Pathway to a Renewable Energy-centric Energy Transition

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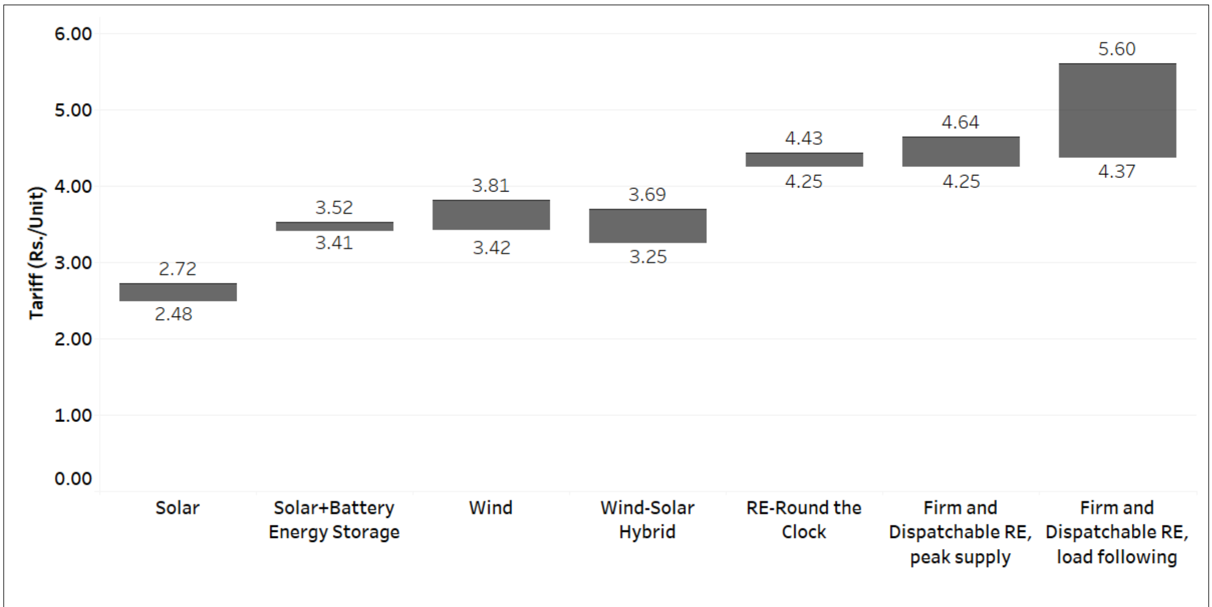
Abstract: *Low-cost renewable energy available at scale has the potential to address, at least partially, the tension between development and environment. India has an opportunity to reimagine the electricity policy-regulatory landscape to not only deliver a clean and reliable electricity system but also enhance the direct developmental benefits of the energy transition to all people. Both will need a strong focus on building institutional capacity.*

Electricity consumption is strongly correlated with the human development index and is a cross-cutting enabler that supports progress across several Sustainable Development Goals. Given the existing low level of per-capita consumption in India (~1,300 kWh/year) and developmental needs (such as, education, health, livelihood opportunities) yet to be fulfilled, electricity demand is expected to grow significantly (between 2.5–4 times) by 2050 even after considering significant improvements in end-use efficiency. Estimating long-term demand is quite complex and the range in the projections are due to assumptions related to economic structure, end-use electrification, population, urbanisation, income level among other factors and discussion about the same is beyond the scope of this paper. Nevertheless, it is clear that vastly higher quantities of electricity generation, coupled with equitable access, will be required to meet basic needs of the entire population.

While meeting this growing demand, electricity policy in India needs to creatively balance various objectives. It needs to balance the requirement of universal, affordable and reliable energy supply, enhanced energy security, minimising the socio-environmental impacts (local and global) of energy production and consumption, high accumulated losses of electricity distribution companies and the entrenched political economy of electricity. While this is no easy task, renewable energy[1] is a crucial element of the solutions to address several of these policy imperatives.

Figure 1: Range of tariffs for RE (wind, solar) and various forms of hybrid RE with different levels of energy storage.



