

Getting to Net Zero: An Approach for India at CoP-26

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Designed by Mukesh Rawat

Getting to Net Zero: An Approach for India at CoP-26

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Introduction

The 6th Assessment Report of the IPCC's Working Group I has issued a "code red" warning: climate change is "widespread, rapid and intensifying" and the world looks set to exceed the Paris target of limiting global warming to 1.5°C above pre-industrial levels as early as 2035. If the process is not halted, we could see global warming reaching +3°C by the end of the century with far more frequent extreme events such as heatwaves, droughts, interruption of normal monsoon patterns, rising sea levels and flooding. Numerous studies have credibly established that India would be among the countries most severely affected.¹

The good news is that if we act fast enough to cut emissions drastically and reduce atmospheric CO₂ concentrations, we will still exceed the +1.5°C limit temporarily, but the warming could be reversed and global temperatures nudged back to around +1.5°C by the end of this century, without any long-term damage to the ecosystem. We have a big stake in ensuring that this happens.

These issues will be discussed in the upcoming G20 meeting in October and CoP-26 in November. The meetings will take place in an environment in which global opinion is much more aware of the dangers of climate change. This is reflected not only in views expressed by NGOs and other thought leaders but also heads of corporations. Governments have also responded. Both the US and the EU have announced longer-term targets of reaching net zero emissions by 2050. Several other governments, including some from developing countries, have also endorsed the net zero date of 2050. China and Indonesia have put forth 2060 as their net zero date.

What strategy should India adopt in the forthcoming international meetings? This paper attempts to answer that question. **Part I** outlines our traditional position, which has been to refrain from making any commitment to reduce emissions, and argues that the time has come to modify our stand because changes in technology now make it possible to grow while also reducing emissions over time. **Part II** assesses whether the transition to renewable energy, which is now "technically feasible", will also be "economically viable" in terms of cost competitiveness. This is critical to determine the immediate costs of transitioning to a low emissions pathway. **Part III** summarises the results of various studies estimating the extent of emissions reduction that is possible over the next three to four decades. **Part IV** highlights the structural changes that shifting to renewables will entail, and the many policy changes required from both the centre and the state governments to manage the transition. **Part V** draws upon the analysis to suggest a new negotiating strategy that we could push for in the CoP-26.

¹ In 2019 alone, absolute losses incurred by India arising from extreme weather events amounted to US\$ 69 billion (in PPP) (Germanwatch 2021).

I. Reconsidering India's Traditional Position on Climate Change

India's traditional position on climate change negotiations has been based on the argument that since global warming is caused by the accumulation of GHGs in the atmosphere, and since this stock is overwhelmingly due to the activities of the developed countries as they industrialised, the burden of reducing emissions should fall mostly on them. India has contributed very little to the stock of GHGs – our current per capita energy use is only a third of the global average – and climate justice requires that we should not be forced at this stage to reduce emissions as that would conflict with our developmental objectives.

The concept of climate justice is acknowledged by the UNFCCC and is reflected in its principle of “common but differentiated responsibilities and respective capabilities”. The Kyoto Protocol of 1997, which was the first international agreement negotiated under the UNFCCC recognised this principle by targeting reductions in emissions only to developed countries and exempting developing countries from this requirement. However, the protocol soon ran into problems, ostensibly because of the absence of commitments on the part of developing countries.²

The Paris Agreement, which emerged from the CoP-21 held in Paris in 2015, was the next major step in building a global consensus on climate change. It was viewed as a landmark agreement for four reasons.

- a) It was the first time the international community set a quantitative target of limiting average global warming to “less than 2°C and ideally 1.5°C above pre-industrial levels”. This reflected a realisation that global warming beyond these levels would be disastrous.
- b) It was the first time that all the participants, including the developing countries, agreed to take some mitigation steps in the form of Intended Nationally Determined Contributions (INDCs).³ India announced the following INDCs (i) a reduction of 33 to 35% in the emissions intensity of GDP between 2005 and 2030; (ii) raising the share of non-fossil fuels-based electricity generation capacity to 40% by 2030; and (iii) increasing land under forests to create additional carbon sink of 2.5 to 3 Gt-CO₂ equivalent by 2030. There was no commitment to reduce emissions, but it did imply acceptance of some responsibility in controlling the growth rate of emissions.
- c) The developed countries (Annex I parties) formally accepted the target of scaling up financial assistance to developing countries, reaching \$100 billion per year by 2020 to support the transition. This responded to some extent to the notion of climate justice.

² The US, having signed the Protocol never ratified it. Canada withdrew in 2011 and Japan, New Zealand and Russia did not continue after the first commitment period (2008 -12). No agreements were signed after the second round (2012-20).

³ “Intended” was meant to convey that these were not penalizable commitments but only an indication of intent. ‘Nationally determined contributions’ conveyed that they were not the result of negotiations but more in the nature of voluntary contributions.

- d) Finally, all countries undertook to regularly submit national data on emissions. This was an important precondition for systematic monitoring of progress in future.

An important limitation of the Paris Agreement was that the INDCs adopted were purely voluntary and were not calibrated to ensure achievement of the global warming target. In fact, it was known that they were insufficient even to limit the warming to below 2°C, but it was consciously decided to leave it to subsequent meetings to “ratchet up” obligations. That time has now come.

The issue we have to face is whether we should continue with our policy of not accepting any emission reduction trajectory and limiting our commitments to specific mitigation actions. We will certainly be under pressure to make a commitment because India is now the fourth-largest emitter after China, the US and the EU and as it is known that we would be among the most severely affected countries, we will be expected to do more. Diplomatic pressure is not a good reason for departing from a policy if it is in the national interest, but in this case there are good reasons for making a departure. Our traditional reluctance to offer an emissions reduction trajectory was based on the perception that the developmental objective of raising our per capita GDP would require an increase in energy use, which in turn would entail higher emissions. This argument is no longer valid because changes in technology now make it possible to increase energy use by relying on green sources which do not generate emissions.

Scope to Reduce Emissions

The extent to which we can control and ultimately reduce emissions depends on the scope of implementing the following three-fold strategy:

- a) Increase energy efficiency as much as possible to reduce the growth of total energy demand. This can be done through a combination of economic pricing of energy, performance incentives for industry, tightened statutory standards of energy efficiency for appliances, shifting freight transport from road to rail, and changes in behaviour especially moving away from personal vehicles towards public transport which is much more energy efficient.
- b) Electrify all sectors as much as possible thus reducing direct use of fossil fuels in final energy demand *and combine this* with a shift to green electricity generation using renewables. Electrification by itself will not lead to emissions reduction if the electricity is produced from fossil fuels, but it can reduce emissions significantly if accompanied by a shift to electricity generation from renewables.
- c) Deal with emissions associated with residual use of fossil through natural carbon sinks supplemented by afforestation and through carbon capture and storage technology, which will hopefully become more economical in future. The extent of residual use of fossil fuels would be reduced if green hydrogen can be produced at commercial scale.

It is important to note that we have already taken action on the lines indicated above. We have launched many energy efficiency missions,⁴ the LED mission being the most well-known. We have an ambitious renewable energy programme (175 GW by 2022 and 450 GW by 2030). We are moving towards full electrification of railways and an expansion in EVs. We have also recently announced the National Hydrogen Energy Mission to develop green hydrogen production capacity in India⁵. Many Indian corporate groups have set targets of moving towards net zero and also announced major investments for developing hydrogen energy.⁶ We need to consider whether these efforts can be scaled up sufficiently.

Scope for Electrification

Table 1 shows the position in 2019 when electricity accounted for only 27% of final energy use. There is substantial scope for scaling up electrification and some of these measures have already begun.

