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DECARBONISING INDIA ISN'T SEQUENTIAL OR BINARY WITH "POWER SECTOR FIRST"

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List of Abbreviations

AR6	(IPCC) Sixth Assessment Report
BAU	Business as Usual
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CCTS	Carbon Credit and Trading Scheme
CEA	Central Electricity Authority
CUF	Capacity Utilisation Factor
DAC	Direct Air Capture
DisCom	Distribution Company
EV	Electric Vehicle
FDRE	Firm and Despatchable Renewable Energy
GDP	Gross Domestic Product
ICE	Internal Combustion Engine
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
L1	Lowest Bidder
LCOE	Levelised Cost of Energy
MACC	Marginal Abatement Cost Curve
NPV	Net Present Value
NREL	National Renewable Energy Laboratory (USA)
PLF	Plant Load Factor
RCO	Renewable Consumption Obligations
RE	Renewable Energy
REMIND	Regional Model of Investment and Development
RPO	Renewable Purchase Obligation
RTC	Round the Clock
tCO_2	Tonne of CO_2
ToD	Time-of-day
UNFCCC	United Nations Framework Convention on Climate Change
VRE	Variable Renewable Energy

Executive Summary

India has a commitment to net-zero greenhouse gas emissions by 2070, which will require emission reductions across sectors such as power, industry, transportation, and even agriculture/forestry. The question then becomes what the optimal pathway to do so is, while keeping in mind additional objectives of cost, energy security, resilience, jobs, etc.

Conventional wisdom states that countries can or should decarbonise their power sector first, given the low costs of clean energy solutions. Wind and solar are already very inexpensive, and even storage costs are declining rapidly. This generalisation turns out to be only partially true. Beyond just seeking the cheapest solution, there can be other trade-offs depending on whether we seek the fastest decarbonisation versus the greatest cumulative emissions reduction.

The Tail of 100% Decarbonisation is Expensive

This paper shows how there are strong non-linearities in decarbonising all sectors, including the power sector. Decarbonising some or even much of the emissions in the power sector may be inexpensive, especially compared to the historical default source, coal, but the tail of emissions is expensive to abate. While the power sector may decarbonise more and faster than other sectors of the economy, India should not lock into an unnecessarily early timeframe for zeroing emissions from the power sector.

India should have a graded plan that accelerates all low-cost emissions across sectors, a calculus that would have higher emissions reductions from the power sector in the short run, but should not treat non-power abatement as a subsequent goal. Because of the inherent variable nature of renewable energy (RE) and demand, even with "cheap storage" secure 100% decarbonisation is expensive. The real need is not cheap RE (or storage) considered as a standalone silo, but using system-wide analysis to determine the lowest cost portfolio of generation, including any judicious use of fossil fuels.

Policy Implications and Recommendations

The current plans for the upcoming carbon credit trading scheme (CCTS) exclude the power sector. Were it to be included, it would put greater pressure on the power sector based on $/t$CO_2$ (US dollar per ton carbon dioxide) in the near term, but after a point, the costs of decarbonising the power sector would grow non-linearly. There is also a range of complexities around path dependency that complicate a narrow focus on the power sector "going first" in the journey of decarbonisation, ostensibly to give some breathing space for industry and hard-to-abate sectors.

There are several recommendations for more cost-effective decarbonisation for India. Firstly, there should be accelerated electrification of other sectors, especially industry and transportation. Secondly, India should emphasise non-supply options such as energy efficiency. In particular, these should focus on electricity grid dynamics such as time-of-day (ToD). The new need will not be saving energy per se but saving energy at the right time and place, especially during the evening peak. Thirdly, planning should focus on the Pareto 80:20, the lower-hanging fruit, which can reduce much of the emissions without worrying about a full zero in any given sector. This aligns with the COVID-inspired "flatten-the-curve" approach, which reduces but delays the peak, lowering total emissions or costs while extending the timeline for zero. In India's case, the ultimate timeline for zero would be 2070, but sectoral zeros need not be much sooner. Fourthly, the energy transition will require detailed, transparent, and granular modelling—assumptions matter, as does the political economy (including how stakeholders respond). It is possible that modelling would show that the power sector does more early heavy lifting for decarbonisation, but that should be an outcome of the analysis, and not a policy constraint. Lastly, we will need to innovate and evolve new instruments for incentivising the right types of instruments and investments. In the power sector, a simple example is ToD pricing, which is missing for most users today.

1. What's the Objective?

Conventional wisdom roughly indicates that decarbonising the power sector is the cheapest method of decarbonisation and should go first over other sectors. The former is mostly true *on average*, but the latter is only partly true. The reality is that the decarbonisation trajectory is not linear or sequential, and a lot of decisions on how we should "best" or "optimally" decarbonise depend on a range of choices and value judgements. Most importantly, is the objective the cheapest, fastest, or greatest *cumulative* decarbonisation?

India has committed to achieving net-zero emissions by 2070, along with its 2030 targets for energy intensity improvements and other enabling steps (United Nations Framework Convention on Climate Change [UNFCCC], 2022). However, what this does not tell us is the cumulative emissions until 2070 (or 2100, the date for many modelling exercises). Most countries that have announced net-zero targets by 2050 have also refrained from stating their cumulative emissions, even prospectively, but some of them have five-year targets or interim points, such as the UK.[1] But what the best path towards decarbonisation is depends on whether there are any restrictions on emissions along the way, either cumulative or peak.

China is an interesting example, not only because it has a similarly sized population and a coal-heavy economy. China has announced a date of net-zero emmissions by 2060, 10 years before India's target. But if we examine the emissions trajectory, India is more than 30 years behind China. China has also announced a reduction of 7–10% by 2035 from the as-of-now-unknown peak (Xinhua News Agency, 2025). India's emissions may still not have peaked by then.

For India, it may be "rational" to have a high peak of emissions and then to allow them to decline by 2070. In fact, it could even have a measurably delayed peak, as long as it is able to handle a more dramatic drop in emissions near the end.

