PUNE INTERNATIONAL CENTRE

Powering India's Energy Self-Reliance by 2047

March 2023

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Executive Summary

India is on the fastest path to development. In the run up to 2047, the centenary year of India's Independence, the country is expected to experience favourable economic and demographic conditions promoting sustained progress over the next two decades. For this economic prosperity to be socially inclusive, environmentally sustainable and cost effective, India will have to focus on becoming self-reliant in sectors that have a direct bearing on its national security, peace and societal harmony.

In this context, energy self-reliance becomes crucial for issues pertaining to the economy, environment and national security. By the year 2047, India's energy demand is expected to skyrocket. In a business-as-usual scenario India will continue to depend on fossil fuels and increase its energy imports. However, this is not desirable for three reasons.

First, energy security is a crucial component of India's national security. It is important for India to have adequate access to energy at an affordable price and in a manner that doesn't make the country vulnerable to fluctuations in global energy supply chains. However, India relies heavily on imports of energy related fossil fuels which account for a third of the total merchandise import bill. At present approximately 90% of oil, 60% of coking coal and 55% of gas is imported. This makes the nation's expanding economy vulnerable to any supply side constraints in the global energy value chains. The weather extremes and uncertainty add to the country's dilemma of energy availability and reliability.

Second, India is also among one of the world's most vulnerable countries to the impacts of climate change. Housing a population of over 1.4 billion people (18% of total global population), India's diverse geographic and relief features with young fold mountains in the north, an expansive coastline in the peninsular and heavy reliance on seasonal monsoons makes it vulnerable to devastating impacts of climate change. Moreover, 80% of its inhabitants reside in districts at a risk of climate-induced disasters[1].

Third, India is on a steep developmental curve and its energy demand is expected to increase significantly by 2047. If the country continues to meets its rising demands with

fossil fuels, it is bound to experience increased greenhouse gas (GHG) emissions from the energy sector. Additional greenhouse gases in the atmosphere can have irreversible climate consequence, which would result in rise in unconventional risks to national security such as climate security, energy security, water shortages and food insecurity.

The dilemma therefore is to balance India's competing priorities of meeting exponential rise in energy demand without compromising sustained economic progress. Additionally, with the Prime Minister announcing India's goal of achieving energy self-reliance by 2047, the challenge ahead of India is to undertake the requisite overhaul of the energy ecosystem in under twenty-five years. Thus, the pace of the transition required will have to be much quicker than any other country has previously experienced.

India must play a significant role in evolving a strategy to a low-carbon energy system in a short span of two to three decades. It should leverage its renewable energy potential and invest in clean energy technology to solve the energy, environment and security dilemma.

This paper highlights various aspects of India's energy transition away from fossil fuels while emphasising the need for self-reliance by 2047. Furthermore, the paper attempts to bring forth the gravity of the climate challenge ahead of a billion-plus people given the human and ecological vulnerabilities due to high degree of energy-related emissions. Its recommendations have been attuned towards guiding policy-makers to take into consideration the paradigm shift required to usher in for a self-reliant India at 2047 with social, economic and ecological prosperity.

Introduction

India is the world's fifth largest economy in terms of gross domestic product (GDP). Just a decade ago, it ranked tenth among the global economies and has made tremendous progress since. The rapid pace of industrialisation, urbanisation and improved standard of living has contributed to the robust growth in energy demand. Today, India ranks as the world's third largest energy consumer. However, its reliance on fossil fuel dominated energy mix has made it the world's third largest GHG emitter. Additionally, its high import dependence for oil, industrial coal and natural gas, have caused the nation's exchequer dearly.

In the past few years since the Covid-19 pandemic, the world has witnessed the impacts of multiple crises taking place simultaneously. Global paradigms of security threats are moving away from conventional land based security concerns to unconventional threats such as climate change, pandemics, cyber-threats, water-energy nexus and food insecurity. Disruptions in global value chains during unstable times are a cause of concern for nations that depend on imports for crucial commodities like energy.

The current energy value chains are spread across continents. They are interconnected and interdependent. However, regional conflicts in oil exporting countries, imposition of embargos, stricter trading norms, and inward looking tendencies, are likely to pose a grave threat to the availability, affordability and reliability of energy globally. In light of this, nations are focusing on 'Energy Security' and 'Energy Independence' for gauging the extent to which they can maintain their strategic autonomy.

Energy security refers to having adequate access to adequate amounts of energy resources at an affordable cost and in a manner not vulnerable to foreign suppliers or international constraints. Whereas, energy independence depends on how much of the nation's energy requirement is met from indigenously produced energy from within the country.

In the light of India's high fossil fuel imports, concerns regarding energy security and energy independence sit at the heart of its energy dilemma. The goal is to meet India's growing demand, while reducing its energy imports. In view of this, the government has announced an aspirational goal of becoming 'energy independent by 2047'. However, this goal needs to take into account that a business as usual will only cause severe environmental disruptions, threatening the peace, stability and progress of the country.

Over the past two decades, the increased energy demand has been met using coal, oil and natural gas. At present about 88% of India's primary energy is sourced from fossil fuels. The

disproportionate share of fossil fuels in the energy sector contributes to majority of GHG emissions in India. High emissions in the atmosphere have a direct impact on human and ecological health and well-being.

As compared to pre-industrial times, atmospheric concentration of carbon dioxide (CO2) has seen a dramatic increase from 280 ppm in 1700s to 414 ppm as of 2021. The increased levels of GHGs in the atmosphere are causing global warming. The manifestations of which are visible through increased frequency of extreme weather events such as floods, heat waves, cyclones, droughts and so on.

The UNFCCC suggests that in order to "avoid dangerous climate change", drastic emission cuts are required . As agreed at COP21 in Paris, greenhouse gas emissions must be substantially reduced to hold the global temperature rise well below 2°C above pre-industrial levels and efforts should be pursued to limit it to 1.5 degrees Celsius above pre-industrial levels. The parties recognised that this would reduce the risks and impacts of climate change. Despite the global recognition, eight years since the Paris Agreement, global temperatures have been rising. The year 2023 was the hottest year on record, with temperatures reaching a record high of 1.46°C above pre-industrial levels[3].

In order to limit global warming to 1.5 degrees Celsius the Intergovernmental Panel on Climate Change (IPCC) suggests that greenhouse gas (GHG) emissions must peak before 2025 and decline by 43% by 2030 (relative to 2019 levels)[4].

For a climate venerable country like India with over 80% of its inhabitants residing in districts at a risk of climate-induced disasters[5], there is an urgent need to take drastic emissions cuts. This is possible if India's energy sector transitions away from fossil fuels.

It is therefore necessary to make a combined effort towards increasing energy self-reliance and reducing emissions from the energy sector by mainstreaming renewable energy, investing in clean energy technologies, and distributing energy production. The next two decades are an opportunity for Indian to invest in sustainable energy infrastructure, reduce its emissions intensity of the GDP and meet its growing energy demands locally.

Literature review

Extensive research is available on the topic of energy independence and increasingly more literature has been written on pathways to achieve energy independence given the alarming impacts of energy systems on the environment. Below is a literature review of some of the most significant and recent works in this area.

Lawrence Berkeley National Laboratory's report, "Pathways To Atmanirbhar Bharat, Harnessing India's Renewable Edge For Cost-Effective Energy Independence By 2047"[6], presents the current decline in clean energy costs as an opportunity to lower the energy imports through investment in renewable energy, battery storage, EVs, and green hydrogen. The paper is focused on India's three largest energy consuming sectors namely, power, transport, and industry – which collectively account for more than 80% of energy consumption and energy-related CO2 emissions.

