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Getting to Net Zero:

An Approach for India at CoP-26

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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, 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. These meetings will occur in an environment in which global opinion is much more aware of the dangers of climate change as is reflected not only in views expressed by NGOs and other thought leaders but increasingly also heads of major 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/Eckstein et al., 2021).

I. Reconsidering India's Traditional Position on Climate Change

India has traditionally opposed the imposition of emissions reduction obligations on developing countries 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.

This concept of climate justice is part of the UNFCCC and is reflected in its principle of "common but differentiated responsibilities and respective capabilities". This is why the Kyoto Protocol of 1997, which was the first international agreement negotiated under the UNFCCC, called for reductions in emissions only by developed countries, exempting developing countries from this obligation. 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 also 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). 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. We did not offer any commitment to reduce emissions, but we clearly accepted 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).

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

The INDCs adopted in the Paris Agreement 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 limit our commitments only to specific mitigation actions as part of our revised INDCs. 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 cannot be a reason for adopting a course of action that is not in our national interest, but in this case there are good reasons for changing our stand. 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. We can aim to meet all our additional energy needs from renewable sources and in due course replace existing fossil fuel use with renewable energy.

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) Some residual use of fossil fuels may remain and the emissions associated with this can be neutralised by 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 reliance on 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,[3] the LED mission being the most well-known. We have ambitious renewable energy (175 GW by 2022 and 450 GW by 2030) and also battery storage programmes.[4] We are moving towards full electrification of railways and an expansion in EVs and urban metro rails for passenger transportation. We have also recently announced the National Hydrogen Energy Mission to develop green hydrogen production capacity in India. Many Indian corporate groups have set targets of moving towards net zero and also announced major investments for developing hydrogen energy. We need to consider whether these efforts can be scaled up and what this implies in terms of an emissions trajectory.

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 (% of FE)	Share of electricity in Final Energy
Primary Energy Supply	425*	233	49	26#	734	
Final Energy Consumption	95 (23%)	191 (46%)	16 (4%)	109	410	27%
Agriculture	-	*1*	-	*19*	*20 (5%)*	*96%*
Commercial bldg.	-	*2*	-	*9*	*11 (3%)*	*78%*
Residential bldg.	-	*25*	-	*26*	*51 (12%)*	*51%*
Industry	*95*	*27*	*4*	*47*	*173 (42%)*	*27%*
Transport	-	*43*	*4*	*2*	*49 (12%)*	*3.5%*
Other	-	*92*	*8*	*6*	*107 (26%)*	*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 Dashboards (niti.gov.in/edm) (accessed 28.08.2021)

Industry accounts for 42% of total energy consumed with a heavy reliance on fossil fuels. Much of this is primarily due to the dependence on coal in thermal power generation,

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

[4] There are plans to set up two GW-scale battery storage capacities in Ladakh (13 GWh) and Gujarat (14 GWh).

which will be reduced 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. Green hydrogen provides a potentially important substitute for fossil fuels in some of these areas, and the extent to which it will help to reduce emissions will depend upon the pace of technological change and on costs (see Box 1).

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 its 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, we can expect a substantial reduction in emissions as 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 also city-buses, which were traditionally powered by petrol or diesel. Better urban planning can further reduce the dependence on personal transport (which has huge congestion implications) by encouraging a shift to public transport including metros running on electricity for mass rapid transportation in urban areas.

Despite these possibilities, parts of transport may remain dependent on fossil fuels for some time. 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 70% 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 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.

Box 1: Hydrogen

Hydrogen (H2) is a potential emissions-free energy carrier because it has the highest energy per mass of any fuel and does not release any CO2 upon usage. H2 is flammable and can be directly burned to produce heat, with water vapour as the only by-product. It can be used in special internal combustion engines or gas turbines, and can also be converted into electricity via fuel cells. H2 can be chemically combined with biogenic or atmospheric carbon, or nitrogen to synthesise carbon-neutral 'e-fuels' fuels (like methane, methanol, ammonia, etc.). Some of these synthetic fuels can be used in conventional applications by making use of the existing logistical infrastructure (pipelines, transport networks, refuelling stations, etc.) without many changes. This flexibility allows H2 to displace fossil fuels in virtually all applications. It also has use in steelmaking as a chemical feedstock in place of coking coal for iron ore reduction.