If plans call for more fossil fuel power in the short run, some analysts worry about stranded fossil fuel costs. There are two counters to that view. First, the sunk cost of fossil fuels is not as high as one might imagine. For a 40-year physical life of a coal plant, the economic life is usually taken as 25 years. The debt is generally paid off early. Add in high discount rates (which adjust for time-value-of-money preferences, where future expenditures are worth less in the present), and any future stranded costs have a much lower net present value (NPV). The second complexity comes from economic growth—if economic growth exceeds emissions growth (or, rather, required decarbonisation rates), the ability to handle the costs of decarbonisation is lower in terms of

[1] It is unclear what legally binding means; e.g., while the UK has binding targets, what happens if they fail to meet them? There is nothing preventing a country from withdrawing from any obligation, either due to changes in legislation, or walking out of international treaties and commitments, e.g., the US pulling out of the Paris Accord citing unfairness or Canada withdrawing from targeted emission reductions under the Kyoto Protocol due to financial implications of compliance, along with domestic pressures.

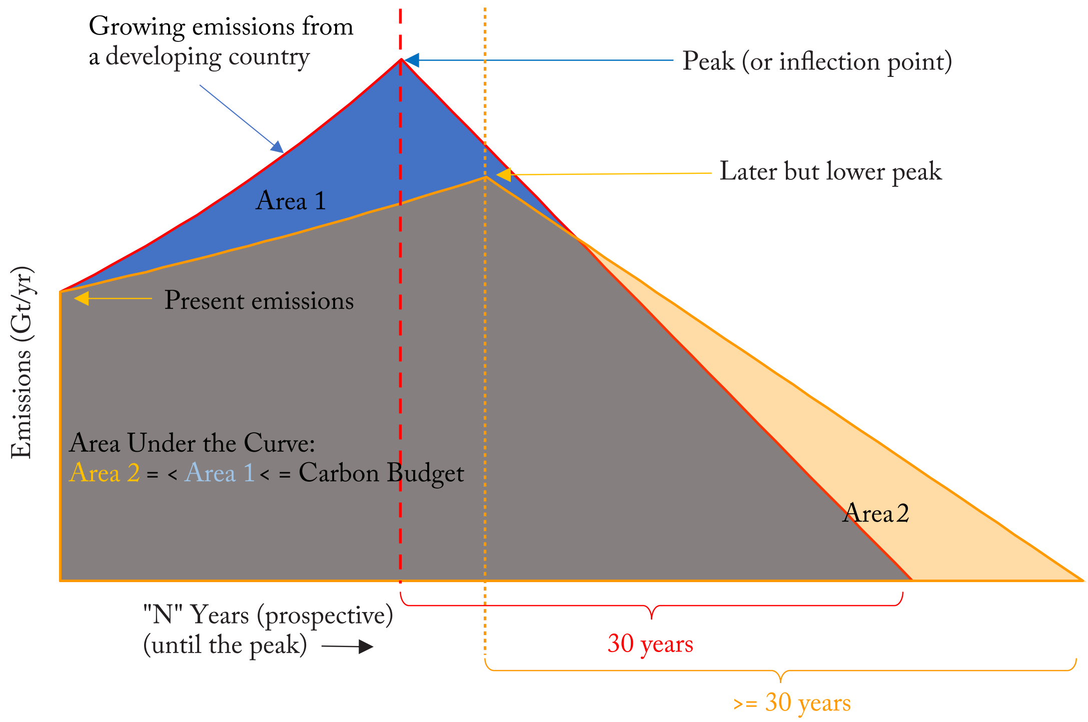
fraction of gross domestic product (GDP). This simplification ignores the time periods for such efforts or adaptation costs and also assumes that the "date of zero" is the only marker, not cumulative emissions. It also ignores any need for future negative emissions to overcome excessive earlier emissions or failures to reduce emissions.

This is linked to the Environmental Kuznets Curve worldview, where countries first get richer and dirtier and then become rich enough to become cleaner—an upside-down U-shape.[2] This is not a "law", and India, like some others, is trying to leapfrog, but it is also true that there is a very strong correlation between being developed and subsequently decarbonising from a high peak. On the other hand, simply waiting until later and letting emissions rise will place a higher burden on decarbonisation down the road, and if there are time constraints, it would lead to higher costs. A mixed plan of some relatively early decarbonisation around an economic growth strategy is likely to be optimal.

There are no indications that India is chasing such "rationality" of allowing a high peak of emissions, but it is also true that deep decarbonisation of any sector entails a premium, more so beyond the lower-hanging fruit of efficiency, fuel switching, and variable renewable energy (VRE; without storage). As Tongia (2021) has shown, an artificial focus on the "date of zero" can lead to higher cumulative emissions and/or higher costs. Instead, for countries like India that are low emitters and have lower human development, the focus should be on early aggressive reductions, even if that leaves a small tail of emissions. This is the COVID concept of flatten-the-curve, where the area under the curve can be the same (or lower), applied to emissions (Figure 1). Similarly, spreading out the timeline for decarbonisation a few years—with total emissions the same or lower—lowers costs as technology improves over time.

[2] An Environmental Kuznets Curve has per capita income on the x-axis and pollution or environmental degradation on the y-axis. The grouping of countries typically approximates an inverted U-shape or a bell-curve shape. This suggests that if there is a trajectory of rising wealth, then as countries get richer, their pollution rises, but then after a point, they get "rich enough" to lower their pollution. This is only a hypothesis, and countries are attempting to leapfrog through the peak of high pollution.

Figure 1: Flatten-the-curve to Focus on Cumulative Emissions Over Time at a Lower Cost



Source: Tongia (2021).

