India: Decarbonisation Pathways - Options & Implications[1]

Where are we?

India[2] is one of the fastest growing developing economies. Housing about 17.5% of the total world population, it faces several developmental challenges such as poverty alleviation, low Human Development Index (HDI) and standards of living, lack of access to basic necessities such as electricity and other clean and modern fuels, proper housing, potable water etc. Furthermore, large areas of the country are exposed to natural disasters, which have been increasing in frequency over the years. Given that much of India's energy infrastructure is yet to be built, it is important to plan the development meticulously to grow in a sustainable manner.

India ratified its Nationally Determined Contribution (NDC) targets for 2030 to the United Nations Framework Convention on Climate Change (UNFCCC) with an aim to combat climate change while ensuring that the country is able to meet development aspirations. In this context, India has pledged to reduce the GHG emission intensity of GDP by 33-35% from 2005 levels, increase forest cover by 2.5-3 $GtCO_2e$ and increase the share of non-fossil power generation capacity to 40% conditional on provision of international finance by 2030, among other qualitative targets on developing mitigation and adaptation capacities. India is yet to submit its national mid-century strategy to the UNFCCC process.

India is actively implementing policies and measures on multiple fronts to grow on a path aligned with the idea of "economic development without destruction". Some of these policies and measures include Perform Achieve Trade (PAT), Unnat Jyoti by Affordable LEDs for All (UJALA), and Standards & Labelling, directed at improving energy efficiency; ambitious renewable energy targets and clean coal technology adoption in the power sector; Bharat Stage-VI (BS-VI), National Electric Mobility Mission (NEMM), and the National Policy on Biofuels in the transport sector[3].

This analysis is based on TERI's MARKAL-India energy system model which is a dynamic least cost optimisation model with a detailed representation of the energy sector of India. The model follows a rational expectation hypothesis for intertemporal optimisation.

Where do we want to go?

Figure 1 shows the emissions trajectory of four energy scenarios for India, namely the Reference and NDC scenarios, and the 2 °C compliant and 1.5 °C compliant scenarios[4]. The cumulative carbon budgets for India

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[3] PAT is a policy directed at energy improvement in industries, UJALA is aimed at deeper penetration of LEDs to replace the conventional and inefficient lighting systems, Standards & Labelling programme deals with labelling of appliances on their energy efficiency potential, India has an ambitious renewable energy target of 175GW of renewables (100GW solar, 60GW wind, 10GW from biomass and 5GW from small hydro systems), policy on clean coal technology adoption aims at shifting from subcritical plants to super critical and ultra-supercritical coal based thermal power plants in India, BS-VI is aimed at emissions reduction from the vehicles, NEMM targets to increase the penetration of electric vehicles in India and the National Policy on Biofuels is aimed at enhancing domestic capacity of biofuel production in India.

[4] These scenarios were developed as part of the CD-LINKS project funded under the H2020 programme. The 2 °C and 1.5 °C compliant scenarios assume that by 2030, India's NDC targets are achieved and further mitigation actions are undertaken only beyond 2030. These two scenarios were an attempt to align India's cumulative carbon budget between 2010 and 2050 with the cost-optimal budget range as provided by the global Integrated Assessment Models (IAM) of the consortium. The cumulative global budget used for 2 °C and 1.5 °C is 1000Gt and

between 2010 and 2050 are 277GtCO_2, 251GtCO_2, 226GtCO_2 and 189GtCO_2 under the four scenarios respectively. The budget for the 2 °C scenario is considerably higher than the range projected by the global Integrated Assessment Models based on cost optimality, which is 88-117GtCO_2 for the 2 °C scenario[5]. This difference arises primarily due to the assumption of inter-temporal and interregional cost-optimisation of global models (i.e. a universal carbon tax is applied across all countries and sectors). This leads to relatively larger allocation of mitigation efforts to the developing countries where much of the infrastructure is yet to be built. Another reason for the disparity is that TERI's MARKAL model assumes a higher economic growth rate (based on India's development aspirations[6]) relative to the global models that assume a slightly lower growth rate for India (based on the SSP2 'Middle of the Road' scenario). For brevity, however, the scenarios presented here are still referred to as `2 °C` and `1.5 °C`.