Notes: Wind-Solar hybrids are projects with a combination of solar and wind capacity but without enery storage. Solar+Battery Energy Storage System (BESS) price is for 2-4 hours storage but for half the solar capacity; RE-RTC has wind, solar combined with storage such that it can broadly supply electricity throughout the day (within defined limits). FDRE similarly combines wind, solar and storage but is so sized/designed to either supply in peak demand hours or to follow the load pattern of the procuring entity.

The reduction in the costs of renewable energy [presently at ₹2.5-3.5/kiloWatt hour (kWh) for solar and wind power[2]] (Figure 1), its vast resource potential[3], coupled with the much-required fall in energy storage [battery energy storage system (BESS) and pumped hydro system (PSP)] prices has made renewable energy a key supply option for the foreseeable future. It is no longer merely a high cost, non-scaleable reluctant answer to the energy sector's environmental problems. It is finally opening a substantially less destructive (socially and environmentally) pathway compared to large conventional (for example, coal thermal) generation projects.

Apart from lower socio-environmental impacts at the local scale (Sovacool et al 2021) and obvious contribution to reducing greenhouse gas emissions, the absence of fuels (especially with respect to wind and solar) and minimal variable costs make them amenable to long-term power purchase agreements (PPA) based on a fixed inflation-proof levelised price. This eliminates electricity generation price volatility and uncertainty. Its low gestation periods, of between 1.5 to 2.5 years depending on the project size, allows policymakers and planners to retain flexibility and avoid infrastructure lock-ins, cost over-runs, and related sunk costs associated with large long-gestation centralised projects. Finally, its contribution to increasing India's energy security by reducing the need for high-cost imported fuels and potential to reduce the country's trade deficit add to its value as a supply resource from a geo-strategic and macroeconomic view. Fuel imports (petroleum and coal) contributed ~33% of the total imports in India over the past two decades and hence are a significant contributor to the trade deficit.

These myriad benefits form the basis for a strong policy and regulatory support for renewable energy from the central and state governments since the last two decades. This has led renewable energy capacity (excluding large hydro) growing to 156 GW (34% of India's total installed capacity) by October 2024, while contributing 225 Billion Units/TWh (13% of total) to generation in FY 23–24 (Table 1). Looking at the broader category of non-fossil fuel (NFF) capacity (including large hydro and nuclear), with 209 GW (46.3% of total) installed capacity as of September, 2024, India is on course to reach its official nationally determined contribution (NDC) commitment of 50% NFF by 2030. Central Electricity Authority (CEA) is projecting renewable energy's share in generation capacity to increase to 65% by FY 2032[4] which will be supplemented by energy storage of 74 GW (~450 GWh/day) (CEA 2023a). This is in line with the Renewable Purchase Obligation (RPO) target of 43.3% of generation and Energy Storage Obligation (ESO) of 4% by 2030. Thus, renewable energy is at the heart of India's future electricity supply strategy that involves *inter alia* enhancing energy security, decarbonisation, electrification of new end uses (mobility, industrial heat, etc), and production of green fuels/chemicals (hydrogen, ammonia).

However, implementing such a renewable energy-focused strategy is not without its social and environmental challenges (Stock and Sovacool 2024). Presently, renewable energy projects are exempted from Environmental Impact Assessments (EIA) or Social Impact Assessments (SIA), making it difficult to systematically assess potential adverse impacts from these projects, especially during their construction phase. A recent example (in the case of a Pumped Storage Plant (PSP), for which EIAs are mandatory) shows the possibility to foresee such impacts and potentially address them (SANDRP 2024; TNN 2024). Two of the important issues that repeatedly come up include (i) impacts on surrounding natural environment (especially ecologically sensitive areas) (Byatnal 2012) and livelihoods and (ii) increase in land use (especially for solar), and the possibilities of irregularities in land transactions and compensation (Gangan 2015). Nevertheless, we believe it is reasonable to assume that the socio-environmental impacts per unit of generation of renewable energy projects (solar and wind energy in particular) are generally much lower than those of coal-based thermal power (which is currently the main source of power in India).