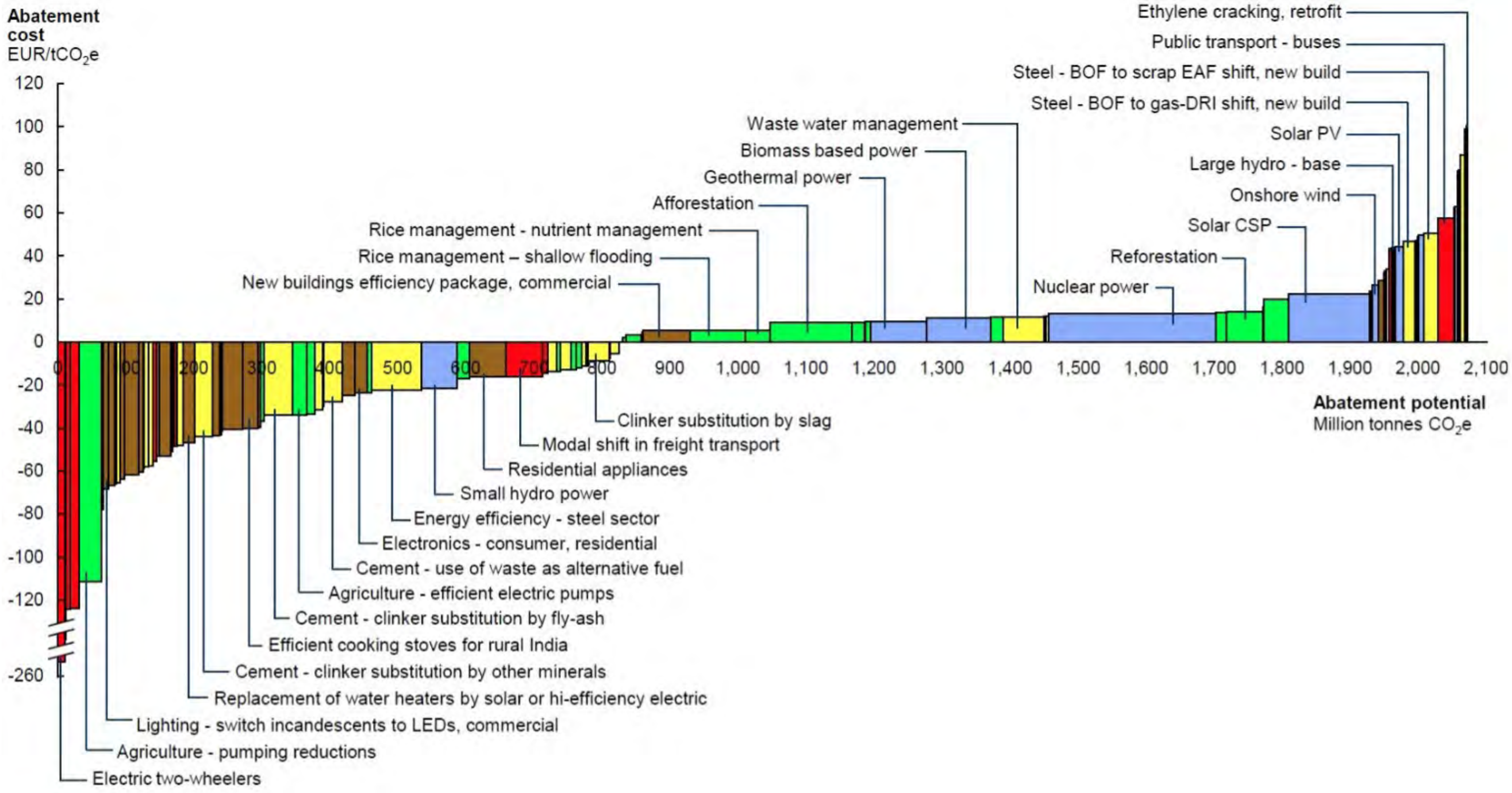
Note: This shows two trajectories of emissions with the same area under the curve. Normally, one expects about 30 years from peaking till zero, plus or minus, depending on the financial lifespan of infrastructure and other choices. This figure emphasises both the limits of an artificial focus on the "date of net zero" for developing countries, and the reality that a smaller tail of emissions can be cost-effective given the continued improvements in technology over time (and rising wealth, meaning affordability, in developing regions).

For decarbonisation, this can mean lower total costs, given technology costs continue to decline in the future—and the poor, low-emitters deserve that option. The learning-curve costs for early adoption of deep decarbonisation solutions should be borne by high emitters today (a measure that correlates to, but is not entirely equal to, richer countries; China is by far a high emitter and is at the cusp of World Bank classification as a high-income country).

2. Decarbonising is not Equal in Cost

Decarbonising the entire economy means covering all fossil fuels across many sectors. McKinsey popularised the Marginal Abatement Cost Curve (MACC), shown for India in Figure 2 (Gupta et al., 2009). This shows the abatement (emissions avoidance) cost ordered by increasing cost per intervention, with the scope (size of potential) as the width of each bar.

Figure 2: India's Marginal Abatement Cost Curve (MACC) for 2030 (Costs Under EUR 100 per tCO_2)



Source: Gupta et al. (2009).

While the exact numbers may have changed for the 2030 estimate, and these do not cover very high-cost options (and thus miss a measurable fraction of required decarbonisation), this shows the heterogeneity across the economy. Such curves emphasise the variable cost of decarbonising different aspects of the economy.

These curves have several implications and limitations. First, the stacked costs showed how some things were cheaper—these became mantras for "going first." In fact, for some forms of decarbonisation, especially VRE, the costs are negative (compared to business as usual [BAU]), a fact the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report (AR6) emphasises for wind and solar energy (Figure SPM.7, IPCC, 2023). But in reality, these are the new BAU—people would build wind and solar even if climate change did not exist. Second, the graphs typically examined one sector as homogeneous—hence the flat steps per sector. Third, the calculations are static calculations of BAU versus non-carbon options and ignore dynamics or path dependencies. [3] The latter are especially critical when we consider the large capital costs of infrastructure, after which the marginal costs may be lower.

However, there are huge non-linearities in decarbonising any sector. For the cement sector, as an example, the ultimate solution might be carbon capture and storage (CCS). For the steel sector, secondary steel can be the lowest-emissions option, but that requires the availability of steel for recycling. In contrast, if more steel must be produced from ores, this may require green hydrogen and electric arc furnace-based steel. However, in the interim, there are also options of higher-efficiency plants and process improvements through existing technologies. There are also huge differences across existing steel plants—the calculus is inherently different for new builds. Retrofits vary in cost and efficacy based on plant vintage and design.

Due to the complexities of technology choices, evolution, learning curves, expected duty cycles, and up-front investments, we cannot separate the answer to decarbonising "what" and "by when" independent of what the objective function(s) (lowest cost vs fastest vs greatest cumulative reductions) is.

