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Shell scenarios | Sketch

India transforming to a net-zero emissions energy system

A call to action to 2030

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Contents

Foreword

The COVID-19 pandemic and Russia's invasion of Ukraine have created a volatile environment around the world. While governments look to enhance domestic security, including energy security, India holds the G20 presidency, putting it in a unique position to lead deliberations on key global challenges including climate change. India has already achieved its commitments to reduce emissions intensity by 33-35% compared to 2005 levels, and to produce 40% of its electricity from non-fossil fuel-based energy sources. India took a further step forward in August 2022 when it enhanced its nationally determined contribution, in line with its goal to achieve net-zero emissions by 2070. However, like many developing countries, India also faces the challenge of balancing environmental sustainability with ensuring energy security and energy equity for its people.

Urgent action to move to low- and zero-carbon energy is the way forward. Besides the climate benefits, this transition could create new jobs, reduce air pollution and lower the country's dependence on imported oil.

The period from now until 2030 is a decisive one for India in terms of climate action, economic growth and overall development. India is one of the most vulnerable countries to the effects of climate change, and it is also one of the fastest growing economies. The choices that India makes this decade will have a major impact on its future, in terms of both its ability to adapt to climate change and to continue to grow economically.

India has made impressive progress in recent years with ambitious pledges and climate actions. At the same time, India has made significant investments in renewable energy. It is now the world's third largest producer of solar power, for example. Policy push is required to sustain this momentum.

In 2021, The Energy and Resources Institute (TERI) and Shell partnered to produce a Scenarios Sketch on India, outlining the options and choices the country faces in developing a technically possible, though challenging, net-zero energy system.

This report builds on the previous Scenarios Sketch to explore what it will take for India to meet its 2030 commitments and its long-term goal of achieving net-zero emissions. It also addresses how India can achieve affordable and secure energy, while meeting its commitments. It explores decarbonisation in India, sector-by-sector, identifying key areas of focus this decade and policies needed to enable the required changes. We offer it in the hope that the findings of this study will encourage further dialogue and benefit policymakers and planners as they chart India's energy transition and journey to net zero.

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1 Introduction

Introduction

At COP26 in Glasgow in 2021, India pledged to achieve net-zero emissions by 2070. Since then, the Intergovernmental Panel on Climate Change has released the synthesis of its Sixth Assessment Report warning of the consequences of inaction and the rapidly closing window of opportunity to secure a liveable and sustainable future for all.[1] The World Meteorological Organization's recent analysis said that global temperatures are now more likely than not to (temporarily) breach 1.5 degrees Celsius of warming sometime in the next five years.[2]

Analysis by the Intergovernmental Panel on Climate Change and other reputable organisations indicate that the 2020s are a decisive decade for action if the world is to enter a trajectory to meet the goal of the Paris Agreement. The energy transition is already under way, requiring action not just to be sustained but accelerated over the course of this decade to keep average global temperature rise well below 2°C, and as close to 1.5°C as possible, above pre-industrial levels.

India submitted its nationally determined contribution to the United Nations Framework Convention on Climate Change under the banner of LiFE – Lifestyle for Environment – a mass movement for "mindful and deliberate utilisation, instead of mindless and destructive consumption".

It commits the country to eight goals[3], with three specific quantitative targets for 2030:

- increasing installed non-fossil power generation capacity to 50%;
- reducing the emissions intensity of GDP by 45% compared to 2005 levels; and
- creating cumulative additional carbon sink of 2.5-3 billion tonnes of CO_2 equivalent through additional forest and tree cover.

India has an opportunity to lead by example. Unlike developed economies with large legacy (fossil-based) energy systems, India has an opportunity to build an energy system based on new lower-carbon technologies and fuels. Some legacy components exist but they represent a smaller proportion of the system, thus reducing the risk for lock-in to traditional fossil fuel infrastructure and increasing the opportunity to leapfrog to a low-carbon energy pathway.

India also can place itself at the forefront of the coming green energy and industrial revolution. By becoming a technology, manufacturing and supply chain hub for low-carbon goods and services, India can attract investment and create new jobs. Moreover, substituting energy imports (largely fossil) with (largely domestic) low-carbon energy can also reduce India's exposure to global energy prices and volatility. Finally, given the strong synergies between climate action and economic development, India has the opportunity to both develop and decarbonise.

In this context, now is a timely moment to look at what India will need to do this decade in order to be on a trajectory to meet its net-zero emissions by 2070 target.

Shell-Teri India Scenario Sketch

The Shell-TERI India Scenarios Sketch explores how to balance economic growth and development with the need to decarbonise the energy system, by 2050 in the **Net-zero emissions** scenario and by around 2070 in the **Towards Net zero** scenario.

The **Net-zero emissions** scenario is designed to assess whether adequate solutions exist to fully decarbonise different energy end use sectors and/or examine the level to which each of the sectors could theoretically move to net-zero emissions by 2050. The **Net-zero emissions** scenario is ambitious and assumes that all social, infrastructure and behavioural barriers can be overcome if the required technologies are available. The **Towards Net zero** scenario highlights the barriers to change that might emerge.

Both scenarios keep in mind the Indian government's goals of significant economic growth, universal electricity access and clean cooking for all.

Overall, the core areas of India's energy transition are energy efficiency, low-carbon electrification and the increasing use of decarbonised fuels such as green hydrogen and advanced biofuels.

The scenarios highlight that making significant progress in these areas would require the development of enabling infrastructure, such as additional power transmission and distribution assets to support increased renewables-based electrification and supply and demand networks for green hydrogen and biofuels. While this will impose additional costs, investments in energy infrastructure are also likely to boost jobs and demand in the near term and increase the economy's capacity for growth in the long term.