Table 1: Growth in RE capacity and generation from 2004-24 and expected growth by 2032

Capacity in GW, Source	2003-04	2013-14	2019-20	2020-21	2021-22	2022-23	2023-24	2029-30	2031-32
Thermal	78.0	168.2	230.6	234.7	236.1	237.6	243.2	276.5	284.4
Nuclear	2.7	4.78	6.8	6.8	6.8	6.8	8.2	15.4	19.6
Large Hydro	29.5	40.5	45.7	46.2	46.7	46.9	46.9	53.8	62.1
New RE (mainly wind, solar) excl. large hydro	4.8	32	87.0	94.4	109.9	125.2	143.6	412.3	507.2
Total RE incl. large hydro	34.3	72.5	132.7	140.6	156.6	172.0	190.6	466.1	569.3
Total	115.0	245.5	370.1	382.2	399.4	416.1	442.0	758	873.3
Share of new RE	4.2%	13.0%	23.5%	24.7%	27.5%	30.1%	32.5%	54.4%	58.1%
Share of RE incl. large hydro	29.8%	29.5%	35.9%	36.8%	39.2%	41.3%	43.1%	61.5%	65.2%
Share of Non Fossil Fuel	32.2%	31.5%	37.7%	38.6%	40.9%	43.0%	45.0%	63.5%	67.4%
Battery Energy Storage							~0.1	41.6	47.2
Pumped Hydro Power (PSP), Energy Storage							3.3	18.9	26.6
Peak Demand	75.1	129.8	182.5	189.4	200.5	207.2	239.9	334.8	366.0

Generation in TWh (BU), Source	2003-04	2014-15	2019-20	2020-21	2021-22	2022-23	2023-24	2029-30	2031-32
Thermal	469	878	1,043	1,033	1,115	1,206	1,326	1,365	1,368
Nuclear	18	36	46	43	47	46	48	92	118
Large Hydro	75	129	156	150	152	162	134	223	246
New RE (mainly wind, solar) excl. large hydro	3	74	138	147	171	203	225	831	934
Total RE incl. large hydro	79	203	294	298	323	365	359	1,053	1,180
Total	565	1,117	1,389	1,382	1,492	1,624	1,738	2,510	2,666
Share of new RE	0.6%	6.6%	10.0%	10.7%	11.5%	12.5%	13.0%	33.1%	35.0%
Share of RE incl. large hydro	13.9%	18.2%	21.2%	21.5%	21.6%	22.5%	20.7%	41.9%	44.3%
Share of Non Fossil Fuel	17.1%	21.4%	24.5%	24.6%	24.8%	25.3%	23.4%	45.6%	48.7%
Battery Energy Storage								76	86
PSP Energy Storage (assuming 7 hrs/day)								48	68

Source: Prayas (Energy Group) compilation based on various reports of Central Electricity Authority.

This paper discusses existing challenges and potential future pathways for grid-connected renewable energy (mainly wind and solar power) for electricity generation primarily from an electricity policy and regulatory perspective. Being cognizant of social and environmental concerns referred above, the paper also presents indicative approaches to address these concerns.

Key Challenges in Maintaining Rapid Scaling Up of Renewable Energy

Since the enactment of the Electricity Act, 2003 (hereinafter EA 2003), the renewable energy sector has seen vibrant growth and competition while the policy-regulatory frameworks have gradually evolved to meet the changing sectoral requirements. However, it now faces some long-standing and structural challenges and constraints with which it must constructively engage to keep pace with the rapid expansion envisaged. These are discussed in this section.

The union and state governments often have differing priorities, capabilities and constraints. The union's perspective is informed more by macroeconomic stability, economic growth, and geostrategic issues, while states are driven more by local concerns and political realities, including energy access and affordability, local jobs, and economies. For example, the union may want to promote renewable energy more aggressively to reduce costs, energy imports, and pollution, as well as to meet international obligations. However, these have implications at the state level that differ from state to state. For example, coal-rich states may in the long run lose jobs and royalty revenue, while states with high renewable energy shares may either face grid instability or must back down renewable energy if it cannot be despatched and sold elsewhere. Addressing such divergent priorities and implications of high renewable energy future is a key challenge. A collaborative, deliberative approach with focus on innovation and accommodation among union and states is critical. For example, several learnings from states have been incorporated into the union government's Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM-KUSUM) (agriculture solarisation) scheme modalities which have helped states rapidly deploy solar capacity.

