# 6. Energy efficiency in India

*Abhishek Malhotra (World Bank) and Ambuj Sagar (Indian Institute of Technology Delhi)*

This chapter examines India's clean energy innovation policies and institutions, focusing on energy efficiency programmes. India's ambitious clean energy programmes, in the face of rapid economic growth and increasing energy demand, have made it a crucial case study for understanding the challenges and opportunities of clean energy transitions in emerging economies. The study explores how India has implemented energy efficiency policies and programmes, including the Standards and Labelling (S&L) programme, the Perform, Achieve and Trade (PAT) programme, and the UJALA programme, to reduce energy consumption and mitigate climate change. It analyses the factors that have influenced policy choices, including the national vision, data collection, international experiences and stakeholder engagement. It also highlights the importance of institutional innovation and the role of the Bureau of Energy Efficiency (BEE) and Energy Efficiency Services Limited (EESL) in driving energy efficiency adoption. By examining India's experiences, this case study aims to provide valuable insights for other emerging economies seeking to enhance clean energy innovation and achieve sustainable development goals.

## Country context

Between 2003 and 2023 India's annual GDP grew on average by 6% per year in real terms, which raised it from a low-income to a lower middle-income country on a per-capita GDP basis in 2008. Over this period, GDP growth was primarily driven by growth in the services sector, which comprised about 50% of India's economy in 2023. The country has also made significant progress in bringing down the share of the population living below the poverty line, from 33% in 2009 to 13% in 2021, and reducing the share of its population living in moderate poverty (USD 3.65 per person per day) to 44%. The country managed to make this progress while keeping inequality in consumption at relatively stable levels, with a Gini index between 33 and 36 over the past 20 years.

These developments were supported by a range of macroeconomic, fiscal, tax and business environment reforms starting in 1991, when India began its transition towards a market-based economy. The country continues to implement reforms to improve the ease of doing business and attract foreign direct investment. More recent reforms include a new inflation targeting framework, energy subsidy reforms, reinstatement of fiscal deficit reduction targets, strengthening of fiscal federalism, improvements in the quality of government expenditure, efforts to

I EA and IITD CC BY 4.0.

improve the business environment and ease inflows of foreign direct investment, the introduction and strengthening of an insolvency and bankruptcy framework, widening access to financial services, promoting digital payment systems, and the implementation of a harmonised GST code. There is also a recent trend of increased investment in infrastructure, with federal government spending on infrastructure rising from less than Indian rupees (INR) 3 trillion (USD 44 billion) in FY2017/18 to a projected INR 11 trillion (USD 133 billion) in FY2024/25.

Despite these positive developments, India will have to overcome several challenges to sustain progress along its development pathway. The government's vision of achieving a poverty rate of 5% by FY2030/31 and middle-income status by 2047 will require inclusive and sustained high growth rates for the next three decades. The challenges include confronting demographic and structural challenges. Although India’s growing working-age population holds the promise of a demographic dividend to drive this growth, the rate of growth of India’s working-age population outpaced the rate of employment growth between 2000 and 2023. Thus, over this period, the share of the total working-age population in employment declined by around 2 percentage points, falling to around 60% in 2023. In 2022 agriculture and its allied sectors employed 43% of India’s total population and formed the major source of livelihood for 70% of all rural households, contributing 20% of India’s GDP. Creating a higher share of non-agricultural jobs therefore appears to be a prerequisite for high and sustained economic growth, yet service sector jobs, which currently drive much of India’s GDP growth, require highly skilled workers and have only a limited capacity to employ India’s large pool of unskilled workers. While India has promoted the development of manufacturing, its share of India’s economy stagnated at around 13-18% between 1990 and 2020.

## Energy sector context

India’s GDP growth has been accompanied by increasing energy consumption and, concomitantly, greenhouse gas emissions. Between 2009 and 2021 India’s total final energy consumption increased at 3.5% on average per year, just over half the rate of GDP growth. However, high levels of inequality and poverty mean that India’s per-capita primary energy consumption remains one-third of the global average.

