Need for evaluation of near-term energy transition policies of India based on contributions to long-term decarbonization goals

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India faces twin challenges of meeting the rising energy demands of a developing economy and ensuring an economy-wide low-carbon transition to stay on track with its decarbonization goal leading to a net zero energy mix by 2070. As emissions from the use of fossil fuels remain the largest source of greenhouse gas emissions in the country, a massive restructuring of the energy sector is needed. This requires integrated planning across all sectors, and the harnessing of all low-carbon energy technologies and emission reduction mechanisms so that affordable and reliable energy is available to everyone during the process of transition and after achieving net zero. This article examines the future energy requirements and surveys a wide range of studies to make recommendations for policy formulation.

Keywords: Decarbonization, energy transition, net zero, policy formulation.

INDIA updated its Nationally Determined Contributions (NDCs) in August 2022 and has taken up an onerous target by committing to achieve net-zero carbon emissions in 2070. The country is also committed to achieving 50% cumulative electric power installed capacity from non-fossil fuel-based resources by 2030 with the help of the transfer of technology and low-cost international finance. Here, we review recent studies and developments to make recommendations for a policy formulation for the energy sector in India.

India must massively restructure its energy sector to meet the target of a net-zero energy mix. This has to proceed simultaneously with the growth of economy that can be achieved only with growth in per capita energy consumption. Carbon-free energy sources making a significant contribution to the energy mix in India as well as globally are hydro, nuclear, solar and wind; and all of them are being used to generate electricity. Since fossil fuels are also used as or for producing feedstock for several industries like steel and fertilizer, in a net-zero scenario, one has to find a way to produce feedstock using electricity. Also, while electricity can be used for rail and road transport directly or using storage batteries, one must develop new energy vectors using electricity for aviation and shipping. New energy vectors might not be sufficient for all applications, for which the use of fossil fuels may have to be continued along with carbon capture and sequestration, a technology that is yet to be demonstrated at scale.

Considering the options available, it is evident that there is a need for massive electrification using low-carbon energy forms, development and deployment of new zero- or low-carbon feedstock and energy vectors for sectors such as aviation, shipping and the production of chemicals where electrification alone will not be sufficient, and scale-up of carbon capture and sequestration technologies for residual emissions. One has to, therefore, rely on low-carbon sources for generating electricity and use electrolysers to produce hydrogen for use in industries, aviation, shipping, etc.

Aspirations of citizens are rising and they are looking for comfortable living conditions as demonstrated by variation in the daily load curve. The load curve in India normally had two peaks, one in the evening and one in the morning, with the evening peak being higher than the morning peak. This shape of the load curve is evolving. In winter, the morning peak is higher than the evening peak, and in summer, a peak in the afternoons has now evolved due to increasing air-conditioning load. This can be seen in Figure 1, where load curves for three different days are shown. Electricity is also needed for maintaining a cold chain for food and for the storage and distribution of pharmaceutical products.

Electricity requirement to achieve net zero

Data from the past decade indicate that the increase in per capita final energy consumption correlates well with an improvement in the composite metric called the human development index (HDI), the correlation being almost linear over the time frame from 2010 to 2019 (ref. 1). India's HDI in 2019 was 0.645, which puts it in the medium human development category. The country must aspire to reach a high HDI like 0.9, similar to what many G20 nations like