The paper puts forth two scenarios, namely, the Reference and the CLEAN-India (Clean Energy for Atmanirbhar) India to draw parallels between the uptake of renewable energy and resultant energy independence achieved till 2047. The reference scenario projects 60% renewable energy deployment by 2047 based on the existing targets and commitments. The CLEAN-India scenario describes the outcomes of an accelerated clean energy transition, with over 90% renewable energy deployment by 2047. The key findings of the paper suggest that energy independence will require investments in renewables, electric vehicles and green hydrogen. Energy independence with increased deployment of clean technologies will be economically advantageous and that the impact on tax revenues will be minimal.

However, clean energy deployment will be capital intensive and will require additional investments up to $1.5 to 2 trillion between 2023 to 2047. The transition away from fossils will require additional policy support. The paper suggests five pillars for a policy framework to facilitate the transition. These five pillars refer to mandates for adopting cost-effective clean technologies, incentives for emerging technologies, long term infrastructure planning, scaling domestic manufacturing and planning for a just transition.

While the paper presents several insights for increasing clean technology deployment for energy independence by 2047, its focus is restricted on only assessing commercial viable technologies. Other upcoming technologies such as non-lithium ion batteries, electrolytic metal reduction and different application of hydrogen in the sectors have not been taken into consideration. Additionally, other considerations such as better urban planning and changes in mobility measures are excluded from the purview of the research. Thus, there is scope for further studies to assess a more holistic pathway to reduce energy imports alongside

deployment of renewable energy.

McKinsey Sustainability's report, "Decarbonizing India - Charting a pathway for sustainable growth"[7], provides a factual basis for policymakers and private players to compare emission reduction approaches in the backdrop of the India net zero by 2070 commitment. Two scenarios are presented, namely, the Line of Sight (LoS) scenario with current (and announced) policies and foreseeable technology adoption, and the Accelerated scenario including policies such as carbon prices and accelerated technology adoption including those of technologies like carbon capture, usage, and storage (CCUS); green hydrogen; natural climate solutions and material circularity. The report does an extensive study of six main sectors: power, steel, automotive, aviation, cement, and agriculture. It further explores implications of inter-linkages across sectors. Through this extensive review, the report suggests ten urgent actions to accelerate India's orderly decarbonisation.

The report doesn't lay down an action plan or a pathway. However, it suggests key actions to be taken to ensure an orderly transition.

"India: Transforming To A Net-Zero Emissions Energy System, Scenarios Sketch"[8] presents a technically possible but highly challenging pathway towards net-zero emissions by 2050, while achieving India's economic development ambitions. Like the previous two reports, this paper also evaluates two scenarios namely, Net-Zero Emissions (NZE) scenario and Towards Net-Zero (TNZ). The second scenario TNZ highlight the barriers to change that might emerge in the path to decarbonise both in policy and technology.

According to its analysis, the industrial and heavy transport sectors are likely to face limits in achieving full decarbonisation owing to technological constraints that are unable to address residual emissions in the system. These challenges need to be addressed using carbon removal options both technical and natural.

The report suggests that policy has a fundamental role in driving the energy transition. A transformative shift towards renewable energy, hydrogen, bioenergy and CCUS requires a comprehensive, coherent and credible policy framework to support it. Economy wide, sectorial and societal considerations form elements of an effective policy framework. This report focuses on biofuels, hydrogen, nuclear and CCUS with limited focus on electrification and energy storage/batteries.

World Resources Institute's "Pathways for Decarbonizing India's Energy Future: Scenario Analysis Using the India Energy Policy Simulator"[9] projects two scenarios for India by 2050 using India Energy Policy Stimulator, an open source modelling system. The first scenario links India's

Nationally Determined Contributions (NDCs) with Sustainable Development Goals (SDGs). The second scenario, called the Long Term Decarbonisation (LTD), explores policies that exhibit high potential for GHG abatement. LTD scenario presents technologies that are currently in the nascent stages such as hydrogen, battery storage and carbon capture and storage.

As compared to the business as usual scenario, in the NDC-SDG scenario, GHG emissions reduce by 24% by 2030 and 37% by 2050, whereas, in the LTD scenario the GHG emissions reduce by 30% by 2030 and by 65% by 2050.

The paper finds that a small sub-set of policies are responsible for majority of emissions reduction in the medium and long term. In the NDC-SDG scenario, majority of emissions reductions were due to three policies, i.e., an industrial carbon tax, industrial energy efficiency standards, and demand reduction for cement, steel, and wastewater through material efficiency, longevity, and re-use. Similar trends were seen in the LTD scenario, with only three policies contribution to almost half of the emissions reductions i.e. industrial fuel switching from fossil fuels to electricity and hydrogen, hydrogen production via electrolysis (using carbon-free electricity), and early retirement of coal power plants. Both the scenarios lead to net cost savings, and a carbon tax has been presented as an important lever in realising these cost benefits.

The paper incorporates the complexity of the energy system by taking into account the social, economic and environmental concerns with growing energy demand and goals of reduced emissions. However, it identifies practical constraints, implementation challenges and financing needs as key factors to translate policies into action, which can significantly impact the goal of deep decarbonisation. It proposes these factors to inform targeted investment plans and time-bound implementation roadmaps.

Through the literature review we glean that the existing studies have many similarities they are based on differentiating the projections of the best case and worst case scenario. These scenarios juxtapose the current commitments against moderate to aggressive decarbonisation efforts. The review largely places policy as a key factor in aiding India's journey to a low-carbon economy and energy transition away from fossil fuels.

Furthermore, literature reviewed reiterates the need for technological solutions and conducive policies to aid the energy transition. The need for a just and orderly transition is further emphasised by taking into account the social and economic aspects of moving away from exiting systems in the energy sector. A need for a more aggressive approach is proved to be technologically possible and economically viable over the next few years.

A common thread in the above literature also puts forth the difficulties of assimilating new

and upcoming renewable and clean technologies into the existing centralised energy systems. However, it doesn't highlight the need for drastic changes to the existing energy paradigm with the aim of reducing GHG emissions.

Furthermore, the existing literature doesn't specify the impact of delaying an energy transition away from fossil fuel on national security, energy security and economic progress. Concerns regarding macro-economic impacts of a delayed energy transition in India need further inquiry.

Research Methodology

The above literature review throws open several questions regarding the extent to which India can become energy self-reliant by 2047. It shows that an energy transition for low-carbon development is possible with collaborative efforts by policy makers, industry and academia. However, the literature lacks to highlight the eminent threat to national security, economic progress and human well-being if India continues to import its rising energy requirements.

Through this paper, the authors aim to discuss the need for energy self-sufficiency by 2047, when India celebrates its centenary year of Independence. It explores the complex dilemma of balancing India's competing priorities ranging from energy self-sufficiency, national security, growing energy consumption, emissions reduction measures and vulnerabilities to climate change.

This paper adopts a secondary research approach. The methodology selected for this paper involved collection and analysis of existing data, literature and scholarly works related to this topic. The primary sources of data for this study include academic journals, reports, government projections and online databases such as NITI Aayog's India Energy Security Scenario's (IESS) and India Climate and Energy Dashboard. These sources were selected based on their relevance, credibility, and authority in the field of energy and environment domain. Furthermore, the themes, trends, and patterns identified in the literature were critically evaluated and analysed to address the research objectives and questions. The articles and sources were vetted based on relevance, publication date with a preference for work undertaken in the past two to five years range, and credibility of the institutions publishing it.