Both scenarios highlight that residual emissions remain in hard-to-abate sectors such as heavy industry (steel, cement, chemicals) and long-distance transport (road freight, shipping, aviation). These residual or unavoidable emissions will need technological solutions, like carbon capture and storage, particularly in heavy industry. Nature-based solutions also have an important role to play in the country's decarbonisation journey, mainly through efforts to increase afforestation, wetlands and agroforestry.

Shell-TERI India Scenarios Sketch, published in 2021, set out potential pathways for the country to drive deep decarbonisation of its energy system, in line with the goal of the Paris Agreement, Can a world desparate for immediate security also meet the long-term challenge of climate change?.[4] It was one of the first assessments of the challenges and opportunities created from the journey to achieving net-zero emissions in the second half of the century, and has been referred to by various policy forums. This report builds on the Shell-TERI India Scenarios Sketch to systematically update sectoral progress towards decarbonisation. It highlights key areas where action needs to intensify this decade for India to be on course to meet its net-zero targets. Regardless of the specific year this century that India achieves net-zero emissions, significant effort will be required this decade to sow the seeds of future success. Hence, this report focuses specifically on the period from now until 2030, on areas for action and policies to enable that action this decade.

2

Global context: The emergence of a security mindset

Global context: The emergence of a security mindset

Amid evolving climate commitments and policies, the world has gone through significant changes and disruptions. It is slowly recovering from the destructive effects of the COVID-19 pandemic, and dealing with the continuing economic, social and political impacts of Russia's invasion of Ukraine.

The COVID-19 pandemic and the war in Ukraine have driven a shift in government priorities, with a security mindset emerging across the world. More than a decade of benign macroeconomic conditions following the 2008 financial crisis meant that governments, businesses and consumers were able to focus to a greater extent on environmental sustainability and the climate impacts of energy. However, the post-pandemic surge in energy prices, which was amplified by the invasion of Ukraine, has brought energy security and affordability into sharp focus. This focus has intensified the global trend towards geo-economic fragmentation that has been under way since the early-2010s, with a shift in supply chains and investment flows to "friend-shoring" with allies and "near-shoring" closer to home. As a result, national governments are increasingly looking at ways to build capacity and enhance domestic security not just in energy but also more widely in areas such as health, climate, the economy and society.

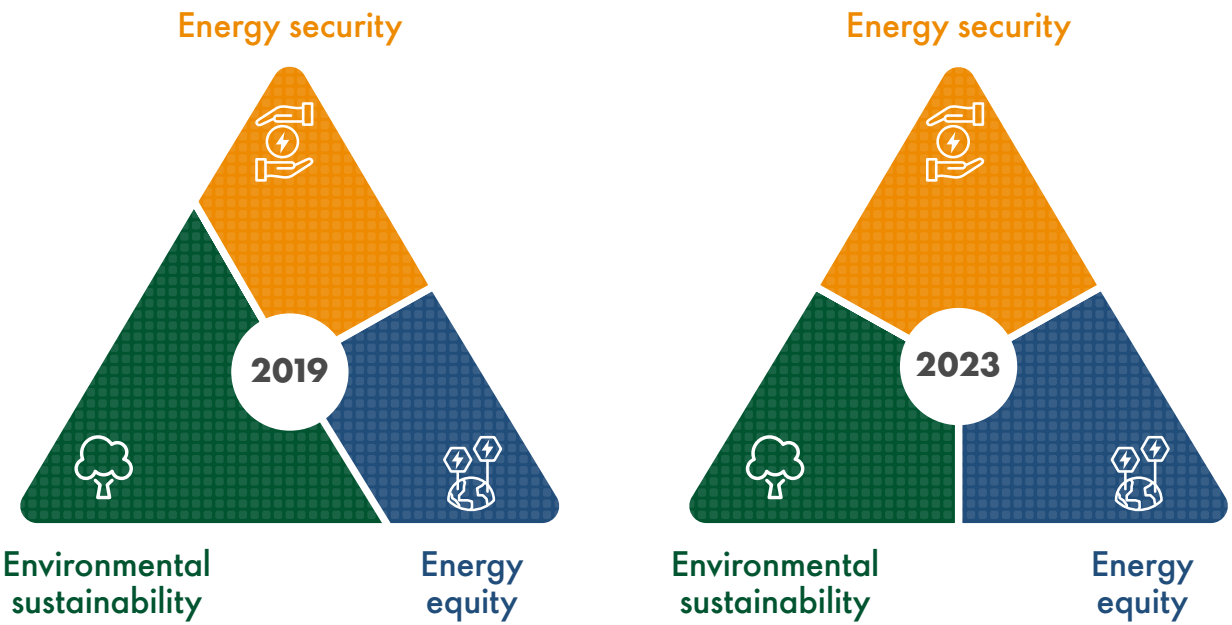
This means that decarbonisation and environmental sustainability need to be balanced with energy security and energy equity, which is known as the energy trilemma. In the context of the energy transition and decarbonising India's energy system, this has meant a shift in the energy trilemma priorities of energy security, energy equity and environmental sustainability (see **Figure 1**).

Energy security refers to the ability to access reliable and modern energy sources. Currently, India is heavily reliant on imported oil, gas and coal, making it vulnerable to global energy price shocks and supply disruptions.

Energy equity means that all citizens have access to affordable, reliable and clean energy. Because a significant proportion of India's population lives near or below the poverty line, high and volatile energy prices – caused by the current energy crisis and the transition to low-carbon alternatives – will have a disproportionate impact on these households.

Environmental sustainability refers to the need to reduce energy-related greenhouse gas emissions and other local pollutants. The decarbonisation of the energy system and the transition to low-carbon energy will produce climate and wider environmental benefits, having a positive impact on environmental sustainability and India's ability to achieve its sustainable development goals.

