CHAPTER 8

INDIA'S ENERGY STORY

A Quest for Sustainable Development with Strained Earth Resources

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India is a rapidly growing economy with a large population aspiring to realize a quality of life comparable to the best in the world. India's energy consumption is thus expected to grow faster than anywhere else in the world. Creating universal energy access, promoting development, and facilitating economic growth are expected to be the key drivers of the growth in energy consumption. Useable energy forms (solid, liquid, gaseous, and electrical) at the consumer end are derived from several conventional as well as non-conventional primary energy sources. India's total primary energy supply basket of around 0.83 billion tonnes of oil equivalent (Btoe) in the year 2015–16 consisted of around 44.8% coal and lignite, 28.2% oil, 5.1% gas, 1.9% renewables (including hydro), and 0.4% nuclear.[1] A significant portion of domestic energy needs was met by using biomass such as firewood and dung cake in a traditional way. Around 42% of the country's total needs were met by imported energy, which was supplied by oil (56.7%), coal (39.1%), and gas (4%).

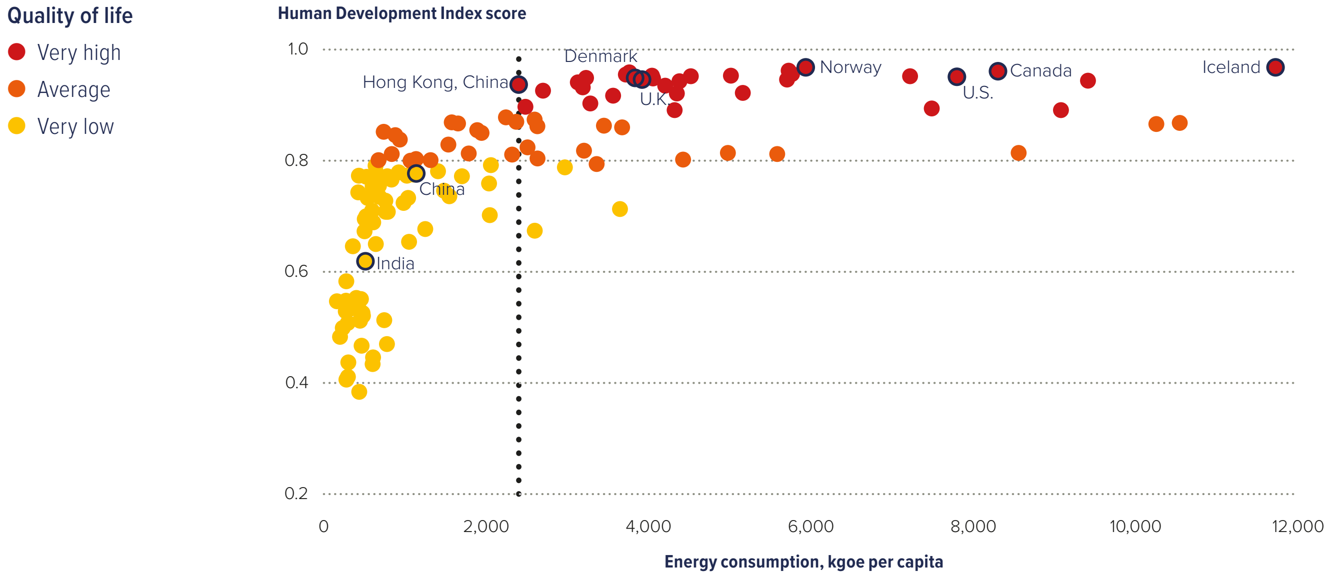
India's average annual per capita energy use stood at around 630 kilograms of oil equivalent (kgoe) in 2014. Going by the correlation between energy use and the Human Development Index (HDI)—which primarily reflects on a country's status with respect to health, education, and income—it is clear that India needs to boost its per capita energy consumption to at least around 2,400 kgoe per year in order to realize an HDI score comparable to the best in world (Figure 1). Such an increase would correspond to a total energy consumption of around 4 Btoe, or around 20–25% of current global energy consumption.