This exercise has helped synthesise existing knowledge and approaches and helped contribute with newer insights and perspectives to existing body of knowledge. However, secondary research is subject to certain limitations. These include reliance on available data, inability to control variables, assumptions and experimental conditions, and publication bias. Awareness of these limitation has been recognised by the authors and has been considered essential for interpreting the findings of the study and perspectives accurately.

India's Energy Landscape

Energy Demand

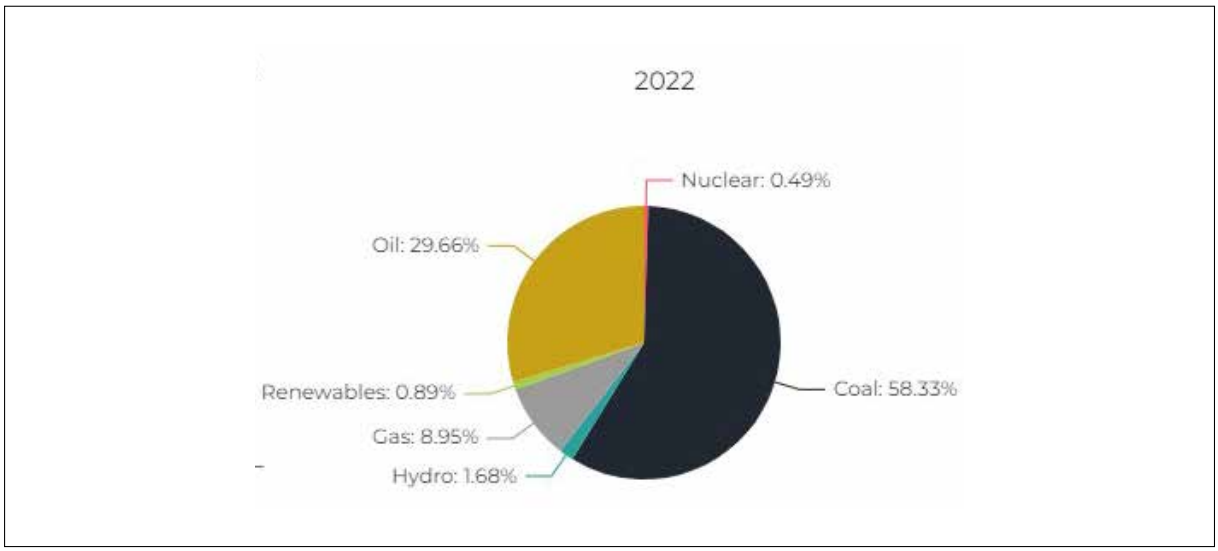
India's energy landscape has drastically evolved in the last two decades. Its energy consumption has doubled since the early 2000s. In the last two decades, India has been responsible for almost 10% of the increase in the global energy demand. Propelled by rapid urbanisation and industrialisation, India stands as the world's third largest energy consumer. Its energy demand is projected to grow at a rate of 3% per annum in the current decade[10], which is thrice that of the global average. The International Energy Agency (IEA) estimates that over the next two decades India will make up the largest share of energy demand globally, comprising a quarter of the total global energy demand by 2047.

India's energy demand is expected to be 1725 Mtoe in the year 2047[11]. Compared to 2022, India's energy demand is expected to triple in a short period of twenty five years. The main drivers for energy demand are expected to come from industry, transport and buildings sector.

Given that India is the 3rd largest energy and oil consumer in the world the IEAs India Energy Outlook Report 2021 suggests that the growing energy needs will make the country more reliant on fossil fuel imports[12]. The increased reliance on fossil fuel imports to meet India's energy demands will prove to be an unsustainable pathway for powering India's economic progress.

Energy Supply

To meet India's robust energy demand, reduce its emissions intensity, and achieve energy self-reliance, there is a need to transition away from fossil fuels and increasingly mainstream renewable energy sources from solar, wind and biomass. This is vastly in contrast with the current energy supply scenario. At present, coal, oil, and solid biomass meet over 80% of India's energy needs[13]. The diagram 1.1 illustrates that the primary energy supply is dominated by coal and oil. It shows that 88% of India's energy supply comes from fossil fuels[14].



1.1 Energy Supply Mix[15]

The high fossil fuel dependence comes at a significant economic cost to the country. At present India imports approximately 90% of oil, 60% coking coal and 55% of gas. Energy related products account for a third of the total merchandise import bill. In financial year 2023-24, India's energy import bill was valued at $260 billion[16], which is approximately 7% of India's GDP.

Moreover, import dependence for energy makes India's economy highly vulnerable to global fuel price fluctuations, regional conflicts and value chain constraints. It further adds strain on the economy, and foreign exchange reserves and exposes the citizens to imported inflation in key segments of fuel, food, and fertilisers.

Furthermore, the economic viability of fossil fuel dominated energy systems is declining owing to depleting resources, rising extraction and processing costs, stricter environmental regulations and commercially viable alternative renewable technologies and advancements in reliable and large scale battery energy storage systems. In contrast, there are significant economic opportunities to be tapped into in the clean energy space. A study suggests that an accelerated transition to net zero can save the world $12 trillion in the coming decades[17]. This is due to the availability and cost efficiency of low-carbon sources of energy.

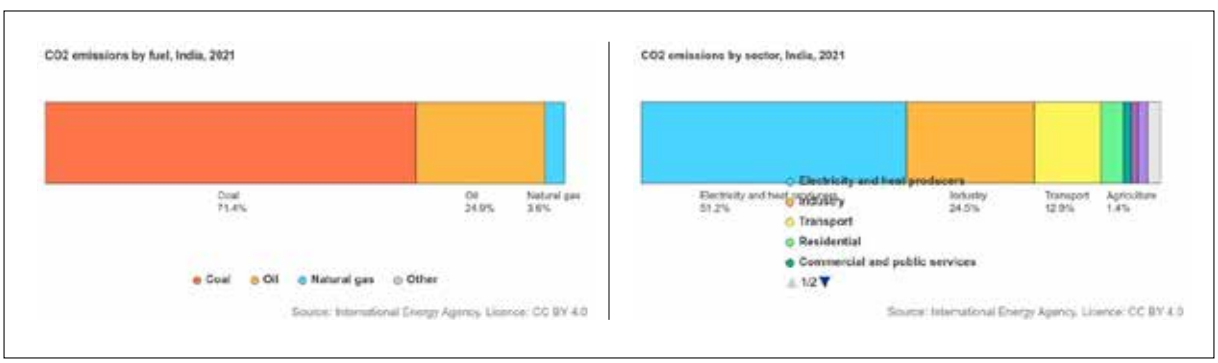
India is expected to see a rise in the share of electricity in the energy grid form 18% as of 2022 to about 50% by 2070[18]. Increased electrification of the energy systems will provide India with an opportunity to move away from thermal power. A gradually slowdown the construction of new coal-based power plants and increasing investments in renewable and

clean energy are expected within this decade. Thus, favourable economics of renewables and increased focus on energy self-reliance are expected to have significant bearing on the energy mix by 2047.

Energy Related Emissions

India's GHG emissions are the greatest from its energy usage. Coal contributes to 71% of India's energy related emissions, followed by oil contributing about 24.9%[19].

A sectoral breakdown of energy-related CO2 emissions suggests that in India, power plants contribute to 51% of the total energy-related CO2 emissions. India's heavy reliance on coal for electricity generation makes it 45% more carbon intensive (632 gCO2/kWh) than the global average (436 gCO2 per kWh)[20]. The second largest contributor to energy-related GHG emissions is industry, which contributes 24.5%, followed by transport, which contributes 12.9% of the energy-related CO2 emissions.