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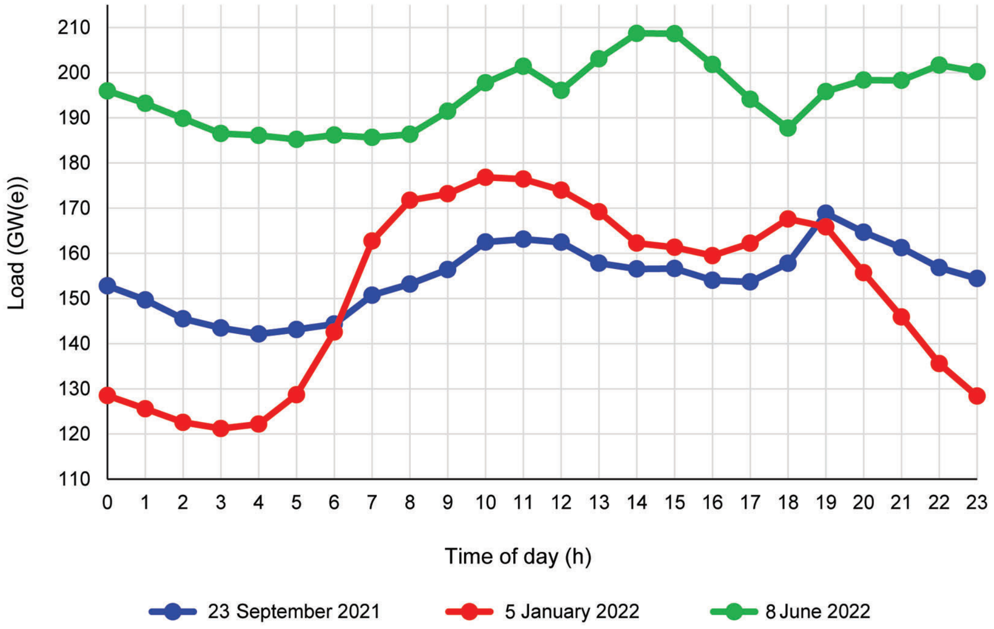

Figure 1. All-India load curves for three different days of the year chosen to convey a shift in the timing of occurrence of the peak load. Note: Based on data obtained from the International Energy Agency, available at https://iea.li/3Hmd90u (last accessed on 26 June 2022).

Australia, Canada, France, Germany, Japan, South Korea, the UK and USA have already achieved.

With this background, one has to estimate the target for the generation of electricity in a net-zero India in 2070. Estimates made by various agencies inform us that a massive increase in electricity generation is needed. Bhattacharyya *et al.*[1] used the correlation between HDI and total final energy consumption to estimate electricity requirements. The study builds several scenarios and concludes that 'a benchmark value for highly developed India's final energy consumption per capita per year can be taken as 16,000 kWh'. Assuming a population of 1.5 billion in 2070, it translates to a total generation of 24,000 billion kWh per annum. A part of it (about 60–70%) will be used as electricity and the rest for the generation of hydrogen by electrolysers. This estimate accounts for likely improvements in the efficiency of energy use, but one must note that the turnover of the existing stock to realize the benefits of efficiency improvement is a challenge for a price-sensitive market like India.

HDI data for 2021 have been just released and HDI for India has come down due to a decrease in longevity. India's HDI now is 0.633, while the world average is 0.732. The change in HDI does not in any way change the estimates made by Bhattacharyya *et al.*[1]. The estimates, such as by Grover[2,3] prior to the commitment made by India to achieve net zero by 2070, are now obsolete. Even after the goal of net zero was announced by the Government of India (GoI), some publications focus only on the power sector while developing future electricity demand. For example, Gulagi *et al.*[4] mention that the use of electricity demand for sectors such as heat, transport and industry was not considered by them in their study.

Technology development in the coming decades can make it possible to produce hydrogen using high-temperature heat from nuclear reactors or solar thermal power plants. Nevertheless, these have to be built to provide high-temperature heat. Another study that forecasts energy requirements similar to Bhattacharyya *et al.*[1], is by the Council on Energy, Environment and Water (CEEW), New Delhi[5]. Other studies have come up with estimates, but are based on optimistic assumptions like very low electricity – GDP elasticity[6], or using complex models with numerous assumptions as done by the Asia Society Policy Institute (ASPI), New York[7]. Optimistic assumptions in studies like that by ASPI have led to the prediction that there is no need to build any more coal-fired power plants, a prediction that has now been challenged by the post-pandemic electricity growth requirements[8]. Bhattacharyya *et al.*[1] have followed a simple and transparent approach with minimum assumptions.