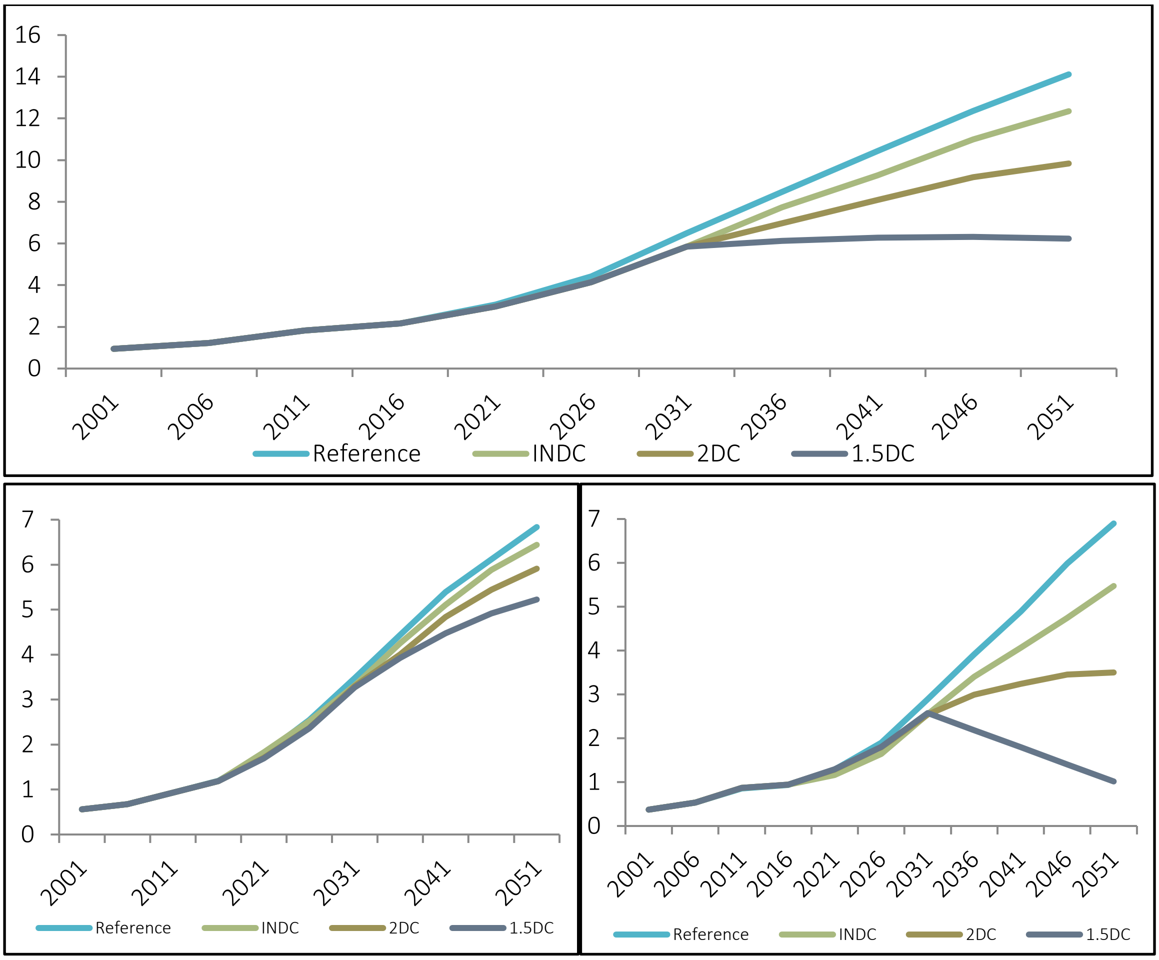

Figure 1: CO_2 Emissions Trajectory (GtCO_2): Total (upper graph), Demand (bottom left) and Supply (bottom right) Emissions (Source: TERI model-based analysis)