H2 as a gas at room temperature has a low energy density by volume, but in the liquid state, it has a very high volumetric energy density. However, since liquefication requires very low temperature/high pressure, a large amount of energy is required to store it as a liquid. It is also highly reactive making it difficult to handle (e.g. it embrittles steel easily). Liquid H2 carriers like ammonia or other organic carriers like dimethyl ether which combine H2 with other chemicals to make stable, non-corrosive liquid compounds at or near room temperature are a viable alternative to liquid H2. They are safe to store/transport and H2 can be easily released from them when needed, through a reverse chemical process. Ammonia, for example, is considered a potential replacement for LNG as an emissions-free marine fuel.

Compared to batteries, H2 has a much higher energy density by weight (since batteries are very heavy) and vehicles running on H2 can be refuelled in a fraction of the time required to charge electric vehicles. This makes H2 fuel suitable for long-distance, weight-sensitive transport applications like freight transport, aeroplanes, etc.

H2 is produced via different methods: Brown H2 from gasification of coal, Grey H2 from steam reforming of natural gas, Blue H2 from steam reforming of natural gas with CO2 capture and utilisation/storage, and Green H2 from electrolysis of water using renewable electricity. Two more relatively less popular methods are Turquoise H2 which is produced using natural gas pyrolysis and Cyan H2 from steam reforming of biogas.

Currently, most H2 produced in the world is either grey or brown and used in the chemical industry as a feedstock. Though cheap, these are the most carbon-intensive forms of H2 production. In sharp contrast, Green H2 does not involve any GHG emissions and is increasingly viewed as a sustainable source of H2. However, the process is energy-intensive and is therefore costly at present, but the cost is expected to reduce as renewable electricity gets cheaper and electrolyser efficiency and lifetime increase. Blue H2, on the other hand, has concerns over the fugitive emissions of methane from natural gas and its higher climate impact, and therefore may not be a sustainable way of H2 production (Howarth & Jacobson, 2021).

The Govt. of India aims to halve the cost of green H2 in the country from currently around $5/kg to $2.2/kg by 2029. There are also plans to implement green H2 consumption obligations in certain industries (e.g. fertilisers) and to introduce PLI schemes for electrolyser and fuel-cell manufacturers. Reliance Industries' chairman, Mukesh Ambani, recently announced plans to set up green H2 production plants in India and to bring down its cost to $1/kg by 2030.

Scope for Switching to Green Electricity

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**. As per the Ministry of New & Renewable Energy, 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.

The Problem of Intermittency

Although the total solar and wind power potential 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.[5]

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

[5] Karnataka, with more than a quarter of its generation from RE, had to reportedly curtail solar and wind power by as much as 25% on some days over the past 2 years in the interest of grid security (kptclsldc.in/recurtail.aspx).

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 GW) 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 reactors[6] can potentially overcome this issue and could 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. Excess power generated at peak times can be stored in a battery 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. The company is currently setting up a 50 MWh battery storage capacity along with a 50 MW solar plant in Ladakh.

Battery storage is expensive at present and the cost on this account must be reflected in the cost of renewable electricity. While the costs of Li-ion batteries have declined by 89% since 2010 (BNEF/McKerracher et al., 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.[7]

[6] 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.

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

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 long-duration grid-scale storage (PNNL/Mongird et al., 2020).[8]

Green hydrogen, produced via water electrolysis using a dedicated renewable generation facility, is also a possible way of storing energy. Hydrogen can be stored as gas in natural caverns or as gas/liquid in tanks and used to produce electricity via fuel cells when needed.[9] There are several large-scale green hydrogen projects under construction around the world and some are also coming up in India[10] 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, for energy buffering and meeting peak demand (European Commission, 2018).