The figure of 24,000 billion kWh per annum may be compared with the present electricity generation of about 1600 billion kWh from all sources. The compounded average growth rate (CAGR) of electricity generation for the decade 2010–11 to 2019–20 (i.e. the decade before the onset of the pandemic) was 5.17% (ref. 9). To achieve its target in 2070, India has to maintain this CAGR for growth in electricity generation for the next five decades, and also nurture all low-carbon electricity-generating technologies in order to achieve the target. As stated earlier, low-carbon electricity-generating technologies in India now making a significant contribution are hydro, nuclear, solar and wind.

Few publications related to India have projected the requirement of electricity generation to achieve high HDI. During discussions on the subject, one encounters several questions and reactions mentioning that the requirement of electricity generation in the country of about 24,000 billion kWh is too high. The first is to think of the correlation between HDI and final energy consumption as causation and start a discussion on the direction of causality. The second is to invoke the Indian tradition of frugality and suggest that we can do more with less. The third is to ignore the concept of life-cycle energy flows as embedded in the concept of EROI, the ratio of Energy Returned On (Energy) Invested, and opine that a lot can be achieved from agricultural residue, municipal solid waste, cow dung, etc. All these are important energy resources with positive externalities (including benefits for health and employment generation) associated with their use. However, they have low energy content per unit mass, and the energy required for their collection and transportation is disproportionately large. As a result, they have a low EROI. In certain cases where biomass is converted into pellets and transported over long distances, such as from the USA to the UK, EROI is close to one. Thus, their use will not make a substantial difference in the estimate of the target generation. Additionally, their carbon neutrality is difficult to verify. Broadly speaking, hydroelectricity has the highest EROI, nuclear and wind are next, and the EROI of solar photovoltaic (PV) sources varies depending on the technology deployed[10].

The *World Energy Outlook* analyses three different scenarios and forecasts a rising share of electricity in the global final energy consumption (FEC)[11]. In the scenario aiming to achieve net zero in 2050, it forecasts global electricity demand to increase from 24,700 TWh (20% of FEC) in 2021 to 62,159 TWh (52% of FEC) in 2050.

Meeting the target electricity requirements

Irrespective of the path followed to achieve the target generation, one has to carefully examine the potential of various technology options to identify what the technology mix to provide the target generation would look like. The potential of renewable energy in India has been assessed by the Ministry of New and Renewable Energy (MNRE), GoI, as well as by academics. One optimistic estimate[12] accounts for all solar, wind, hydro, biomass, wave, marine currents, ocean thermal and tidal energy. According to this estimate, the total electricity generated could range from 1803.9 to 5854.6 billion kWh per annum, with the actual generation achieved somewhere between the two extremes. To arrive at solar potential, Sukhatme[12] assumed a range of areas devoted to the installation of solar PV plants resulting in a range of generation capacities (500–2000 GW). He also assumed a very large generation capacity based on wind, an estimate not accepted by GoI.

Estimates by Sukhatme[12] may be compared with those of Gulagi *et al.*[4], who assumed that 6% of the total land area in each of the Indian states could be covered by solar PV plants, resulting in an installed capacity potential of 14,223 GW. They assumed a wind-installed capacity potential of 1062 GW. However, they report that by 2050, only 3000 GW of PV and 410 GW of wind capacity will be exploited. MNRE estimated the total solar potential as 750 GW, wind as 300 GW at a hub height of 100 m, small hydro potential as 20 GW and bio-energy potential as 25 GW (ref. 13).

In any case, the total potential, even with technological developments in the coming decades, is not likely to reach anywhere close to the target generation. Therefore, one has to deploy other low-carbon sources, particularly nuclear.