Table 1: India Energy Consumption in 2019[@] (Mtoe)

	Coal	Petroleum Products	Natural Gas	Electricity	Total	Share of electricity in Final Energy
Primary Energy Supply	425*	233	49	26 [#]	734	
Final Energy Consumption	95	191	16	109	410	27%
<i>Agriculture</i>	-	1	-	19	20	96%
<i>Commercial bldg.</i>	-	2	-	9	11	78%
<i>Residential bldg.</i>	-	25	-	26	51	51%
<i>Industry</i>	95	27	4	47	173	27%
<i>Transport</i>	-	43	4	2	49	3.5%
<i>Other</i>	-	92	8	6	107	6.1%

@Excluding biomass, *Includes 120 Mtoe imported coal and 12 Mtoe lignite

[#]Consists of 11.6 Mtoe Hydro, 11.2 Mtoe RE and 3.3 Mtoe Nuclear

Source: NITI Aayog, India Energy Dashboard (accessed 28.08.2021)

Industry is a major user of energy with a heavy reliance on fossil fuels. Much of this is primarily due to the dependence on coal in thermal power generation, which will be reduced

⁴ An example for this could be the Perform, Achieve and Trade scheme of the Bureau of Energy Efficiency. A market-based compliance mechanism for specific energy intensive industries to trade energy saving certificates.

⁵ The Government of India plans to halve the cost of green hydrogen production from currently \$5/kg to \$2.2/kg by 2029. There are also plans to implement green hydrogen consumption obligation in certain industries (e.g. fertilisers), and to introduce Performance Linked Incentive (PLI) schemes for electrolyser and fuel-cell manufacturers.

⁶ Reliance Industries' chairman, Mukesh Ambani, recently announced plans to set up green hydrogen production plants and to bring down the cost of green hydrogen in the country to \$1/kg by 2030.

over time as we shift to green electricity (see below). But there are also “hard to abate areas” i.e. processes requiring very high-temperature heat (e.g., smelting and cracking) or those emitting CO₂ during chemical reactions (e.g., cement) or those requiring fossil fuels as feedstock (e.g. steel, fertilisers). Electric arc furnaces can replace coal-fired furnaces and green hydrogen can be used instead of coking coal as the reducing agent in steelmaking, and to replace natural gas to make ammonia for fertilisers. The extent to which these alternatives will help reduce fossil fuels consumption over time depends upon the pace of technological change and on costs.⁷

Transport sector is the second-largest consumer of energy and there are good prospects for reducing fossil fuel use in this sector. Indian Railways is targeting full electrification of the broad-gauge track network by 2024 and net zero emissions for all its operations by 2030. If this is accompanied by a significant increase in the share of freight moving by rail,⁸ we can expect a substantial reduction in emissions especially if electricity is increasingly produced from renewables.

There is high potential for electrification of two/three-wheelers, passenger cars, light commercial vehicles, small industrial trucks, and even city-buses, which were traditionally powered by petrol or diesel. The expansion of metros as a mode of mass rapid transportation in urban areas provides another means of shifting towards electricity.

Despite these possibilities, there are parts of transport that may remain dependent on fossil fuels. These include long-distance freight and passenger transport by road, heavy earthmoving machinery, ocean-going vessels and aeroplanes, all of which may remain dependent on fossil fuels for some time. Here again, technology may offer a solution through the use of biofuels, hydrogen derived e-fuels and hydrogen fuel-cell engines.

Buildings both residential and commercial rely almost entirely on electricity for lighting and also for cooling. The latter is an area where energy demand is expected to rise several folds as household incomes increase, urbanisation expands and temperatures rise. About half of our population will be residing in urban areas by 2050 and it is projected that much of the stock of buildings that will exist by then have yet to be built. This offers a huge opportunity for India to leapfrog by choosing more energy-efficient building designs, including air conditioning equipment, and sustainable building materials especially cement and steel. Most commercial buildings at present rely on diesel generators to deal with power

⁷ Transitioning to greener processes is expected to remain costlier than conventional processes in the short- to medium-term. CEEW 2021, for example, estimates that cost of producing green steel would be 22% higher than regular steel.

⁸ This is expected once the construction of the dedicated freight corridors connecting the major industrial centres in the country is complete.

interruptions, but this demand for fossil fuel can be eliminated if grid supply becomes more reliable, and large capacity batteries get cheaper.

Cooking (and sometimes lighting) especially in rural areas, is dominated by biomass and kerosene (or even coal). Households are currently moving towards using LPG as a safer and more reliable cooking fuel. As rural grid connectivity improves, switching to electricity for cooking may occur though there are cultural factors that have to be taken into account.⁹

Scope for Switching to Green Electricity

A key part of the strategy is that electrification must be accompanied by switching from electricity generated from fossil fuels to green electricity from non-polluting sources. The conventional options for non-polluting electricity are hydroelectricity and nuclear electricity. The scope for expansion in both is limited.

India has currently 46.4 GW (or 12% of the total) of large **hydropower** capacity but the scope for expansion is limited because of geographical factors and environmental concerns. Our **nuclear power** generation capacity is 6.8 GW and another 6.7 GW is under construction. The development of an additional 9 GW capacity has been sanctioned and is expected to be commissioned by 2031. We should continue expanding nuclear power as planned but even so, nuclear power will remain a small part of the total electricity supply.

The real scope for expanding non-polluting electricity at the scale needed in future is from non-conventional renewable energy sources i.e. **solar and wind power**. About 750 GW of solar power can be potentially installed by exploiting just over 3% of India's wasteland area, with the currently available PV technology. The potential for on-shore wind power capacity is estimated at 300 GW and this can be expanded substantially by increasing hub heights in the future and by exploiting the offshore potential.

Although the total potential solar and wind power is adequate, both sources present problems of intermittency. Solar generation has large variations within the day, while wind has seasonal variations which differ with location. Since demand and supply of electricity have to be balanced at all times, intermittency poses a problem for grid management. It is not a serious problem when the total dependence on these sources is small, as at present, but it will become much more problematic when the share of these intermittent sources increases, as it will, if the objective is to reduce total emissions drastically.¹⁰

⁹ Cost of the fuels aside, owing to certain beliefs, some people for example think that food cooked using traditional biomass fuels (wood or cow-dung cake) is healthier; others find it tastier.

¹⁰ Karnataka, with more than a quarter of its generation from RE, had to reportedly curtail its solar and wind power by as much as 25% on some days during the past 2 years in the interest of grid security (<https://kptclsltd.in/recurtail.aspx>).

Dealing with Intermittency

There are several ways of handling the problem of intermittency. Since the pattern of variation in solar and wind supply differs, optimising the solar to wind capacity ratio would help to moderate the degree of variation in total supply. Spatially spreading out wind turbine installations to locations that complement summer and monsoon peaks in wind will also help reduce seasonal variation. Similarly, off-shore wind tends to be more consistent than on-shore wind and can help to balance supply. Off-shore wind electricity is currently 3 to 4 times costlier than on-shore wind, but the differential is expected to narrow in future.

Hydropower can in principle be used for balancing the power supply, but the scope for doing so is limited because its availability varies seasonally and is also constrained by irrigation requirements. It can be combined with wind or solar generation to inexpensively store some power for balancing. A few hydropower projects in India (4.8 GW¹¹) have the facility to pump and recharge water, and several more are under construction/ consideration.

Natural gas power plants are another possibility for balancing because power generation from these plants can be easily ramped up or down to match supply variations. Though not entirely clean, they have much lower CO₂ emissions per unit of electricity produced compared to coal-based power plants. The emissions from such plants can be reduced further by blending natural gas with biogas or hydrogen. If combined with CO₂ sequestration using CCS systems, these plants can generate virtually clean electricity.