Historically, energy access has been one of the most important priorities for energy policy in India, with a prominent emphasis on electricity access in rural India. At the time of enactment of the Electricity Act in 2003, just 65% of India’s population had access to electricity, yet by 2019 it was announced that 100% had been achieved. This can be attributed to the greater emphasis on increasing electricity access in the Electricity Act and subsequent policies, including the National Electrification Policy in 2005, the Rural Electrification Policy in 2006, and

I EA and IITD CC BY 4.0.

a series of schemes allocating public funds towards investment in infrastructure for electricity access, including the 2005 Rajiv Gandhi Grameen Vidyutikaran Yojana, 2014 Deendayal Upadhyaya Gram Jyoti Yojana and 2017 Pradhan Mantri Sahaj Bijli Har Ghar Yojana. In parallel, the Indian government has made efforts to improve access to fuels, specifically kerosene and liquefied petroleum gas (LPG), by providing them at subsidised rates through the public distribution system. Efforts to displace the use of traditional biomass for cooking with LPG received a boost under the 2016 Pradhan Mantri Ujjwala Yojana, which aimed to distribute 50 million LPG connections.

Energy security and affordability have also been major historical drivers of Indian energy policy. India's energy sector is highly regulated, with price controls for electricity, oil and gas. In the electricity sector, energy security has largely been achieved through the exploitation of India's cheap and abundant coal and hydropower resources, which together constituted 83% of power generation in FY2022/23. In addition, affordability for end users has been ensured through a combination of regulated tariffs, direct subsidies for distribution utilities, and cross-subsidies for residential and agricultural customers. Despite the high degree of energy independence in the electricity sector, India has been largely dependent on imports for oil and gas for transport, industry, heating and cooking, as well as for energy technologies. India has made efforts to enhance its energy security by supporting domestic production of fossil fuels through the Hydrocarbon Exploration and Licensing Policy (HELP) and building up a strategic petroleum reserve. Oil imports continue to be the largest use of India's foreign exchange reserves. While historically petrol and diesel in India were subsidised, subsidies have been gradually phased out since FY2014/15, partly by capitalising on the window of opportunity provided by low global oil prices. Today, the excise duty charged on petroleum is one of the largest contributors to India's indirect tax revenue, accounting for over 45% in FY2020/21.

In the last three decades, reforming the power sector has also been a major policy objective, with the goal of increasing the efficiency of electricity supply, and unlocking private sector participation and investment to meet India's growing energy needs. The 2003 Electricity Act directed India's state governments to unbundle their vertically integrated utilities and to corporatise the resulting companies. It also allowed for private sector participation in power generation and distribution and directed distribution utilities to procure power competitively. As a result, India's power generation capacity grew by 300% to 440 GW between 2002 and 2024. Private sector participation in power generation, which was below 5% in 1992, reached 25% in 2012, and 51% in 2023. In 2015, India's power generation was larger than its demand for the first time, alleviating blackouts and load shedding. However, further expansion is needed, and the government estimates

I EA. and IITD CC BY 4.0.

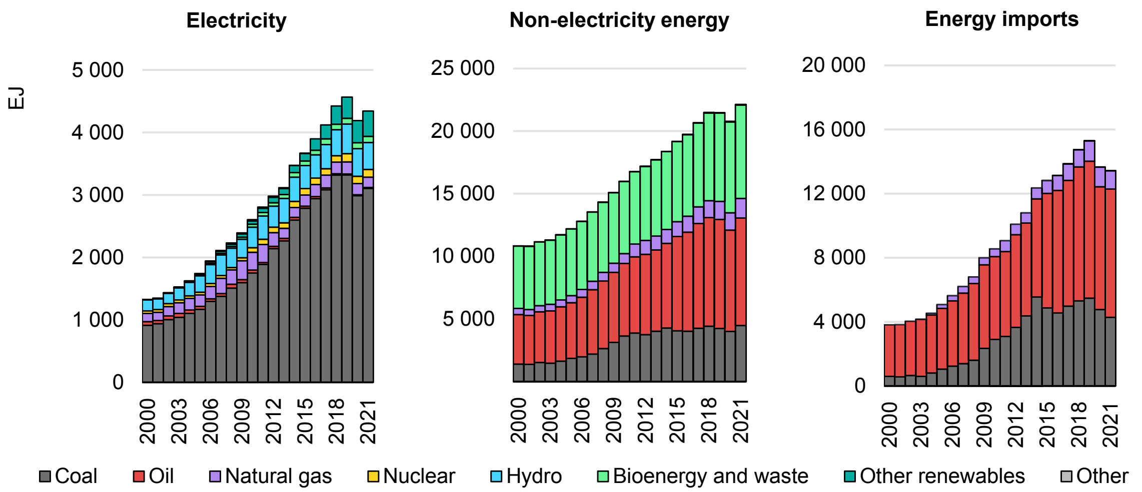
that India will require around 818 GW of power generation capacity by FY2029/30, and may need to add generation capacity equal in size to that of the European Union by 2040.