Weak institutional capacity for policy-regulatory analysis, enforcement of regulations and long-term planning especially within states is a well-known and long-standing structural weakness within most of the electricity sectoral institutions. While electricity generation and consumption has grown exponentially, investment in, and attention to institutional capacity (adequate number of qualified personnel, data systems, tools, models, etc,) in state electricity institutions has remained woefully inadequate resulting in suboptimal processes, especially at a time when planning is becoming more complex.

Complex regulations and lax implementation of the same is another major challenge that needs to be addressed. The present-day electricity policy-regulatory architecture has become a complex patchwork of myriad rules, regulations, state and national policies and laws, built incrementally over time and which varies significantly across states. For example, since 2003, the state electricity regulatory commissions (SERCs) were entrusted to set RPO targets for their states as per Section 86 (1) (e) of the EA 2003 while being guided by the national policies. However, with the amendment of the Energy Conservation Act in 2022, these targets are now set by the Ministry of Power along with the Bureau of Energy Efficiency (BEE). The result is that two acts with different objectives, penalty mechanisms, and institutional authorities have jurisdiction over the same issue, viz., minimum RPO targets, creating potential legal complexities (Mannur et al 2023). Similarly, the Government of India notified a series of Rules (MoP 2024) under the EA 2003 from 2020–2023 covering diverse areas such as green open access, consumer and prosumer rights, delayed payments by electricity distribution companies (Discoms), etc. These rules nudge and, in some cases, mandate states to implement several much-needed policy and regulatory changes. However, at times, these provisions are too detailed and specific leaving little room to modify them and innovate in accordance with state realities. For example, the Electricity (Rights of Consumers) Amendment Rules, 2023 specify a uniform 20% rebate in tariff during solar hours while the

Forum of Regulators has recommended a banking charge of 8% of banked energy for all states for renewable energy-based open access transactions. Suboptimal implementation of existing policy and regulation is also not uncommon. For example, despite notifying RPOs, most SERCs do not have strict RPO compliance monitoring and even when non-compliance is found, penalties are hardly levied in line with their own regulations (Mannur et al 2023). Similarly, in line with the Green Open Access Rules of 2022, nearly 20 states have formulated their Green OA regulations, but actual implementation of several provisions of these regulations is still far from normalised (ETPI 2024). Thus, such complex regulatory provisions, with lax implementation can slow down renewable energy deployment.

Financially, the loss-making electricity sector poses another significant challenge to scaling up of RE. With electricity being such a critical input to development and economic growth, it is no surprise that "*Indian electricity remains deeply woven into the fabric of Indian politics."* (Dubash 2019) Political compulsions such as the provision of free or subsidised electricity and restriction on competition in some parts of the sector has constrained much needed structural reforms as well as measures to improve accountability and performance of sector institutions and processes. Some of these areas include power procurement planning and contracting, reducing transmission and distribution losses, tariff reforms, and regulatory independence. These shortcomings manifest in a continued inability to achieving financial viability of the sector for over nearly four decades. For example, at the end of FY 2023, the accumulated losses of Discoms were ₹6.47 lakh crores (in comparison, the total revenue of the electricity sector was ₹9.57 lakh crores), while the revenue subsidy to agriculture and small domestic consumers in some states amounted to ₹1.69 lakh crores (17.7% of the total revenue) (PFC 2024). Revenue subsidy is very likely to be over ₹2 lakh crore for FY 24. Such a financially weak sector also constraints long term planning and often leads to a crisis driven operation of the sector. This is reflected in repeated bailouts for the sector (Josey et al. 2024).

Desired Pathway to Rapid Scale-up of Renewable Energy

Initially, renewable energy was viewed with a limited perspective of supplementing conventional generation sources with an environmentally and socially less harmful source of electricity generation. However, with its favourable economics and growing scale, it now needs to be seen in the Indian context as a primary least-cost, energy-secure choice for national self-interest with potential for large-scale deployment to substantially mitigate local, social, and environmental impacts of electricity generation. Climate change mitigation can be seen as a strong co-benefit rather than the primary driver for renewable energy in India. This paradigm is yet to be fully internalised in policy thinking and discourse.