For mobility, such as four-wheelers, electric vehicles (EVs) are viewed as the solution. While it is true they have a pathway to zero emissions, in the near term, an EV is similar in terms of CO_2 emissions compared to a good hybrid internal combustion engine (ICE). This is because of the high carbon intensity (g-CO_2 per kWh electricity) of the Indian grid at present. While the grid is getting greener, the challenge of ToD—that is, when you charge an EV—is critical (Das, 2024), more so given that most of India's RE growth is coming from solar power. Even worse, India's swing producer for electricity—the source that produces more or less in response to short-term changes

[3] A simple example of path dependency is whether a country should build out a natural gas network, especially to replace coal. This lowers emissions, especially compared to coal, but can never get to zero. However, once built, the marginal cost of gas falls. This path dependency is exacerbated when we consider what is the benchmark. When this original graph was made, the cost of RE was much higher than today. But all industries worldwide have been improving their efficiency through innovation, learning, and new solutions—what is "incremental" or "additional" remains a nuanced accounting or framing exercise.

in demand—remains coal in the near future,[4] and adding a unit of coal power at the margin (i.e., incrementally) has much greater emissions than the average emissions of the grid. Unfortunately, a lot of calculations in literature and planning documents rely on average emission factors, instead of ToD-linked marginal emission factors.

If the objective is to reduce a modest amount of emissions, moving from a normal ICE to a hybrid EV might be cheaper than an EV for mitigation, more so for consumers who do not drive a high volume of kilometres per year. A hybrid can save around 30–35% of emissions per kilometre and have a higher payback per tonne of CO_2 removed ($/t$CO_2$ abatement cost), but will never have a path to zero emissions. However, a market mechanism would prioritise these, since most markets ignore lock-ins, path dependencies, etc. An ICE engine may only have a lifespan of around 15 years or a maximum of 20 years, so it would still be compatible with 2070, but a new steel plant may last 50 years. On the other hand, starting the journey towards EVs accelerates the learning curve as well as signals to the rest of the ecosystem (especially charging infrastructure), and can also ensure export competitiveness. Given the electricity grid is getting greener, the cumulative emissions with EVs may end up lower, but that is only if we consider cumulative emissions instead of shorter-term cost–benefit calculations.

Given the high growth ahead for India and the fact that India has more time than higher-emission countries to reach zero emissions, this emphasises the need for flexibility in achieving the ultimate goal. Thus, having sectoral caps and early dates of net-zero emissions (where the power sector comes first) is unnecessarily constraining, more so if we recall a flatten-the-curve approach that emphasises low-cost cumulative emissions. It is also a truism that the tail of emissions is always expensive, as MACCs show. Given that there is always a learning curve for new technologies, that premium should be borne by high-emission countries.

3. Decarbonising the Power Sector

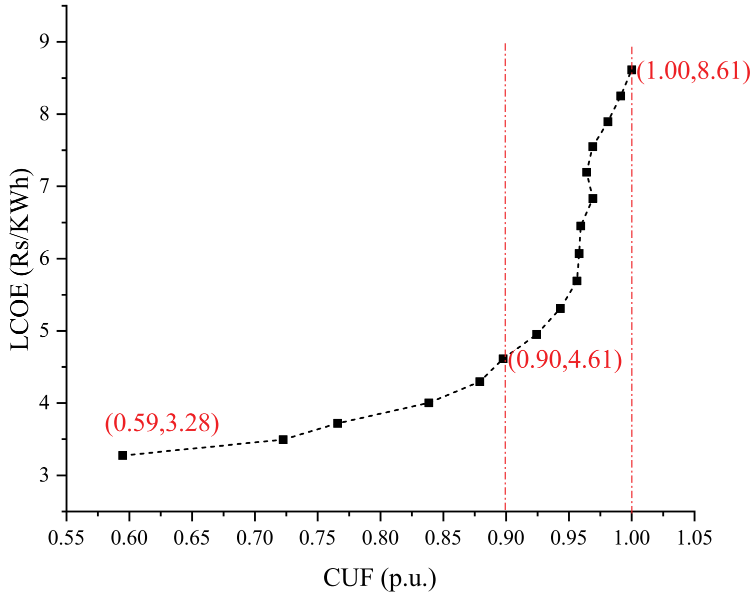
RE, like wind and solar in India, is quite cost-attractive, and there are now bids with storage as well that appear competitive, but the challenge becomes one of apples-to-apples comparisons. Bids for RE labelled "round the clock" (RTC) or "firm and despatchable RE" (FDRE) are often nowhere near 24x7. They have some output beyond "vanilla" solar (VRE solar), but do not have nearly enough storage (or oversizing) to provide true 24x7 power. Stated another way, these bids are firmer than VRE, but not fully firm (available on demand all hours of the year, i.e., despatchable).[5]

[4] VRE is a "use-it-or-lose-it" resource, and hence, it is never a swing producer. One does not produce more solar power just because demand increased. This remains true until the point one has surplus RE which is being curtailed (throw away), but that is unlikely to happen during the non-solar hours, at least for years if not decades.

[5] State Load Despatch Centers (also spelled Dispatch in some countries) procure power, both in advance and in real-time, to match demand. Ostensibly, they start with the cheapest power first, but there are technical and practical limitations that place restrictions on so-termed "economic despatch." For example, coal power plants have a technical minimum they cannot operate below, and VRE may be erratic and unreliable.

Ongoing analysis of these technologies at the Centre for Social and Economic Progress (CSEP) shows that as there is an increase in the hourly firmness of RE + storage, the costs rise non-linearly, with a hockey stick of costs after a point. This is because one has to charge the battery, which needs RE, which varies in output seasonally, especially for wind but even for solar. This is compounded by seasonal demand changes, as Vijay and Tongia (2025) show, which means we do not need the battery equally in full every day (let alone twice a day, which some current bids assume for paper calculations of costs).[6] Figure 3 shows one sample system-level calculation for India (subject to a range of assumptions, and thus useful for showing trends more than specific numbers).