In 2016 India imported 80% of its crude oil and about 40% of its gas.[2] The country's increasing energy requirements, coupled with a slower than expected increase in domestic fuel production, has meant that India requires a rapidly growing volume of imports in its energy mix to meet demand. Clearly, in the business-as-usual mode, rising Indian demand would lead to attendant pressure on oil prices, compounding the rising cost of energy imports. In turn, this would constitute an additional and significant element to the energy security challenge. An exploration of domestic alternatives, beyond aggressive exploration for oil and gas, is urgently needed to meet India's energy needs. New technology and innovation will be essential for India to successfully address this serious challenge alongside the challenge of climate change.

As India moves forward in its development and prepares for higher energy consumption, coal and oil are expected

Figure 1.

Correlation between the Human Development Index score and energy consumption



Source: Data are from the Watt, available at http://www.thewatt.com/.

Notes: The dotted vertical line, at 2,400 kgoe per capita, represents the threshold value for per capita energy consumption beyond which a country reaches the highest quality of life, represented by HDI scores. For India, this corresponds to a total of approximately 4 Btoe. The Human Development Index score ranges from 0 to 1, with 1 being the highest possible score. It combines health, education, and income to measure quality of life. Btoe = billion tonnes of oil equivalent; kgoe = kilograms of oil equivalent.

to continue to dominate the country's energy supply. Sizeable assets in end-use devices and equipment will continue to run on oil. Electricity and gas are expected to increase their share in energy consumption. Electricity is a very convenient energy carrier, which is compatible with most modern equipment. The outlook for gas seems better than oil. The three drivers mentioned earlier—universal energy access, development, and economic growth—also favour the greater use of gas. The share of electricity in India's overall energy consumption is expected to rise in the residential housing/buildings, transport, industry, and commercial sectors. Rapid electrification of the transport sector can be expected to alleviate a significant part of the demand for oil, which is not being met by domestic oil. India's electricity generation, at present, is primarily from coal, which also constitutes the largest component of the country's primary energy supply. Indian coal has a high ash content. To realize its efficient use and minimize its environmental impact, India-specific technological solutions (not normally available from other countries) are needed. India is among the top five greenhouse gas emitters globally.[3] Efforts towards cleaner coal technology have been launched in the form of ultra-super critical technology.[4]. Coal gasification, in unmined coal as well as in plants, could be a game changer in the Indian context. Moreover, coal bed methane and gas hydrates could provide additional gas sources with a high potential for making India energy independent.

A significant share of India's current energy consumption (around 20–25%) is met by biomass,[5] which is used primarily for cooking in rural areas. Apart from poor efficiency in its use, this leads to serious health burdens and environmental issues. To address these difficulties, large-scale deployment of efficient biomass-based smokeless cookstoves as well as affordable cooking gas distribution networks in rural areas are needed.

The Government of India has been aggressively pushing the development of renewable energy to produce electricity from non-fossil fuel energy sources. The country is expected to realize its target of 175 gigawatts electric (GWe) installed capacity, which will consist of solar photovoltaic (100 GWe), wind (60 GWe), bioenergy (10 GWe), and small hydro (5 GWe) sources by 2022. The government has also been strongly supporting the development of nuclear energy, as can be seen from its recent sanction of 10–700 megawatts electric (MWe) nuclear plants of indigenous design to be constructed in fleet mode with an assured annual equity support for the purpose. In addition, around 20 nuclear plants are expected to be set up through international co-operation.

Although these efforts would facilitate the growth of non-fossil energy–based electricity generation in the country, on the hydrocarbon front, the Indian economy will face significant challenges in catering to the country's energy needs in the coming decades. It will therefore be important to explore alternative modes of producing hydrocarbon energy within the country, including solar and nuclear energy sources. Clearly this would require major initiatives in developing and adopting relevant new technologies and their innovative deployment.