India's energy sector is the largest and fastest-growing source of GHG emissions in the country, contributing 71% of its emissions in 2021, and almost all of the growth in emissions over the period 2010-2020. India's GHG emissions almost tripled from 0.98 gigatonnes $CO_2$ equivalent ($GtCO_2$-eq) to 2.83 $GtCO_2$-eq between 2002 and 2022, representing 7.6% of the global total, and making India the third-largest GHG emitting country in the world. Even though India's per-capita income and emissions are very low – 19% and 36% of the global averages, respectively – it still needs to decouple economic growth from carbon emissions. Thus, climate change mitigation is a further key policy priority for the energy sector, as demonstrated by India's targets for renewable energy and energy efficiency. India aims to achieve net zero emissions by 2070, 500 GW of renewable electricity generation capacity by 2030, 50% of energy from renewables by 2030, and a 45% reduction in the emissions intensity of GDP by 2030. Renewable energy and energy efficiency have been identified as key policy priorities as they can play a crucial role in not only meeting India's growing energy needs, but also reducing its dependence on fossil fuels, including for transport, mitigating their environmental impact, and creating jobs in environmentally sustainable sectors.

India has taken several measures to support the renewables sector. The Jawaharlal Nehru National Solar Mission was launched in 2009 with the ambitious target of deploying 20 GW of solar PV by 2022, achieving grid parity by 2030, and setting up 4-5 GW of solar PV manufacturing capacity by 2020. Its success in achieving cost reductions resulted in the deployment goal for 2022 being revised upwards in 2015 from 20 GW to 100 GW. 2021 saw a greater push to promote manufacturing through a production-linked incentive scheme, under which INR 18.5 billion in government support is being provided to a total manufacturing capacity of 48 337 MW. As of November 2023 India's solar electricity generating capacity was 72.31 GW, a 30-fold increase in just nine years. India has also made progress in deploying wind power, ranking fourth in terms of installed capacity globally. Overall, as a result of its efforts to promote renewables, India has made remarkable progress in the past two decades. Its installed non-fossil fuel capacity has increased by roughly 400% in the last 8.5 years and stands at 180 GW (including hydropower and nuclear), about 42% of the country's total capacity in 2023.

I EA. and IITD CC BY 4.0.

**Figure 6.1 Energy sources for electricity and other uses, and level of imports, India, 2000-2021**




IEA AND IITD. CC BY 4.0.

Notes: Electricity and non-electricity energy are shown on a final consumption basis. Imports are shown net of exports. “Other” refers to imported or exported electricity. In 2021 India exported 0.1 EJ of electricity, and between 2010 and 2014 it was a net exporter of up to 3 EJ per year of bioenergy and waste.
Source: IEA (2024), World Energy Balances.

## Innovation context

India has long emphasised the importance of science, technology and innovation, and has promoted it nationally. India developed its first science policy in 1958 – one decade after independence – called the Scientific Policy Resolution, to "foster, promote and sustain" the "cultivation of science and scientific research in all its aspects – pure, applied, and educational". In parallel, under India’s second and third five-year plans (1956 to 1966), there was an emphasis on nationalising and investing in heavy industries through the public sector, and the imposition of high tariffs and strict import licensing to bring about import substitution in key sectors of the economy. It was in this period that India’s public R&D and technical education institutions were strengthened, and the role of state-owned enterprises in indigenising the production of capital and consumer goods was cemented through licensing and technology transfer agreements with other countries.

Easing of the licensing regime and increased participation of the private sector in the Indian economy began in the 1980s with the relaxation of the Monopolistic and Restrictive Trade Practices Act (1969) and the announcement of the Industrial Policy Statement (1980).[1] This process was accelerated in 1991 when India started economic liberalisation. These developments in economic policy were reflected in three updates to innovation-related policy in India – the Technology

[1] It allowed for automatic expansion of licensing capacities and “broadbanding” of licences, which now allowed firms to produce other goods within the same broad industrial category.



IEA and IITD CC BY 4.0.