Nuclear power is a zero-carbon source of energy and can be used as a baseload generation capacity, however they have very high loading times. Small modular nuclear reactors¹² can potentially overcome this issue and can be a solution for balancing.

Battery storage at grid-scale is perhaps one of the most viable solutions to deal with the problem of intermittency by storing the excess power generated at peak times for use when generation tapers off. Electric utility companies in California and Australia have successfully tried grid-scale battery storage for a couple of years and are now scaling their capacities to several hundred megawatts. In some cases, the cost of electricity from storage facilities is already at par with that from gas turbine peaking power plants. In India, a 10 MWh Lithium (Li)-ion battery storage system, installed by Tata Power at a substation in Delhi, has been operational since 2019.

¹¹ https://cea.nic.in/wp-content/uploads/hepr/2020/12/pump_storage.pdf

¹² The small size (under 300 MWe) and modular fabrication of the small modular nuclear reactors is intended to make them cheaper, safer and easier to install than conventional nuclear power plants. There is even the possibility of setting them up in the sites of old/retired thermal power stations to benefit from the existing infrastructure.

The cost of battery storage must obviously be built into the cost of renewable electricity. While the costs of Li-ion batteries have declined by 89% since 2010 (BNEF 2021), future trends depend on what will happen to the prices of key metals needed in such batteries as demand increases because of the expanded use of both EVs and grid-scale storage around the world.¹³

One reason for uncertainty in future trends in battery costs is that much of the available mineral sources have been pre-empted by China and reserves of many of these metals are also in conflict-prone regions of the world, e.g. cobalt in the Democratic Republic of Congo and lithium in Afghanistan. However, if the world is going to need much more battery storage, one can expect heightened efforts at finding more sources for these minerals and also technological progress in identifying possible alternatives (such as cobalt less Li-ion batteries), along with recycling. Redox flow batteries, for example, may be a potentially cheaper option than Li-ion batteries for grid-scale storage.^{14,15}

Green hydrogen,^{16,17} produced via water electrolysis using a dedicated renewable generation facility, is also a possible way of storing electricity. Hydrogen can be stored as gas in natural caverns or as gas/liquid in tanks and used to produce electricity when needed. There are several large-scale green hydrogen projects under construction around the world and some are also coming up in India¹⁸ but energy storage using hydrogen at a commercial scale is still some years away. The EU, as per its 2050 Long-term Climate Strategy, has projected deployment of 9 Mtoe of hydrogen storage capacity by 2050,¹⁹ for energy buffering and meeting peak demand.

In practice, India may need to retain a mix of different technologies in the energy sector for some time until the renewables plus storage ecosystem gets fully robust. Some thermal

¹³ Although to a much less extent currently, this can be a problem going forward with wind turbines and hydrogen electrolyzers and fuel cells as well (due to the application of rare earth/precious metals in making some of the components).

¹⁴ In a redox flow battery, positive and negative electrolytes are stored in large tanks are pumped through a cell where electric current gets generated. The battery capacity is equivalent to the volume of electrolyte storage tanks (see illustration [here](#)).

¹⁵ <https://www.pnnl.gov/ESGC-cost-performance>

¹⁶ Another colour-variant of hydrogen, Blue hydrogen, produced via steam reforming of natural gas and capturing CO₂ using CCS, can also “arguably” be an emission-free fuel. However, there are concerns over the supply-chain emissions from natural gas and its higher impact due to greater global warming potential. See Howarth & Jacobson 2021.

¹⁷ Other variants of hydrogen, apart from blue and green, are: grey hydrogen produced via steam reforming of natural gas without CO₂ capture; brown hydrogen from coal gasification; and turquoise hydrogen from pyrolysis of biomass and other organic materials. Currently, most hydrogen produced globally is either grey or brown (the two are also the cheapest among all the colour-variants).

¹⁸ Indian PSUs, Indian Oil Corp. and National Thermal Power Corp., are planning to setup green hydrogen plants in Uttar Pradesh and Gujarat, respectively. ACME Group, a private Indian firm active in solar energy generation, is developing a 5 tonnes/day green hydrogen-derived ammonia production plant in Rajasthan.

¹⁹ https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf

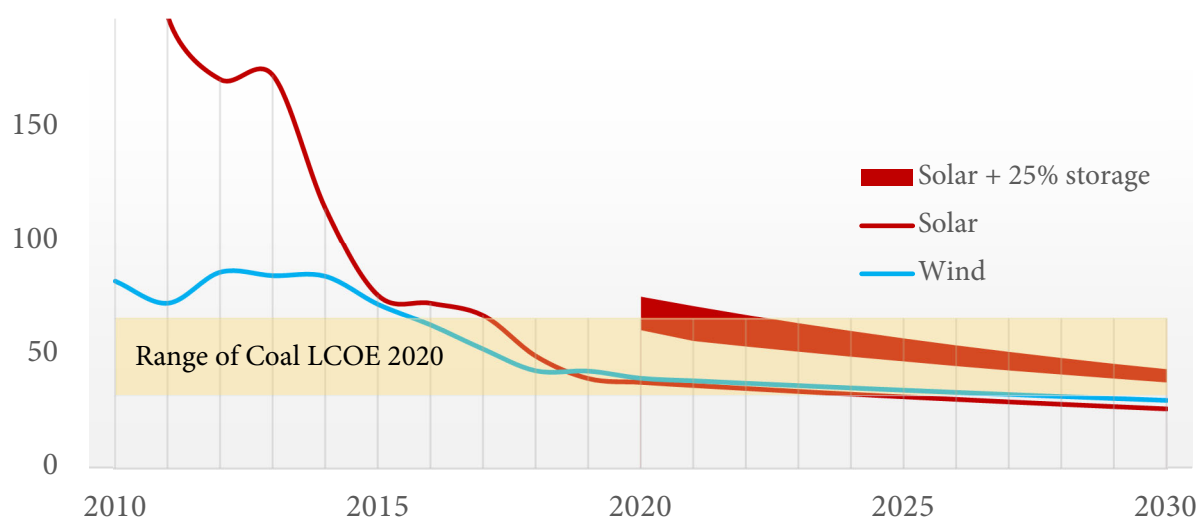
plants may be worth keeping in the fleet to help stabilise supplies when needed, relying on CCS to mitigate emissions.

The supply-side measures listed above can be supplemented by demand-side interventions such as time-of-day metering with sufficient variation to nudge the consumers to align their demand patterns with supplies and minimise the mismatch. Shifting agriculture load to solar peak hours, for example, is a low hanging fruit to extend the overlap of demand response onto solar hours. The availability of dedicated distribution networks for agricultural consumers in certain states (e.g. Karnataka) makes this a feasible option.

II: Will Green Energy be Economically Viable?

The fact that the intermittency problem can be tackled does not mean that a transition to green energy is economically viable, in the sense of making green energy fully competitive with conventional energy. There is no doubt about the sharp decline that has taken place in the levelized cost of energy (LCOE) from renewables which has made both solar and wind electricity competitive with the electricity from coal-based thermal power plants in India. This can be seen in Fig 1 where the lower bound of the shaded region denotes the LCOE from an old (amortised) pit-head power plant, which incurs no coal transportation cost,²⁰ and the upper bound denotes a new non-pit head plant.

Figure 1: Comparing LCOE from Renewables & Coal power plants (US\$/MWh)



Source: IRENA 2021, for historical LCOE of RE; Several sources for battery prices; Authors' projections.

