was first launched in 2007 for new commercial buildings, but it has been revised and upgraded (e.g. in 2017) to include residential buildings and other sectors (see https://beeindia.gov.in/sites/default/files/BEE_ECBC%202017.pdf for more details).

7. Key success factors and lessons learned

The experience of BEE in implementing energy efficiency programmes holds several valuable lessons with the potential for application in similar contexts. The main lessons are presented in the remainder of this section.

A tailored approach is required as innovation needs vary:

BEE recognized that innovation is a complex, multi-actor, multi-level process that requires a combination of cross-cutting activities (e.g. at the national level) and customized strategies that focus on a particular sector or geographical area. 'Catch-all' energy efficiency initiatives aiming to cover all sectors and subsectors through a single policy directive yield limited results as already limited resources are spread too thinly across target areas, resulting in unimpressive outcomes. Accordingly, although BEE is engaged in a range of technological domains and initiatives, each programme has been customized to cater to sector- or domain-specific challenges and needs. In doing so, BEE has developed a diverse set of strategies, including technology-push and market-pull strategies, rewards and penalties, and loans and waivers.

Bridging sector-specific gaps is key:

BEE, through experience and learning, developed a thorough understanding of the failures and gaps in the Indian energy innovation ecosystem. Consequently, the Bureau's interventions have been designed to bridge those gaps and strengthen the weaker links in the system. For instance, the development of energy auditors and managers (under the PAT mechanism), perfor¬mance standards for LEDs or appliances (under the UJALA and S&L programmes respectively) and testing facilities (under the S&L programme) were unambiguously aimed at ensuring that an enabling ecosystem was generated to implement the respective programme in a robust, sustained and effective manner.

Innovation activities need to be strategic, iterative and evolutionary:

BEE acknowledged the evolutionary nature of innovation processes. BEE revised and upgraded its initiatives in response to technological developments, market transformations, political mandates, collaborative learning outcomes, international influences, changing actor capabilities and evolving user needs. For instance, the S&L programme gradually broadened its scope (in terms of equipment and sectors covered) as the market matured and the programme garnered greater acceptance by end users. Similarly, the deployment of CFLs under the BLY programme was replaced by LEDs under the UJALA programme as LED technology was determined to be more energy efficient.

BEE's choice or prioritization of focus sectors has been strategic. The Bureau has prioritized its efforts and assets towards interventions that can accrue maximum energy savings and GHG emission reductions ('biggest bang for the buck'). It has driven BEE to focus on the appropriate sector or appliance type in the particular context.[52] Besides resource optimization and delivery of maximum gains, this approach has also helped build the Bureau's credibility and legitimacy as an implementing agency.

Coordination and integration of NSI elements is crucial:

BEE's story highlights the role and efficacy of a coordinating agency (system operator/aggregator) in initiatives with multiple goals (innovation for sustainability through, e.g., energy saving, GHG mitigation and energy security), multiple sectors and multiple actors. BEE, as a coordinating agency, assesses domain-specific gaps and designs programmes to alleviate them; takes on board the multiple perspectives of different actors; undertakes institutional framing to support activities; facilitates interactions between actors; encourages market formation; and taps into international expertise and funds. Moreover, BEE builds on the experience and learning of

52 According to IEA (2021) statistics, industry accounts for the lion's share of total energy consumption, at 41 per cent, followed by the domestic sector at 26 per cent. Owing to near-universal household connectivity to electricity and rising incomes, electricity consumption in the buildings sector has almost doubled in the past decade. Energy use in buildings is primarily driven by the use of lighting, fans and appliances.

one programme to better design subsequent programmes, making the process cumulative and evolutionary. As a system operator/aggregator with a bird's eye view of the overall NSI in the energy domain, BEE undertakes trust-building exercises and facilitates the synergistic engagement of different actors (technology providers, financiers, technocrats, policymakers, end users, etc.) to develop effective networks. A deep, empirical understanding of the Indian innovation space helps BEE design innovative governance and market models that are win–win for all. Consequently, after the initial trigger and push by BEE and application of policy incentives, energy efficiency initiatives become self-sustaining successful business models that lead to cascading impacts (delivery of systemic functions) in the NSI.

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8. Good practices

On the basis of the lessons learned from the BEE case study (set out in section 1.1.7 above), the following good practices have been identified, which could lend themselves to replication in other countries and contexts.

- Map the NSI before designing and implementing strategies: Obtain a deep understanding of the structural elements and functions of the sector-specific innovation system, the GHG mitigation opportunities vis-à-vis costs and technologies required at the sector or country level, the main actor groups, the state of resources and capabilities, the barriers to and missing links in the innovation ecosystem, the potential synergies and trade-offs with other initiatives and policy frameworks, and the role of international collaborations.

- Look for win–win measures: Develop win–win strategies (through innovative governance and market models) to ensure participation by all relevant stakeholders and minimization of the risk factors.

- Coordinate and integrate with local needs and the local agenda: Ensure that the initiative is in synergy with or integrated into the overall policy framework of the country and that it facilitates the broader development and climate objectives of the region.

- Learn iteratively and be adaptive: Design learning mechanisms so that the strengthening of functions and structural elements of the initiative or changes in the characteristics (opportunities, strengths, needs, etc.) of the context in which the initiative is being implemented can lead to further strengthening in an iterative way.

- Create complementary knowledge and infrastructure: Facilitate the creation and maintenance of complementary knowledge, relevant skill sets and a trained human resource base in order to promote and implement technological innovations effectively and consistently in the long term and to aid the monitoring, measuring and upgrading of technologies developed through innovation.

- Allow flexibility in achieving policy goals: Highlight, policy goals and provide stakeholders with the flexibility to adopt the technology or other means best suited to them to achieve those goals (i.e. be 'technology-neutral') in order to generate credibility , manage risk perceptions of stakeholders and facilitate swift attainment of policy goals. This approach is particularly relevant in the developing country context.

- Establish a clear role for a system integrator or coordinating agency: Establish, in situations where diverse stakeholders need to come together to make an intervention or innovation effective, a clear role for the coordinating agency or system integrator, keeping in mind that coordinating agencies with a holistic understanding of the strengths and flaws of the NSI can address system gaps, tap into system resources, utilize respective strengths of actors involved and maximize positive impacts of network of actors interventions.

About the Technology Executive Committee

The Technology Executive Committee is the policy component of the Technology Mechanism, which was established by the Conference of the Parties in 2010 to facilitate the implementation of enhanced action on climate technology development and transfer. The Paris Agreement established a technology framework to provide overarching guidance to the Technology Mechanism and mandated the TEC and CTCN to serve the Paris Agreement. The TEC analyses climate technology issues and develops policies that can accelerate the development and transfer of low-emission and climate resilient technologies.

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