Figure 1: Global energy trilemma: an illustration of shifting priorities



India's reliance on imported oil, gas and coal has created challenges during the current energy crisis. By accelerating the transition to domestic and low-carbon sources of energy, India has the opportunity to increase energy security while also reducing emissions.

With its skilled and educated workforce, and technological capabilities, India also has the opportunity to become a world-class centre of low-carbon manufacturing and solutions, especially against the backdrop of countries seeking to diversify their low-carbon supply chains and investors seeking greater geographical diversity in their low-carbon investment portfolios.

3

Global context: Implications for the energy transition

Global context: Implications for the energy transition

Shell's new global scenarios – The Energy Security Scenarios[5] – investigate the implications of an increasingly fragmented world focused on energy security (Figure 2). The scenarios ask the question: "Can a world desperate for immediate security also meet the long-term challenge of climate change?"

At the global level, a security mindset, with national interests taking precedence, means that a potential tension emerges between national climate pledges and what countries must do to address immediate energy concerns. The scenarios indicate that we are collectively entering a world of competitive – rather than collaborative – transition.

However, the nature of the competition leads to two very different scenarios.

The focus in **Archipelagos** is on achieving security through domestic self-interest. Countries race to secure their energy supplies and systems, irrespective of the wider impact of their actions, particularly on countries outside their regional blocs and/or sphere of influence. This unleashes a *vicious cycle of competition and protectionism*.

The focus in **Sky 2050** is on achieving security through mutual or enhanced self-interest. Countries aim to change their energy system as a way to improve their resilience to global forces, for example, by substituting imported energy for domestic energy sources such as renewables. This unleashes a *virtuous cycle of competition and innovation*.

Figure 2: Features of a world focused on security

Security (energy, health, economy) becomes a national priority...

...leading to the end of an era of globalisation and market liberalisation...

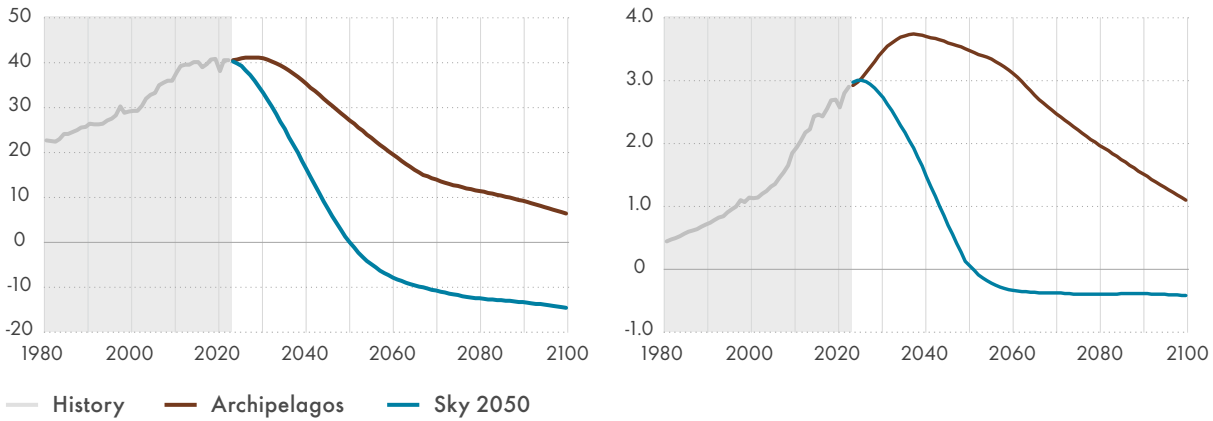
...and uneven progress in the energy transition, as countries seek to strengthen security in different ways

In turn, this leads to very different outcomes for the energy transition in each of the two scenarios (**Figure 3**). While the world achieves net-zero emissions by 2050 in **Sky 2050**[6], emissions in **Archipelagos** peak in the 2030s and then decline, but do not reach net zero by the end of the century. In temperature terms, **Sky 2050** is consistent with the goal of the Paris Agreement, with global average temperature stabilising at around 1.2°C above pre-industrial levels by the end of the century.

Temperatures in **Archipelagos** begin to plateau in the second half of this century and stabilise at around 2.2°C above pre-industrial levels by 2100.

At a superficial level, the emerging security mindset, and the shift from a collaborative to a competitive energy transition, would suggest a slowdown in progress towards deep decarbonisation. However, the scenarios analysis illustrates that energy security considerations can in fact accelerate the energy transition.

Figure 3: Energy transition outcomes in the two scenarios



Source: The Energy Security Scenarios, Shell International, March 2023

For example:

- the focus on energy security accelerates the shift from imported energy (usually fossil fuels) to domestic energy sources (usually low carbon); and
- as result of fragmentation, decisions to change the energy system are based on regional or geopolitical alignment rather than global consensus, so that pockets of accelerated energy transition action can emerge relatively rapidly.

Combined with the accelerated pace of technological progress in the past 10 years, for example, as renewable generation and electric vehicles have edged closer to cost parity with their fossil fuel counterparts, there is increasing momentum behind the energy transition. As a result, scenarios with global average temperatures stabilising above 2.5°C by 2100 no longer appear probable. Compare this to just a few years ago when scenarios based on a 3-4°C temperature rise were considered the norm.