India's journey thus far

The energy sector has grown by leaps and bounds, largely driven by short-term demand–supply gaps experienced by different stakeholders at different times. Energy consumption has risen from ~50 million tonnes of oil equivalent (Mtoe) per year in 1965 to present levels of ~800 Mtoe, around a 16-fold increase. Even so, 780 million Indians still lack access to clean cooking facilities and rely on biomass for cooking.[6] Although nearly 100% of households in urban areas and around 80% of households in rural areas have been electrified, as of February 2018 around 35 million households did not have electricity.[7] As of 2015, the number of registered motor vehicles was around 21 crores and over 167 million out of 234 million households had a television set. Out of around 160 million hectares of cultivated land in India, only around 39 million are irrigated by ground water and around 22 million are irrigated by canals. About two-thirds of cultivation in India still depends on monsoon rains. Recent emphasis on standalone solar energy–powered pumps could thus make a big difference to agricultural output, along with the optimum use of water and greater efficiency of grid management.

Several innovations have taken shape to address challenges that arose in the context of efficiency of energy use. It has been difficult to balance demands from energy consumers from diverse sectors such as industry, agriculture, domestic, commercial, and transport in an environment of shortages. The need to support weaker segments of society has also presented a major challenge. This has often resulted in cross subsidies—when industrial production and commercial operations have to pay for electricity for weaker sections of the economy, making commercial operations less efficient and undermining the financial health of electricity companies. There have also been issues related to energy waste by consumers getting free or highly subsidized energy. Separation of consumers paying commercial rates and those getting highly subsidized electricity through using different feeders, subsidized standalone solar-powered pumps for agriculture, incentives for the rapid deployment of renewable energy, and so on have been some of the innovations to usual practice that have made significant impact.

On the technology development front, progress has been made towards the development of ultra-super critical technology in coal-based power generation to enhance efficiency that could lead to significant reduction of carbon emissions. Furthermore, India's strides in taking the refinery sector to a globally competitive level have also been noteworthy. Recently deployed indigenous INDMAX technology at the Indian Oil Corporation's Paradip refinery that leads to a significantly larger LPG output is significant in the context of the relatively larger demand for gas that is expected in the years to come. A 500 MWe Prototype Fast Breeder Reactor (PFBR), a commercial prototype of Fast Breeder Reactor–based power plants that would constitute the second stage of India's nuclear power program, is currently being commissioned.[8]

The Solar Urja Lamps (SoUL) Project of the Indian Institute of Technology, Bombay has been a very successful innovation wherein millions of study lamps for school children are being assembled in rural areas, fulfilling a previously unmet need and creating a new source of income in these areas.[9] This open source technology model is an excellent example of creating momentum in terms of jobs and value addition in rural areas in the new digital society. In fact, a unique initiative implemented in Dungarpur block of Rajasthan through forming of partnership with cluster level federations of self-help groups has gone beyond solar study lamp intervention to include other solar products, such as photovoltaic modules and other lighting solutions.

The development of solar direct current micro grid technology by the Indian Institute of Technology, Madras for both off-grid and on-grid homes,[10] which could lead to better economy as well as efficiency and create a pull for solar power deployment, was recognized for the 2017 Technology in the Service of Society Award by the *IEEE Spectrum*.

Recently introduced direct benefit transfer schemes have helped efficient targeting of subsidies.[11] The country has also done well in terms of more efficient energy use. Driving the prices of light-emitting diode (LED) lights down through policy action as well as mass procurement has resulted in large savings of electricity. Over 28 crore LED bulbs have been distributed under the Ujala scheme, leading to savings of electricity worth around Rs. 14,000 crores. The LED lighting market in India is projected to register a compound annual growth rate of over 30% during 2016–21.[12]

The Bureau of Energy Efficiency has put in place several measures such as prescribing a reduction in specific energy consumption norms for energy-intensive industries, star labelling of 21 appliances, promoting energy efficient LED lamps, and so on that have led to energy savings of about 83 billion kilowatt-hours in the year 2015-16.[13] Thanks to concerted efforts in realizing greater energy efficiency, today several production activities—such as petroleum refining, aluminium and cement manufacturing, and so on—are globally competitive. Vigorous efforts are underway to reduce the emissions intensity of GDP by 33% to 35% from 2005 levels and to achieve about 40% cumulative electric power installed capacity from non-fossil fuel–based energy resources by 2030 as a part of India's Intended Nationally Determined Contribution (INDC) communicated to the United Nations Framework Convention on Climate Change. India's INDC is premised on the help from the transfer of technology and low cost international finance including from the Green Climate Fund.