Policy Statement in 1983, Science and Technology Policy in 2003, and Science Technology and Innovation Policy in 2013. This acknowledged the role of a broader set of stakeholders in the innovation process (including the private sector), highlighted the importance of making innovation inclusive – by improving access, availability and affordability of solutions for as much of the population as possible – and orienting it toward national sustainable development challenges, including but not limited to climate change.

However, despite policy attention to innovation, India still scores low on several key metrics, including R&D investment, research personnel and patenting activity. India's public and private spending on R&D was equivalent to only 0.64% of its GDP in 2021 and the country ranked 40th in the 2023 despite having the third-largest national economy (on a purchasing power parity basis) and the second-largest population. Not only is this spending low compared to the global average of 2%, but it is also lower than that of other major emerging economies, such as Brazil (1.3%), Russia (1.1%), and China (2.4%). Furthermore, India's R&D spending is skewed towards the public sector (36.4% is from the private sector, compared with a global average of 71%), and more patent applications are from publicly owned entities, unlike in most other developed and emerging economies. In addition, the university system plays a less prominent role, with 85% of India's public R&D spending going to public autonomous research institutes. Overall, India has a relatively weak industrial innovation system, with weak ties between R&D institutions (research labs and universities) and industry, leading to a low rate of translation of research to commercial application. India's spending on industrial R&D is concentrated in the pharmaceutical, software and automobile sectors.

Entrepreneurship is seen by policy makers as a means of generating employment, connecting academia with industry and promoting innovation. In the past three decades, policy support for entrepreneurship has expanded significantly. A growing and dynamic entrepreneurial ecosystem and venture capital sector has emerged, focusing largely on e-commerce, healthcare, financial technologies, education, travel, artificial intelligence and customer services. Today, India has the third-largest startup ecosystem in the world, with USD 141 billion in funding raised in 2023 and a total valuation of USD 450 billion.[2] There are early signs of the emergence a high-tech manufacturing start-up ecosystem, including in defence, aerospace, mobility and energy.

# The case of energy efficiency policy

In the late 1990s energy efficiency in India was impeded by many obstacles typical of energy efficiency markets, including financing, awareness, technical and

[2] For comparison, start-ups in the United States raised USD 2.5 trillion and those in China raised USD 816 billion in 2023.



I EA. and IITD CC BY 4.0.

capacity barriers. In response, the government undertook a series of policy, regulatory and institutional steps to address these barriers. In 2001 India enacted the Energy Conversation Act, which empowered the government to:

- Enact standards and labelling for energy-consuming appliances and machinery.
- Prescribe and enforce energy conservation norms for a specified list of energy-intensive industries.
- Prescribe guidelines for building energy efficiency codes, which would then be implemented by state governments.
- Specify procedures for the training and certification of accredited energy auditors.

The act also established the Bureau of Energy Efficiency (BEE), which has helped develop policies and strategies, and exercises the powers given to it under the act since 2002.

In 2009, Energy Efficiency Services Limited (EESL) was launched as a publicly-owned "super ESCO" in 2009 to address the challenges of financing, awareness, technical capability and skills facing energy efficiency.. In 2019 BEE laid out a strategy and vision document for Unlocking National Energy Efficiency Potential and in 2022 India amended the Energy Conservation Act to expand its scale and scope.

India saved 50.81 mtoe (2.1 TJ) in FY2022/23, an amount valued at over USD 22.8 billion. The government estimates that achieving its target of net zero GHG emissions by 2070 will require an increase in the rate of improvement of the energy intensity of India's GDP of 5% per year.

## Promotion of energy efficiency technologies aligned with the national vision for economic development

India does not have an explicit vision for how energy innovation can support its socio-economic goals, but expectations for energy technology innovation have been lifted by a national consensus around economic growth (including via import substitution) and climate change at different times in the past half century. However, only in the past few years have these two policy pressures coincided and reinforced one another.

Energy efficiency can help achieve cost savings while mitigating GHG emissions and reducing energy consumption. As early as 1970, the government was cognisant of the need to manage India's domestic energy resources efficiently to meet the country's increasing energy demand, and to reduce its dependence on oil imports to reduce pressure on its foreign exchange reserves. Starting in the mid-1960s, the government appointed committees and commissioned studies at regular intervals to analyse issues related to fuel substitution and energy efficiency (also referred to as energy conservation in government documents), keeping in



I EA. and IITD CC BY 4.0.

mind targets for GDP growth, income distribution, regional economic balance and balance of payments.[3] Energy efficiency was promoted as a means to reduce the need for capital investment in energy infrastructure, meet India's growing energy demand in a more cost-efficient way, and strengthen energy security.