Figure 3: Electricity Decarbonisation Cost vs Firmness (Hourly Minimum Output, Translated to Annual Generation) Based on Good Renewable Energy Sites



Source: Vijay and Tongia (in press).

Note: This figure shows the cost (levelised cost of energy [LCOE])[7] *vs annual capacity utilisation factor (CUF)*[8] *for a mix of solar, wind, and storage, assuming very good wind profiles and solar output. The annual CUFs are translated from increasingly stringent hourly requirements. If we assume more typical RE generation profiles across India instead of the best wind sites, the costs for 100% decarbonisation increase in the order of 50% to cover a mix of oversizing RE and additional storage.*[9]

6 Even if you want a second cycle per day, how would you charge it? Overnight charging for morning use cannot be from solar.

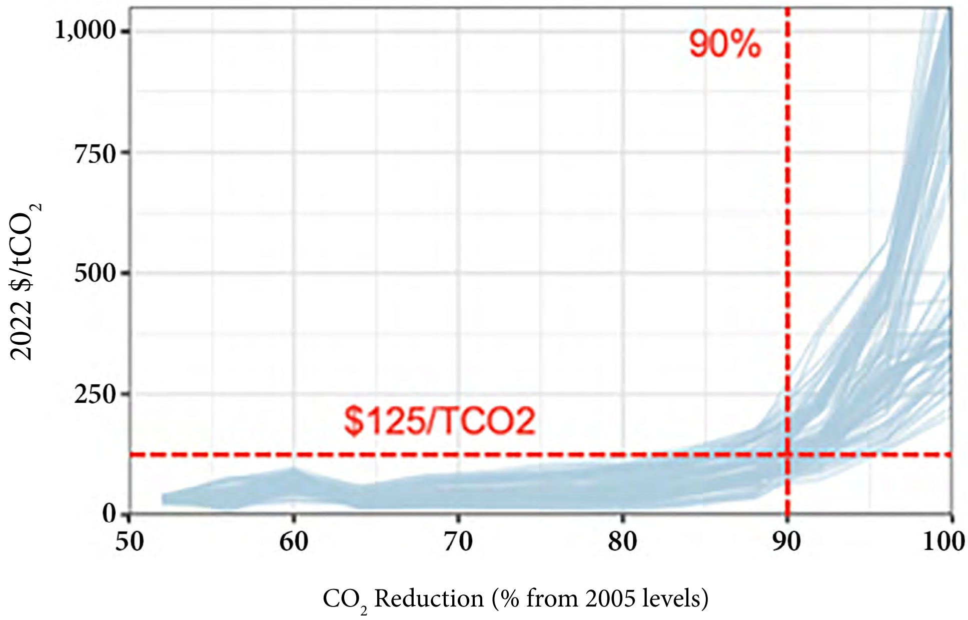
7 Levelised cost of energy (LCOE) is the calculated per unit energy cost in present value terms, discounting future costs but ignoring system-wide costs (e.g., costs of transmission or the need for more balancing capacity to offset RE's variability).

8 Capacity utilisation factor (CUF), also termed Plant Load Factor, or PLF, for supply, is the fraction output in a time period compared to 100% output based on capacity. A 1 kW solar panel cannot produce 24 hours output in a day (or 24 kilowatt-hours). Typically, daily outputs from large solar farms average under 6 kWh per kW of panel, or 6/24, for a CUF of 25%. In contrast, coal power plants can operate at a CUF of 90% or more.

9 The non-monotonicities (kinks, where costs appear to fall with greater decarbonisation) are due to the individual optimisations, which thus ignore any path dependency/scaling from a specified base or prior level. These annual outputs are a conversion from hourly firmness, and that is also a reason for the non-monotonicity. Just like the EV vs hybrid internal combustion example, some interim levels of decarbonisation solutions for a given level of decarbonisation are cheaper, but cannot be scaled further to full zero.

These are the total costs for all the units of electricity, and thus, the marginal costs become very high after a point. Converting to $/t$CO_2$, marginal costs cross many hundreds of dollars at the tail. For the United States, with a more flexible grid with more gas than coal, the estimates are also high, as shown in Figure 4 (multiple simulations).

Figure 4: United States Grid—Marginal Abatement Cost



Source: Liebreich (2025), as taken from underlying 2022 publications of the National Renewable Energy Laboratory (NREL) and other work by Liebreich Associates.

This means we should aim to have a hybrid approach to decarbonisation. The power sector can start more aggressively, but that should only be up to the point where its mitigation costs are at par with other sectors (as well as any path-dependency adjustments). We should plan for a tail of emissions from the power sector to continue beyond 2050 (e.g., as modelled under the Integrated Assessment Model of Regional Model of Investment and Development [REMIND], Patel [in press], which shows that power sector peaking can happen as soon as the early- or mid-2030s in some scenarios, but even then, power sector emissions in 2060 remain at an estimated 14% of present levels). In parallel, we should not wait to decarbonise other sectors later, but rather start with efficiency, fuel switching, and more, especially for new builds. However, it is true that the power sector can, and likely will, deliver more decarbonisation earlier than many other sectors. As we electrify end use, those sectors will also have lower emission intensity as the power sector decarbonises.

4. What Does Partial Decarbonisation Look Like?

Figure 3 shows how a measurable fraction of emissions can be decarbonised relatively cheaply, using a benchmark of new coal in the order of more than INR 5/kWh (ignoring some recent higher bids—this space is no longer liquid). Even if we have more average-performing wind profiles instead of just the best locations, there is still a reasonable fraction that can be decarbonised cheaply.

But then what? What do we do for the rest of the demand?

This is where an overly simplified or LCOE-based approach fails at all-inclusive system-level analysis. Several researchers have highlighted the limits of using average costs, typically shown as LCOE, where, instead, a portfolio or system-level approach is important (Moraski et al., 2025; Tongia, 2022).

It is not as simple as saying that RE + storage can be blended to achieve Rs 4.5/kWh, which can cover supply equal to demand for 85% in optimistic scenarios, with 15% of coal at its own benchmark price (or even Rs 6/kWh). That is because there are system-level implications of any generation source, which LCOE extrapolations miss.