Against this global backdrop, India achieves net-zero emissions by 2051 in **Sky 2050** (Figure 3). In **Archipelagos**, India's emissions begin to decline after 2040, but the country does not achieve net-zero emissions by the end of the century. **India's 2070 net-zero emissions target falls between Sky 2050 and Archipelagos, with the two scenarios providing bookends for the range of possible outcomes.**

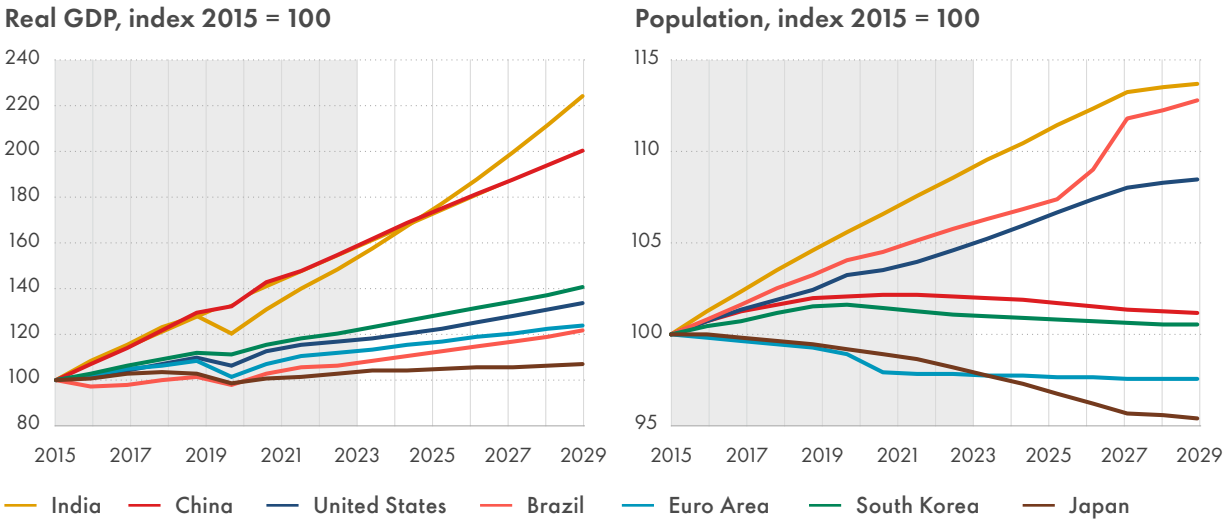
4

India: A bright spot in the global economy

India: A bright spot in the global economy

India has reached some significant economic milestones in recent years (**Figure 4**). In 2022, the country became the fifth largest economy in the world. And in 2023, India is estimated to have surpassed China in terms of population, an economically significant milestone given the relatively young population – an average age of around 28 years compared to the average (and ageing) Chinese population of 39 years. In advanced economies, in contrast, populations are ageing, which will likely lead to slower growth of the labour force and economy and rising budgetary pressures.

Figure 4: India's economic performance and outlook compared to other major economies



Source: International Monetary Fund, World Economic Outlook, April 2023, and United Nations population projections

While the global pandemic and the energy and food crises triggered by Russia's invasion of Ukraine have significantly disrupted the global economy, India has recovered strongly from the recent economic turbulence.

The Indian economy is expected to grow by 5.9% in 2023, following 6.8% growth in 2022 and 9.0% in 2021. Moreover, the rise in consumer prices has slowed considerably, with the annual rate of headline inflation falling to 4.7% in April 2023. However, core inflation remains stubbornly high around 5%, and the risk of second-round effects from higher fuel and food prices – on wages and overall price levels – persists.

India's economic growth is projected to average around 6% per year this decade, according to the International Monetary Fund. The export of goods and services in the first nine months of the 2022-23 financial year was up 16% compared to the same period in the previous financial year. However, a slowdown of the global economy, amid tighter international financing conditions and reduced international co-operation, could negatively affect India's medium-term growth prospects.

At the same time, India appears well positioned to benefit from the ongoing global diversification of supply chains, through so-called friend-shoring to allies and near-shoring production closer to home. India's advances in digital infrastructure have improved its resilience to global shocks as well.

Despite the economic and geopolitical turbulence of recent years, the government continues to recognise climate change as critical to India's growth and development aspirations. India's economy is one of the most vulnerable in the world to the physical effects of climate change. While climate impacts alone are not likely to stop the relatively rapid rates of economic growth this decade, it is likely to mean that longer-term output and income convergence with richer economies will be slower. Thus, addressing climate change – reducing emissions and increasing resilience to climate impacts – is fundamental for India to deliver economic development and prosperity to its citizens.

Climate change also offers new growth opportunities for India in the manufacture and supply of low-carbon goods and services, as the world transitions to low-carbon energy. India is already taking steps to seize these opportunities and create new jobs, economic growth and a more sustainable natural environment. For example, the government has set ambitious targets for deploying renewable energy and improving energy efficiency, which creates domestic demand for these products. It is also investing in research and development in sustainable manufacturing.

With much of the infrastructure required to grow a low-carbon goods and services industry yet to be built, particularly as it relates to low-carbon electrification, the present decade will be critical for increasing climate resilience and laying the groundwork for a thriving low-carbon industry.

5

Recent policy action towards the 2030 climate goals

Recent policy action towards the 2030 climate goals

India is seeking to find a balance between energy security (reducing its dependence on imported energy), energy equity (ensuring access to affordable and modern sources of energy), and environmental sustainability (clean energy that reduces greenhouse gas emissions and protects the natural environment). This balance must be achieved within the broader context of economic progress, as set out in the UN Sustainable Development Goals for 2030.

India's National Action Plan on Climate Change is based on the shared benefits of climate and economic development. It aims to achieve this by, for example, introducing industrial policies to generate economic opportunities related to the energy transition and policies that ensure households and industrial sectors have access to affordable and low-carbon energy.