With costs expected to continue falling, both solar and wind will be competitive even with old plants by the later years of the decade. However, this comparison does not include the costs of balancing the demand and supply in the system. Including these costs gives us the dark

²⁰ The average transportation cost of coal across all plants is about ₹1,107 (\$15.2) per tonne (The Times of India, Feb 01, 2021).

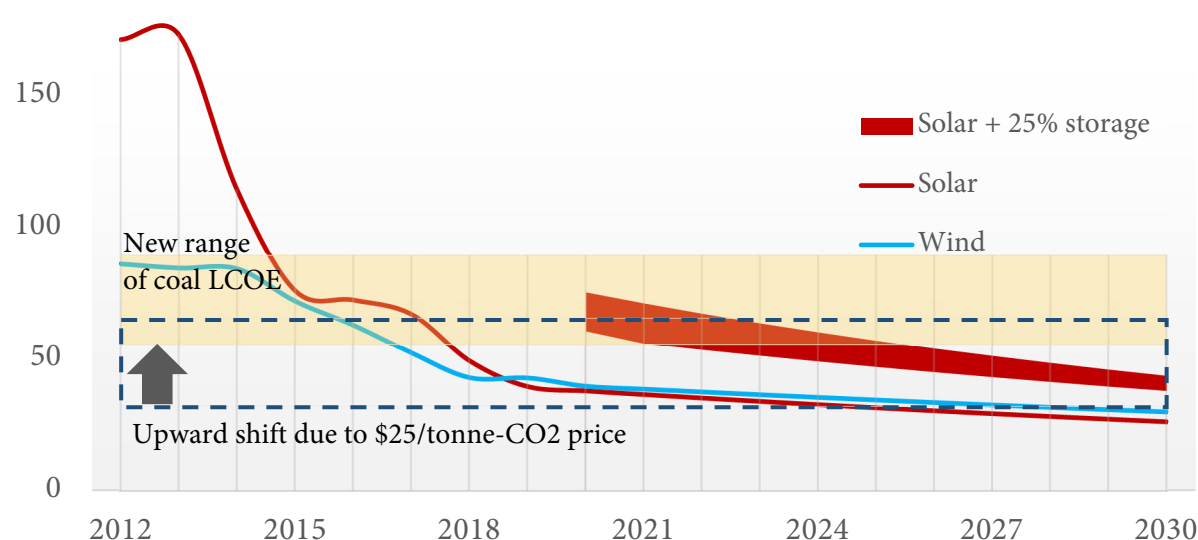
region in Fig 1, which shows the LCOE from a solar power plant with a co-located battery capacity to store 25% of daily generation, based on different estimates of storage costs.²¹ If the cost of storage is included, solar electricity will become competitive vis-à-vis old coal-based plants only towards the end of this decade. However, this may not pose a problem because, as Tongia et al. (forthcoming) show, the planned growth in renewable generation may be manageable within the system without needing any grid-scale storage in the short term.

Effect of Carbon Prices

Renewable energy becomes unambiguously competitive if carbon pricing is introduced to reflect the social and environmental costs of fossil fuels. The IMF, in a recently released staff paper,²² proposed a carbon price floor for the world's top emitters, differentiating it by income levels – \$75/tonne-CO₂ for the US and the EU, \$50 for China and \$25 for India.

Imposing an additional²³ tax of \$25/tonne-CO₂ will nearly double the price of domestic coal in India and raise the cost of coal-based electricity by as much as 27–43%. Fig. 2 shows that if a carbon tax is imposed on coal, electricity from solar plants with co-located storage becomes cheaper than coal-based electricity much sooner than otherwise.

Figure 2: Cost Comparisons with Introduction of a Carbon Price (US\$/MWh)



Source: IRENA 2021, for historical LCOE of RE; Several sources for battery prices; Authors' projections.

Imposing a carbon tax of the order indicated will not be easy. The EU is reportedly considering imposition of Border Adjustment Taxes on imports from countries that do not

²¹ Studies estimate that storage capacity amounting to 25% of daily generation from solar power plants would be sufficient to balance electricity supply with demand (Abhyankar et al., forthcoming).

²² Proposal for an International Carbon Price Floor Among Large Emitters. IMF 2021.

²³ Environmental cess, rebranded into GST compensation cess, of ₹400/tonne, equivalent to \$3.5/tonne-CO₂, is levied on coal in India. This is little higher than the international average of \$3/tonne-CO₂ (IMF 2021).

have a carbon tax on polluting fuels. If this indeed happens, and duty is imposed on our imports, we would need to consider whether it is better to avoid the duty by imposing an explicit carbon tax on coal. It should be noted that at present petrol and diesel are very heavily taxed at rates that more than make up for the absence of a carbon cess.²⁴ If these taxes are split into a carbon cess element and a normal excise duty, there would be no need to impose any further carbon tax. In the case of coal, the existing environmental cess is only \$3.5 per tonne of CO₂ and an increase in the tax would raise coal prices and also prices of coal-based electricity. It would also raise additional revenue which could be earmarked for promoting the energy transition in various ways.

III: Alternative Trajectories for Emissions Reduction

The scope for reducing total emissions in the medium term, based on an energy transition of the kind discussed above, has been examined in several different studies using mathematical models of the economy. These models make different assumptions about the likely energy demand from each sector, after allowing for potential efficiency gains, with alternative assumptions about the scope for electrifying each sector and meeting the enhanced electricity demand from green electricity. The results vary across studies, but they all show that a very substantial reduction in emissions is possible over the next thirty to fifty years.

Table 2: Growth rate of GDP, Energy Demand, Electrification & RE Generation (%)

Study	Sector	Time period	GDP	Net zero year	Final Energy	Electricity Demand	RE Gen.
TERI/Shell	Energy	2020 – 2050	4.8	2050	2.0	5.1	10.4
BP (<i>primary energy</i>)	Energy	2018 – 2050	6.0	2070	2.5 [#]	3.8 ^{##}	11.4
IEA	All	2019 – 2040	5.4	2065	1.5	4.0	14.0
CEEW (High H ₂ + CCS)	All	2020 – 2070	5.1	2070	2.8	4.8	10.8 [*]
CEEW (Low H ₂ , no CCS)	All	2020 – 2070	5.1	2070	2.7	5.3	11.5 [*]

[#]Primary energy; ^{##}Inputs to power

^{*}For CEEW study, RE generation column refers to generation by only solar.

The main results from four studies we reviewed (two economy-wide and two on the energy sector only) are summarised in Table 2. GDP growth projected over the period varies

²⁴ Excise duty and value added tax combined are 56% and 50% of the retail price of petrol and diesel in India, respectively (as on 1-Sept-2021; daily prices available [here](#)). Even if half of the taxes collected on per litre of petrol and diesel is calculated in per tonne-CO₂ terms, it would amount to \$164 and \$114, respectively.

from a low of 4.8% per annum in the TERI/Shell study to 5.4% in the IEA study and even higher at 6% in the BP report. These growth rates are more modest than the 7–8% growth frequently talked about in setting growth targets for India, but we have to keep in mind that the higher targets are usually for shorter periods. Over a longer period, one can expect some slow-down in growth especially since population growth is slowing.

In all the studies, the growth of total energy use is significantly lower than the growth of GDP reflecting the fact that energy efficiency is expected to increase. The elasticity of energy consumption with respect to GDP varies from a low of 0.28 in the IEA study to 0.55 in the CEEW study. These are much lower than the historical elasticity of 0.83 over the past 13 years indicating that the pace of improvement in energy efficiency is projected to accelerate.