Several power sector modelling studies (Abhyankar et al 2023; Rodrigues et al 2023; BloombergNEF 2023), exploring scenarios of high renewable energy (40%–50% by 2030) and very high (>80%–90%) shares of renewable energy by 2047/50, broadly conclude that a combination of low-cost renewable energy (especially solar + wind) coupled with energy storage (BESS+PSP for now) and demand-side flexibility (demand response, time of day tariffs, smart metering, and load shifting, etc,) can meet demand in a cost-effective, reliable, and low-carbon manner. Many more granular studies are still needed to understand finer details of the expected systemic changes and possible policy responses. However, the dominant discourse in the power sector does not explicitly account for various well-known local (air, water pollution) and global externalities (climate change and its impacts on Indian population, (Ricke 2018)), and risks (fuel cost escalation/volatility, high gestation periods and cost over-runs, international carbon taxes, etc,) of conventional energy sources. This undermines the benefits of renewable energy not only for the energy sector, but for the entire economy and well-being of the citizens, especially compared to a future based on conventional generation sources.

India needs a significant increase in the speed and scale of renewable energy deployment from current 20–25 GW/year to keep pace with the increase in demand (average annual increase in energy and peak demand was 5.8% and 7.1% respectively from FY20–FY24). To reach a share of 43.3%renewable energy generation by 2030 from the existing 21% (FY 24) will need a ~4%/year increase in absolute share of renewable energy. In comparison, the share of renewable energy (excluding hydro) has been increasing only at 0.75%/year in the past five years while the share of renewable energy (including hydro) has plateaued at 21% over the past few years. Given the expected growth in demand, renewable energy generation will need to triple by 2030 (from 359 BU in FY24 to 1058 BU) and thus capacity addition needs to ramp up to 50 GW RE/year coupled with total energy storage deployment of 60 GW (336 GWh/day) (CEA 2023b). Additionally, if one were to consider electrification of new end uses (such as green hydrogen, some low-medium heat industrial applications) and greening of captive demand, renewable energy capacity addition would need to further ramp up to 65–70 GW/year. While some steps in this regard are already underway, such as the Ministry of Power directive for tendering a minimum of 50 GW RE/year (MNRE 2023a) and developing the required transmission infrastructure (especially at the Inter-State Transmission System [ISTS] level), many more structural and systemic changes are needed, some of which are elaborated below.

Simple, clear and consolidated policy-regulatory frameworks: As discussed earlier, with multiple and at times conflicting priorities and objectives, electricity policy making is and will likely continue to be complex and dynamic, but such tensions also open spaces for innovation. Union and state policymakers need to clearly articulate both, short- and long-term objectives and priorities, and build consensus around that. There is a need to simplify the policy and legal landscape and reimagine it while critically examining several foundational constructs which may no longer fully hold true. For example, captive projects get a waiver from "cross-subsidy surcharge" while those procuring power from open access do not. Most renewable energy-based open access get free or highly concessional "notional energy banking" which undermines the time and seasonal price/value of electricity, resulting in discom's regulated consumers subsidising such services and dis-incentivises investments in much needed energy storage. A simplified, harmonious long-term open access framework which addresses such inconsistencies and balances the risks and rewards for open access consumers, discoms, and their non-open access consumers is required (Prayas [Energy Group] 2023).

Similarly, broader, medium-term outcome-based renewable energy targets as opposed to detailed year-wise, source-wise renewable energy and energy storage targets which are uniform for all states and obligated entities might be easier to implement and aid optimisation in procurement planning. Another step in moving away from administratively determined resource mix would be to consider moving away from resource specific competitive bidding guidelines and move towards a generic resource agnostic procurement strategy. Specific energy and capacity needs would be identified based on rigorous integrated resource planning (IRP) and resource adequacy (RA)-based modelling studies. This will allow for better and more agile planning as well as market innovation to deliver on procurer-specific needs (a certain generation profile, firm capacity, peaking, or seasonal needs, etc,). This will enable scale-up of cost effective renewable energy resources without the crutches of administrative targets, incentives, and subsidies.

Some minimum level of uniformity in policy principles across states would also be useful. This is not to argue for a one size fits all approach for states (impossible given the diversity), but for broader agreement on policy principles leaving enough room for innovation and adaptation to local realities. Development of clear policy, regulatory framework needs to be supplemented by effective implementation and accountability. For example, if mechanism of target-setting through RPO is continued, then strict monitoring of RPO targets (43.3% by 2030) in letter and spirit is essential. Without such monitoring and compliance not just the whole RPO construct but any policy framework loses meaning.