The total range of reductions in carbon dioxide emissions in 2050 between Reference and the 2 °C scenario is 4.3 GtCO_2, of which 0.9 Gt come from the demand side transformations (industry, transport and buildings), whereas 3.4 Gt come from the supply side low-carbon transition. Similarly, between the INDC and 2 °C scenario, the total emission saving potential is 2.5 GtCO_2 of which 2.0 Gt come from the supply side (Figure 2). While the largest potential comes from the power generation sector, the highest emissions reduction potentials in the demand

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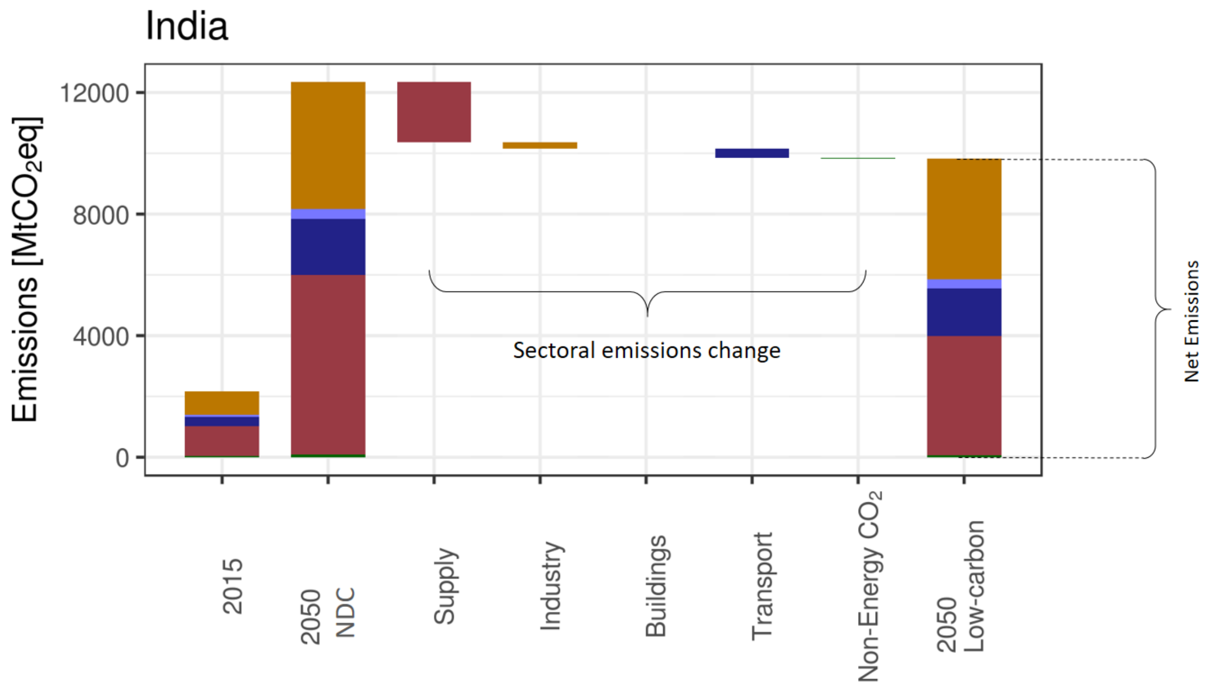
400Gt respectively. It is worth noting here that the budget range for India will change if different effort sharing principle is used instead of cost optimal carbon budget allocation or if the global carbon budget changes.

[5] Similarly, the cumulative budget for the 1.5 °C scenario is also considerably higher than the range projected by the global IAMs based on cost optimality, which is 32-91 GtCO_2.

[6] This growth rate is in line with the target set by the Government of India in its NDC submission. The growth rate assumed here is 8.3% until 2030 and 7% thereafter.

sectors are in the industry and transport sectors. It is worth noting here that the emissions of the residential & commercial sector are reflected in the power sector because energy consumption in buildings is largely based on electricity.