For starters, any generation source operating at low utilisation factors (capacity factors or plant load factors [PLF]) will have high fixed costs per unit of electricity. Then there are operational issues in terms of starting/stopping, ramping, minimum output, and part-load efficiency penalties. No one would build a coal power plant to operate at 15% capacity factor, even if it could technically operate on such a schedule. In other words, any partial supply creates system externalities that have to be carefully calculated.

To show how the total hours and LCOE are not appropriate, consider two hypothetical residual demand profiles after RE (or RE + limited storage). In one case, assume we had two hours of shortfall every day, which is 730 hours/year, or a bit under 10%. But say these same 730 hours were sporadic or concentrated in a few weeks (which is what happens post-monsoon when the winds change and die down, what in German is the *dunkelflaute*, or "dark doldrums", periods of low RE). If one simply calculated fixed cost amortisation based on the hours of generation, that would give a gravely misleading answer. Two hours a day could be ideal for a two-hour battery, used in full and equally, every day, but that would fail miserably in the second scenario. On top of this, we have RE supply variability, demand variability, and a range of other technical issues. Forthcoming CSEP studies quantify such issues—from LCOE to system level—for "pure RE + storage" solutions.

The exact details of the blended cost of RE integration over time are evolving and highly complex, with a range of uncertainty. But it is recognised worldwide that as VRE's share grows in the mix, its marginal value declines and its marginal cost of integration rises. In India, there are reports of significant curtailment (throwing away) of solar energy in October 2025, and power exchange prices routinely crash to near zero—and in Europe, they routinely drop into negative territory. Importantly, India plans to double solar power in five years, which suffers from significant overlap in output, unlike wind, which is more spread out.

One additional wrinkle in doing such calculations is the interplay between the power sector and other sectors—e.g., green hydrogen, EVs, and more. These impact the power sector, not simply by increasing the total demand in the sector, but by changing demand profiles (shapes) and impacting the costs of incremental decarbonisation. Many industrial loads are inelastic and may even demand firm power (or raise intermediary storage costs, like storing green hydrogen). As of now, EVs disproportionately charge overnight. Electrifying such uses make decarbonising the power sector harder and makes simplified power sector "vs" non-power decarbonisation cost comparisons very complex.

This also becomes another reason to not have caps on power sector emissions—such emissions may still be worthwhile if they reduce greater emissions elsewhere. Any accelerated decarbonisation of other sectors through increased electrification raises pressure (and costs) on the power sector. As an example, the label of "green hydrogen" is not zero emissions (per current norms)—but it still may be greener than the alternative, namely, traditional "grey" hydrogen produced from natural gas (or even "blue" hydrogen where gas-based hydrogen is stripped of its production-linked CO_2 through carbon capture). Thus, India can still have lower emissions overall, even if power sector emissions do not fall as much.

This non-linearity of the tail can cross sectors. If we find that the power sector is easier to decarbonise than other sectors, the more other end-use energy shifts to the (cleaner/cheaper) power sector, the residual decarbonisation from other sectors will also be non-linearly more difficult.

5. The Power Sector is the Key to Growth and Decarbonisation

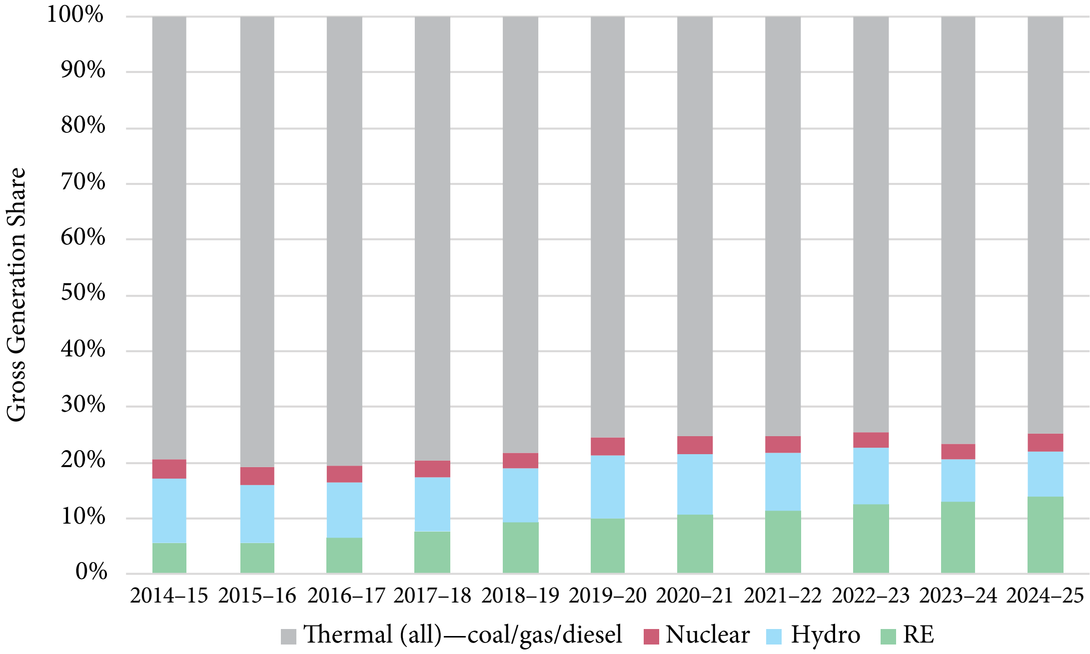
The historical focus on power sector *capacity* is becoming secondary—it is the output that matters. Given the low annual output (CUF or PLF) from RE, we need a lot more RE capacity. Adding 50 GW of RE is only equivalent to about 20 GW of coal capacity in terms of output. This is one reason India's installed grid capacity exceeds 450 GW, yet the instantaneous peak load met is only about 250 GW.[10] RE is capital-intensive, and this brings with it the challenges of not just finance but also of land, human capacity, and systems planning—which type of source do we need, by when, and where?