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Momentum on actions taken towards sustainability and climate change issues has opened up a number of opportunities for innovation. These include innovations in policy, business, and technology for processes, products, and society engagement. Although it is very heartening to see this momentum, India's innovation ecosystems need to improve significantly, which presents both a governance challenge and a cultural challenge. Specifically, in the context of promoting domestic technology development efforts, it is necessary to pay a lot of attention to smoothing hurdles faced during the transition from laboratory research to marketable products. The resources required for such a transition are at times much larger than the resource expenditure on development in the laboratory per se. Clarity about the relative performance assessment of a diverse set of people who all work together in driving such a transition also needs to evolve. The possibility of a disruptive innovation is higher in a group composed of people with very diverse backgrounds and capabilities working together than in a relatively homogenous group, which might tend to move innovation forward in smaller, incremental steps.

Driving the future with innovation

Although the energy scene will continue to be driven by rising demand and the technologies already available in the market as well as those emerging, it is important to recognize some key opportunities for innovation in the Indian context. The most significant areas of opportunity are described below.

Dependence on imports: As discussed earlier, India's immediate challenge is its growing and already-heavy dependence on imports for its hydrocarbon needs. This dependence has led to intensified activity in terms of exploration, and it is hoped that this will produce positive results quickly. In this context, it may also be prudent to use coal to produce fuel gas and liquid fuel. Some activity has begun to extract coalbed methane.[14] Technologies for in-situ coal gasification as well as on surface conversion of coal to gas or liquid fuels should be developed. A significant India-specific emphasis on R&D in this area is necessary because the country's coal has such a high ash content.

Potential of gas hydrates: Gas hydrates represent a huge energy potential for India and can free the country from energy dependence on external sources. While there has been significant progress in resource mapping, developing the technology needed for stable extraction has been a challenge. Presumably some of the initiatives for field experiments currently being implemented will open up this field to rapid growth in the near future.

Increasing share of gas: Along with electricity, the share of gas in overall energy use in India is expected to increase in the coming years. The development of a gas grid to cater to large industrial consumers as well as city domestic consumers, along with a gas distribution network to cater to the needs of rural consumers, could make a major difference to indoor and outdoor air quality and the demand/supply mismatch. Apart from the increasing role that gas is likely to play in the global energy supply, there are good signs of increase in domestic gas production as well.[15]

Significance of biomass: The potential of biomass as an energy source has significantly gone up as a result of new technologies that can convert a much wider variety of biomass into commercial biofuel. Biomass thus represents a significant energy source that may be large enough to meet current needs. Although agricultural residue and municipal solid waste represent significant energy value, they continue to inflict heavy costs on society by way of serious air and water pollution and an attendant health management burden. Technologies that allow the liquidation of practically any kind of biomass in an environmentally friendly manner and create value are evolving quickly. A decentralized collection and processing network for agricultural residue from fields and for municipal solid waste from residential areas could be a game changer both in terms of reducing the environmental burden and in creating value through energy, manure, and even char. Significant new ways to generate income would be an added advantage. Recent occurrences of large-scale smoke plumes from fires at garbage landfills and from agricultural residue burning by farmers, both causing serious degradation of air quality, should trigger quick actions in this regard. While selecting technology for bio-mass-to-energy conversion plants, it is crucial to keep in mind the need to enrich soil quality by applying manure or char.