The growth of electricity demand is projected to be faster than the growth of total energy in all studies, indicating an increasing share of electricity in final energy consumption. Further, all studies project the growth rate of renewable electricity generation in the double-digit range making renewables the dominant source of electricity at the end of the period.

The **TERI/Shell report**²⁵ projects the energy sector to reach net zero by 2050, with electricity meeting 47% of the final energy demand in 2050. Solar and wind are projected to produce 88% of the total electricity.

The **IEA report**²⁶ in its most ambitious scenario (Sustainable Development Scenario), has economy-wide emissions reaching net-zero by around 2065. The share of renewables (excl. large hydro) in electricity generation rises from 10% in 2020 to 69%, by 2065 mainly driven by solar and wind (60%).

The **CEEW study** by Chaturvedi and Malyan (forthcoming), uses a modified version of the GCAM²⁷ model, developed by Pacific Northwest National Laboratory and University of Maryland. It simulates different pairs of peaking and net zero years viz. 2030/2050, 2030/2060, 2040/2070, and 2050/2080. Each of the simulations is further broken down into two cases: one where hydrogen and CCS technologies are commercially available and another without them.

Electricity generation is projected to grow at about 4.6% p.a. in the CEEW scenario which assumes commercial availability of carbon capture and hydrogen production technologies. It is even higher in the scenario with no CCS and hydrogen since in that case, the use of fossil fuels has to be further reduced. Nearly two-thirds of the electricity is projected to be produced via solar PVs (incl. rooftop), implying an installed capacity of 4,800 GW in 2070

²⁵ <http://www.shell.in/Indiasketch>

²⁶ <https://www.iea.org/reports/india-energy-outlook-2021>

²⁷ Global Change Analysis Model, <http://www.globalchange.umd.edu/gcam/>

which will have to increase to 6,570 GW in the low H2, no CCS case (the share of wind is assumed to be very limited).

The differences in the quantitative projections from these various studies reflect different assumptions about the pace at which technology will evolve, highlighting the uncertainty associated with long-term projections. However, the point to note is that all the studies suggest a high probability that India could realistically aim at peaking emissions by around 2035 and declining thereafter reaching net zero by 2070.

IV: Structural Changes Required by the Transition

A transition on the scale indicated above cannot possibly be achieved by making strategic changes in only a few areas. In fact, it involves deep structural changes in different areas of the economy with implications for policy actions some of which are in the domain of the central government while others are in the domain of the state governments and in some cases even in that of local governments. Managing the transition will require close cooperation across these levels of government. Some of the changes needed are elaborated below.

Building New Power Transmission Infrastructure

The shift to renewable electricity will involve a major change in the geographical concentration of electricity production towards the West, where solar irradiance is higher and the South where wind power is more easily tapped due to the nearness of the sea. Surplus electricity generated in these areas will have to be transferred to the rest of the country.

The fact that we have one interconnected national grid is a great advantage as it can allow seamless transmission of power from one region of the country to another. Nevertheless, a new interstate transmission infrastructure²⁸ (“green corridors”) will have to be built to facilitate the large electricity transfers needed. Power Grid Corporation of India could be made responsible for building the necessary infrastructure in the first place, which could in due course be “privatised” along the lines of the “asset monetisation” currently being considered by the government. This will help to recover the money invested and enable it to be used for financing new infrastructure.

Changes in Electricity Markets

Our electricity markets would also need to become more robust to enable power trading across regions with better price discovery. Wholesale provisioning of renewable electricity on a near real-time basis is now possible at India’s energy exchanges (IEX and PXIL), but it would

²⁸ New high voltage direct current (HVDC) transmission network would allow for rapid changes in power supply, as will be the case with RE, without affecting the transmission network stability.

need to get more flexible as the availability of renewable power increases. The introduction of Green Term Ahead Markets at the exchanges now allows renewable generators to sell power directly in the open market without entering into long-term PPAs. Further, adding Integrated Day Ahead Market (with separate price information) for renewable and conventional generators in the portfolio could pave the way for market-based economic dispatch of electricity.²⁹

Financing the New Energy Infrastructure

The energy transition will require massive investments. IPCC (2018) had estimated that developing countries together will need \$600 billion per year in the period 2020 to 2050 by way of additional investment in just the energy sector to achieve the transition necessary.³⁰ The estimated requirement for India alone is at least \$150 billion per year or about 2% of GDP over the period as a whole.

Additional investments of this order cannot come from the central and state government budgets alone. Some of it could come from central and state public sector entities, relying on their internal resources plus resources mobilised from the markets which may be in the form of equity or debt, both from the domestic capital market and from abroad. Much of the investment will have to come from new private investors (both domestic and foreign) and the extent to which this happens will depend on whether the investments are seen to be financially viable. This in turn will depend critically on whether the distribution segment, which collects revenues from the ultimate consumers, is financially viable. We return to this issue a little later.

In past climate change negotiations, the international community has accepted that it has a role to play in financing the investment needed and the Paris Agreement had assured international support reaching \$100 billion per year by 2020 for developing countries. Actual performance has been much below expectations and estimates of the extent of the shortfall also vary because it was never clear what categories of flows would qualify under the commitment.

The G20 meeting is the place to set realistic targets for the latter, especially multilateral flows. Stern (2021)³¹ has suggested that the G7 should at least double its climate finance commitment and increase the share of grants in international transfers to be able to deliver beyond what was committed in Paris in 2015. Bhattacharya and Stern (2021) have argued for

²⁹ Market-based economic dispatch of electricity would enable all power transactions to occur through an exchange without needing PPAs. This system for power procurement could lower the variable cost of electricity. See draft proposal from the Ministry of Power at <https://powermin.gov.in/en/announcements> (June 01, 2021). Liquidity issues of Discoms can get in the way of such reforms.

³⁰ McCollum et al. 2018, in 2020 US\$.

³¹ <https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2021/05/G7-leadership-for-sustainable-resilient-and-inclusive-economic-recovery-and-growth.pdf>

raising the \$100 billion per year Paris commitment by doubling bilateral concessional finance by 2025 from its 2018 level and tripling multilateral climate finance over the same period, yielding \$200 billion per year in international public climate finance by 2025. This can be paired with increased private sector resources to mobilise around \$300-\$400 billion in annual climate finance by 2025.

Table 3: Estimates of International Climate Finance Provided to Developing Countries since the Copenhagen Accord (2009), US\$ billion

Data Source	2013	2014	2015	2016	2017	2018
OECD	37.9	43.5	42.1	46.9	54.5	62.2
Biennial reports to UNFCCC	25.4	26.6	33	37.5	-	-
Oxfam	11 – 21		15 – 19.5		19 – 22.5	

Source: Roberts et al., 2021

They further suggest that multilateral development banks should be tasked with providing and catalysing long-term finance that is linked to domestic reforms aimed at achieving the energy transition, with suitable arrangements to overcome the single borrower limit in the World Bank. Multilateral flows can also catalyse private flows by reducing perceived political risks arising from arbitrary government action. This would lower the cost of capital which tends to be much higher in developing countries making renewable electricity costlier than it needs to be. There is a growing number of investors in global markets with an appetite for investing in green businesses provided these investments are not associated with too much risk. Multilateral development banks could help mitigate risk perceptions through a variety of instruments. The fiscal impact on the developed countries could be greatly reduced by using the SDR allocations that have been made to these countries.

Improving the Financial Condition of the Distribution Companies (Discoms)

A major factor discouraging a flow of private investment into renewable energy is perceived payment risk because of the financial condition of our discoms.