Right: CO2 Emissions by Fuel, India 2021
Left: CO2 Emissions by Sector, India, 2021

In 2021, India emitted 3.9 billion metric tons of carbon dioxide equivalent ($GtCO_2e$)[21]. Without any drastic deviations in technology advancements or policy environment, the World Data Lab forecasts that India will emit upto 7.4 $GtCO_2e$ by 2050. However, if the country wants to stay consistent with limiting global warming to under 1.5 degree Celsius, its emissions will have to drop to one $GtCO_2e$ by 2050. Thus, India needs to reduce its existing emissions by three-fourths. This will require eliminating emissions intensive fossil fuels entirely from the energy mix and implement means for carbon capture utilisation and storage (CCUS) where it is unable to replace its use of emissions intensive energy commodities.

Outlook for Energy Self-Reliance by 2047

In 2020, the Government of India launched the Aatmanirbhar Bharat Mission to promote self-reliance. The mission was announced with the aim of boosting the economy during the Covid-19 pandemic years. It lay down a long-term strategy to increase India's domestic manufacturing as a safeguard against external shocks such as the pandemic in the future. The mission focuses on five main components, namely, Economy, Infrastructure, Systems, Vibrant Demography and Demand. Under the larger ambit of this mission, the Honourable Prime Minister, announced an ambitious target of achieving energy independence by 2047. These targets were announced with an aim of reducing import dependence for energy commodities and increasing efforts to reduce emissions intensity across the energy consuming sectors. The announcement was shortly followed by the Vision 2047 document by the Ministry of New and Renewable Energy (MNRE), which presents a roadmap to increase the uptake of renewable energy (RE) in generation capacity and in electricity generation.

Moreover, a recent study suggests that about 75% of the infrastructure required by 2050 is yet to be built[22], thus, giving India an opportunity to invest and design sustainable energy infrastructure. In order to understand the extent to which India's goal of energy self-reliance can be met, this section corroborates the energy scenario for 2047 by looking at various projections and analysing the extent to which India's can meet its demands domestically.

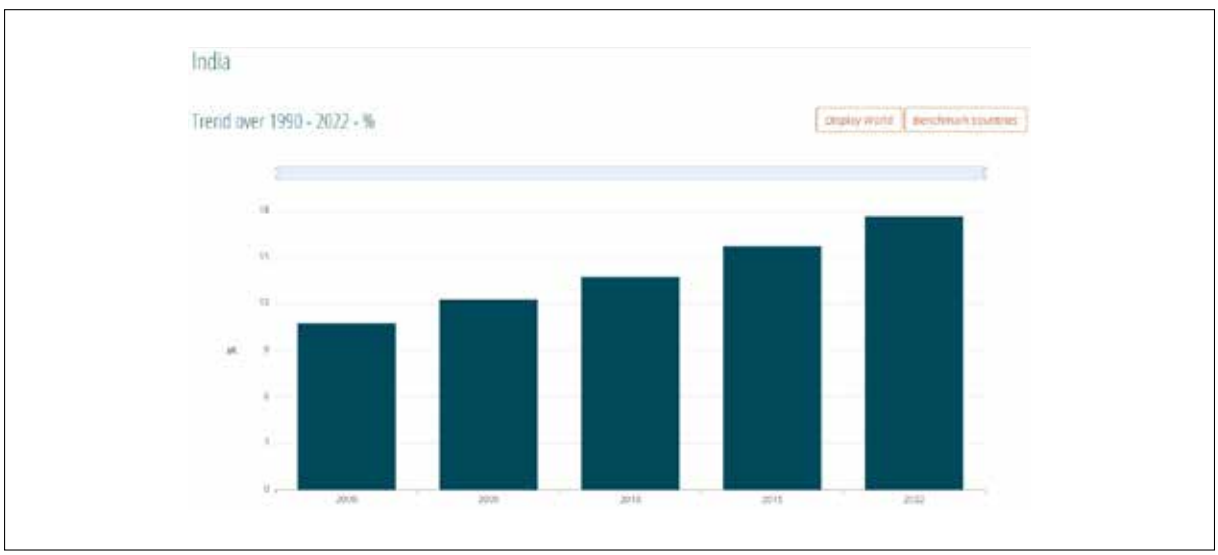
Projections for 2047

Electricity Use in 2047

India's electricity use has seen a tremendous transformation in the past few decades. Historically, it lacked sufficient power generation capacity to meet its demands causing frequent power deficits. In the last decade India's power sector has made remarkable progress with almost 100% electrification, overcoming energy deficits and nationwide synchronisation of the grid.

Between 2005 and 2022 the per capita electricity consumption has almost doubled from 631 kWh to 1255 kWh[23]. At current levels of consumption India is the third largest electricity market in the world. However, the country's per capita electricity consumption is only a third of the global average[24]. This shows that despite high levels of aggregate consumption, the optimal levels of electricity at a per-capita level are not comparable with other economies.

India has shown robust growth for electricity generation. Barring the two pandemic hit years from 2019 to 2021, the country has witnessed sustained growth in electricity generation over last decade[25]. The growth rate has averaged around 6.2% between the periods 2009-10 to 2018-19. Additionally, over the past two decades the share of electricity in total final consumption has steadily increased (refer to the chart below)[26].



3.1 Share of electricity in total energy mix

As of 2022, electricity constituted 18% of the total energy mix. In the coming years, the share of electricity in the energy mix is expected to increase to 50% by 2070[27]. According to Niti Aayog projections, India's electricity demand is expected to be in the range of 5800 to 6500 TWh by 2047 from 2022 levels at 1300 TWh.

There is potential for meeting this increasing electricity demand using renewable energy by tripling the presence of renewable energy in India's electricity grid. The Vision 2047 document by MNRE suggests that India has abundant renewable energy (RE) potential. This includes 750 GW from Solar, 695 GW from Wind, 42 GW from Bio-energy and 5 GW from Waste-to-Energy.

According to MNRE, the generation capacity by 2047 is expected to be 1,325 GW, out of which renewable energy will constitute 1,125 GW of the total generation capacity. This is an ambitious target as it aims at reducing the role of fossil fuels to less than 15% of the electricity grid.

The Vision 2047 suggests a phased approach to increasing renewable generation capacity. It projects that the share of renewable energy (RE), namely Solar, Wind, Biomass, Hydro, Small Hydro and PSP, in electricity generation capacity will increase from 39% in 2022, to 62% in 2030 and reach 85% by 2047. The projection for RE share in electricity generation is projected to increase from 22% as of 2022 to 40% by 2030 and increase to 67% by 2047.

This vision is supported by The National Electricity Plan (NEP) for the period 2022-32. It projects that by 2030, renewables will constitute 66% of the likely installed electricity capacity. Whereas, conventional capacity entailing coal, gas and nuclear will constitute only 33% of the total likely installed electricity capacity.

However, the plant load factor (PFL) for renewable energy sources is relatively lower compared to that of coal-based power plants. For solar the PLF is in the rage of 20 to 25%, for wind it is in the range of 30 to 35% whereas, in India, the PLF for coal-based thermal power plants is in the range of 55% to 65% and is expected to further improve in the coming years. Therefore, increasing renewable energy integration in the grid will have to be supported with advancements in energy storage technologies, research and innovation in clean technology, and behavioural shits towards energy conservation and demand side management.

The NEP suggests that Battery Energy Storage Systems (BESS) are projected to see a four-fold increase from their levels in 2026 to 2030. The increased uptake of BESS is a positive sign for overcoming challenges associated with intermittency of renewable energy like wind and solar, and challenges with improving the plant load factor of renewables.