**"Buildings" stands for Residential and Commercial sector, which includes appliances and energy required for cooking in the Residential sector and commercial buildings in the Commercial sector.

Figure 2: CO_2 emissions in 2015 and by 2050 in the NDC scenario (NDC), emission reductions between the NDC and low-carbon scenario (2 °C) by sector (energy supply, industry, residential and commercial buildings, transport, non-energy CO_2), and 2050 emissions in the low-carbon scenario (consistent with 1000 $GtCO_2$, i.e. 2 °C, starting from the 2030 NDC emission levels). Non-energy CO_2 includes emissions from Industrial Processes.

The emission trajectory of India depends on certain development needs and aspirations, which directly impact the energy system. These include economic growth, urbanisation, uniform access to affordable and clean energy, uniform access to mobility services and sustainable stimulation of Indian industries.

In the quest of providing uniform access to affordable and clean energy to all, the electricity demand in the country is expected to increase rapidly, despite significant strides in energy efficiency. Figure 3 presents some of the decarbonisation indicators for the 2 °C scenario. The significant fall in share of renewables in primary energy results from increased replacement of traditional biomass (which is used as a fuel for cooking in residential sector) by liquefied petroleum gas (LPG) and piped natural gas (PNG).

Figure 4 illustrates the capacity needed to generate electricity and the corresponding generation of electricity across the four scenarios in 2030 and 2050. The high decarbonisation potential of the power generation sector comes from the assumption that renewable electricity coupled with storage will be commercially viable at scale by 2030, thereby overcoming the intermittency challenges (for wind and solar power). However, the adoption of renewables has to be complemented with grid improvements to handle higher share of variable renewables in the electricity. The task becomes more challenging because of the sheer scale of implementation that is required for India. Another important issue here is the management of the existing fossil fleet. As is evident from panel (a) of figure 4, coal-fired electric capacity is projected to decline by nearly 40% in the 2 °C compliant scenario relative to Reference in 2050. This implies that even the relatively new and more efficient coal power plants will need to be pre-maturely retired in this scenario. The analysis shows that around 40% of the more efficient coal based thermal power plants remain unused in the 2 °C scenario. It is also clear from Figure 4 that investment in gas-based plants needs to be critically assessed because the contribution of natural gas appears to decline as the level of mitigation actions deepens - as high as 65% of the gas based thermal power plants remain unutilised in the 2 °C scenario.