This is clearly the elephant in the room. Most discoms in India are owned by state governments and make large losses year after year because of a combination of unviable tariffs and managerial inefficiency preventing them from reducing their aggregate technical and commercial (AT&C) losses. The central government has made repeated efforts to incentivise state governments to improve the functioning of the discoms. The UDAY³² scheme, introduced in November 2015, had set a target of (a) reducing the national average AT&C losses to 15% and (b) closing the gap between average cost of supply and average revenue realised per unit of

³² Ujjawal Discoms Assurance Yojana (Plan)

electricity, by March 2019. AT&C losses came down from 24% in 2015-16 to 22% in 2018-19, while the gap between ACS and ARR narrowed from Rs 0.76 per unit to Rs 0.72. The scheme ended in 2020 and was replaced by a new Reforms-based and Results-linked, Revamped Distribution Sector Scheme. It remains to be seen whether the new scheme will be more effective.

Improving the financial condition of the DISCOMs is the responsibility of the state governments and action will be needed on several fronts. State governments need to desist from interfering in the tariff fixation mechanism to keep tariffs down in order to please consumers. This often takes the form of public sector discoms being “persuaded” to limit the demand for raising tariffs by exaggerating the pace at which efficiency can be improved! The political pressure on state governments to keep electricity prices low is understandable but it is inherently unsustainable.³³

The states also need to strengthen the regulatory authorities by equipping them with adequate expertise to fix viable tariffs³⁴ and empower them to ensure compliance.³⁵ Looking ahead, the regulator also needs to be encouraged to evolve more flexible systems of time-of-day metering and energy storage to meet the challenges of intermittent supply.

Privatisation of discoms, or at least of a part of the distribution system, could also help to obtain efficiency gains. Private discoms in many states have achieved AT&C levels in the single-digit range.³⁶ This would be particularly useful for industrially and commercially important cities. This approach will be criticised as allowing the private sector to cherry-pick areas with consumers with a much higher ability to pay, saddling the public sector with unremunerative rural areas and small towns. However, this criticism can be countered if the resources generated by such a scheme (which could be in the form of a revenue share) are used to subsidise the public sector distribution system which has to deal with rural areas and smaller towns.

³³ Burgess et al. (2020) question this “rights-based” approach and find that the problem of poor electricity access and unreliable power supply common to developing countries is because electricity is treated as a public good. They say that such a norm and concomitant policies set off a cycle that promotes wide expectations for subsidies and propagates theft and non-payment. As a result, discoms bleed large sums of money, and ultimately resort to rationing of supply to limit losses, which further disincentives the consumers to pay. It is possible to break out of this cycle, as Mahadevan (2021) finds – Indian states where reliability of electricity supply improved, firms, which were otherwise relying on costly captive power generation, increased their consumption of electricity from the grid and were willing to pay a higher price in lieu of reduced power cuts.

³⁴ There is a view that customers should be charged at a rate close to the cost of generation while the costs of transmission and distribution should be recovered through taxes. This should help in bringing down the price of electricity and increase the consumer base.

³⁵ The Electricity (amendment) Bill 2021 has proposed measures like establishment of an Electricity Contract Enforcement Authority.

³⁶ The private licensees that took over the power distribution in Delhi in 2002 have reduced AT&C losses from over 50% to 9% by 2018-19.

A host of other reforms are also needed in this sector and technology can support in achieving some of them. *Aadhar* or the unique identity number can help to target subsidies to the poorest households through direct benefit transfers instead of relying on low tariffs for all groups.³⁷ Similarly, digital transformers³⁸ enable real-time monitoring to identify unauthorised loads and check theft, and prepaid metering ensures timely payments to reduce commercial losses and increase revenue realisation.

Some of the regulatory provisions which have been introduced to promote the use of renewables need to be rethought. At present, discoms are obligated to purchase all electricity that is generated by the contracted renewable power generator. This forces the discoms, in times of low demand, to back down coal plant operators with whom they have power purchase agreements, under which they have to pay the fixed costs even when no power is purchased. This has deterred discoms from signing new PPAs with renewable power producers. Another problem is that some state governments (Andhra Pradesh, Uttar Pradesh, Rajasthan, Gujarat and more recently Madhya Pradesh) have cancelled signed contracts on the grounds that prices have since fallen. Similarly, for roof-top solar producers, the current rate of feed-in tariffs notified by the discoms in some states are too low to incentivise the installation of roof-top solar PVs.

A temporary solution to the payments risk problem for renewable power has been provided by creating the Solar Energy Corporation of India, a central government PSU, which signs power purchase agreement for renewable power from new producers and takes on the responsibility for selling it to states, who then sell it to the discoms, or sometimes directly to the discoms. This maintains the momentum of investment in renewable energy until the financial problem of discoms is solved, but it cannot be a sustainable solution for all future private investment in renewable energy.

Phasing Down Coal Production

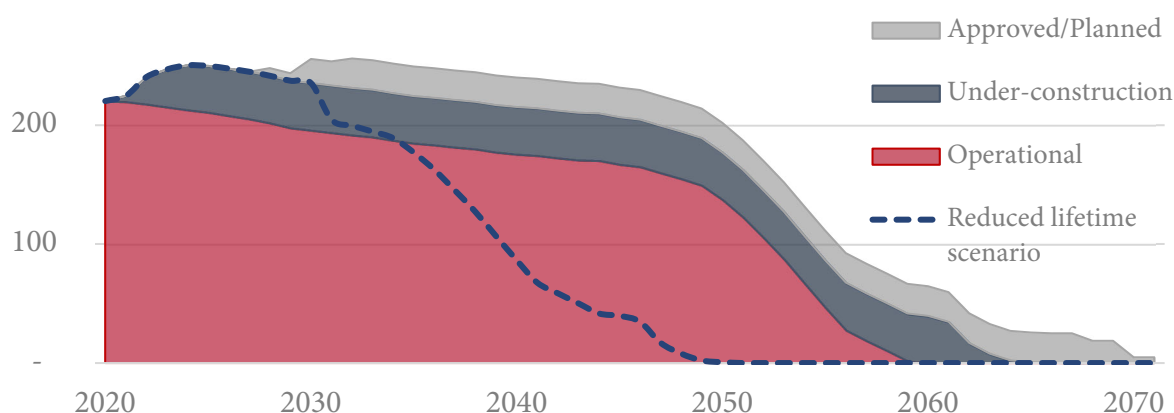
India's ambitious targets for renewable energy generation have been widely applauded but the other side of the coin is phasing out coal-based electricity generation. We have about 210 GW of coal-based capacity currently in operation, with 39 GW under construction, and another 25 GW under different stages of approval where construction has not yet begun. Fig 3 shows the current profile of coal power capacity if each of the existing and upcoming plants serves its 40-year life as the CEA normally assumes. This profile suggests that we will have

³⁷ This is happening, for example, in domestic LPG distribution under the PAHAL scheme of the Govt. of India for availing subsidy.

³⁸ Many existing transformers are overloaded during peak generation hours and require upgrading. However, a higher capacity transformer would remain underutilised for most part of the day. Investing in battery storage capacity could defer the investment requirement for transformers and would also serve to store electricity.

nearly 200 GW of thermal capacity still in operation by 2050 and the power sector will not get to zero emissions until 2070!

Figure 3: Pipeline of Existing and Planned Thermal Power Plants (GW)



Source: *Global Coal Plant Tracker* (accessed 13.06.2021).

There is a strong case for phasing out coal-based generation sooner than their normal life would allow. For one thing, the capacity that was planned but is yet to begin construction could be dropped. If we reduce the retirement age of operational plants to 25 years, say after 2030 we get the dashed line in Fig 3. Earlier retirement of older plants, which are less efficient and also more polluting, would give way to higher utilisation of newer more efficient plants which are currently underutilised. Ghosh and Sindhu (2021), citing a recent CEEW study,³⁹ point out that 50 GW operational capacity is currently surplus to India's electricity demand, and of that 30 GW consists of some of the oldest and least efficient plants, which should be decommissioned at the earliest.