Beyond clear policy frameworks and effective implementation requirements, scaling up of renewable energy needs three key enablers—viz. land, transmission infrastructure, and low-cost capital. Regarding land, several states, as part of their renewable energy policies, have brought in a facilitating framework along with standardised leasing agreements and lease rates (for example, Andhra Pradesh) (Government of Andhra Pradesh 2024). Similarly, 50 solar parks (infrastructure ready land parcels for solar) with a capacity of 38 GW have been sanctioned across states of which 10 GW have been established (MNRE 2023b). Some aspects of land are further discussed in the section, *Need for a Development-centric Approach.*

The interstate transmission (ISTS) charges waiver for renewable energy is coming to an end in FY25 and with over 200 GW of connectivity applications in the last 1–2 years (India Transmission Portal 2024), ISTS renewable energy transmission connectivity is practically booked until FY 28-29, making it extremely challenging to add large capacity connected to ISTS. Hence, the next phase of renewable energy growth would be dominated by renewable energy connected to the state grids. States are well placed to plan for such renewable energy growth (for example through geographically spread renewable energy park development with associated transmission planning).

With the scaling-up of renewable energy capacity, the cost structure of most of the new electricity sector elements, such as generation (solar, wind), transmission, and distribution network, and energy storage such as BESS or PSP infrastructure is becoming more capital heavy but with low operating costs. The transition to renewable energy may need an estimated investment of ₹45 lakh crore ($530 billion) in financing by 2030 (Anand 2024). While availability of capital per se may not be the issue, provided there are appropriate credit-worthy buyers, availability of low-cost capital and certainty of the same is critical for success of renewable energy scale-up. This hinges on long-term electricity sector policy stability, and a balanced risk-reward for investing in such projects. While Ministry of Finance has recently initiated the sovereign Green Bonds program, there is need for further work on the broad theme of green finance which will lead to risk sentient and enthusiastic investment flows into the Indian renewable energy and storage space. These areas include careful recording of end use to avoid greenwashing by green instrument issuers, setting and measurement of quantifiable goals for green instruments and market participants maturing to accommodate a commensurate “greenium” for such instruments (especially with sovereign issuers).

Fundamental restructuring of the industry structure: An ever-growing number of discom consumers now have the technology option, legal eligibility, supporting framework, and economic incentive (low-cost renewable energy+ storage) to reduce their dependence on discoms and directly source or generate their power. Discoms have been historically discouraging such sales migration through various operational and procedural barriers to protect revenue and cross-subsidy requirement. An alternative approach for discoms could be to accept the inevitable and instead focus on building excellence in network (transmission and distribution) planning and operation and allow for serious long-term open access based on clear regulatory frameworks and supportive policies which incentivise a fair risk-reward sharing for all stakeholders. This would imply changing primary role of discoms from supplier of electricity to provider of network services (Josey et al 2024).

Another such essential reform is in the electricity pricing framework. High fixed cost and extremely low variable cost, coupled with long term fixed price contract regime in India (tariffs for renewable energy projects are fixed for entire 25-year duration of the PPA) and cost reduction trends of RE+storage will necessitate fundamental changes in the consumer tariff design philosophy. First, it will begin to put a natural ceiling on consumer tariffs as alternative supply sources (through captive and open access routes) become cheaper than discom supply. Consumer tariffs also need to reflect the increasing share of fixed costs (RE, storage, T&D network) and reducing share of variable costs (fuel). Increasingly, day-ahead prices on the power exchanges are being strongly influenced by renewable energy (at least in day-time periods). With solar capacity presently at 33% of peak load, day time prices are consistently the lowest. By 2027, solar could be 70% of peak demand and reach ~100% by as early as 2032. This is likely to substantially depress day-time prices (many countries like Germany already experience significant hours of negative pricing). All these aspects need to be factored in consumer tariff structure as well in market rules governing the exchange prices.