In 1970 the government set up the Fuel Policy Committee to project India's energy demand up to 1990/91, explore options for fuel switching away from oil, and estimate the potential for higher fuel efficiency. Its recommendations, published in 1974, were heavily influenced by the first oil shock of 1973, and included guidance on the substitution of imported oil by domestic coal, the promotion of higher energy efficiency in the electricity sector, and the promotion of indigenous R&D in energy technologies. The committee also suggested measures to systematically integrate India's energy planning into national economic development planning. This suggestion was taken up in 1980 by the Advisory Board of Energy under the Planning Commission of India, which published multiple reports on India's energy outlook and energy conservation and whose findings acted as inputs for India's five-year plans.[4]

While the passage of the Energy Conservation Act created the first legal and institutional framework for energy efficiency in India, only in the late 2000s was energy efficiency articulated as a national priority. This occurred when India published its National Action Plan on Climate Change in 2008, which declared climate change adaptation and mitigation as national priorities and was partly in response to increasing global momentum to address climate change. This plan identified eight priority "missions", including the National Mission on Enhanced Energy Efficiency, which announced four new initiatives to complement those under the Energy Conservation Act (2001). The four initiatives were:

- A market-based mechanism to incentivise energy efficiency in energy-intensive sectors.
- Measures for energy efficiency in appliances.
- Demand-side management.
- Fiscal instruments to support energy efficiency.

In 2016 this priority was reinforced in India's NDC to the Paris Agreement, which it signed in 2015. The NDC promotes energy efficiency as a priority area and includes the target of reducing the emissions intensity of GDP by 33-35% by 2030 from the 2005 level. This target was further raised to 45% in the 2022 NDC update.

[3] Examples of government-led energy modelling exercises for policy include the Energy Survey Committee (1965), the Fuel Policy Committee (1974), the Working Group on Energy Policy (1979), and the Integrated Energy Policy Committee (2006).
[4] See, for example, Ramesh, J. and J. N. Maggo (1985), "Towards a perspective on energy demand and supply in India in 2004/05", Advisory Board on Energy.



IEA, and IITD CC BY 4.0.

The need to intensify efforts related to tackling climate change helps explain how energy efficiency policy came to the forefront of the government's priorities. However, technology innovation was not included as a core part of this until an amendment to the Energy Conservation Act in 2022 empowered BEE to promote or undertake R&D in the field of energy conservation. The recommendations relating to R&D and indigenous technology made by the Fuel Policy Committee in 1974 were not repeated in the first national climate change policy documents, which focused more on the benefits of technology transfer to India from other countries and capacity building. For example, the National Mission on Enhanced Energy Efficiency was concerned with raising awareness of energy efficiency technologies, upgrading technical knowledge, and improving the ability of the financial sector to appraise energy efficiency investments. One reason for this was that the national vision for mitigating climate change emerged in the framework of an international negotiation that included consideration of responsibility for past emissions, an area in which India stressed its lack of responsibility to date. As a result, many poorer countries downplayed their opportunity to innovate for a new clean energy economy and instead stated that advanced economies bore more responsibility for investing in clean energy technologies as well as transferring them to developing economies, given that these economies had been primarily responsible for reducing the remaining "carbon budget", i.e. the headroom for any future emissions from all countries.

## India's energy efficiency policy choices reflect the maturity of the available technologies

Decision-making for energy efficiency policy in India takes place in the context of limited public sector resources and a need to prioritise efforts. This has involved the selection of specific energy end uses – such as lighting, appliances, buildings and industry – for policy support, as well as the types of policy tools used to target them.

To identify priority sectors, India has a history of data collection and analysis, which have guided technology choices. In 1981 the government's Interministerial Working Group on Energy Conservation and the National Productivity Council audited energy use in 12 different energy-intensive industries and other sectors. The resulting report showed that investment in energy efficiency in industry, transport and agriculture could save capital and energy expenditure two and a half times the cost of the interventions. Similarly, in the early 2000s, when several energy efficiency programmes were being scaled up, the relative prioritisation of areas for support was guided by studies on energy demand, projected growth and savings potential. For example, one market study showed that lighting was the fastest-growing contributor to residential and commercial electricity demand, and that refrigerators and air conditioners consumed the most energy in India among

IEA and IITD CC BY 4.0.

home appliances. Accordingly, lighting, refrigerators and air conditioners were designated as early areas of focus. Since then, BEE has developed internal capacity for gathering the data to monitor and evaluate its programmes in these areas.