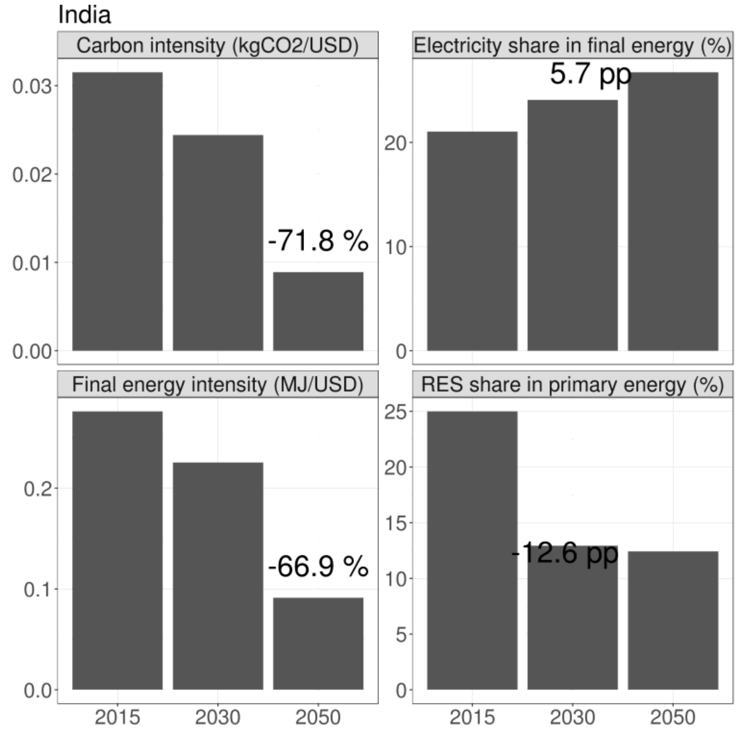
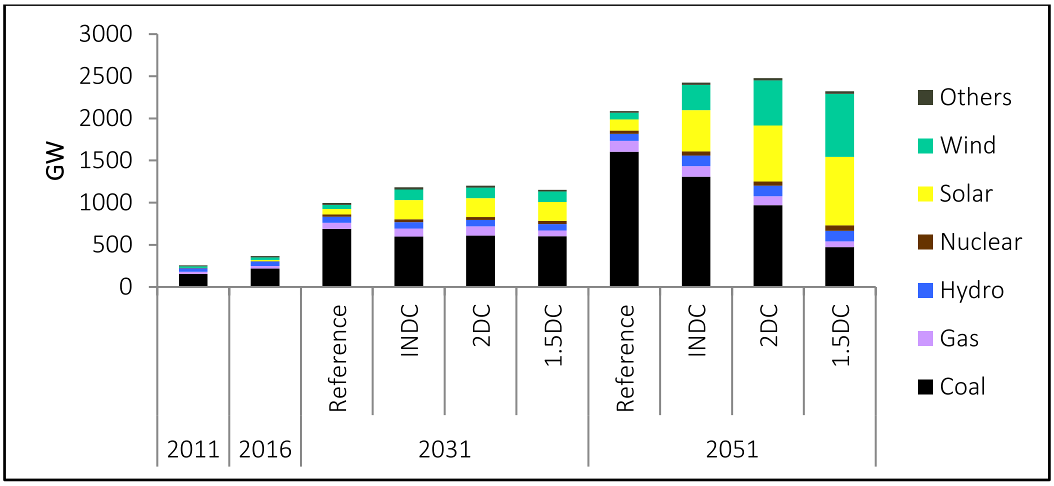


Figure 3: Decarbonisation indicators for the 2 °C scenario (starting from NDC emission levels in 2030). Numbers in graph indicate change between 2015 and 2050 (intensity indicators: %, share indicators: percentage points, pp)

The two sectors in the demand side that offer the largest mitigation potential are industry and transport. In the industrial sector, the PAT-I cycle successfully realised the benefits of low hanging fruits in seven energy-intensive industrial sub-sectors[7]. However, achieving higher levels of energy efficiency improvement will become increasingly challenging and cost-intensive as well. In this regard, Micro, Small and Medium Enterprises (MSME) present a unique case because apart from investment barriers, they also lack the advantage of scale which prohibits them from moving to efficient processes and technologies. Thus, in the industrial sector, not only cost is likely to become a deterrent, but implementation of disruptive processes like deep electrification might also require hand-holding and efforts towards capacity building to reap the benefits of these changes.

The transport sector is one of the fastest growing sectors in terms of energy consumption, as incomes of households increase. While on the one hand increasing income of households leads to large growth of private vehicles, on the other hand inefficient public transportation system is failing to support the increasing demand for mobility. The Indian transport system is locked into conventional fossil fuel-based vehicles, especially the road-based freight segment, which has no commercially viable alternative to diesel. Electrification of vehicles can serve the purpose of tail-pipe emission reduction (also given that the power system would be deeply decarbonised by 2050) but issues related to associated battery recharging infrastructure and large-scale manufacturing are currently prohibiting the penetration of electric vehicles (EVs). In the interim period, Compressed Natural Gas (CNG) can bridge the transition between conventional fossil fuels (gasoline/ diesel) and electricity, with EVs projected to be massively deployed in the 2 °C scenario after 2030. However, this can imply high risks for India locking itself into infructuous and carbon-intensive infrastructure.