Figure 5 shows that despite record growth rates of RE in recent years, the share of RE in the power generation mix has improved, but not by much. Calendar year 2025 has seen low demand, which lowers coal's output, given that RE is "must run"—coal remains the annual-basis swing producer for India. Hydro is now part of the RE accounting for United Nations (UN) purposes, while RE shown in Figure 4 excludes large hydro. Through the bifurcation shown, we can see that much of the growth of RE (wind and solar) is offset by a falling share of hydro. Thus, the total "non-fossil" electricity supply

[10] India is one of the only countries that quotes gross electricity capacity and generation, instead of net (deliverable to the grid, i.e., "busbar"). The difference between gross and net is the so-termed auxiliary consumption, almost 7% of generation. The 250 GW of peak "demand met" is that delivered to states, and not the consumption by end-consumers, which would further lower by state transmission and distribution losses.

over the last five years has been largely flat.[11] It is worth noting that this is only the picture for the power sector—if we consider all primary energy economy-wide, the story is even more stark, in part because industrial use has had little RE use, and in part because biomass use has fallen as modern fuels have displaced it, especially in cooking.

Figure 5: Share of Utility Electricity Generation by Fuel Type (Excludes Captive Power or Imports)



Source: Central Electricity Authority (CEA) data (General Reviews, Monthly Executive Summaries).

The point remains—a less than 1% annual climb in the share of RE is not going to be nearly enough to meet the 2070 net-zero ambitions. As Vijay and Tongia (2025) have shown, the capacity targets for 2030 are not even enough to meet plausible growth in demand till then. In addition, there are inevitable longer-term shifts of energy across the economy into electricity. Lastly, while the current RE growth has been easier to manage, mostly VRE, deeper penetrations will require not just storage but grid revamps, including more transmission, dynamic pricing and control, and more buffers.

To accelerate RE, we have to undertake a series of reforms in planning. We are already asking for more RE through bids, but those bids are often lying unfulfilled—there is no power supply (offtake) agreement despite bids with low prices. This means that there is a need to address the planning problem and the distribution company (DisCom) problem to help scale RE. We will need not just more RE but more RE at the right time and place. Storage helps, but some storage bids are "successful" on paper yet lag in offtake or deployment schedule. The problem is that Indian bids are geared towards squeezing the cheapest bid ("L1" terminology), and not the highest *value proposition*

[11] FY 2025–2026 data will show a fall in the share for thermal, but that is because of muted demand (a wetter/cooler year), and coal remains a swing producer.

overall.[12] This requires things like factoring system-level costs (like transmission and reliability) but also recognising ToD pricing—at both wholesale and retail levels. The latter will take time, along with appropriate digital or smart meters.

The need to think about the hourly output of RE is not just about grid balancing. Europe's newest carbon border adjustment mechanism (CBAM) regulations indicate that they want hourly accounting of input electricity ("Physical Delivery of Electricity"), meaning the industrial producers cannot just grow their total RE and aim to comply "on average." The bottom line remains that India needs to grow RE not just in total, but in a manner that aligns with hourly demand. That is the next rung of the RE journey, going beyond VRE. Storage is an important tool in this mix.

6. A Flexible Approach Without Unnecessary Constraints

Scaling up RE in the power sector is key for economy-wide decarbonisation, but we should avoid unnecessary restrictions if the objective is to not just reach net zero by 2070, but to do so in the most cost-effective manner, and perhaps also to minimise cumulative emissions. Even if the latter is not yet an explicit goal, we should not declare interim peaking or sectoral zero dates.

There are five steps that will help this journey.

First, as previously discussed, we have to electrify the economy and simultaneously decarbonise the power sector.

Second, most deliberations around solutions are on the supply side—we must also focus on the demand side (efficiency is sometimes called the "first fuel"). More than efficiency, we should focus on saving energy at the right time and place, more so for the power grid, where ToD for consumption will matter. At an energy level, this extends to smarter and flexible appliances and processes. Building design should extend to urban design, which inherently must factor in transportation and logistics. This is not just more public transportation but also the use of the railways for freight. The first need is availability and accessibility of such solutions (like railways and public transport), but these may also require a behavioural shift. At the extreme, behavioural changes *within existing infrastructure* have virtually zero cost (but, unfortunately, these cannot get us to full decarbonisation).

Third, we should focus on the Pareto 80:20, where we cut down most emissions aggressively, but in return do not focus on the balance tail of emissions just yet. Before winding down existing coal power plants, we should work to plateau coal power. If developed countries aim to reach net zero by 2050, they have approximately 25 years, which is about 4% annual decline (if linear). In contrast, we have to decarbonise the existing economy and simultaneously grow at a higher rate, ideally around 7–8%. The growth in the coming 25 years dwarfs the size of the current fossil infrastructure. Doing both is an unprecedented challenge for a country the scale of India—no country has yet achieved it.

[12] There are documented cases of "irrational" bids across infrastructure in India, where the prices offered are not expected to be viable. These either require the winning bidder to resell the project or risk failing to deliver.

Fourth, we need more integrated planning instead of silo-based top-down targets. There is a range of studies within and outside the government on trajectories and pathways—these are all heavily assumption-driven and need much more discourse and transparency. There is also enormous uncertainty over decadal timescales. The recent Transition study by NITI Aayog (2026) is a great step, but its launch event declared the report as only a starting point. It shows possible scenarios, without going into the details of the policies, instruments, or levers to move to net-zero 2070. It is also a nationally focused document, without details on sub-national actors and activities.

Ultimately, the energy transition is about trade-offs, not just environment vs cost (or even including security, which forms the so-called energy trilemma), but also involving objectives such as jobs, consumer choice, and distributional aspects. This last point—the political economy—cannot be overstated. Winners and losers are a major challenge that will determine what can be done beyond the low-hanging fruit.

Fifth, we have to figure out the landscape of policy instruments needed for decarbonisation. How much should be sector-specific vs economy-wide? How can we ensure all the systems interplay effectively—across sectors, supply/demand, etc.?

One solution would be a carbon price, which works best when it is uniform and universal.[13] India has chosen a market mechanism instead of a tax for carbon prices, the Carbon Credit and Trading Scheme (CCTS). For now, the power sector is not part of the CCTS.[14] This means it will not give signals everywhere. Thus, we may still need to continue sector-specific policies, including mandates/standards like renewable purchase obligations (RPOs, now recast as renewable consumption obligations [RCOs]), new industrial policy, etc.