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

Intermittency can also be handled by supplementing the supply-side measures listed above by demand-side interventions such as time-of-day metering designs 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 segregated feeder systems for rural agriculture consumers[11] in certain states (e.g. Gujarat, Karnataka) makes this a feasible option.

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[8] 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.

[9] Green hydrogen-based energy storage however has poor round-trip efficiency – in the process of converting electricity into H2 and back, nearly 2/3rd of the energy is lost with the current technology (Sepulveda et al., 2021)

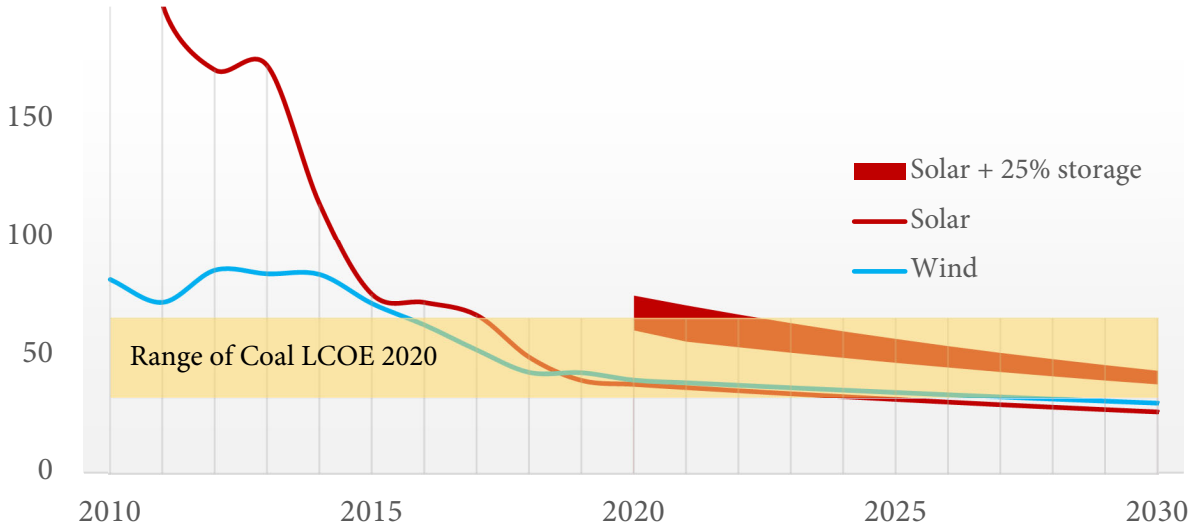
[10] Indian PSUs, Indian Oil Corp. and National Thermal Power Corp., are planning to setup green hydrogen plants in Uttar Pradesh and Gujarat, respectively. ACME Group, a private Indian firm active in solar energy generation, is developing a 5 tonnes/day green hydrogen-derived ammonia production plant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

[11] Started first in the state of Andhra Pradesh in 2001, electricity supply feeders for agriculture and non-agriculture consumers in rural regions were separated in order to regulate the amount of power supplied to farmers for irrigation (which is usually free), while ensuring uninterrupted supply to non-agriculture consumers. Many states have implemented the system since.

II: Will Green Energy be Economically Viable?

Handling intermittency is not enough to ensure that a transition to green energy is economically viable, in the sense of making green energy fully competitive with conventional energy. That depends on whether green energy is competitive after considering the cost of handling intermittency. There is no doubt that the levelized cost of energy (LCOE) from renewables has fallen sharply making 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, and the upper bound denotes a new non-pit head plant. With costs expected to continue falling, both solar and wind will be competitive even with old plants by the later years of the decade.

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.

However, this comparison does not include the costs of balancing the demand and supply in the system. Including these costs gives us the dark region in Fig 1, which shows the LCOE from a solar power plant with a co-located battery capacity to store up to 25% of daily generation, based on different estimates of storage costs.[12] 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.