To spur the growth of renewable energy, particularly solar and wind, the GoI has provided policy support and incentives like renewable purchase obligations, creating green energy corridors, waiving-off inter-state transmission charges, making available 100% foreign direct investment in wind and solar power projects, enabling accelerated depreciation on capital investments and concessional interest rates to finance these projects, etc. and results are visible. The PLI (production-linked incentives) scheme for solar cells and modules has been formulated to incentivize indigenous manufacturing. The only policy pronouncement in favour of nuclear is its inclusion in the non-fossil fuel-based portfolio.

The electricity demand grew steadily at about 4.1% annually during the last decade, and it is projected to grow by about 6% annually during the next decade[8]. The baseload capacity has to grow to meet the demand, but the narrative around and focus on renewable technologies created an impression that nothing more than renewable is needed. The result is power supply shortages in India, first during the winter of 2021 and then in the summer of 2022. This has now been understood and the Central Electricity Authority (CEA), GoI, has projected that apart from the under-construction coal-based capacity of 25 GW, the additional coal-based capacity required till 2031–32 may vary from 17 to around 28 GW (ref. 8).

Considering the importance of baseload capacity, as highlighted by several studies summarized later in this article, the projection by CEA is not surprising. However, considering the target of net zero to be achieved by 2070, it is desirable that, to the extent possible, the baseload capacity is provided by nuclear rather than coal. Therefore, near-term policies must be formulated to enable the growth of nuclear-installed capacity in a sustained manner.

There are many other issues associated with the expansion of variable renewable energy (VRE) installed capacity and these are described in the following sections.

Integration of VRE in the grid

In addition to their overall potential being limited compared to the target demand of electricity in India, the inherent intermittency of solar and wind poses challenges when integrating them into the power grid. In an electrical system, demand and supply always have to match. An additional investment must be made in the electricity system when the supply is intermittent to match demand and supply. This could be in the form of systems to store electricity as in batteries or pumped hydro storage, using electrolysers to shape the demand, or by flexing generation from assets such as fossil fuel-fired generators or large hydro plants. All this is technically possible but adds to the cost of providing electricity to consumers. The cost becomes exorbitant when the level of penetration of renewables in the grid becomes high. This has been highlighted in several studies and also from experiences in the recent past. Here we review relevant studies that consider the necessity of having firm low-carbon electricity sources as a part of the electricity grid.

To start with, one needs clarity on the terminology used to refer to various generation sources. Building on the classification by Sepulveda *et al.*[14] by integrating what has been left out, we present the following classification for low-carbon technologies.

(1) VRE resources: These include run-of-river hydropower, solar PV, concentrating solar power without storage and wind power.

(2) Storage, balancing and demand-shaping technologies: These technologies are key to integrating intermittent VRE and include short-duration energy storage as in Li-ion batteries, synchronous condensers, long-duration storage as in pumped hydro storage systems (PHS), demand-shaping technologies such as vehicle-to-grid technologies, deploying electrolysers for producing hydrogen and creating dispatchable load, or price-responsive demand-shaping by deploying smart meters, geographical aggregation by grid extension over a large area, etc. Technologies such as battery storage are energy-constrained, and their future role depends on steep price reductions and the continued availability of materials. The dispatchable load provided by hydrogen electrolysers has good potential and provides green hydrogen, but price reduction is key to their large-scale deployment. All technologies in this category add to costs, but are necessary for large-scale deployment of VRE resources.

(3) Firm low-carbon resources: These technologies can meet demand during all seasons, over long durations, and some can even flex in response to demand. These include nuclear power plants (which may or may not be capable of flexible operation), hydroelectric plants with high-capacity reservoirs, coal and natural gas plants with carbon capture and storage (CCS) and capable of flexible operations, biomass and biogas fuelled plants and geothermal power. These plants provide power at all times, except when they are under maintenance and repair. The scheduled maintenance period of firm low-carbon plants is known well in advance.