Let us assume the power sector has a marginal abatement cost (even with non-linearities) lower than the cost for present levels of decarbonisation along the curve of a sector like steel or cement. A market would simply signal $/$tCO_2$, which should guide where to focus. However, this calculation ignores the downstream effects of such a price. Suppose we had a $30/$tCO_2$ price—small by some global benchmarks. This would be quite modest in terms of inducing change in the steel sector but large for the power sector (more so for one dominated by coal).

In terms of propagated costs, this would raise the price of coal power by some Rs 2.75 per kWh, if not more, increasing utility power procurement costs by about a third (given that coal accounts for over 70% of grid supply). In contrast, this would increase the price of steel by only about 10–12% (per discussions with industry). The impact on the price of a car or a fridge would again be much lower. The question then remains: How much emission reduction would we see in the steel sector? If there were a uni-

[13] Most carbon markets (and even taxes) have not been applied universally across the country's economy. In addition, there are issues of grandfathering and allocations that determine the prices. An International Monetary Fund (IMF) staff paper has suggested a differential price across countries (Parry et al., 2021), but this then becomes subject to CBAM.

[14] The upcoming CCTS is a market for trading around emissions intensity instead of absolute emissions for notified sectors (a list that includes most major industry but excludes the power and transportation sectors).

fied (economy-wide) carbon market, we would simply find transfers of abatement away from other sectors into the power sector.

This would then amplify the issue of scaling and timing. Suppose we want to decarbonise more through the power sector, and we want to use a carbon price (through CCTS) to signal this. Until the time such additional clean electricity capacity comes online to absorb the shifts from other sectors to the power sector, we will still have emissions but at higher costs—a *de facto* tax.[15] Admittedly, this may be paid by other sectors, but it would have spillover effects. Ultimately, we need reasonably steady expectations of forward-looking carbon prices to handle the gestation period of large infrastructure planning.

The bottom line remains that India should not have a policy with sector-specific hard lines, e.g., requiring the power sector to decarbonise by a specified date, that too unnecessarily early or fully at first. Analysis may find that the power sector decarbonises faster than other sectors, but that should be an output of the models and planning, and not a starting objective or constraint.

Not only should India have flexibility in terms of when this occurs (naturally, before 2070), but we should also plan for a tail of emissions from all sectors, including the power sector. In almost all sectors, there is an expensive-to-abate tail. If we consider the fact that there are *some* residual emissions in the non-power sector to be dealt with via other means (perhaps carbon capture and sequestration, nature-based removal, direct air capture or more), then we have to allow the same for the power sector, even if the power sector's ultimate tail beyond mitigation is smaller. Correspondingly, India should aggressively decarbonise much of its power sector quickly, but not focus on full zero *yet*. This also means focusing on new builds, instead of worrying about existing fossil fuel capacity immediately.

[15] This is a reason why market design is critical for carbon markets, especially baselines and any grandfathering of existing emissions.

References

Das, S. (2024). *Demystifying the climate benefit of EV transition in India* (CSEP Working Paper 84). Centre for Social and Economic Progress. https://csep.org/working-paper/demystifying-the-climate-benefit-of-ev-transition-in-india/

Gupta, R., Sankhe, S., & Sarma, S. (2009). *Environmental and energy sustainability: An approach for India.* McKinsey & Company. https://www.mckinsey.com/capabilities/sustainability/our-insights/environmental-and-energy-sustainability-an-approach-for-india

IPCC. (2023). *AR6 synthesis report: Climate change 2023*. The Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/sixth-assessment-report-cycle/

Liebreich, M. (2025, May 19). Decarbonising the last few percent. Thoughts of Chairman Michael. https://mliebreich.substack.com/p/decarbonizing-the-last-few-percent

NITI Aayog. (2026). Scenarios towards viksit bharat and net zero - Sectoral insights: *Power* (Vol. 7). https://niti.gov.in/publications/division-reports

Moraski, J., Malwina, Q., & Spokas, K. (2025). *Beyond LCOE: A systems-oriented perspective for evaluating electricity decarbonisation pathways*. Clean Air Task Force. https://www.catf.us/resource/beyond-lcoe/

Parry, I. W. H., Black, S., & Roaf, J. (2021). *Proposal for an international carbon price floor among large emitters* (IMF Staff Climate Notes). International Monetary Fund. https://www.imf.org/en/publications/staff-climate-notes/issues/2021/06/15/proposal-for-an-international-carbon-price-floor-among-large-emitters-460468

Patel, U. (in press). *High-growth low-carbon development pathways for India: Results from REMIND Integrated Assessment Model* (CSEP Working Paper). Centre for Social and Economic Progress.

Tongia, R. (2021). *Flatten-the-curve: Why total carbon emissions matter much more than 'date of zero'* (CSEP Working Paper 14). Centre for Social and Economic Progress. https://csep.org/working-paper/flatten-the-curve-why-total-carbon-emissions-matter-much-more-than-date-of-zero-new/

Tongia, R. (2022). Balancing India's 2030 electricity grid needs management of time granularity and uncertainty: Insights from a parametric model. *Transactions of the Indian National Academy of Engineering*, **7**(4), 1127–1150. https://doi.org/10.1007/s41403-022-00350-2

UNFCCC. (2022). *India's updated first nationally determined contribution under Paris Agreement (2021–2030): August 2022 submission to UNFCCC.* https://unfccc.int/sites/default/files/NDC/2022-08/India%20Updated%20First%20Nationally%20Determined%20Contrib.pdf

Vijay, R., & Tongia, R. (2025). *India's renewables target falls short of growing demand: Planning and time-of-day balancing gaps* (CSEP Working Paper 93). Centre for Social and Economic Progress. https://csep.org/working-paper/indias-renewables-target-falls-short-of-growing-demand-planning-and-time-of-day-balancing-gaps/

Vijay, R., & Tongia, R. (in press). *Techno-economic assessment of 24x7 renewable energy supply* (CSEP Working Paper). Centre for Social and Economic Progress.

Xinhua News Agency. (2025, September 25). *Xi Jinping delivers video address at the UN Climate Change Summit.* https://www.gov.cn/yaowen/liebiao/202509/content_7042187.htm

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