With 85% of the grid decarbonised, the vision document lays down that 2.5 billion tonnes of CO2 emissions are expected to be averted. This transition away from coal-based power generation will call for an investment in the range of INR 50 to 60 lakh crore. It is expected that an investment of INR 30 lakh crore will be required by 2030 for meeting India's 2030 targets under the UNFCCC, which entails meeting 50% of its power generation capacity from non-fossil fuels.

- Thus, in concurrence with the MNRE Vision 2047, we recommend that 85% of electricity generation capacity should be sourced from renewable energy such as solar and wind by 2047.
- A collaborative effort by public and private players for increasing investments in large scale renewable energy projects and supporting the development of Battery Energy Storage Systems to ensure reliable electricity from a pre-dominantly renewable energy driven grid by 2047.
- Promoting Distributed Renewable Energy (DRE) solutions for electricity consumers, including on-grid and off-grid renewable energy and bio-energy projects across rural and urban areas.
- Concerted efforts towards promoting energy efficiency measures among decision-makers and citizens alike, with a goal of pursuing behavioural change for increased energy consumption.

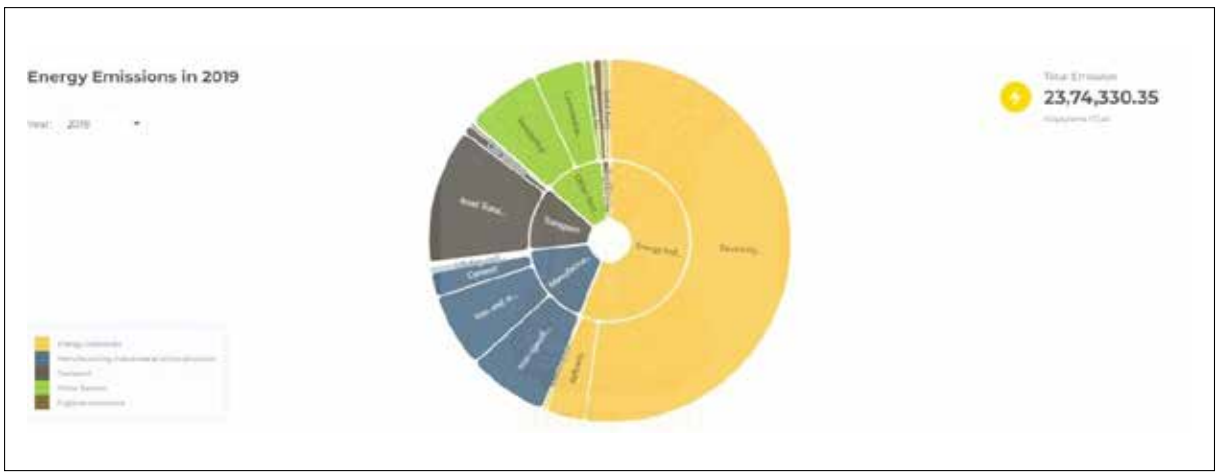
Non-Electric Energy Use in 2047

India derives its self-reliance in the electricity generation form its vast reserves of coal and public sector leadership in the sector. Similar domestic capacity for self-reliance in oil and gas has not been possible as yet. The country heavily relies on hydrocarbon imports for its industry and transport. At present India imports approximately 90% of oil, 60% coking coal and 55% of gas. India's sustained economic growth and rapid urbanisation makes it one of the world's largest hydrocarbons consumers. It ranks as the world's largest consumer of Oil and LPG, 4th largest LNG importer, 4th largest refiner and is ranked as the 4th largest automobile market in the world. High import dependence in this regard makes the domestic economy vulnerable to external price shocks and supply side constraints.

Moreover, industry and transport combined contribute to more than a third of the total energy related GHG emissions. For reducing energy imports, increased electrification of the industry and transport sectors is necessary. However, there are certain limitations to the extent to which electricity can replace oil, coking coal and natural gas, especially in their application in industry and transport. These have been explored in details below:

Role of Non-Electricity Energy in Industry

India is a leading producer of iron and steel, cement, fertilisers, and petrochemicals. These four industries combined consume 80% of the industrial energy used and are responsible for more than half of all energy related CO2 equivalent emissions from the manufacturing sector. According to data from the India Climate and Energy Dashboard, in 2019, iron and steel accounted for almost 40% of CO2 equivalent emissions from the manufacturing sector.



Energy Emissions in 2019, India Climate and Energy Dashboard

Sectoral classification of energy emissions, 2019

India is the second largest steel producer in the world, accounting for 6% of the global steel production. The production of Indian steel is driven by indigenously available high grade iron ore and non-coking coal. The industry is structured on three broad categories based on production routes, namely, blast furnace and basic oxygen furnace (BF-BOF), Electric Arc Furnace (EAF) and Electric Induction Furnaces (IF). As per the National Steel Policy 2017, BF-BOF constitutes 40% of India's total steel capacity. The BF-BOF production makes the process more emissions intensive compared to the gas based directly-reduced iron (DRI) and electric arc-furnaces used by other countries. However, there is significant progress in emissions reduction in the steel industry. It has reduced its average CO2 emissions intensity from 3.1 T/tcs in 2005 to 2.64 T/tcs by 2020, and aims to further reduces it to 2.4 T/tcs by 2030. Therefore it is estimated to reduce approximately 1% carbon emissions per year[28]. While this addresses the environmental concerns regarding steel production, Indian steel industry's heavy reliance on imports of coking coal and non-coking coal are alarming for its energy security considerations. As of 2023, steel manufacturers are importing 23% of their coking coal requirements and 76% of their non-coking coal requirements[29].

The cement industry is the second largest emitting sub-sector within manufacturing sector in India. As per the data from India Climate and Energy Dashboard, in 2019 the cement industry constituted 13% of the total CO2 equivalent emissions from manufacturing. The cement industry mainly relies on coal and oil as the main sources of energy. This is a cause of concern mainly because India produces 8% the global cement supply and relies on energy imports for its manufacturing sector. For India to make substantial progress towards its goal of energy self-reliance, it will have to ensure that to the greatest extent possible the energy needs of India's industry are met from domestic sources. For making this vision to a reality will require a collaborative effort among industry, academia and government.

Moreover, there is a need for industrial decarbonisation to be deliberated and acted upon as projections for 2047 based on NITI Aayog's India Energy Security Scenarios dashboard suggest that in a scenario wherein least efforts are made towards energy security, the energy related GHG emissions from 'industry' will be much larger than power sector. Industry is likely to constitute 47% of the total energy related GHG emissions by 2047. This indicates that consistent efforts will be required for reducing industry's current fossil fuel import dependence and greenhouse gas emissions from their processes and operations. Energy-efficient manufacturing of India's key export commodities like iron and steel, and cement will propel India's industry to stay compliant with international environmental norms and help the commodities retain their competitive edge in the foreign markets.

- In lieu of the above, we recommend, that India's major industries should minimise their import dependence on coal, oil and natural gas by replacing them with increased use of electricity, investments in green hydrogen ecosystem and adoption of the Best Available Technologies.
- The twenty-five year period between 2022 to 2047 should be divided into five periods of five years each with the aim of reducing current energy demand from industry (approx. 270 Mtoe) by 10% during each five year period. This will result in halving the existing industrial demand by 2047.
- The additional energy demand from industries must be entirely met from renewable and clean energy. Export related incentive should be given to companies following these guideline and severe penalties should be imposed on industries deviating from the goal of energy self-reliance by 2047.
- Industries should ensure they are compliant with international emissions reductions and energy savings benchmarks to retain their global competitive advantage.
- Industrial bodies must play a proactive role in promoting collaboration with the public sector for supporting research and innovation for clean technology, material-circularity, and recycling solutions.
- Industries must cluster-wise adopt a decarbonisation plan, laying down the timeframes for

transitioning away from imported fossil fuels, year of emissions peaking and adoption of alternative energy sources.