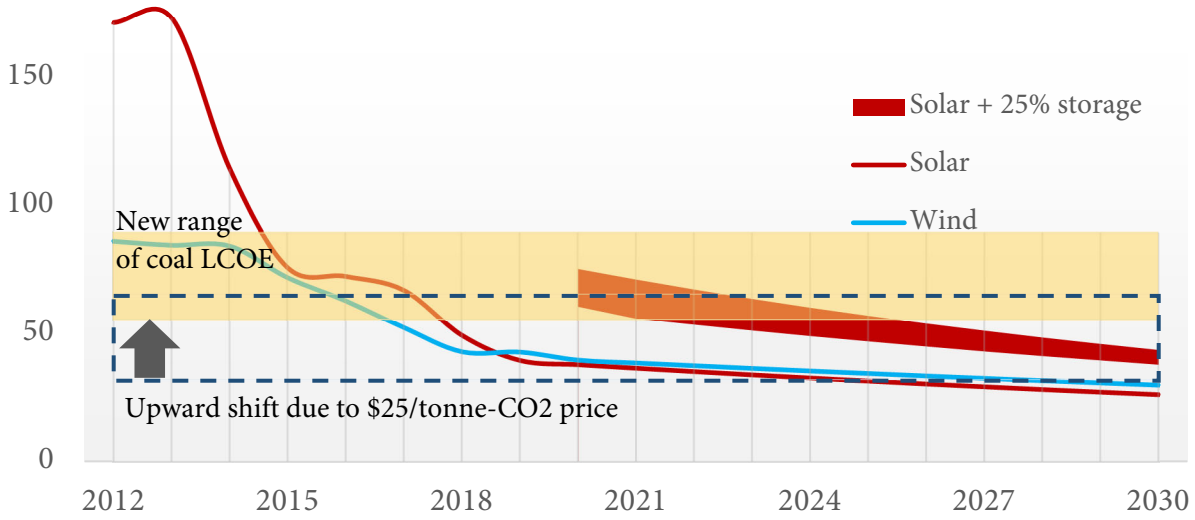
[12] Assuming that storage capacity amounting to 25% of daily generation from solar power plants would be sufficient to balance electricity supply with demand (in the absence of load shifting).

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,[13] 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 additional 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 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. Technically, a carbon tax would also have to be imposed on petrol and diesel, but these fuels are already taxed heavily at rates that more than make up for the absence of a carbon cess.[14] If the taxes on petrol and diesel are split into a carbon cess element and a normal excise duty, there would be no need to impose any further carbon tax. The case

[13] Parry et al., 2021

[14] 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). 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.

of coal is quite different since the existing cess[15] is only ₹400/tonne of coal or about $3.5 per tonne of CO2. An increase in the tax on coal would raise coal prices and also prices of coal-based electricity. However, the tax 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 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: Annual 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 *(primary energy)*	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 H2 + CCS)	All	2020 – 2070	5.1	2070	2.8	4.8	10.8*
CEEW (Low H2, 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 from a low of 4.8% per annum in the TERI/Shell study to 5.4% in the IEA study and 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.

[15] Earlier clean energy cess, under the National Clean Energy Fund created in 2010, now rebranded into GST compensation cess since 2017.

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 expect 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 (2021)** 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 estimated to produce 88% of the total electricity.

The **IEA report (2021)** in its most ambitious scenario (Sustainable Development Scenario), has economy-wide emissions reaching net-zero by around 2065. The share of electricity in the final energy consumption in 2040 is projected to be 30%, and that of renewables (excluding large hydro) in the electricity generation rises from 10% in 2020 to 69%, by 2040 mainly driven by solar and wind (60%).

The **CEEW study** by Chaturvedi and Malyan (forthcoming), uses a modified version of the GCAM[16] 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 4.8% 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. In the two cases, the share of electricity in final energy is expected to be 63% and 81%, respectively. Nearly two-thirds of it is projected to be produced via solar PVs (including rooftop), implying an installed capacity of 4,800 GW in 2070 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

[16] Global Change Analysis Model, globalchange.umd.edu/gcam

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

An energy transition on the scale needed is not something that can be achieved by making a few strategic policy changes. It involves deep structural changes in different areas of the economy with consequential effects, all of which require policy actions on several fronts. Some of the actions are in the domain of the central government, others in the domain of the state governments, and some 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 Infrastructure and Augmenting the Electricity Markets

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 an important advantage as it can allow seamless transmission of power from one region of the country to another. However, this will require new interstate transmission infrastructure[17] ("green corridors") to be built to facilitate the electricity transfers needed. The 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.