Though India's electricity demand will continue to grow to meet its development needs, demand-side measures too will be necessary and can add a lot of value. As renewable energy share increases, implementing an effective time-of-day and seasonal consumer tariff structure with lower threshold of applicability (for example, consumers above say 10 kW load) would be necessary. This will encourage load shifting to times with high renewable energy availability (subject to load elasticity) and enable cost recovery of procuring high price electricity in peak periods by discoms. Second, improving energy efficiency has a huge potential to reduce electricity demand, thereby lowering capacity addition and investment needs (Bureau of Energy Efficiency 2019). While some progress has been made in the large industry sector under the Perform, Achieve, and Trade (PAT) scheme, there is still significant scope of improvement in the residential sector with appliances such as air conditioners, fans, etc (Sreenivas 2023).

A recent study underscores the importance and role of energy efficiency and electrification in the global context. The existing global energy system is extremely inefficient with only 36% (59 Peta Watthour [PWh]) of the global primary energy supply (165 PWh/year in 2019) producing useful work or heat for the economy (Tesla 2023). Therefore, energy efficiency is a crucial but under deployed and underappreciated piece of the transition story which India can ill-afford to ignore. The same paper explored a

'path to reach a sustainable global energy economy through end-use electrification and sustainable electricity generation and storage' and found it to be *'technically feasible and requires less investment and less material extraction than continuing today's unsustainable energy economy'. (Tesla 2023)*

Most importantly it estimates that electrification helps reduce the total energy requirement by 50%. Therefore, India can view electrification of more end uses (transport, low-medium industrial heat applications, cooking, etc) as one of the best indirect energy efficiency policies.[5]

Need for a development-centric approach: The social and political acceptance as well as desirability of a transition in a crucial and resource-intensive sector, like energy, also hinges on the broader developmental benefits of the transition beyond just meeting energy needs of the population and economy. While renewable energy projects certainly outperform conventional power plants in most environmental, social, and increasingly economic criteria, they can still have some local impacts on the surrounding natural environment and livelihoods. Until now, adequate consideration to such local socio-environmental issues in renewable energy development has been lacking. A meaningful energy transition should also strive to minimise renewable energy's social and environmental impacts and support deeper developmental needs, such as livelihoods, dispersed industrialisation, etc. As renewable energy scales up rapidly, it is critical that such issues are identified and addressed in a comprehensive and balanced manner. Inherent advantage of most renewable energy technologies such as modularity, higher propensity for decentralised deployment, very low operating costs need to be used innovatively to prioritise the needs of communities through appropriate policy interventions and innovations. A good example of a policy that seeks to achieve this is the Maharashtra Saur Krishi Vahini Yojana (MSKVY) 2.0 policy (Government of Maharashtra 2023), which envisages universal distributed solarisation of all agriculture electricity demand whereby farmers experience reliable day-time electricity without any change in tariffs through deployment of small MW-scale solar plants at the substation. While a detailed scholarly discussion of this topic is beyond the scope of this paper, this section indicates the potential of renewable energy-based electricity sector in contributing to such essential societal objectives.
Some aspects that need to be considered in this regard include: (i) A RE-specific land-use policy that encourages long-term land leasing with fair compensation to the landowners coupled with transparency in land transactions. For instance, under MSKVY 2.0, Government of Maharashtra (GoM) has fixed a minimum land lease rate of ₹1.25 lakh/hectare (ha) with an annual escalation of 3% for 25 years. Nearly 10,000 farmers have voluntarily registered their land, under this initiative, totalling ~ 1 lakh acres which could support 25GW of solar capacity. Similarly, in Rajasthan, under the Saur Krishi Ajivika Yojna (SKAY), farmers can lease land on pre-fixed rates. Such measures would offer sustained income for farmers and they need to be promoted instead of a one-time compensation approach. Needless to say, care needs to be taken that less productive and ecologically less valuable land is prioritised for any renewable energy project. (ii) Institutionalising EIAs and SIAs with active community involvement to identify, prevent, or minimize adverse impacts and uphold informed local consent in letter and spirit. The renewable energy and energy storage sector needs to hold itself to a higher standard and strive towards becoming more responsible and inclusive (REI 2024). (iii) An institutional structure for benefit-sharing with the community where projects are located. An example of such local benefit sharing was instituted in Maharashtra, wherein wind power projects must pay local taxes (₹15,000/MW/year) (Prayas (Energy Group) 2017). In a slightly different vein, under MSKVY 2.0, GoM has initiated a social development grant of ₹.5 lakh/year to gram panchayats for three years. While these are some fledgling beginnings in this regard, a lot more needs to be done to make it truly inclusive and more locally development-oriented.