- The government should carefully craft incentives for industries to align their operations with India's energy self-reliance goal by 2047.

Role of Non-Electricity Energy in Transport

- Transport sector constitutes only 1/5th of India's final energy consumption, however it relies heavily on oil imports. As one of the main fuels used in road transport, the sector accounts for 50% of India's oil consumption[30]. This makes India's transport sector the third largest emitter of energy related greenhouse gases. As per the India Climate and Energy Dashboard, the transport sector accounts for approximately 13% of the total energy related emissions as of 2019. Within the transport sector, road transport constitutes 90% of all transport related CO2 equivalent emissions. It accounts for, roughly 87% of passenger traffic and 60% of freight traffic movement in India[31].

With increased economic development, India is expected to see a rise in passenger and freight mobility. With the aim to become a logistics hub, NITI Aayog's IESS projections suggest that if steps towards energy security are not taken then the transport sector is expected to more than triple its current energy related GHG emissions, and continue its import dependence on oil from 87% in 2022 to 91% in 2047. These projections suggest that there is a need to eliminate dependence on oil imports from road transport segment to the greatest extent possible.

Solutions such as increased electric mobility, hybrid vehicles, biofuel blending, and green hydrogen will form the basis of this transition away from oil imports. However, these technologies are at different levels of innovation, commercialisation and adoption in the market. For instance, at present, the total cost of ownership of an electric vehicle (EV) is lesser than that of an internal combustion engine (ICE). However, hydrogen mobility technology is yet at a nascent stage.

However, with regards to new and upcoming solutions, there is a need to focus on overcoming perceptional challenges among its end users. To elaborate, a common issue hampering the uptake of EVs in the markets is 'range anxiety'. It refers to apprehensions regarding adequacy of the vehicle's battery charge to complete a journey. This perceptional challenge is further heightened by the limited charging infrastructure available for electric mobility. Similarly, improving the availability of blended fuels across the country is a pre-requisite for a behavioral change towards low-carbon mobility.

- We recommend that efforts for reducing oil imports should be mainly focused on road

transport, which accounts for roughly 87% of passenger traffic and 60% of freight traffic movement in India[32].

- Electrification of road transport should be achieved alongside integration of renewable energy in the electricity generation and creation of robust battery charging infrastructure.
- By 2030, at least a third of all new vehicles sales in all segments should be electric. By 2040, this should increase to two-thirds of all new vehicles sales in all segments to be electric.
- However, aggressive push for increased charging infrastructure will be needed. Private sector participation and entrepreneurial pursuits should be channelised into creating a robust infrastructure for EV charging ecosystem and services.
- Increase availability of blended fuels at 35% of all petrol dispensing stations by 2030, 70% by 2040 and 90% by 2047.
- Efforts towards making public transport fleet completely electric should be undertaken with significant participation by sub-national governments.

Cross-Sectoral Challenges to Energy Transition

At the United Nations Climate Change Conference (UNCCC) held in Glasgow (COP26) in 2021, India committed to reaching net-zero emissions by 2070. The near term targets were also revised upwards by India at the COP26. The recently updated Nationally Determined Commitments (NDCs) under the Paris Agreement have reiterated India's resolve to act on the climate crisis and set more ambitious targets. These updated goals entail achieving "about 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, with the help of transfer of technology and low-cost international finance including from Green Climate Fund (GCF)" ; reducing "Emissions Intensity of its GDP by 45% by 2030, from 2005 level" and a "mass movement for LIFE – Lifestyle for Environment"[33].

Achieving the stated targets will require significant transformation in the existing energy paradigm. NITI Aayog's India Energy Security Scenarios simulations suggest that India can transform its energy systems to support the twin objectives of energy self-reliance and emissions reductions by 2047. However, a low emissions-intensity growth pathway will require several measures related to land, labour and capital.

Investments

In order to achieve carbon neutrality by 2070, the International Energy Agency (IEA) approximates that an average of $160 billion per year will be required across India's energy sector from 2022 until 2030. This will require tripling current levels of investment towards an energy transition away from fossil fuels. Another recent study estimates that the country will

require a cumulative of USD 14 – 17 trillion between 2022- 2070 in order to achieve energy transition in alignment with India's net zero targets. This will be a significant investment for a developing country like India, who's GDP for FY23 was around 3.7 trillion USD. India will need to strategise a way of raising these funds internally and externally. This mammoth task will require political will and dedicated support from private players, international financial institutions and other actors.

However, the greatest challenge in investing for climate resilience will be to overcome people's perceptions regarding the climate crisis. There is a need for highlighting the cost of inaction with regards to energy emissions reductions. With every additional tonne of CO2 in the environment will trigger irreversible climatic catastrophes which will result in destructions of critical infrastructure, loss of human lives and livelihoods and ecological damage.

There is a need for undertaking drastic measures to avert a business as usual scenario. Methods for quantifying the impacts of emitting every one tonne of CO2 in the atmosphere should be widely publicised amongst decision makers and citizens alike. The social cost of carbon is one such metric which will help communicate the gravity of the issue.

Moreover, the macro-economic impacts of an energy transition will have monetary and fiscal policy implications. For instance, moving away from a fossil fuel dominated energy system will cause a loss of State and Central government revenue from fossil fuel taxes, duties, and royalties, as well as electricity duties. Strategies to offset these revenue losses will have to be worked on with a view that social and human development pursuits by national and state governments are not impacted.

Furthermore, India is one of the top five countries providing fossil fuel subsidies. According to a recent study by the International Monetary Fund (IMF), India ranks fourth highest in terms of subsidies distributed for fossil fuels. The study estimates that India provides fossil fuel subsidies to the tune of $346 billion or 10 per cent of its GDP[34]. These include both explicit subsidy (undercharging for the supply costs of fossil fuels) and implicit subsidies (undercharging for environmental costs and forgone consumption tax revenues). Thus, the reduction in subsidies for fossil fuels will have a bearing on the pace of the energy transition.

Technology

On the technological front, adoption of new and emerging technology such as green hydrogen, small and modular nuclear reactors, carbon capture utilisation and storage, bio-fuels and battery energy storage systems (BESS) will determine the pace of the energy transition. However, economic and social factors will determine the scale at which these technologies are

adopted. Here policy makers will have to analyse the unknown costs associated with critical minerals necessary for these technologies. Keeping in mind India's goals of self-reliance and climate-resilience, the entire life-cycle of these new and upcoming technologies should be carefully analysed. Sourcing critical minerals for India's low-carbon pathways should be sustainable and reliable in terms of their sourcing, processing and manufacturing. Once this background work is undertaken, the government should prioritise technologies and set benchmarks for the industry at a nascent stage. Policy support for these sectors will play a crucial role in overcoming challenges of investments, commercialisation and economies of scale.

Land Requirements for RE

Adoption of largescale renewable energy projects like solar parks, wind farms, green hydrogen plants, etc. will require land in specific resource rich regions. As per the National Electricity Plan 2023 notified by the Central Electricity Authority, land has been considered as the second most important resource after solar irradiation required for solar power plants. The government estimates that 1 MW of solar power addition will require approximately 4 acres to 5 acres of land. Thus one GW of solar power addition will require 4000 to 5000 acres of land. In order to meet Government of India's commitment of achieving 500 GW from non-fossil fuels by 2030, the Ministry of New and Renewable Energy (MNRE) has initiated efforts add 50 GW of renewable energy capacity every year starting from 2023-24 to 2027-28[35]. If all renewable capacity was to be sourced from renewables for a year, the land requirement would be to the tune of 810 square kilometres every year. This indicates a need for land equivalent to the size any big metro city in India, each year.