Substantial investments will also be needed in storage capacity. The renewable generators themselves could undertake half of this which will help in evening out the supply over a longer period and reduce the need for larger evacuation capacity. Transmitters and distributors could provide about a third of the capacity. This will help in improving the utilisation of existing transmission assets.[18] Behind-the-meter storage mostly with commercial/industrial consumers could make for the rest of the storage capacity. It will help

[17] 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.

[18] Many existing transformers are overloaded during peak generation hours and would need to be upgraded. 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.

with storing decentralised generation (i.e. rooftop solar) and improve reliability.[19] Appropriate pricing mechanisms that reflect the supply costs of electricity could provide the necessary incentives for the different players to invest in storage (e.g. time-of-day metering with sufficiently large variation for commercial users).

Our electricity markets need to be made more accessible to allow for power trading across regions which will lead to better price discovery.[20] Further, India's energy exchanges would need to get more flexible in order to trade large amounts of renewable electricity as their generation increases. The addition of an integrated futures market for renewable and conventional power at the exchanges could also pave the way for market-based reforms in electricity dispatch.[21]

Financing the New Energy Infrastructure

The investments required for the energy transition are massive. IPCC/McCollum et al. (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.[22] 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 be financed from the central and state government budgets. 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 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 as this is a critical weakness at present, but it is important to put the scale of international support needed in the context of the total effort.

The Paris Agreement had incorporated the international community's commitment to provide financial support to developing countries for the transition. A global compact on

[19] Bidirectional charging or Vehicle-to-Grid technology for EVs could be a solution to behind-the-meter storage in the future. EV owners could offer the vehicle batteries to store and supply power back into the grid when the vehicles are not in use.

[20] See for reference Ryan 2021.

[21] Market-based economic dispatch of electricity could enable trading of all sources of electricity through the exchanges without requiring PPAs. Such a reform could lower the cost of power procurement and reduce the variable cost of electricity. See draft proposal from the Ministry of Power (India) at powermin.gov.in/en/announcements (Jun 01, 2021). Liquidity issues of the discoms can get in the way of such reforms.

[22] In 2020 US$.

climate change was agreed upon which assured that international finance would be scaled up to $100 billion per year by 2020. 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.

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

The G20 meeting is the place to set realistic targets for international bilateral and multilateral support. Bhattacharya and Stern (2021) have argued for 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.

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)

As noted above, it will not be possible to mobilise private investment into renewable energy unless the financial condition of the discoms is improved. This is clearly the elephant in the room since it poses too large financial risk to attract private investment.

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 Ujjawal Discoms Assurance Yojana (UDAY) 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 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 fourth reform effort, the Reforms-based and Results-linked, Revamped Distribution Sector Scheme. The scheme envisages financial incentives to state governments conditional on performance improvements. It remains to be seen whether the new scheme will be more effective.

Improving the financial condition of the DISCOMs is entirely in the realm of the state governments and they have to be willing to take strong action which may not be politically popular. They must 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 important to explain to the public that it is inherently unsustainable.[23]

The states also need to strengthen the regulatory authorities by equipping them with adequate expertise to fix viable tariffs and empower them to ensure compliance.[24] 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, for example, the private licensees that took over the power distribution in Delhi in 2002 have reduced AT&C losses from over 50% then to 9% by 2018-19 (NITI Aayog/ RMI/ Regy et al., 2021). This would be particularly useful for industrially and commercially important cities. This approach may attract political criticism 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 by pointing out that the resources generated by such a scheme (which could be in the form of a

[23] 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.

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

revenue share) can be used to subsidise the public sector distribution system to manage distribution in rural areas and smaller towns.