[7] PAT-I covered seven industries viz. Iron & Steel, Cement, Aluminum, Fertiliser, Paper & Pulp, Textile & Chlor-Alkali in industrial sector and Thermal power plants in power sector



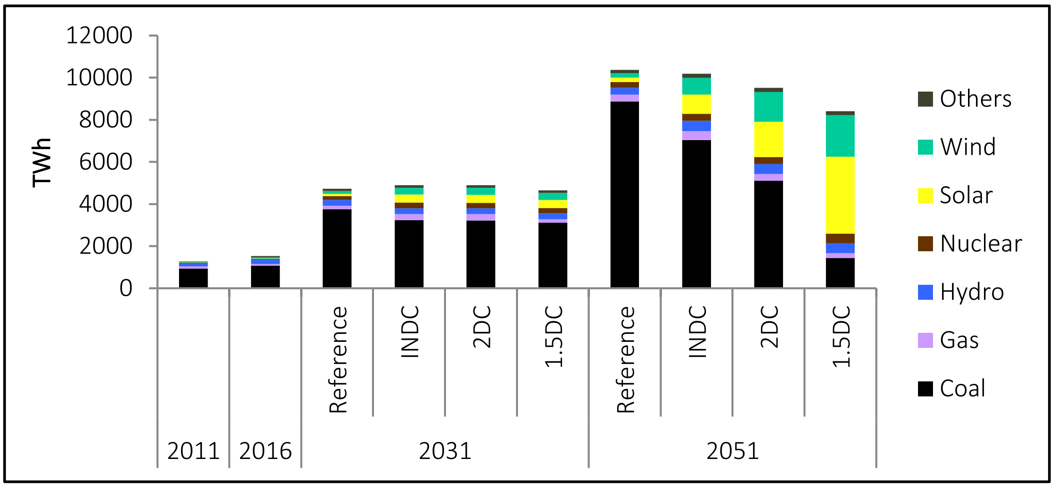
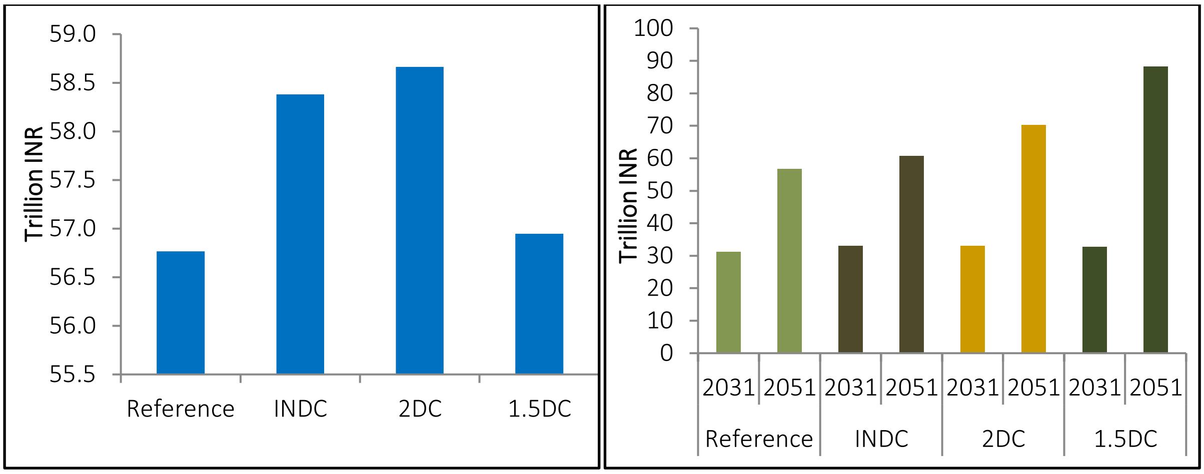


Figure 4: Electricity generation capacity (upper graph) & Electricity Generation (bottom graph)

How do we get there?

As enumerated in the previous section, the three key strategies towards a 2 °C or 1.5 °C world are: increased penetration of renewables in the energy supply sector, end-use electrification and energy efficiency in transport, industries and buildings.



**These costs do not reflect the additional investment required to develop the associated infrastructure like charging stations for EVs, grid strengthening to handle increased share of variable renewable electricity etc.