Sepulveda *et al.*[14] analysed two US regions, a northern system with modest renewable resource potential (New England) and a southern system having a significant renewable resource (Texas). The study concluded that firm low-carbon resources contributed to containing the overall cost of decarbonization even in regions with abundant renewable resources. It reported that 'in the absence of firm low-carbon resources, affordable decarbonization of the power sector would simultaneously require further steep reductions in the cost of VRE and battery storage technologies, significantly over-sizing installed capacity relative to peak demand, significantly greater demand flexibility, and expansion of long-distance transmission capacity connecting wide geographical regions.' The study did not model technologies capable of long-term storage, such as PHS that can moderate the cost of integrating VRE. It advocated greater public support for firm low-carbon sources.

The Nuclear Energy Agency has explained the issue of total costs (the sum of plant-level and grid-level costs) through a three-dimensional plot (Figure 2)[15]. The horizontal axis pointing left represents carbon constraint, while the horizontal axis pointing right represents the share of variable renewables. The blue line represents variation in the total cost when the carbon constraint is set at 50 g per kWh. The total cost is highest (125–150 USD/MWh) when the mix has only VRE and lowest (75–100 USD/MWh) when the mix has a mix of VRE and nuclear. When the carbon constraint is set at 1 g per kWh, the corresponding figures are 275–300 USD/MWh for only VRE and 75–100 USD/kWh for a mix of VRE and nuclear.

The study by Cohen *et al.*[16] focused on California, USA, and arrived at similar conclusions. Three groups were convened to model California's energy system and despite distinct approaches to the calculations, all the models concluded that 'solar and wind can't do the job'. The study referred to a large-scale weather pattern extending over large geographical areas and driving out solar and wind. It concluded, 'If wind and solar are pushed to do all the heavy lifting themselves, the system requires enormous excess generating capacity and storage (most of which is seldom used) to provide reliable electricity and completely drive out greenhouse emissions. The strategy is much more expensive and demanding of land and infrastructure than other possible pathways'[16]. Finally, the study recommended developing clean firm power: 'Nuclear power can steadily provide very large amounts of energy in a small footprint'[16].

The relationship between electricity supply and demand in low-carbon systems was analysed by the International Energy Agency (IEA)[17]. The analysis revealed that due to the presence of VRE, multiple services are needed to provide electricity reliably and these include 'meeting peak capacity requirements, keeping the power system stable during short-term disturbances, and having enough flexibility to ramp up and down in response to changes in supply or demand'[17]. The IEA study quantified the energy and service contribution of different technologies to maintain electricity