Since India submitted its first nationally determined contribution in 2015, the country has made substantial progress towards its goals. For example, it has already achieved its commitments to reduce emissions intensity of the economy by 33-35% compared to 2005 levels (34% lower emissions intensity was achieved in 2021) and to produce 40% of its electricity from non-fossil fuel-based energy sources (42% non-fossil electricity was achieved in 2022).

The country is taking climate and energy policy action in several areas. For example:

- **Improving energy access** through initiatives to increase electricity grid connections and last-mile connections; provide continuous power supply to rural areas; provide liquified petroleum gas connections for household use; and ensure energy security for farmers by using solar power for agricultural pumps.
- **Enhancing energy efficiency** through standards and labelling for energy-efficient consumer products and appliances and for the energy-efficient design and construction of buildings; by supporting the switch to more efficient LED lightbulbs; and incentivising energy-efficient behaviour through measures like Perform Achieve and Trade.[7]
- **Accelerating renewable electrification** by implementing smart-grid policies and programmes; through renewable purchase obligations on electric utilities; through policies that optimise solar and wind generation; and by net-metering policies that encourage distributed generation and prosumers (consumers who use and generate electricity at different times).
- **Enhancing the role of bioenergy** through procurement policies and ethanol blending targets for petrol and diesel; through fiscal and financial incentives, not just for first-generation biofuels but also for the development of second- and third-generation biofuels; through mandates for blending biomass into coal-fired electricity generation; through initiatives to support the production and use of biogas in transport; and through programmes to promote the use of environmentally sustainable fuels that reduce India's dependence on imports.
- **Accelerating the decarbonisation of mobility** through initiatives to support the manufacture of hybrid and electric vehicles and through initiatives to encourage faster adoption. These include guidelines for a safe, reliable, accessible and affordable charging infrastructure; reforms to increase the adoption of liquefied natural gas as a transport fuel (including in the mining sector); and the adoption of ambitious fuel and emissions efficiency norms.

- **Promoting the development of a hydrogen economy** by setting a target for the production of 5 million tonnes of green hydrogen by 2030 (including the development of renewable generation capacity); by reducing cumulative fossil fuel imports by around INR 1 trillion and annual CO_2 emissions by 50 million tonnes; by supporting both the production and use of green hydrogen; and by developing the hydrogen industry into a destination for investment of around INR 8 trillion and a source of about 600,000 new jobs.
- **Developing carbon markets** by approving the carbon credits trading scheme to set up India's first domestic regulated compliance carbon market. The scheme will be implemented in two phases. The first phase, starting in 2023-24, will be limited to the power sector. The second phase, starting in 2025-26, will be expanded to include other sectors, such as industry and transportation.
- **Developing a market for carbon capture and storage (CCS)** by setting out plans to promote the development and deployment of CCS technologies in a detailed report by the National Institution for Transforming India.

India is also taking a leadership role in global energy transition initiatives like the International Solar Alliance and in collaborative platforms like the Mission Possible Partnership, the Leadership Group for Industry Transition, and the First Movers Coalition. Through its leadership in the Clean Energy Ministerial and now through its presidency of the G20, India is continuing to engage and drive progress in the global energy transition. It is also collaborating on specific technologies and fuels. For example, it is working with other leading biofuel producers and consumers through the Global Biofuels Alliance to facilitate co-operation and the use of sustainable biofuels.

6

Looking ahead to 2030, sector-by-sector

Looking ahead to 2030, sector-by-sector

In assessing where India could be in 2030, on the road to its 2070 net zero emissions target, we consider four deep decarbonisation scenarios for India – the two bookend Energy Security Scenarios and the two previously published Shell-TERI scenarios. In each scenario, the Indian energy system approaches net-zero emissions sometime in the second half of the century (**Figure 5**).

Despite setting out very different decarbonisation pathways, the four scenarios identify common areas for accelerated action this decade to put India on a trajectory to decarbonise in the second half of the century.

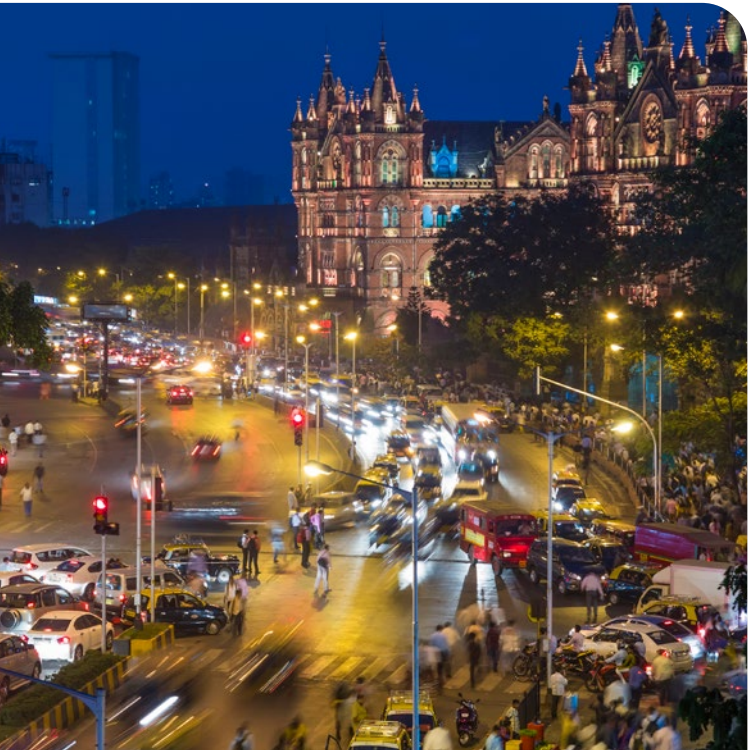


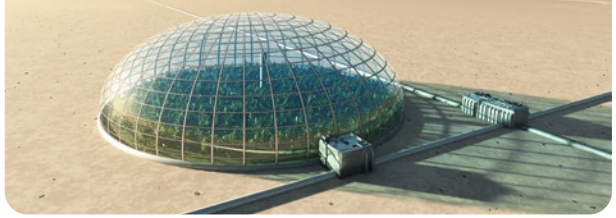
Figure 5: Four potential deep decarbonisation pathways for India