Figure 5: Energy System (left graph) and (Undiscounted) Investment Costs (right graph) of the alternative scenarios

The total discounted energy system cost (at a discount rate of 10%) for the period 2010 to 2050 increases by 2.8% between Reference and NDC and 3.3% between Reference and 2 °C compatible scenario[8]. A key point to note here is that these strategies highly depend on the development of associated infrastructure whose cost is not reflected in Figure 5 (i.e. charging stations for EVs, grid strengthening to handle increased share of variable renewable electricity, etc.).

The investment requirements of each of the four scenarios are presented in Figure 5(b). The increase in investment between Reference and NDC[9] scenario in 2031 is only 6%. However, by 2051, the investment requirements increase by 24% in the 2 °C scenario relative to the Reference scenario. The huge requirement in investment towards the 2 °C scenario is considered a major challenge towards realisation of the low-carbon transition pathways. Furthermore, if India's dependence on imports of materials and technologies increases in the higher mitigation scenarios, the uncertainty on costs may also increase as trade policies across countries/ regions change.

The mobilisation of funds for financial assistance is one of the conditions on which India's NDC relies. The NDC target no. 4[10] relies on technology transfer and Green Climate Fund (GCF) whereas target no. 7[11] seeks additional international funds to successfully adopt and implement mitigation and adaptation strategies. While it is difficult to assess whether the funds are going towards the development of clean technologies or towards the broader development agenda, the available finance under current conditions is definitely lower than what is needed for the low-carbon transition.

When it comes to technology transfers, the issues associated with the Intellectual Property Rights and other legal aspects need to be resolved. Consideration needs to be made on the mode of technology transfer that should be

[8] Interestingly, the overall discounted system cost for 2010-2050 is nearly the same for the Reference scenario and the 1.5 °C compatible scenario for India. This is because the 1.5 °C scenario heavily relies on renewables, which lead to reduced fuel purchase expenditure (relative to Reference). Even though the upfront cost of clean energy technologies is higher relative to fossil fuels, the fuel cost declines dramatically, which leads to only a 0.1% increase in the total energy system cost in the 1.5 °C scenario (relative to Reference).

[9] By design of the scenarios (India's NDC targets are achieved in all scenarios in 2030 and further mitigation actions are undertaken only beyond 2030), the investment cost in 2031 is (roughly) the same across the NDC, 2 °C and 1.5 °C scenarios.

[10] "To achieve about 40% cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with help of transfer of technology and low cost international finance through Green Climate Fund (GCF)"

[11] "To mobilise domestic and new & additional funds from developed countries to implement the above mitigation and adaptation actions in view of the resource required and the resource gap"

adopted in India. Whether India should import a manufactured product, or import the capacity to produce the technology within the country, or be involved in R&D activities jointly with other countries needs careful assessment to determine the most appropriate mode for India. However, an issue that resonates within each of these modes is the need for capacity building. Development of new and clean energy technologies needs to be associated with an innovative supply chain mechanism especially given that changes in India need to be adopted at massive scale. While some strategies and business models such as mass procurement of LEDs to reduce their unit cost and the PAT scheme for energy efficiency in industrial sectors have been successful, similar innovations are needed in order to make clean energy technologies affordable to the wider public.

The next step in this process is to ensure that entities are willing and able to adopt these technologies and reap the associated benefits. The former calls for certain behavioural changes by energy consumers (for instance in case of electric cooking) and elimination of markets for second hands products (to improve the energy efficiency of the stock of technology) whereas the latter calls for capacity building, even handholding to equip the users with the appropriate information to be able to use these advanced technologies.

This entire framework of new, clean and energy-efficient technologies has a direct bearing on the existing technology and infrastructure and the bridging technologies (such as CNG). The biggest challenge that India faces right now is to efficiently manage the existing fossil fleet and carbon-intensive infrastructure; the large-scale shift to renewables is likely to generate stranded assets (of coal-based power plants), thereby increasing the social cost of renewable electricity. The transition needs to be carefully planned to maximise the use of current assets and minimise further lock-ins.