Technology can also support other reforms that can help improve viability. *Aadhar* or the unique identity number can help to target subsidies to the poorest households through direct benefit transfers instead of relying on low electricity tariffs which benefit all groups. This is happening, for example, in domestic LPG distribution under the PAHAL scheme of the Govt. of India. Similarly, digital transformers 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.

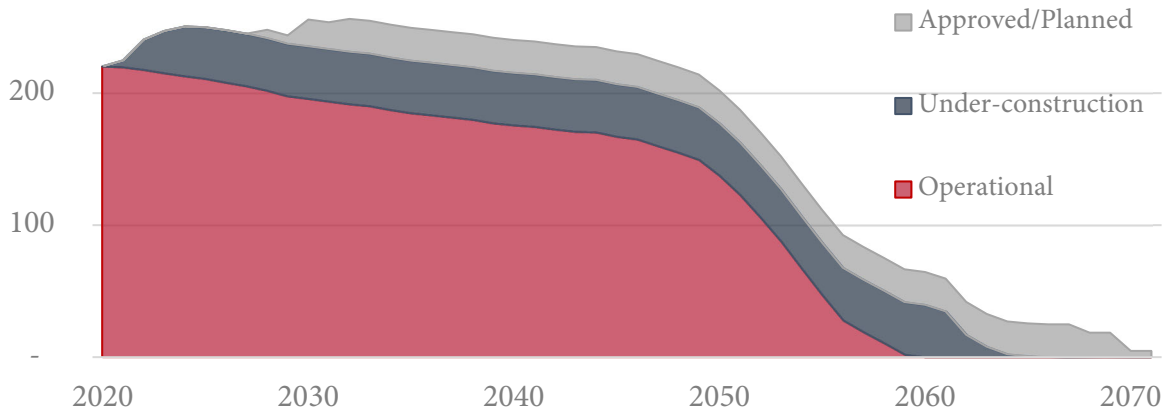
Some of the regulatory provisions which have been introduced to promote the use of renewables may need to be rethought. For example, discoms are obligated to purchase all electricity that is generated by the contracted renewable power generator, forcing the discoms, in times of low demand, to back down coal plant operators with whom they have power purchase agreements and requiring them 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 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 Energy Monitor, Coal Plant Tracker (endcoal.org/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 on which construction has not begun could be dropped. A strong case can be made for earlier retirement of older plants, which are less efficient and also more polluting. This would provide room for higher utilisation of newer more efficient plants which are currently underutilised. Ghosh and Sindhu,[25] citing a recent CEEW study,[26] point out that 50 GW operational thermal 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 (NOx) and particulate matter (PM10, PM2.5) adding to air pollution in the country. Cropper et al. (2021) find that an estimated 78,000 deaths in 2018 can be attributed to PM2.5 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.[27]

[25] 4 key steps to decommissioning coal-fired power plants, World Economic Forum, 12-Aug-2021 (weforum.org/agenda/2021/08/4-key-steps-decommissioning-coal-fired-power-plants)
[26] Ganesan & Narayanaswamy (2021)
[27] The Ministry of Environment (India) 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. Initially, this may only lead to lower coal imports but it will in due course have to be reflected in phasing out of domestic coal production. The coal-producing states are in general low-income states. This will mean a loss of employment in coal mining and the many businesses supporting the 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 railways since the movement of coal is a source of high earnings for the railways, enabling 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. 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 indications 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 about 10%,[28] but 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 electrification in this area. 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.[29] 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.

Fiscal incentives are another option. Government of India's FAME II[30] 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.

[28] BNEF/McKerracher et al., 2021.

[29] 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.

[30] 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 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 existing component manufacturers, pivoting to battery components manufacturing, assembling and recycling could be an option. Of course, while encouraging battery production[31] is essential, we must also invest in research and development. This is an area where technology is expected to change rapidly and it will be important to avoid getting locked into dated domestic production technologies that are shielded from import competition.

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.[32] 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.

[31] The government plans to achieve 55 GWh of domestic battery manufacturing capacity and has introduced production linked incentive (PLI) schemes to support manufactures/investors.