Net-zero emissions pathway – developed jointly by Shell and TERI in the India Scenarios Sketch – in which India achieves net-zero emissions (NZE) by 2050.[8]

Sky 2050 pathway – developed in Shell's The Energy Security Scenarios – in which India achieves NZE by 2051.[10]

Towards net zero pathway – developed jointly by Shell and TERI in the India Scenarios Sketch – in which India achieves NZE around 2070.[9]

Archipelagos pathway – developed in Shell's The Energy Security Scenarios – in which India does not achieve NZE even by 2100, although emissions begin to decline after 2040.[11]



6.1. Power

The power sector is the single largest source of India's greenhouse gas emissions. Coal-fired generation accounted for about 50% of installed capacity in 2023, and most emissions. The power sector is also leading India's energy transition, with the country achieving its 2030 target of 40% of installed electricity capacity coming from non-fossil energy sources in 2021.[12]

The power sector holds a strategic position in the energy system in meeting energy demand from end-use sectors such as industry, transport and buildings. **In this context, most deep decarbonisation scenarios highlight the need to increase overall electrification of end-use sectors and the need to replace fossil-based power generation with renewable sources such as solar and wind (Table 1).**

While the size of the electricity system increases by 2-2.5 times between 2019 and 2030 across the four scenarios in Table 1, the volume of demand met by coal declines in the two more ambitious decarbonisation scenarios – **Sky 2050** and **Net-zero emissions**. Even in the less ambitious scenarios, (**Towards Net zero** and **Archipelagos**), demand for coal decouples from overall power demand, increasing by about 36% – less than the increase in overall power demand.

Table 1: India's power mix across the four scenarios

	2019	2031 electricity generation mix by primary energy (TWh)	
		Low case	High case
Size of the electricity system	1,310	2,544	3,316
Coal	951	329	1,295
Oil	5	0	0
Natural gas	52	29	135
Nuclear	37	68	108
Hydro	139	251	319
Solar	42	464	1,984
Wind	56	337	683
Biomass based power	25	51	97
Waste-to-energy	1	4	12

Source: IEA historical data, **Net-zero emissions**, **Towards net zero**, **Sky 2050**, **Archipelagos**

Across the four scenarios, no additional coal-fired power generation capacity is likely to be required beyond 2030. This is also starting to be recognised in policy development, with the government reportedly considering no new coal-fired power plants beyond those already in the pipeline.

India has abundant solar and wind resources; with rapidly declining equipment costs, these renewable resources will become increasingly competitive with coal-fired generation. Even in the two less ambitious decarbonisation scenarios, solar and wind generation increase at least eightfold from today, and by anywhere between 17 to 25 times in the two more ambitious scenarios.

All four scenarios indicate an increase in demand for natural gas to generate power, from 60% to 200% depending on the scenario. In these scenarios, natural gas is used mainly as a lower-carbon alternative to coal, as it provides grid stability and supports intermittent renewable energy. While energy storage solutions are not currently cost-competitive, they are expected to become increasingly viable after 2030 to support a fully decarbonised grid.

The scenarios show that this decade India should focus on:

- reducing its reliance on coal and decoupling demand for coal from overall demand for power;
- accelerating the deployment of solar and wind generation;
- accelerating the use of technologies for energy storage and that facilitate demand-side response[13] while using gas-fired generation to provide security of supply during the transition; and
- harnessing the benefits of digitalisation to optimise energy supply and demand by, for example, using modelling and data-driven simulations to reduce the impact of air turbulence at wind farms and using digital technologies to drive energy efficiency in industrial processes.

Policies needed to enable the required change:

- Policy and regulatory reforms in the power sector to accelerate the use of renewable energy and to compensate flexibility technologies such as energy storage, demand-side response and gas-fired generation.
- Investment in infrastructure (direct public investment and/or incentivising private investment) to (i) expand the power grid and connect renewables-rich regions with urban energy demand centres; (ii) provide greater interconnection between regional grids to connect regional wholesale markets and increase grid stability; and (iii) optimise grid operation through smart power grids at the transmission and distribution levels.
- An enabling finance environment to encourage investment in generation, storage and infrastructure and reduce surcharges and cross-subsidies that distort incentives to invest.
- Resource adequacy plans for the near- and medium-term to ensure system reliability, setting out specific generation and flexibility needs this decade.
- Create demand for green electricity through new markets and by improving compliance in existing markets, such as through stricter compliance mechanisms for renewable power obligations.

6.2. Transport

The transport sector accounts for a significant – and growing – share of India's total greenhouse gas emissions, with road transport accounting for most energy consumption and emissions.

Transport is expected to experience robust growth in energy demand over the next few decades, as standards of living rise, increasing demand for passenger and freight transport by road, air, rail and ship. The sector covers a range of segments – from passenger road transport (one of the most advanced sectors in the energy transition) to shipping (one of the least advanced sectors in the energy transition).