The choice of energy efficiency policy tools in India has been strongly influenced by technology availability. Lighting efficiency policies were enabled by the international availability of tubular and compact fluorescent lamps (CFLs), which had been shown to reduce lighting energy consumption by 80%, yielding savings worth more than the initial capital outlay. The 2008 Bachat Lamp Yojana or "Savings Lamp Scheme" therefore focused on CFLs, which were eligible under the Clean Development Mechanism of the Kyoto Protocol for the sale of emissions reduction certificates. These allowed the government to sell the more costly CFLs at the same price as cheaper incandescent bulbs. This approach changed in 2014, when light-emitting diode (LED) bulbs were shown to have greater efficiency than CFLs and were available to upgrade the streetlighting infrastructure of Puducherry and rebuild that of Visakhapatnam after a cyclone. These policies, and the nationwide Unnat Jyoti by Affordable LEDs for All (UJALA) scheme that followed them in 2015, operated via bulk procurement and distribution of LEDs. UJALA targeted the sale of 770 million LED lightbulbs in the residential sector by early 2019. This scheme was implemented by EESL, which has the ability aggregate demand, negotiate prices and deliver a uniform set of financing and other services. It also had a mandate to support and grow the private sector ESCO market.

Similarly, the emergence of inverter-based air conditioners, which are more efficient across a wider range of ambient temperature as compared to fixed-speed models, stimulated significant adaptations to air conditioner testing and certification protocols, energy efficiency standards and manufacturers' product mix. For example, the Indian Seasonal Energy Efficiency Ratio (ISEER) was defined in 2015, which defines the energy efficiency of air conditioners across a range of temperatures rather than at a single temperature. This values the better performance of inverter-based models and accelerated technological change by providing an incentive for manufacturers to adopt and manufacture the new technology, driving down its cost and resulting in the majority of air conditioner sales in 2020 being inverter-based models.

Learning from international experiences and ensuring buy-in from key stakeholders when designing policies has also contributed to the successful adoption and adaptation of energy efficiency technologies. Bilateral aid agencies (such as Germany's GIZ) and private consultancies (such as CLASP) were engaged for their technical expertise and their familiarity with experiences elsewhere and technology options. Both entities were involved in the design of BEE's Standards and Labelling (S&L) programme for energy-efficient equipment and appliances in 2006. Consultative approaches involving multiple stakeholders

I EA and IITD CC BY 4.0.

from government, industry and civil society were also used. The S&L programme was voluntary for an initial trial period from 2006 to 2009 to ensure buy-in from appliance manufacturers by giving them time to adapt, but today it prescribes mandatory energy consumption labels and minimum standards for 11 types of appliances as well as overseeing voluntary labels for 19 other appliances. The Perform, Achieve and Trade (PAT) programme has operated since 2010 to incentivise energy efficiency improvements in energy-intensive sectors via improvement targets and tradeable certificates, and was similarly designed to ensure buy-in from industry stakeholders. For example, extensive data collection and consultation with industry representatives and technical experts were needed to set targets that were neither too stringent nor too lax.

With UJALA, India chose to support technologies like LEDs through market pull measures, but did not only seek the lowest-cost imports: provisions were included to ensure development of a domestic supply chain. The country's familiarity with public sector-led policy implementation created an opportunity to address both market creation and technological development goals through a large-scale public procurement model. Specifically, UJALA promoted domestic manufacturing by mandating a certain share of domestic value-addition for the procured LEDs, and by procuring LEDs from domestic small-scale manufacturers. By 2018 it had contributed to the creation of around 25 medium-sized and large, and around 400 small-scale manufacturers of electronic drivers, heat sinks and bulb encasements and final assemblers of LEDs.

In 2021 market pull measures to promote the manufacturing of LEDs and air conditioners were further bolstered with manufacturing incentives in the form of Production-Linked Incentives (PLI), which, as of September 2024, had provided incentives for domestic manufacturing of these products to 66 applicants with committed investments of USD 830 million. The PLI was reopened for applications in July 2024. Over time, market pull measures have fostered an energy innovation ecosystem around energy efficiency technologies – one that can produce, adapt and tailor the technology to the local context – with only modest use of resource push measures.