[32] 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 145 thousand charging stations may be needed (assuming 20 charging points per station. Business Standard, Sept 07, 2021, business-standard.com/article/opinion/rolling-out-the-ev-charging-network-121090701693_1.html). The requirement of urban land for such an expansion would be difficult to meet.

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 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%) (MoEFCC, 2021). 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.

The scale of solar power capacity anticipated[33] will require acquisition of large tracts of land in rural areas. Since the average farm landholding size of rural households in India is small,[34] it will be difficult for private developers to acquire the requisite amount of land on their own. State governments would need to provide necessary assistance to facilitate land acquisition, taking care of the interests of farmers.

As land gets diverted to solar power generation and also urbanisation, a much greater thrust will be needed on raising agricultural productivity for food and biofuels production. This is especially so because the adverse effects of unavoidable climate change will lower agricultural productivity. Land productivity in India is much lower than its potential and there is great scope for improving productivity through much more scientific use of water, and use of better seeds and production techniques.

A full statement of the policy agenda needed in the agriculture and land-use 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 analysis presented in this paper has implications for the strategy we should adopt at CoP-26 in November. It suggests that we need to depart from the traditional position we have adopted so far in climate change negotiations, but the new approach need not undermine our development objectives. The main elements of the strategy are spelt out below.

[33] See for reference van de Ven et al. 2021.

Why 2050 as the net zero date is not the right target

Much of the discussion in the run up to CoP-26 has focussed on getting countries to adopt 2050 as the target net zero date. As a slogan this has captured the imagination of the public and NGOs in industrialised countries and is now increasingly being advocated by the corporate world. However, it is not necessarily the best way of structuring a global agreement on climate change.

The 2050 date is derived from the IPCC (2018) assessment that if the global temperature rise above pre industrial levels is to be limited to +1.5°C by the end of the century, the remaining carbon budget for the world is limited, and the global CO2 emissions must start to decline at the earliest and reach net zero by around 2050. This conclusion, though valid for the world as a whole, does not necessitate all countries to reach net zero at the same time.

Ideally, we should be able to apportion the carbon budget available to the world across countries in a manner that is deemed to be fair, reflecting the concept of "climate justice" that is built into the UNFCCC by way of "common but differentiated responsibilities" taking account of "respective capabilities". If we could agree on such carbon budgets for each country, the mitigation strategy should focus on ensuring that each country adopts an emissions trajectory that keeps its cumulative emissions within its respective carbon budget. The date of net zero in such a case would not matter. Agreeing on a net zero date by itself, without specifying the trajectory makes little sense because a convex trajectory that achieves net zero by the target year would emit a great deal more emissions than a concave trajectory.

As a practical matter, there is little chance of CoP-26 reaching an agreement on the criteria for determining each county's fair share of the carbon budget. The best we can expect from CoP-26 is a continuation of voluntary commitments, with individual countries indicating their enhanced INDCs, similar to CoP-21 in Paris. If countries announce net zero dates without an explicit emissions trajectory, an implicit trajectory will have to be inferred from the net zero dates and their current emission levels. Since these trajectories will not be derived from an explicit country carbon budget, there is no guarantee that they will be consistent with our global warming target.

A better approach would be for each country to indicate the actions it is prepared to take through a new set of INDCs and also indicate the emissions reduction trajectory resulting from these commitments. CoP-26 could ask the IPCC to compute the implications for global warming of the proposed trajectories combined and the results of this exercise could be reviewed subsequently in 2023, which was when the global stocktake was originally scheduled, to see what modifications are needed. If it turns out that the total emissions generated exceed the levels consistent with the global warming target, it will be necessary to modify the country specific targets emerging from the voluntary exercise. It then makes sense, in the interest of

climate justice, that advanced countries bear a larger brunt of adjustment. They should aim to reach net zero well before 2050 – Germany, e.g., has already indicated 2045 for itself – while developing countries are allowed to get there later. China and Indonesia have mentioned 2060.

Should India offer an Emissions Reduction Trajectory?