Globally, the passenger road transport sector has undergone unprecedented change, with electric vehicle adoption rates exceeding expectations year after year. India is no exception, with the share of electric vehicles expected to rise to around 3% of new car sales in 2023.[14] This trend is likely to continue for the rest of the decade, accounting for most of the increase in electricity demand in transport across all four scenarios. The Economic Survey 2022-23 predicts that India's domestic electric vehicle market will see a 49% compound annual growth rate between 2022 and 2030, from around 1 million in annual sales today to 10 million by 2030.[15]

Across the four scenarios, electrification of the transport sector is between 3-10 times today's level, mainly in the passenger segment (**Table 2**). However, only some parts of the transport sector – such as passenger, last-mile and light-duty road freight transport, along with rail – are suitable for electrification. Other parts, such as long-distance road freight, aviation and shipping will require low-carbon fuels, including hydrogen, biofuels and compressed natural gas made from biofuels (bio-CNG).

Many low-carbon alternatives in the harder-to-electrify sectors, such as hydrogen and advanced biofuels, are not likely to reach commercial scale until after 2030. Creating the right policy frameworks and appropriate incentives this decade will be critical to accelerate the pace of change in subsequent decades. For example, to decarbonise aviation will require sustainable aviation fuel in the 2030s. This in turn will require policy support this decade to develop adequate supplies of bioenergy feedstocks (such as forestry and agricultural waste, municipal waste and used cooking oil), to create demand for sustainable aviation fuel and to invest in the necessary refuelling infrastructure.

Table 2: Decarbonising transport

	2019	2031 decarbonisation trajectory: Low case	2031 decarbonisation trajectory: High case
Electricity (TWh)	19	56	183
Hydrogen (Mt)	0	0	0.27
Bioenergy (Mtoe)	1.1	2	26.8
Fossil Fuels (Mtoe)	107	140	192

Source: IEA historical data, **Net-zero emissions**, **Towards net zero**, **Sky 2050**, **Archipelagos**

A similar approach will be required in other hard-to-electrify sectors – such as long-distance shipping and freight road transport – to incentivise simultaneous investment in new supply sources, in new demand markets and in building the necessary infrastructure. This will help reduce the cost of these fuels, develop experience in their supply and use and accelerate the process of commercialisation. This approach is a departure from how technologies have historically been developed, deployed and diffused – through sequential and incremental investments in new supply, new demand and new infrastructure.

Fossil fuels will still have a role in the transport sector this decade, even in the two most ambitious decarbonisation scenarios (**Net zero** and **Sky 2050**). As demand for transport rises, in line with economic development and higher standards of living, and as demand for electric and other low-carbon vehicles continues its exponential increase, demand for fossil fuels also increases by 30-80% between 2019 and 2030 across the four scenarios. For example, during the energy transition, natural gas provides a lower-carbon alternative to fuel oils like heavy fuel oil in shipping, while low-carbon alternatives such as methanol and hydrogen-based fuels are under development.

The scenarios show that this decade India should focus on:

- accelerating the deployment of infrastructure for electric vehicle (EV) charging to speed up the adoption of EVs as performance improves and total cost of ownership falls significantly;
- enhancing the capability and operation of electricity distribution networks to accommodate the additional load from EV charging and to make the most of the potential benefits of EVs (for example, as a storage solution to help manage renewables intermittency);
- taking a segment-by-segment policy approach to hard-to-electrify parts of the transport sector to accelerate the commercialisation of low-carbon fuels through simultaneous investment in new supply, demand and infrastructure; and
- adopting an integrated view of the transport system, increasing investment in low-carbon infrastructure such as public transport, and encouraging other low-carbon options including walking and cycling.

Policies needed to enable the required change:

- Support the use of digital technology to reduce congestion and traffic jams, as a way of increasing fuel efficiency and reducing transport emissions.
- Integrate state-level policies and regulations to deliver transmission, distribution and charging networks that optimise and decarbonise the power system, enhance inter-operability[16] and speed up the electrification of transport.
- Implement policies that drive innovation in low-carbon technologies for long-distance road transport by, for example, tightening energy and emissions efficiency standards for heavy-duty vehicles and encouraging the use of alternative fuels such as biodiesel, compressed natural gas and hydrogen.
- Incentivise the domestic production and use of drop-in lower-carbon fuels in heavy-duty road freight. Drop-in fuels – such as bioethanol, biodiesel and biomethane – are relatively interchangeable with hydrocarbon fuels and do not require significant adaption of a new engine or fuel system.
- Accelerate operational improvements in heavy-duty road transport by increasing and standardising truck dimensions and optimising routing.
- Further develop rail infrastructure to encourage modal shift to rail from other types of transport.
- Use the government's industrial strategy to transform domestic air and ship transport and establish India as a global hub for low-carbon shipping and aviation solutions.

6.3. Industry

Similar to transport, industry accounts for a significant – and growing – share of India's total greenhouse gas emissions. It is likely to be one of the fastest growing sectors of energy demand over the next few decades as India industrialises. The country is already the second largest cement and steel producer in the world, with cement capacity expected to triple and steel capacity expected to double by 2050. Across all four scenarios – **Net-zero emissions**, **Towards Net zero**, **Sky 2050** and **Archipelagos** – energy demand from industry rises by 30-40% between 2019 and 2030.

Decarbonising industry, even as it grows, will mean improving energy efficiency and using resources more efficiently. This includes creating a circular economy for industrial materials; electrifying light industry, including paper and textiles; and switching to low-carbon fuels such as hydrogen and bioenergy in heavy industries like steel, chemicals and cement. The use of low-carbon technologies such as carbon capture and storage will also be important for decarbonising industry.

India's industrial sector is complex and faces many challenges because of the different scales of operation and large variations in fuels and processes. Efficiency and electrification alone are unlikely to deliver the level of decarbonisation required.