Significance of solar energy: Solar energy, as the major primary energy source for India's energy future, needs to be seen as an energy source not only for electricity production but also for the production of non-fossil fuels, including hydrocarbons. Concentrated solar power (CSP; also called 'solar thermal power') capable of producing high temperatures should receive greater attention than it has thus far. India's prevailing commercial dynamics has led to solar thermal power being more expensive than photovoltaic power. The fact is, however, that almost 100% value addition within the country is possible with solar thermal; this is not the case with photovoltaic power generation. Furthermore, with large CSP plants one could get higher efficiency and also energy storage would be much cheaper. Given the needed addition of a large solar energy capacity programme, it makes sense to leverage the large demand to depress costs associated with large domestic CSP plants.

Built-in low-cost energy storage would also prevent additional grid and system costs that would be incurred when the proportion of variable generation sources in the grid increases. This would also pave the way for the use of solar energy for pyro-chemical/pyro-metallurgical applications such as thermochemical splitting of water.[16] Efforts to build megawatt scale solar thermal power demonstration plant (which would allow credible scale up to commercial capacity) with a receiver on the ground (by the Bhabha Atomic Research Centre/Oil and Natural Gas Corporation) as well as a solar thermal plant that can run on a continuous basis despite the variable nature of solar energy (by the Indian Institute of Technology Bombay/National Thermal Power Corporation) are noteworthy in this context. With the development of advanced thermodynamic cycles and the associated advanced power-conversion equipment, the performance of CSP technology could become even better.

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On the photovoltaic front, innovative business models for the commercially competitive domestic manufacture of solar products, including silicon and other materials, must be devised.

Decentralized nature of solar energy: Solar energy by its very nature is decentralized and thus well suited for decentralized use. Since solar electricity production generates direct current (dc), and dc end-use devices enable higher efficiency particularly at part loads, it makes sense to directly connect decentralized solar photovoltaic production to direct current end-use devices. There is thus a case for scaling up the IIT/M innovation mentioned earlier. Local low-voltage direct current micro distribution networks would lead to savings both in capital cost as well as in energy consumption. Such networks could be linked to the alternating current grid network at discrete locations optimized to minimize power transmission losses. This would amount to a major reshaping of electricity distribution networks and would produce significant dividends. Some initiatives that are currently underway by the Indian Institute of Technology, Madras and Indian Institute of Technology, Bombay in this context need to be taken forward to reshape the electricity markets.[17]

Potential of nuclear energy: Nuclear energy is the only non-fossil energy source of large magnitude that does support base-load generation without the need for large energy storage. This makes nuclear energy an inevitable energy option for India. Nuclear power plants have large exclusion zones and mandatory green belts to mitigate the risks of a severe nuclear accident. There is thus a good scope for synergy between nuclear, solar, and biomass at nuclear power plants. These three non-fossil primary energy sources together can supply electricity as well as non-fossil hydrocarbon/hydrogen. At coastal sites, nuclear power plants can also be a good source of fresh water. Between high-temperature reactors and solar thermal power plants, some technologies—such as molten salt systems—are common. The systems need to be configured in a manner that virtually eliminates any large-scale impact in the public domain, as the Advanced Heavy Water Reactor has done.[18] There is also a need to better address public sensitivity, particularly through engagement that more directly benefits the local population.

Given the strong technological capability that the country has acquired in all aspects of nuclear power technology, including in the manufacturing of nuclear power plant equipment, it makes sense for India to explore the export potential of nuclear power. With Indian capability in the use of thorium, its vast thorium resources, and the inherent advantages that thorium offers in terms of proliferation resistance as well as safety, India can make a significant contribution to the global energy supply that is free from CO_2 emissions and is safe and nuclear proliferation resistant.

Electric batteries: The development of electric batteries has become crucial for both stationary as well as mobile applications. In the context of additional demands arising out of large-scale renewable energy applications and electric mobility, this perhaps is the most important area for research and innovation. A number of battery variants are possible, each with its relative strengths and weaknesses. Cost, battery life, abundance of the materials involved, energy density, and charge/discharge performance are the key parameters on which various developers are actively working. Along with battery development, the development of fuel cells and steam electrolyzers also needs attention. A paradigm change through decentralized energy production and use may be expected in the near future, once these systems make a significant market entry.