There are also strong health reasons for phasing down coal-based power. Coal power plants emit sulfur dioxide (SO₂), nitrogen oxides (NO_x) and particulate matter (PM₁₀, PM_{2.5}) adding to air pollution in the country. Cropper et al. (2021) find that an estimated 78,000 deaths in 2018 can be attributed to PM_{2.5} pollution from operational coal power plants alone. The burden of deaths can rise by 43% if the planned coal-based capacity is commissioned without any stringent pollution control measures!

Strict enforcement of pollution control laws will force the plant operators to install much needed pollution control equipment and the resulting increased cost will make many of the plants uncompetitive leading to their early retirement.⁴⁰

³⁹ Coal Power's Trilemma - <https://www.ceew.in/publications/thermal-decommissioning-and-cost-efficiency-of-coal-power-plants-india>

⁴⁰ The Ministry of Environment had notified new pollution control laws for thermal power plants in 2015, but these are not yet in force.

Implications for Coal Production

The phasing out of coal from power generation, and ultimately from other uses also, exemplifies the far-reaching structural change implied by the energy transition. The coal-producing states are in general lower-income states. Phasing out of coal production will mean a loss of employment not only in coal mining but also in the many businesses supporting the mining industry. There will be offsetting increases in employment in renewable power generation and in supporting businesses in the areas where renewable power capacity will be concentrated, but these will be in the western and southern states, and not in the east where the coal producing states are. The social consequences of the change need to be recognised in advance and plans evolved for adjusting to it.

The decline of coal production also implies a sharp drop in income from royalties for the coal-producing states. The extent of this decline will depend upon how far developments in CCS technology allow some continued use of coal, but there can be no doubt that royalties will drop substantially. This can perhaps be accommodated through higher shares of revenue sharing for these states through the central Finance Commission devolution process.

Phasing out of coal will also have an impact on the railways. Movement of coal has been a source of high earnings for the railways which have enabled subsidisation of other segments, particularly passenger fares. This draws attention to the need to accelerate establishment of a Rail Tariff Regulatory Authority to rationalise railway tariffs over a period of time. Small changes in rail tariffs stretched out over several years would make the final transition much easier to absorb, but we should anticipate the need for these and start implementing them.

Decarbonisation also implies a similar phasing out of petrol and diesel as the mainstay of the transport sector. Taxes on these products contribute a disproportionate amount to the revenues of both the centre and the states, and their elimination will be a blow to government budgets. But since most of the petroleum products we consume are imported, a fall in consumption would also save foreign exchange. If economic growth remains robust, it should be possible to mobilise offsetting tax resources from other parts of the expanding economy through GST. This points to the need to start restructuring the tax system to anticipate the decline in revenues from petroleum sales.

Structural Changes in the Automotive Industry

Electrification of the transport fleet also implies a major structural change in the automotive sector which also calls for careful planning. EVs have arrived on India's roads, and most of the major car manufacturers are introducing or have plans to introduce electric models. However, EV sales at present are insignificant, accounting for only a little over 1% of sales in numbers, dominated by two- and three-wheelers. This percentage has to increase massively in

the years ahead if we are to make a significant difference to emissions in the transport sector. Early projections from industry representatives point to as much as 30% of the sales being EVs by 2030. The figure is optimistic compared to Bloomberg's projection of 10%,⁴¹ and even if we get there, it would make only a limited contribution to emissions reduction because it will take many years before petrol/diesel vehicles are completely phased out. A faster transformation is needed.

Supportive action from both the central and state governments will be needed to accelerate the pace of the transition. A simple first step is for the central government to announce that all vehicles bought or hired by it after say 2023 will have to be electric. An earlier effort to acquire EVs was not very successful but the sector may be better able to respond now.⁴² Central PSUs could be encouraged to make similar announcements regarding a switch to EVs. Karnataka has announced replacing 50% of the government-owned vehicle fleet with EVs by 2024. The central government, state governments and municipal corporations of 64 cities have jointly planned to introduce 5,595 electric city-buses over the next few years to push for clean mobility for inter- and intra-city transportation. State governments could also announce that no new tourist vehicle licenses will be granted other than electric vehicles after say 2023, with a five-year extension for already licensed vehicles by paying a higher license fee.

There are fiscal incentives already in place for EVs. Government of India's FAME II⁴³ scheme offers subsidies on EVs, a lower rate of GST at 5% is currently charged on the vehicles and first-time buyers can also get income tax exemptions under some conditions. Several state governments have announced similar subsidies or reimbursement of state-GST, along with exemption from registration charges and certain state taxes like road tax. States like Karnataka and Telangana have also announced capital subsidies and concessions for investors in EV manufacturing and charging services sectors to incentivise their production and adaptation.

Fiscal incentives may need to be supported by regulatory compulsion. The EU has announced that cars with internal combustion engines (ICE) will not be allowed for sale after 2035. We need to consider something similar. Since older cars with ICE will remain in the fleet for several years, we need to consider announcing now that no new ICE car will be allowed for sale after say 2040. This would give almost twenty years to the industry to shift out of ICE based production lines and into EV manufacturing. The longer the notice, the less excuse the industry will have for not complying.

⁴¹ BNEF Electric Vehicle Outlook 2021

⁴² Energy Efficiency Services Ltd., a central sector PSU, which implemented the LED lamps scheme, had floated a tender for 10,000 EVs in 2017 but acquired only 2000 vehicles, due to poor performance and low acceptance rates. Hopefully, the models now available are much better but some such initiative is necessary to put enough EVs on the roads to demonstrate their acceptability.

⁴³ Faster Adoption and Manufacturing of Hybrid and Electric vehicles, phase II, now extended up March 2024.

Another associated structural change will arise from the fact that EV motors require far fewer components, and so a large part of the existing components industry will have to be restructured. If this group is not to become an obstacle to change, imaginative ways must be devised to give them a role in the longer-term transformation of the sector.

While the extent of automotive component production may be reduced, the scale of battery production will increase. Batteries are clearly a sunrise industry, as they will be needed not only for automobiles but also for grid-scale storage. For the automotive sector, pivoting to battery components manufacturing, assembling and recycling could be an option. Of course, while encouraging battery production it will be important to avoid getting locked into inferior quality domestic production that is shielded from import competition. This is an area where technology is expected to change rapidly, and we need to guard against insulation from new technology because of protection.

As ICE vehicles are phased out, the number of petrol/diesel fuelling stations within the city may need to change. One can expect that EVs would be charged at home overnight or at offices during the day. The former option, however, could pose supply-side challenges because renewable generation tapers off during the night, with no sun. Hence, promoting the installation of chargers at all commercial buildings and public charging stations would need to be emphasised over residential charging. And since domestic consumers are charged at a higher rate for higher levels of electricity consumption, and if time-of-day tariffs are implemented, at-home charging would be a less sought option. This calls for increased availability of fast chargers at what are currently fuelling stations.⁴⁴ Oil marketing companies have to plan for these changes.

Fuelling stations can also be converted into battery swapping stations. Battery swapping can be particularly useful to further reduce the upfront cost of EV ownership using the “battery-as-a-service model”. It can also be less demanding in terms of urban land requirements compared to charging stations which require parking space and additionally allows flexibility in charging times so that maximum electricity demand can be met during solar hours. Standardised chargers and batteries that are compatible across models of different EV makes would help to achieve the scale needed.