## Implementation and monitoring of energy efficiency policies has had to be adapted to local capacities

India's experience with implementing its chosen energy efficiency programmes and measures shows the importance of adaptation to the local context and innovation system. Despite technology innovation not being a priority outcome of the measures, the need to improve the understanding and testing of technologies for effective administration did lead to an improvement in the overall energy efficiency technology ecosystem in India.



I EA. and IITD CC BY 4.0.

As an example of how the adaptation of policies to local contexts can delay or hinder policy outcomes, India has had to adjust and update its measures for energy efficiency in buildings several times since the National Mission on Sustainable Habitat was announced as one of the eight missions in the 2008 National Action Plan on Climate Change. “Green buildings” are a key policy intervention area of this mission and building codes with energy conservation standards have been pursued accordingly. However, the actual implementation of building codes and standards continues to face challenges with compliance and enforcement due to the fragmented and informal nature of India’s construction sector, as well as the limited resources of regulatory authorities. This is despite successive updates to prescriptive standards for energy efficiency in residential and commercial buildings including:

- The Model Building Bye Laws (2016).
- The revised National Building Code (2016).
- The updated Energy Conservation Building Code (2017).
- The Eco-Niwas Samhita (2018).

One learning from the implementation experience has been the importance of sub-national co-operation and engagement, including raising the level of regulatory enforcement. State governments now play a supporting role by channelling funding as well as translating the standards into state-level guidelines for their construction sectors.

The most successful programmes have been PAT, S&L and UJALA. Of the estimated 50.81 mtoe (2.1 TJ) saved in FY2022/23 – an increase from 2.46 mtoe (0.1 TJ) saved in FY2012/13 – 51% has been attributed to the PAT programme, and 44% to the S&L and UJALA programmes.[5]

Energy efficiency education, skills and awareness have had to be built from a relatively low level in India since the early 2000s. In the early stages of the S&L programme, India had limited capacity for the design, manufacture and testing of energy-efficient appliances, and limited awareness among end users regarding the performance of energy-efficient appliances. Therefore, MEPS and energy performance labels had to be complemented with the creation of institutions, capacity and networks within the energy efficiency ecosystem.[6] These institutional capabilities are often already present in more mature industrial and innovation ecosystems when embarking on a new policy direction. To illustrate this issue, the S&L programme was delayed after its 2006 launch because there were no accredited test laboratories. BEE and CLASP worked closely with several international and local bodies (including national labs such as the Central Power

[5] The 2023 savings are equivalent to 8% of India’s total energy consumption.

[6] This ecosystem includes policymaking agencies, standard setting agencies, research labs, testing labs, manufacturers, energy auditors, energy service companies and other actors.

IEA and IITD CC BY 4.0.

Research Institute and academic institutions like IIT Delhi and IIT Bombay) to support the development of new labs to meet the demand, and to develop accreditation procedures and standards for these labs. This enabled manufacturers to supplement their existing capabilities for in-house testing by collaborating with labs and strengthening their capabilities for more advanced testing procedures (for example, balanced ambient calorimeter labs for testing air conditioners). It also allowed BEE to conduct check testing of labelled products in accredited third-party laboratories, thus enabling monitoring and enforcement of the programme. A consequence of this capacity building has been the generation of technical expertise on energy efficiency technologies in Indian government and academic institutions, which provides a platform for future innovation.

Experiences with implementing energy efficiency policies in India have helped inform subsequent policy designs for energy efficiency and other areas. The design, measurement and verification elements of the PAT tradeable certificates programme have informed India's forthcoming Carbon Credit Trading Scheme. EESL has adapted and replicated the LED programme for other energy-efficient technologies such as brushless fans, air conditioners and electric buses. Among the learnings from these programmes has been the importance of continuous assessment and enforcement, as well as flexibility and responsiveness to evolving technological and market contexts. For the PAT programme, BEE created "accredited energy auditors" that could be engaged by Designated Consumers to carry out the necessary energy audits, establish a baseline for their energy intensity and periodically measure progress towards their targets. Once the auditors were trained and certified, the data they collected were critical for the effective issuance and trading of certificates, as well as for setting targets in subsequent phases of the programme. In addition, as the PAT programme covered highly heterogeneous sectors, it became necessary to adopt "performance buckets" to enable equal treatment of similar firms. For EESL, a key learning relates to the value of a payment security mechanism to mitigate the risk on non-recovery of capital, something that affected the finances of its street lighting programme for which the customers were municipalities. For EESL's recent electric bus programme for state transport utilities, such a security mechanism is included. [7]