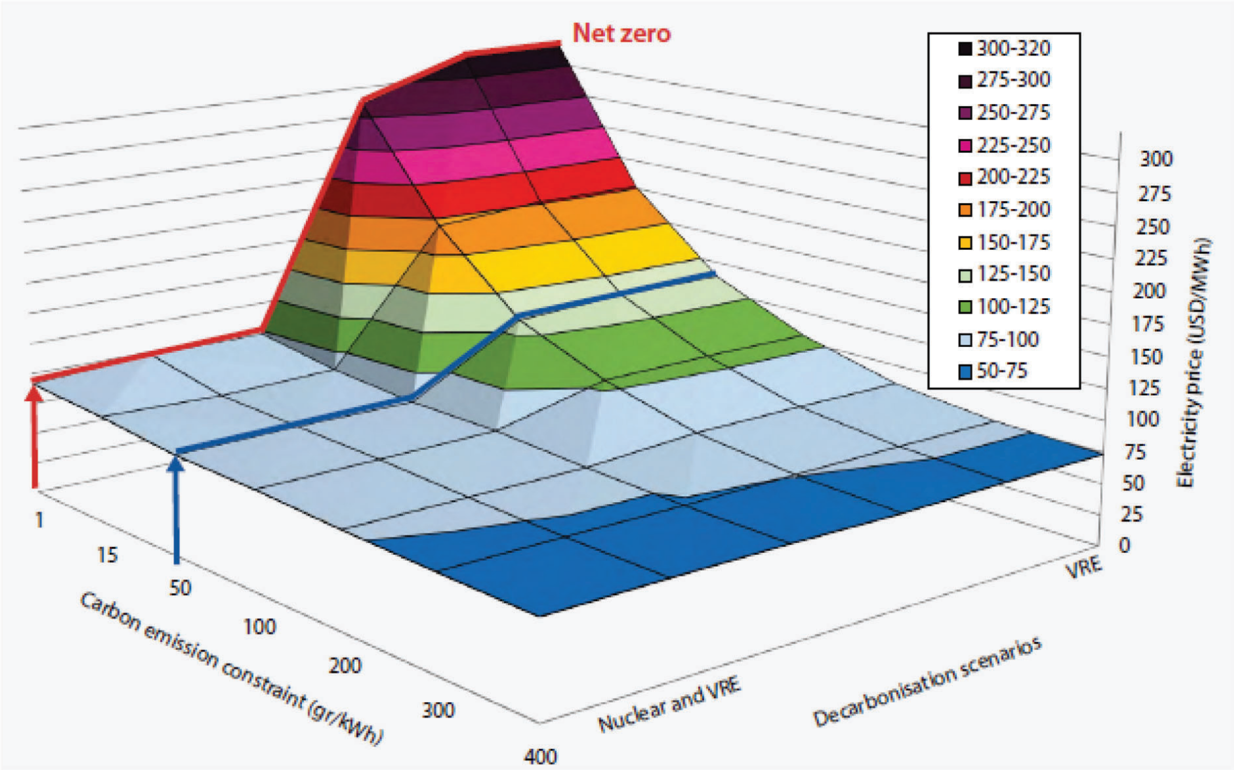

Figure 2. Total cost of different mixes of electricity (driving to net zero emissions). Note: The blue line represents variation in the total cost when the carbon constraint is set at 50 g/kWh. The total cost is highest (125–150 USD/MWh) when the mix has only variable renewable energy (VRE) and lowest (75–100 USD/MWh) when it has both VRE and nuclear sources. When the carbon constraint is set at 1 g/kWh, the corresponding figures are 275 to 300 USD/MWh for only VRE and 75 to 100 USD/kWh for a mix of VRE and nuclear. (Source: OECD/NEA (2022), Meeting Climate Change Targets: The Role of Nuclear Energy, https://www.oecd-nea.org/jcms/pl_69396/meeting-climate-change-targets-the-role-of-nculear-energy, reproduced with permission.)

security in China in Announced Pledges Scenarios, 2060 (ref. 17). While VRE majorly contributes to energy, contribution to system stability comes from firm power sources, namely nuclear and abated thermal. The contribution of VRE to even the peak capacity is much less than its contribution to energy. Using Monte Carlo assessments to simulate the power system under many possible conditions, they captured aspects like the amount of load not served or frequency of the unserved load. They concluded that 'Maintaining operational security requires both system stability – supported by power system inertia and operating reserves – and the flexibility to ramp up and down to maintain a balance between supply and demand'. VRE cannot provide system inertia, flexing or operating reserves (at all times).

Ancillary services in the electricity market

The Indian Electricity Grid Code (IEGC) is a regulation made by GoI. It defines ancillary services as 'the services necessary to support the power system (or grid) operation in maintaining power quality, reliability and security of the grid, e.g., active power support for load following, reactive power support, black start, etc.'. These consist of services required to maintain load-generation balance (frequency control), keep voltage and reactive power support, and maintain generation and transmission reserves[18]. The salience of these services has increased due to unbundling of the power sector, increased penetration of VRE and the aspiration of consumers who expect assured electricity supply round the clock in all seasons. Before unbundling of the power sector, these services were provided by vertically integrated utilities along with energy. During the era of shortages, the tool used to maintain the load-generation balance was load-shedding.