Agriculture, Land use and Water

The agriculture sector and land-use change currently account for 15% of India’s GHG emissions. These are mainly methane (CH₄) emissions from enteric fermentation in ruminant

⁴⁴ There are at present less than 2,000 charging stations in India compared with over 70,000 fuel stations. If 30% of all private passenger vehicles sold in 2030 are electric as some studies project, and if these have to be charged at commercial stations, as many as 2.9 million charging points may be needed (Business Standard, Sept 07, 2021). The requirement of urban land for such an expansion would be difficult to meet.

livestock (52%) and from anaerobic decomposition of soil organic matter in flooded rice paddies (17%), nitrous oxide (N₂O) emissions from fertilisation and soil management (15%), CH₄ and N₂O emissions from manure decomposition (6%), and CO₂ from livestock grazing in grasslands (5%). These can be handled by improving cattle feed (using bypass proteins, e.g.), new methods of rice intensive cultivation and direct seeding of rice, applying enhanced fertilisers that inhibit nitrification in soils (e.g. neem coated urea), better manure management and controlled grazing.

As land gets diverted for solar power generation⁴⁵ and also for urbanisation, a much greater thrust will be needed on raising agricultural productivity. This is especially so because the adverse effects of unavoidable climate change will lower the productivity. Since land productivity in India is much lower than its potential, there is great scope for improvement if productivity enhancing methods are systematically applied. These would have to include much more scientific use of water, which is expected to get scarcer because of the impact of climate change.⁴⁶

A full statement of the policy agenda needed in the agriculture sector goes well beyond the scope of this paper. We have mentioned it only to emphasise the wide-ranging areas where the government has to act.

V: A Negotiating Strategy for CoP-26

The conclusion emerging from this paper is that the time has come to break from our traditional position of not committing to any emissions reduction trajectory and put forward what we think is a reasonable pathway for India. We have in any case begun taking many of the steps needed for the energy transition, and many Indian corporates have announced their own net zero targets. There is an advantage in spelling out a national emissions reduction strategy as an instrument for building a greater domestic understanding of the need for change and also signalling how future policy will move. A national emissions reduction target would also contribute to developing a global consensus on action needed to mitigate climate change.

The main components of our negotiating strategy are outlined below.

Focussing on Net Zero Dates Misses Some Important Points

While public announcements of 2050 as a net zero target date helps to focus public attention on the need to reduce emissions, it is important to recognise that having a common

⁴⁵ See for reference van de Ven et al. 2021

⁴⁶ However, as thermal plants are phased out there will be a significant saving in fresh water.

net zero emissions date for all countries is not the best way of tackling global warming.⁴⁷ The logical way of structuring international action would be to apportion the remaining carbon budget available to the world (as determined by the IPCC) between each country, or at least among the G20 nations, which account for close to three-quarters of the global emissions.

In determining each country's share we should obviously reflect whatever consensus we can evolve on climate justice, including consideration of "respective capabilities" which is part of the UNFCCC. The objective should then be to ensure that each country adopts an emissions trajectory that keeps its cumulative emissions within the respective carbon budget. A trajectory that gets to net zero by the time committed but exceeds the country's carbon budget, is much worse than following a trajectory which keeps within the budget but reaches net zero later.⁴⁸ Climate justice also suggests that the advanced countries should get to net zero earlier than 2050 while allowing developing countries, with very low per capita emissions, to get there later.

While the carbon budget approach described above is logical, it is unlikely that the CoP-26 can reach an agreement on the criteria for determining each country's fair share of the carbon budget. We are most likely to see a continuation of voluntary commitments, with individual countries indicating their trajectories. Since these trajectories will not be derived from an explicit country carbon budget, there is no guarantee that they will be within the global carbon budget consistent with our global warming target. CoP-26 could ask the IPCC to compute the consequences for global warming of the proposed trajectories, and the results could be reviewed subsequently to see if some modifications are needed.

What Emissions Reduction Trajectory Should India Offer?

A national emissions trajectory has to be determined as part of a national energy plan. The NITI Aayog could take a consolidated look at the many studies of emissions trajectories that exist (some of which have been reviewed in this paper), consult with all stakeholders including state governments, and come up with an acceptable trajectory. Any such trajectory is bound to be tentative because of the many uncertainties involved, but it is worth spelling out a trajectory and modifying it as we gain experience and technology improves.

As noted above, there is no logical reason for all countries to adopt 2050 as their net zero date. China and Indonesia have already announced that they will reach net zero by 2060. The studies reviewed in this paper suggest that India could reach a peak around 2035 and get

⁴⁷ The 2050 net zero date is derived from the IPCC assessment of models that project global temperature rise limited to +1.5°C by the end of the century. The models in such a scenario suggest that global CO₂ emissions reach net zero by around 2050.

⁴⁸ It can be argued that one can expect to have negative emission technologies like CCS in some decades hence which can help offset the excess CO₂ a country emits. However, it would be dangerous to rely on a potential solution that is yet to be proven on large-scale and whose implementation at the scale then needed is unknown.

to net zero sometime between 2065 and 2070. We could offer something along these lines at CoP-26, provided other major countries make similar commitments.

Establishing Shorter-term Decarbonisation Targets

Longer-term trajectories, extending over the next three decades need to be supplemented by more granular targets over the next ten years or so, which lend themselves to closer monitoring. In this context, the stated objectives of the US and the EU to halve emissions by 2030 are encouraging.

The best short term target India could offer would be a planned phasing out of coal-based power generation. We have already adopted ambitious targets for expanding renewable energy capacity to 450 GW by 2030. A serious commitment to reducing emissions will require further expansion of this target in subsequent years. These targets imply phasing down of coal use in power generation, but we have not quantified this as yet. We could offer a peaking of coal-based capacity before 2030, followed by a reduction in the total operational capacity to some fraction of the peak by 2040.

International Financial Support

Any credible global compact on climate change should include commitments of support from industrialised countries to help finance the energy transition. International financial support can be in the form of bilateral and multilateral assistance, which requires government action, plus private flows of debt and equity which depend on market conditions though they could be incentivised by government action and also be influenced by corporate commitments to achieving social objectives (i.e. green bonds).

Instead of focussing on the \$100 billion that was promised in Paris and not delivered, we should work towards a new global compact with mechanisms to ensure adherence. The IPCC's assessment of \$600 billion per year as the amount of additional energy sector investment needed in developing countries is a starting point. It should be broken down into (a) a component that will be financed internally, (b) a component that will reflect likely private flows responding to market conditions, and (c) additional bilateral and multilateral flows which can take the form of direct finance or funds aimed at risk mitigation helping to leverage much larger private flows.

The forthcoming G20 meeting could make a substantial contribution by clarifying the multilateral component that can be expected from the various MDBs in terms of additionality to existing flows. Additional funding of around \$100 billion per year from the MDBs alone over the next ten years would be a good target. The delivery of this amount can then be pursued in the Boards of the concerned institutions.

Since flows to India are limited by arbitrary country limits, as exist for example in the World Bank, an appropriate way must be found around this. Limits determined by the ability of the country to repay make perfect sense, but there is no logic to applying them for financial assistance linked to climate change mitigation.

The approach described above would amount to a major change from the traditional approach we have followed. There will be understandable resistance to making such a major break. However, the issue needs to be examined in the context of the enhanced warnings about the impact of global warming and the technological changes that have taken place which allow for making a shift to renewables both feasible and economic. An explicit change of strategy at this stage would signal to the world that India is serious and also signal to the domestic public the scale of the structural changes in many areas that must be planned for. By taking this initiative, India would give a new impetus to climate change negotiations and help to generate a global compact that is very much in our interest and also in the interest of the world.

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