# Findings

India's experience with energy efficiency policymaking provides several insights for the development of policy on energy technology innovation. While the policy framework was not explicitly targeted towards technology innovation outcomes, it

[7] One part of the payment security mechanism is an escrow account that provides payment security for 3 months. If payments are not provided by state transport utilities beyond this period, the government of India can put tax-related payments to the state on hold.

I EA. and IITD CC BY 4.0.

nonetheless highlights aspects of policy design that are important in emerging market economies. In particular, the insights highlight the need for such support to be relevant and tailored to the local context. The insights can be summarised as follows:

- Policymaking and implementation are effective when well aligned with national visions for technology change and when technology areas are strategically identified. In India, energy efficiency fitted well with the national vision for ambitious climate mitigation at a time when household appliances, in particular, were a national concern for their contribution to rapidly rising energy demand, exacerbating financial strain on the national electricity system.
- In nascent policy areas, early successes are important for political buy-in as well as public support. In this context, the selection of appliances and lighting among the main policy targets enabled more visible and rapid results than, for example, building codes or industrial processes.
- In emerging market and developing economies there is sometimes a trade-off between promoting rapid deployment of a new technology and domestic economic development aspirations, including development of domestic industrial capabilities and employment opportunities. This is especially true for clean energy technologies for which the country has only weak R&D and manufacturing capabilities at the outset of the policy development process. For LEDs, India chose not to include very strict requirements for domestic manufacturing or R&D. Instead, it benefited from the low price of LEDs from other countries, which allowed the rapid scale-up of the programme at lowest cost and secured wide support from EESL's customers. However, it has been suggested that this impeded the development of local technological capabilities in this space, something that was indirectly supported by the need to develop effective testing facilities and manufacturing for certain LED components and assembly.
- When dealing with end users, feedback on technologies is typically slow and for energy efficiency technologies it is even slower. Given the wide range of users and the challenges of monitoring their use of the technologies, it can take time to understand if and how the technologies need to be adapted to local markets. Specifications for both LEDs and industrial efficiency equipment needed to be adjusted once the behaviour and criteria of local users was better understood. Additionally, the energy savings from the deployment of these technologies accumulate over time, which means that their performance is often only understood several years after the upfront investment. Unless the end user makes regular use of the installed equipment as expected, something that depends on well-designed business models by suppliers like EESL, performance may never be fully understood. Attention to financial and business elements of a new technology deployment programme, as well as the broader social and economic contexts, are therefore essential elements of well-designed clean energy innovation policies in addition to more traditional elements such as R&D projects and risk finance.

IEA and IITD CC BY 4.0.

- Adaption of technologies for use in a new local context requires appropriate technological capabilities. These are generally not R&D skills, but are more closely related to the technical skills of procurement managers, installers, retailers and programme auditors.
- Consultation is essential, and by engaging a range of institutions in policy design it is possible to make use of existing skills and knowledge. In the case of the appliance programme, consultation helped bring the industry on board and ensure that there was a latent market for energy-efficient appliances. In India, BEE has played a critical role as a "systems integrator" and helped organise an energy efficiency innovation ecosystem by marshalling the relevant actors. It has facilitated the engagement of academic and other research institutions, financial entities such as banks or donor institutions, and other actors that might provide technical support or market knowledge. This type of role may be particularly important for developing countries where the ecosystems are fragmented or suffer from significant gaps.
- New institutions may be needed to take responsibility for certain activities, especially if they require policy creativity or could conflict with the primary objectives of existing ministries or state-owned enterprises. Both BEE and EESL were created to support India's energy efficiency policies. The establishment of EESL, in particular, was critical for its ability to aggregate LED demand and use new financial approaches. This finding is not necessarily specific to developing countries – the establishment of ARPA-E as a new government entity in 2009 significantly changed the momentum behind clean energy innovation in the United States and illustrates that even well-functioning innovation ecosystems can benefit from new institutions with the flexibility to find alternate approaches to arising challenges.

IEA and IITD CC BY 4.0.