Another crucial aspect in this regard is integration of renewable energy within industrial policy of the country. Importing low-cost commoditised capital equipment[6] (which is presently made in India at a lower scale and with a slight cost premium) with a life of 15–25 years is a much lower risk compared to the continued dependence of importing energy flows (petroleum and coal) which can be instantly disrupted and are not replaceable. It is worth noting that India's fuel import bill in FY24 was 17.2 lakh crore (31% of total import bill). Nevertheless, there is a case for becoming self-sufficient in manufacturing renewable energy equipment as well. Otherwise, if India continues to import equipment (solar panels, wind turbines, battery storage packs, etc) that converts renewable energy into electricity, our import dependence continues, albeit in a significantly different form. Therefore, the existing policy emphasis on manufacturing such equipment within the country is welcome but the question as to which parts of the manufacturing chain we are well placed to add value to needs more careful consideration. Manufacturing everything at any cost in India may risk slowing down the transition. Here, it needs to be noted that job creation in renewable energy project's construction, operation and maintenance (O&M) is likely to be far higher than hi-tech jobs in manufacturing. Manufacturing locally increases energy security and opens new avenues for exports. This has taken the form of various production linked incentive (PLI) schemes for solar panels, advanced batteries, green hydrogen, etc, coupled with high customs duties for imports and restrictions (eligibility criteria, registration, domestic content requirements) on models of wind turbines and solar panels which are approved for sale in India (Rajshekhar 2024). Such aspects need to be considered from multiple objectives and priorities (investments, jobs, advanced technology knowhow, etc), while understanding their relative trade-offs to develop an optimal pathway to achieve the right balance. Green industrialisation is an area where more strategic and nuanced thinking could help find common ground between conflicting objectives of accelerating the energy transition, energy affordability, and manufacturing in India.

Substantial and rapid scale-up of renewable energy is essential considering India's energy needs, and renewable energy's social, environmental, and economic advantages over conventional generation. While India has made remarkable progress in scaling up renewable energy, the energy transition should not be viewed simply as transition to renewable energy, but as an opportunity to orient the energy sector such that it truly contributes to providing necessary energy services to society at the lowest social and environmental costs. A renewable energy-centric energy sector is now substantially amenable to such a contribution. But this will not happen automatically and unless conscious efforts are made, it may not yield desirable outcomes. This would require a fresh and open look at policy formulation through a much more deliberative and inclusive process which critically hinges on building our technical and institutional capacity. It also requires multidimensional interventions and coordinated actions across sectors such as land, water, agriculture, and manufacturing. If negotiated well, India could avoid many inefficient lock-ins and their associated significant economic and environmental costs.

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Notes

[1] While RE includes resources like wind, solar, hydro, biomass, geo-thermal etc, this paper will be focussed largely on solar and wind power.

[2] These are not only the lowest generation tariffs for any electricity resource in India, but also one of the lowest RE prices in the world.

[3] The existing official resource estimates for solar and onshore wind power are 748 GW and 1,164 GW (at 150 m hub height) respectively. The solar potential is based on a restrictive criterion assuming availability of only 3% of the waste land area. At 4 acres/MW, 1% of India's land mass can support over 2,000 GW of solar. Similarly, the off-shore wind potential has been estimated by one study as '*3,941 GW within depths of 30–200 meters'*

[4] The target of 5-10 million metric tons (MMT) of green hydrogen by 2030 will require ~100-200 GW of RE (wind & solar). It is not clear if this is part of the 500 GW non fossil fuel goal by 2030 or additional.

[5] For e.g.; Electric vehicles are ~ 4 times more efficient than internal combustion engine vehicles.

[6] In FY 24, the avg. price of importing coal for electricity was ₹8.5/kg. Assuming a specific coal consumption of 0.38 kg/kWh, the imported fuel cost is ₹3.28/kWh. In contrast, price of imported solar panels is presently ~9.2 ₹/Wp which increases to 17.3 ₹/Wp (accounting for 40% basic customs duty (BCD) and 35% oversizing). Assuming a capacity utilisation factor (CUF) of 25% and a life of 25 years, the cost of the imported panel works to a mere ₹0.32/kWh, an order of magnitude lower than imported coal.