Furthermore, if India wants to achieve a net zero emissions target by 2050, it will necessitate allocating 1.7% to 2.5% of the nation's total land area exclusively for solar energy production [36]. The main challenge for making land available for renewable energy projects is with regards to land acquisition. The land acquisition processes can often prove to be lengthy owing to social cultural norms around land ownership, loss of livelihoods and differences regarding monetary compensations. Consequently, the timely completion of renewable projects can face delays.

Just Transition

Furthermore, supporting greater integration of renewable energy in the grid will need to be undertaken in a just and inclusive manner. According to a study conducted in 2021, approximately 284 out of India's 736 districts (about 40%) rely on the coal industry for their livelihoods. This dependency encompasses workers and their families living in the coal

industry dependent districts, pensioners, or residents whose districts benefit from existing coal supply chains and corporate social responsibility (CSR) funding provided by coal companies. For these districts to plan an orderly transition, the government central and state should work together. However, synergising energy self-reliance policies would be challenging owing to India's federal set up. States have the authority to design renewable and new energy policies as per their state requirements. In addition to varied policies across states, the central government haven't laid down a clear roadmap detailing out the year emissions will peak, number of thermal power plants to be phased out and by when, support for battery energy storage systems, in addition to short, medium and long term emissions reduction targets for delivering on their international climate commitments.

Enablers for Energy Self-Reliance by 2047

New and Emerging Technological Enablers

While wind and solar energy technologies have already achieved commercial scale, there is a need for looking at the next generation of solutions which are on their path to maturing into reliable energy systems that will help India further its goal of energy self-reliance by 2047.

Distribute Renewable Energy (DRE)

A distributed energy system is essentially a tool of efficient demand side management of energy requirements. Enablers for a demand side transformation in the power sector can be pursued by a paradigm shift in the way electricity is traditionally generated and distributed. This will transform the consumers into "prosumers". A term used to refer to consumers who "both produce and consume energy"[37]. It will thereby bring the sources of electricity production and consumption closer.

At present DRE finds itself at a unique advantageous position. It is supported by several favourable factors. First being the drastic decline in costs of solar and wind energy. For instance, in 1950s the cost of one watt of solar capacity was $1,825. As of 2021 costs of utility-scale solar are as low as $0.70 per watt. Both wind and solar has shown a dramatic decline in its costs over the last decade. Nose-diving by 71% and 90% respectively, these have become the cheapest soruces of energy[38].

Second, a distributed generation circumnavigates the roadblocks faced by large electricity utilities in making the transition away from fossil fuels despite attractive costs. These are with regards to long term investments also referred to as carbon lock-in, policies and infrastructure. The uptake of distributed generation is benefiting from declining system costs and increasing electricity rates. Making the economics of distributed systems more attractive to the retail consumer.

Enablers for Adoption of DRE

- The ecosystem for supporting a decarbonised and distributed energy transition will require local community level entrepreneurship, capacity building for localised servicing and support, access to low cost-financing and a systematic shift towards low-carbon infrastructure.
- The interoperability of distributed energy systems can be enhanced by application of blockchain technologies to facilitate peer-to-peer trading, real-time monitoring and

evaluation of energy generation capacities. The localised distributed generation and consumption will enable communities to be accountable for their resource management. Locally fixing accountability will emerge as a driver of energy efficiency at the consumption side of the spectrum.

- A robust policy framework and regulations can provide clear pathways for defining the role of DRE in India's larger energy self-reliance.
- A bottom-up, rather than only focusing on a top-down approach for DRE. These distributed micro-grids will be crucial in localise carbon accounting which is an essential precursor to carbon taxation. These systems together will make the transition bottom-up, rather than only focusing on a top-down approach.
- Furthermore, adoption of DRE will allow for creation of a highly skilled workforce for installation, operation and servicing of these systems. The private sector in partnership with the sub-national governments can conduct capacity building workshops and trainings for re-skilling and up-skilling the existing workforce.

Case Study: Peer-to-Peer Trading of Solar Power in India

In New Delhi, Tata Power, in collaboration with the India Smart Grid Forum and the Australian technology company Power Ledger, has pioneered unique initiatives for peer-to-peer trading of solar power. This endeavour fosters the creation of a comprehensive ecosystem comprising grid-connected, decentralised energy resources.

Application of Blockchain in Distributed Renewable Energy

- Increased adoption of Distributed Renewable Energy (DRE) can help circumnavigates the complex challenges of decarbonising a centralised grid. Advancements in information technology, blockchain and AI can further augment the transition by enhancing the connectivity among other grids, data monitoring and evaluation, and computational power to predict trends in electricity generation and use.
- At present there is an increased penetration of variable distributed generation such as rooftop solar systems in India. As of March 2023, the cumulative rooftop solar capacity was approximately 9.3 gigawatts (GW). Nearly 58% of the added capacity in the January to March quarter of 2023 was from residential consumers. In the same quarter, rooftop solar accounted for 26% of total solar installations[39]. Application of block-chain in DRE will further democratise the power sector, giving the 'prosumer' tools to make data backed decisions and facilitate a digtial infrastructure of peer-to-peer trading, metering, etc.
- In order to support increased penetration of DRE, blockchain, a distributed public ledger can vastly be used. It securely records the transactions in a chronology with cryptographic links to preceding and succeeding blocks. This makes the technology resilient against any data tampering. Blockchain in DRE can help optimise the grid management. It can enable real-time pricing, monetising excess electricity, peer-to-peer renewable energy trading and more.

Green Hydrogen

In addition to the above measures, green hydrogen has an important role to play in reducing dependence on emissions intensive and imported fuels. Green hydrogen is produced by the process of electrolysis, where the water is split into hydrogen and oxygen using electricity sourced from renewable energy sources like solar, wind or hydropower. There are several applications for green hydrogen in fuel cells to power vehicles and provide electricity. Furthermore, green hydrogen can also be used in industry for producing ammonia, methanol and steel.

In 2021, the Government of India launched the National Hydrogen Mission with the aim to increase annual green hydrogen production to a minimum of 5 MMTPA by 2030[40]. Adoption of green hydrogen will also result in reduction of 3.6 gigatonnes of CO2 emissions between 2020 and 2050[41]. In the same timeframe, energy import savings are likely to range between $246 billion to $358 billion[42].

Enablers for Green Hydrogen

- Emphasis should be on reducing cost of producing green hydrogen in India. At present green hydrogen production is about three times higher than grey hydrogen which is produced using coal or lignite gasification. There is scope for reducing cost of green hydrogen by giving a boost to domestic electrolyser manufacturing, low cost renewable energy plants, implementing waiver of inter-state transmission charges and green hydrogen purchase obligations modelled on Renewable Purchase Obligations (RPOs).
- The government should focus on investing in transport and storage infrastructure around industrial clusters to help spur demand for green hydrogen. This will have a crowding-in effect on private long term capital investments for the green hydrogen ecosystem.
- Production linked incentives for manufacturing sector mainly targeting export market can encourage an increased uptake of green hydrogen.
- On the fiscal front, a carbon tax should be implemented and subsidies for fossil fuels should be diverted toward capacity building and skill development aimed at promoting employment generation in green hydrogen production.
- A crucial enabler for a vibrant green hydrogen ecosystem would entail streamlining clearances for businesses manufacturing electrolyser or advanced technologies that produce green hydrogen.