Offering an emissions reduction trajectory would represent a major departure from our traditional stand in climate change negotiations. We have thus far resisted accepting any obligations to reducing emissions on the grounds that this would compromise our development objectives. However, as pointed out earlier in this paper, a departure is now justified because technological developments make it possible to adopt an energy pathway that relies on a combination of electrification of energy use wherever possible and a shift to renewables, notably solar and wind, to meet all additional needs of electricity while also progressively phasing out current fossil fuel-based energy sources.

A review of several studies on the scope for decarbonising India's development in this paper suggests that substantial emission reduction is possible. Any trajectory projecting thirty to forty years ahead is bound to be tentative because of the many uncertainties involved. However, the studies reviewed do suggest that India could peak its emissions in the next decade and get to net zero sometime between 2065 and 2070. We could do better than this if some of the technologies currently under development become commercially viable earlier than expected.

Any decarbonisation pathway incorporated in international agreement has to be determined as part of a national energy plan. This is best done by the NITI Aayog reviewing the many quantitative studies of emissions trajectories that exist (some are reviewed in this paper), consulting with all stakeholders including state governments, and coming up with an acceptable trajectory. This trajectory could then be the basis of our offer, provided other major countries make commensurate commitments.

Establishing Shorter-term Decarbonisation Targets

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

The best short term target India could offer would be a planned phasing out of coal-based capacity. We have already announced ambitious targets of adding 450 GW renewable electricity generation capacity by 2030, going beyond what was promised in Paris. This would have to be scaled up further in subsequent decades. This expansion of renewables implies

phasing down of coal use in power generation. The extent to which such an expansion would allow scaling down of coal-based electricity has not been quantified but it is bound to be substantial. We could offer peaking coal-based capacity before 2030, followed by reducing the total operational capacity to some fraction of the peak by 2040.

International Financial Support

The energy transition needed for reducing emissions on the scale required will call for massive investments. As cited earlier in this paper, the IPCC has estimated that about $600 billion per year will be needed as additional investment in the energy sector in developing countries. India alone will require about $150 billion per year or about 2% of GDP between now and 2050. These estimates are much larger than the amounts of financial assistance earlier agreed, i.e., the $100 billion per year climate finance from advanced to developing countries, to be reached by 2020.

The $100 billion promise was made in 2009 when the full scale of the energy transition needed was not realised. It remains unfulfilled and the failure on this count will be criticised by developing countries including India. However, the more important point to note is that the scale of what is actually needed for the energy transition is much larger. We should, therefore, now work to get CoP-26 evolve a new compact reflecting the larger amounts of financial assistance that are necessary.

The full amount of $600 billion per year cannot be expected to come just from international financial assistance. Some will have to come from domestic sources both public and private and some from international private flows responding to market conditions and investor perceptions of risks and returns. The third component of financing is bilateral and multilateral assistance and it is here that CoP should focus. As mentioned earlier, doubling bilateral assistance and trebling multilateral assistance by 2025 could yield an additional $200 billion from these sources alone. Multilateral flows can take the form of direct finance for energy projects or mechanisms of risk mitigation that would stimulate private flows.

The forthcoming G20 meeting is the critical forum for getting an agreement on the scale of multilateral financing needed and how it can be sourced from the various multilateral development banks in terms of additionality to existing flows. The actions needed to deliver this amount in terms of capital expansion or other innovative guarantee mechanisms can then be pursued in the executive boards of the concerned institutions to be ready by the time of the stocktake in 2023. A part of the new $650 billion SDR created by the IMF, for instance, could be used for this purpose.

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 represents a major change from the traditional approach we have followed so far because it implies acceptance of an emissions-reducing trajectory as part of a new global compact in which other countries take commensurate steps to reduce emissions and the international community makes credible commitments to provide financial assistance. There may be some domestic resistance to making such a major break from our past position, but what is proposed is consistent with the fact that technological developments now make it possible for us to offer a trajectory which peaks emissions in the next decade and then reduces them to net zero by some time around 2065–2070, without compromising on our development objectives.

The new strategy would signal to the world that India is determined to fight climate change and generate a global compact that is very much in our interest and also in the interest of the world.

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