Unbundling of the power sector has given the responsibility of providing ancillary services to the National Load Dispatch Centre, New Delhi and in the future, it will be passed on to the state load dispatch centres as well. Energy not supplied in 2020–21 and 2021–22 was only 0.4% (ref. 8). Therefore, one can state that India has achieved generation adequacy. However, the power supply continues to be unreliable, particularly in rural areas. It is due to problems mainly with the distribution network and inadequate paying capacity of the customer (or the subsidizing agency). From the point of view of generation, reserves of various kinds, such as spinning, high ramping, non-spinning, etc. must be maintained and kept ready for the disposal of the respective load dispatch centre. Since VRE generators are intermittent, do not supply reactive power and have no rotating inertia, the cost of providing ancillary services increases with increased penetration of VRE in the grid. CEA has now come up with draft guidelines for a resource adequacy planning framework and has identified the need for energy storage to manage the intermittency and variability of VRE sources[19].

Ancillary services must be available on demand at different speeds and over timescales ranging from seconds to hours. Various generation and storage technologies have different minimum operational levels, and feasible rates and directions of ramping. They thus offer different kinds of ancillary services. Therefore, a generation mix of diverse low-carbon technologies along with energy storage capabilities can help alleviate the extent of ancillary services needed.

The role of hydrogen

Considering the role of hydrogen in sectoral decarbonization, estimates for its production are included in the forecasts of electricity requirements in India in 2070 by Bhattacharyya *et al.*[1] as well as by CEEW[5]. The most important and early-use cases for low-carbon hydrogen are in the industries currently using natural gas-derived hydrogen, such as ammonia production for the fertilizer sector and chemical synthesis (such as methanol, etc.). The petroleum industry uses a large amount of hydrogen to remove sulphur from petroleum products like gasoline and diesel employing hydro-treatment-based desulphurization technologies. With the electrification of the transport sector directly or using battery electric vehicles, demand for diesel and gasoline will decrease in the long term, lowering hydrogen consumption in this sector. However, hydrogen and its derivatives like ammonia, methanol and other synthetic fuels would still be needed for emerging sectors where low-carbon alternatives do not exist or are techno-commercially unviable. Thus, hydrogen demand will rise in the approach to a net zero Indian economy.

It is estimated that about 30–40% of final energy consumption in net-zero India in 2070 may be in the form of low-carbon hydrogen (including production, transmission and distribution) in energy and industrial applications[1]. This implies a hydrogen requirement of about 120–150 million tonnes per annum by 2070, which is 20–25 times greater than the current consumption of 6 million tonnes per annum. Thus, the dedication of a significant portion of low-carbon electricity towards producing hydrogen will be needed. Hydrogen produced by the banking of VRE will not necessarily be green hydrogen. A diverse mix of all available low-carbon electricity generators will have to cater to the green hydrogen demand. There has been a recent initiative to convert Indian coal to hydrogen through gasification and a roadmap has also been issued in this context[20], but a fossil fuel-dependent programme should only be an interim strategy.

Carbon capture and storage technologies

The Indian electric power sector is heavily dependent on coal-based thermal power plants; about 70% of generated electricity in India today comes from them. The carbon emissions intensity of this electricity ranges from 900 to 1100 g CO_2-eq/kWh (e) (ref. 21). These are the largest contributors to India's overall GHG emissions every year. To move towards the target of net zero, CCS is essential for all new and existing thermal generating stations that have substantial useful life left as well as for new or upcoming projects and also in other industries such as steel and cement, which make use of coal or coke as part of their feedstock and energy requirements. However, an energy penalty (which may be a drop in plant thermal efficiency of 11–23% points) is associated with carbon capture in a thermal power plant[22]. Costs for carbon capture alone currently range from USD 50–180/tonne CO_2 captured, depending on technology, scale and concentration or partial pressure of CO_2 in the gas mixture being processed[23].