Small Modular Nuclear Reactors

At present nuclear power plants (NPPs) generate 10% of the world's electricity. This helps

avoid 180 billion cubic metres of natural gas demand and 1.5 billion tonnes of CO2 emissions every year. Increasingly, there is a need for supporting wind and solar energy with more reliable and affordable sources of energy. Nuclear energy presents the best solution for reliable, affordable and 24/7 supply of power. This is significant for the industrial clusters as it takes away from the variability of renewable energy while also reducing the emissions intensity and import dependence. However, as of 2022, nuclear energy in India is abysmally low, only constitution 1.5% of the total energy supply (IESS Dashboard).

Nuclear Power Plants (NPP) have several advantages such as low cost grid integration, efficient use of land and high-skilled job creation, however they often experience cost and time overruns. Thus, there is a need for increased uptake of nuclear energy without the drawbacks of conventional NPPs. Suitable alternatives to be considered for this purpose are Small Modular Nuclear Reactors (SMR) with a maximum capacity of 300 MW.

SMRs are designed to operate for 40 to 60 years with an estimated capacity factor/plant load factor of 85-90%. The small size lends to enhanced safety from seismic activity, which has not been the case with conventional NPPs. These units are manufactured in factories and assembled on site, reducing the potential risk of time and cost overruns. Several technological studies have shown that SMRs are safe, cost effective and reliable source of clean energy. However, there are several challenges ranging from high cost of SMRs and problem of public acceptance.

Enablers for Adoption of SMRs

- Inform public about nuclear energy with the aim of reducing misinformation and generating awareness about SMRs, especially the security aspects.
- In the short term, proper dissemination of comprehensive environmental, social and economic benefits should be undertaken.
- Additionally, pilot models of SMRs should be installed and operationalised in order to change public perception. Awareness campaigns disseminating data from these facilities must be run for promoting this clean technology.
- Additionally, SMRs should be looked at as a medium to long term solution in the twenty-five year energy transition. SMRs will require reduced costs with increased scale of manufacturing and technology transfer from advanced countries. India and the U.S. are looking at collaboration for promoting SMRs.
- Encourage involvement of manufacturers such as BHEL, L&T, or Godrej Industries along with technology transfer from the U.S. or other advanced countries will help drive the costs down. As seen with solar power, market forces have led to steep decline in prices of the technologies.

- Universally accepted benchmarks and operational standards should be established for promoting SMRs in the energy mix. At a domestic level, legal and regulatory changes such as amending the Atomic Energy Act 2015 will have to be amended to facilitate greater participation by the private sector for setting up SMRs.

Biofuels

While electrification of mobility is a crucial component of decarbonising transport, there is a need for enabling increased uptake of alternative fuels to reduce oil consumption and import dependence. At present merely 2% of fuel requirements for India's transportation sector are being met by biofuels[43], while the remaining transport fuel requirements are met by fossil fuels.

Enablers for Boosting Production of Biofuels

- These range from investing in land productivity in alignment with principles of land degradation neutrality, water and food security concerns. The industry must promote technological innovation ranging from processing different feedstocks such as agricultural and forestry waste residues to improving efficiency of existing processing technologies. The long-term strategies supporting biofuel economy require to work closely with global markets to create an ecosystem for production and consumption of biofuels.
- A step in this direction has already been taken by India at the G20 in 2023 by launching the Global Biofuels Alliance (GBA), to bring together largest producers and consumers of biofuels. Leading producers of biofuels such as the United States of America and Brazil have joined the GBA, with the aim to accelerate the energy transition.

Cross-Sectoral Enablers

Achieving energy self-reliance in a short span of twenty-five years will require tapping into India's renewable energy potential and mainstreaming it in the energy mix. However, this transition will have to be supported with multitude of policy, technological and business-oriented solutions.

- This calls for a cross-sector framework for systematic reduction in energy related emissions among sectors ranging from industries, transportation, building and infrastructure. This should include concerns associated with just transitions, in order to address these as the transition is underway.
- The framework must mandate accounting for GHG emissions across all the sectors. Accounting and reporting of GHG emissions will help policy makers make data-backed

targeted and sector specific measures for emissions reduction measures, best available technology and efficiency measures.

- It must also standardise and set industry wide benchmarks for carbon and energy budgets.
- In order to meet Net Zero target by 2070 commitment, the government should identify a year of peaking for GHG emissions. This will help the many sectors align their pace of energy transition with the country's envisioned pace of transition.
- At a sub-national governmental level, there is scope for planning and implementing area specific emissions reductions targets as well as generate successful public-private partnerships (PPP) models for sourcing their energy demands locally.
- The sub-national governments have a significant role to play in reducing their jurisdiction's dependence on imported energy and promoting renewable energy.
- Central and State governments must support sub-national governments to create a financially viable model for achieving energy self-reliance at a district or at a local body level.
- For the power sector, India is on track to achieve more than 50% of installed capacity from non-fossil fuels by 2030. However, renewable energy's inherent challenges of intermittency and low plant load factor will pose a risk to the grid stability and 24/7 energy supply. Thus, there is need for government support for development of economically viable and scalable solutions for meeting long duration utility scale energy storage, along with gradual phase down of coal-based power plants.
- Moreover, beyond production of electricity, distribution and transmission should be looked into. India loses more than twice of the electricity in transmission compared to the global average. A reduction in transmission losses will improve the delivery or electricity to the last mile.
- Taking into account MNRE Vision 2047 document projections, to achieve 85% of the installed capacity from renewables in India's grid, the government will have to create a favourable ecosystem for developing RE technologies domestically. Support from the government is required for research and innovation in new and upcoming technologies such as electrolyser manufacturing for green hydrogen, vertical axis wind-turbines, waste-to-energy technologies, battery storage and artificial carbon capture and sequestration technologies.
- Similar to support for boosting domestic manufacturing, the government should provide appropriate fiscal and financial incentives and lay down a roadmap for substantially increasing the value addition within the country in a short span of time.
- The government should support the entrepreneurial inclination for those involved in new and upcoming technologies focused on energy efficiency improvement. The government should help ensure access to low-cost funding, assured demand from the industry and private players for an initial period till this ecosystem fully matures.
- Furthermore, adoption of DRE will allow for creation of a highly skilled workforce for

installation, operation and servicing of these systems. The private sector in partnership with the central and state governments can conduct capacity building workshops and trainings for re-skilling and up-skilling the existing workforce. This will help shift energy demand from the central grid to the distributed renewable generation.

- While government support and public-private partnership for nascent technologies and industries is necessary, there is also a need to create a healthy mix of penalties and rewards for actions that impact the emissions reduction efforts. These can range from penalties on exceeding certain emissions threshold for industries, to rewarding businesses that improve energy efficiency year on year.

Conclusion

India's national security imperatives are driving its 2047 energy self-reliance agenda. The paper identifies that India can meet its rising energy demand domestically to the greatest possible extent by mainstreaming renewable energy in its energy mix. Various challenges associated with diversifying its energy mix and adding more renewables have been identified and addressed in the paper. These range from financial investments required for undertaking this transition, technological advancements, land requirements for adding renewable energy to the energy mix and issues concerning justice and inclusion while undertaking this transition away from fossil fuel dominated grid.

Several enablers for guiding policies for this energy transition away from fossil fuels have been discussed in the paper. A main theme that has emerged is the need for a paradigm shift in the way energy is produced and consumed. Furthermore, the enablers have been identified keeping in mind a need for equal efforts required on the demand as well as a supply to enable the overall transition without compromising on any of India's developmental needs and aspirations.

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