Challenges to transport as a consumer of energy: The transport sector is one of the largest consumers of fuel oil. Electric mobility, which is fast gaining importance in view of its emission-free nature at the user end and its increased operational convenience, could lead to a significant displacement of oil from the energy consumption basket. The country is thus rightly emphasizing the deployment of electric mobility. There are, however, several challenges that must be met. Competitively priced high-energy density batteries that would permit long enough endurance and include a convenient user-friendly recharging infrastructure are the two main challenges. In the interim, hybrids that can lead to considerable fuel efficiency could play an important role.

Cost advantages of integrated renewable energy systems: Building integrated renewable energy systems could lead to significant cost advantages. Energy system elements such as solar panels, electric battery walls, cold storage rooms, hot water systems, water recycle systems, and so on could be configured as building elements. This transition is already becoming visible.

The above is only an illustrative list of several domains where technological innovations could make a large impact in the Indian context. As mentioned earlier, we however need to significantly improve our innovation eco-system that nurtures the working together of diverse groups with complementary capabilities and liberally supports translational efforts over a full spectrum of activities, ranging from laboratory research to entry into market place. There is also a need to pay attention to raw materials, manufacturing technology, and processes as well as the policy issues involved to derive full advantage of domestic innovation efforts.

Closing remarks

Energy is central to human development, and a transition to the use of sustainable, non-fossil energy sources is central to the sustainability of Earth's environment. Embedded within this overall dynamic is the issue of energy sustainability for individual countries. Thus, although generic issues can be addressed through generic solutions, some country-specific issues need country-specific solutions. Clearly, while each country must benefit from developments elsewhere, it must ensure that its specific issues are not ignored and must establish specific solutions through its own priority research and innovation.

In the long term, it is clear that solar and nuclear are the only two sustainable energy sources that can meet India's energy needs. Thus, while working through the ongoing national programmes to address India's growing energy demand, and with due regard to the considerations of the effects on climate change, we should remain focussed on the long-term target of building the country's energy infrastructure based on solar and nuclear as its primary energy sources. This would be consistent with the strategy of ensuring energy sustainability while also meeting the climate change challenge.

Notes

1 Data are from the Central Statistics Office, Ministry of Statistics and Programme Implementation, Government of India, Energy Statistics 2017, available at www.mospi.gov.in.

2 See the Ministry of Petroleum and Natural Gas, Govt. of India, Indian Petroleum and Natural Gas Statistics 2015–16.

3 Janssens-Maenhout et al., 2017.

4 'Super critical technology' refers to technology that uses steam at a temperature of 600–610°C and above.

5 See Technology Information, Forecasting and Assessment Council (TIFAC), TV 2035 – 2015, draft sectoral report on energy.

6 IEA, 2017.

7 Government of India. Saubhagya Dashboard, Garv App 2018. New Delhi. Available at http://saubhagya.gov.in/dashboard/main.

8 500 MWe Prototype Fast Breeder Reactor (PFBR) at Kalpakkam, Tamilnadu, India.

9 Chetan Singh Solanki, IIT Bombay, personal internal Communication 31st January 2018.

10 Jhunjhunwal et al., 2016.

11 Information about the Government of India's Direct Benefit Transfer programme is available at https://dbtbharat.gov.in/.

12 TechSci Research Press Release.

13 Reply to unstarred question no.1839 in Rajya Sabha on 14 March 2016.

14 Abdi, 2017.

15 Abdi, 2018.

16 ABB, 2016.

17 Ali T-Raissi, No date.

18 Information about the Advanced Heavy Water Reactor (AHWR) from the Government of India's Department of Atomic Energy, Bhabha Atomic Research, is available at http://www.barc.gov.in/reactor/ahwr.html.

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