Concluding remarks and recommendations for policy formulation

Harnessing low-carbon energy forms will enhance dependence on mining activities since new metals/minerals like silicon, copper, nickel, lithium, manganese, cobalt, vanadium, titanium, platinum, palladium and others will be required in massive quantities. India is not self-sufficient in many of these mineral resources and is still to deploy the technologies for indigenously producing solar PV panels, water electrolysers, grid-scale batteries, etc. at scale. However, the country does have a high degree of supply security with respect to nuclear fuel for its existing and upcoming power reactors, ensured through international agreements[24]. Uranium can be stored for long durations to address any supply disruption. Domestic fuel fabrication facilities have already been established and can be expanded to meet increased demand. India also has significant domestic resources and extraction capabilities of other nuclear materials, such as zirconium. It has standardized and completely localized the entire manufacturing process for PHWRs, thus shielding the nuclear power programme from technology, currency, market, and supply-chain risks. So, a rapid increase in the deployment of nuclear-generating capacity is within reach for the country to attain net zero. India's programme for fleet-mode deployment of 700 MW(e) PHWRs indicates a long-term commitment to harnessing nuclear energy. It is one of the few countries to have explicitly included nuclear power in its arsenal of non-fossil energy sources for climate change mitigation as part of its NDCs. Policy support to ensure on-time, on-budget completion of projects (particularly those based on well-proven technologies like PHWRs) is needed so that the contribution of nuclear power towards climate action is fully realized.

India's massive energy demand and the simultaneous need to attain a net-zero economy require a structural shift in energy generation and utilization across all sectors. Energy use is not just electricity use – the entire energy system needs to transition to low-carbon alternatives. Certain sectors will require synthetic fuels and other energy carriers, such as hydrogen and its derivatives, whose production requires at least one electrochemical operation and hence electricity input. Electrification will be the cornerstone of the energy transition in most sectors. The electricity supply side needs an optimal blend of all low-carbon technologies. This mix should be determined by considering capital cost, dispatchability and reliability of generators, environmental footprints, resource utilization efficiency, climate resilience, contribution to energy security and affordability.

The estimated potential of renewables may get revised upwards in the light of technology improvements (e.g. commercial availability of higher-efficiency solar panels, use of bi-facial panels, taller wind turbines with larger rotor dimensions, etc.). Still considering their variability and resultant high system cost, nuclear and coal with CCS also need to be nurtured. An energy mix comprising all low-carbon technologies will have built-in diversity, which is a hedge against unforeseen disruptions. This requires clear policy articulation.

Based on our assessment, we recommend the following.

(i) Nurture all low-carbon technologies: Domestic ecosystems for all the required low-carbon technologies should be nurtured and sustained; indigenous supply chains for materials and components should be established; the required human resources for analysis, design, manufacture, operation and decommissioning should be developed; socio-economic–environmental consequences of the transition pathways should be analysed and any associated externalities must be fully appreciated and accounted for in the planning process.

(ii) Develop an all-round understanding of generation technologies as well as end-use technologies: To objectively understand environmental and sustainability characteristics and impacts of different energy generation, conversion and storage technologies, life cycle analyses must be carried out to support policy decisions. Energy benchmarking exercises are required to determine baseline energy consumption in different industries, and to track the effectiveness of energy efficiency and other decarbonization measures over time.

(iii) Provide a level playing field to all low-carbon technologies: To align domestic and international financial flows with activities that contribute to net-zero initiatives, many countries have developed green taxonomies. Some countries have issued explicit statements outlining the share or role of nuclear in the energy mix to achieve a net zero. An initiative to prepare a green taxonomy is needed in India to ensure that all low-carbon technologies are provided with a level playing field.

(iv) Shape the load curve by deploying electrolysers: In addition to the generation of hydrogen, electrolysers should be positioned as a dispatchable load so that the must-run status given to nuclear can continue and there is a minimum need to curtail VRE even after its percentage share in the energy mix increases beyond the present values.

Reaching net zero is just one of the objectives, not the end. We also must ensure that resources are available for sustaining high electricity generation after 2070. Near-term policies have to be formulated to ensure that all technologies needed for the long-term sustenance of electricity generation are nurtured and developed so that long-term decarbonization goals become achievable and sustainable.

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