Investment in research and development for low-carbon energy solutions will be crucial in sectors that are hard to electrify such as steel, cement and chemicals. A shift towards greater efficiency in the use of resourses, including using recovered and recycled materials to create new products, will also be crucial. For example, reusing and recycling construction materials can reduce emissions in the sector by 38% by 2050[17] while also eliminating waste. The challenge for India's industrial sector will be to decarbonise while maintaining – and enhancing – its global competitive position.

While the range of electrification varies widely across the four scenarios (**Table 3**), three of the four see a significant increase in electrification this decade, mainly in light industry. However, low-carbon molecular fuels, including hydrogen, are required for some of the hard-to-electrify heavy-industry sectors.

Table 3: Decarbonising industry

	2019	2031 decarbonisation trajectory: Low case	High case
Electricity (TWh)	861	792	1,892
Hydrogen (Mt)	0	0.3	1.3
Bioenergy (Mtoe)	66	13	76
Fossil Fuels (Mtoe)	261	291	355

Source: IEA historical data, **Net-zero emissions**, **Towards net zero**, **Sky 2050**, **Archipelagos**

Hydrogen production, demand and infrastructure will need to be developed significantly to meet the large volumes that India will eventually require. Bioenergy could also have an important role to play, to help displace fossil fuels and provide a source of negative emissions after 2030 when combined with carbon capture and storage (CCS).

Fossil fuels will continue to play an important role in the industrial sector to 2030 and beyond, even as low-carbon fuels become more widespread. And for some of the most difficult and expensive-to-abate industrial sectors, CCS will be required to remove the carbon produced.

The scenarios show that this decade India should focus on:

- forming coalitions with partners from across industrial value chains to trigger collective action, drive increased public and private investment and deliver tangible emission reductions by, for instance, developing renewable energy hubs to decarbonise industry;
- continuing to drive energy efficiency through mechanisms like Perform Achieve and Trade which encourage improvements in energy efficiency by allowing energy savings above the baseline to be sold (in the form of energy saving certificates);
- commercialising low-carbon fuels and technologies to replace fossil fuels (including imports), such as using hydrogen to produce steel, bioenergy as a feedstock for chemicals, and CCS to reduce emissions from cement plants;
- managing domestic competitiveness and carbon leakage effects through, for instance, industrial strategies to enable industry to take advantage of the global opportunities presented by the energy transition; and
- supporting the shift to a circular economy that uses resources more efficiently, enhances competitiveness and encourages the development of green industrial products like low-carbon steel.

Policies needed to enable the required change:

- Increase carbon pricing over time to encourage low-carbon fuel and technology choices and to avoid export penalties imposed by proposals such as Carbon Border Adjustment Mechanisms and carbon clubs.
- Build capacity to increase knowledge and use of low-carbon fuels and technologies to help micro-, small- and medium-scale businesses reduce emissions while driving innovation and economic vibrancy in the sector.
- Overcome financing barriers to industrial transformation by, for instance, requiring compliance with sustainability reporting requirements; implementing environmental, social and governance initiatives; and providing time-limited fiscal and financial support to build momentum this decade for industrial low-carbon transformation.
- Create demand for green industrial products such as steel and cement through, for example, public procurement and government tenders specifying or qualifying the use of green materials.
- Create an enabling environment (through policies and infrastructure investment) to support the future hydrogen economy, develop advanced bioenergy, scale up industrial carbon capture and storage, and support a circular economy.

6.4. Buildings

Energy consumption in buildings is a significant contributor to India's overall greenhouse gas emissions; it is used mainly for lighting, heating, cooling, cooking and operating equipment and appliances. While cooking forms a much larger share of energy consumption in residential buildings, commercial buildings such as hotels and restaurants also use energy for cooking. It will take significant improvements in energy efficiency to reduce energy consumption, and greenhouse gas emissions, from buildings.

India has made substantial progress in some areas, for example through programmes to increase the adoption of energy-efficient LED lighting for residential customers and street lighting.[18] By April 2023, more than 13 million LED streetlights had been installed across 29 states and union territories. Benchmarking of energy-efficient household appliances, such as through the Star energy efficiency labelling, is also driving more informed consumer choices.

The design and construction of new buildings – residential and commercial – provide further opportunities to improve energy and emissions efficiency (alongside the decarbonisation of power generation). As demand for cooling (and heating to a lesser extent) is expected to surge in the decades ahead, constructing energy-efficient buildings will be important to manage overall energy demand.

Commercial buildings are subject to mandatory building standards for new builds and retrofits. These standards are being increasingly implemented for government and commercial buildings. Residential building standards are currently voluntary. New high-end residential buildings tend to comply with the standards, but there is potential for improvement in other types of new and existing residential buildings.

Cooking is another area with significant need – and potential – for decarbonisation. The most used cooking fuels are liquefied petroleum gas (LPG) and piped natural gas (PNG). Electricity is more suitable for cooking in commercial buildings, given that commercial establishments are more likely to have reliable power supply and may be more suitable for policy and regulatory interventions favouring cleaner cooking fuels.

Electrification of residential cooking, however, faces some challenges. While the health and wider economic and social benefits associated with clean energy are well established, the transition from biomass, LPG and gas to electric cookstoves is constrained by the relatively high upfront costs and lack of a reliable electricity supply. Preferences for cooking fuels also deter the widespread use of electric cooking.

While electrification provides the best option for decarbonising residential cooking, it will require reliable access to low-carbon electricity. Moreover, a share of cooking energy demand is also likely to be met by LPG and PNG (for example in urban areas with gas networks) and by biogas (in rural areas where biomass is readily available). And these unabated emissions are likely to require carbon removals in order to be offset (see section 7).

The scenarios show that this decade India should focus on:

- improving the design and construction of commercial and residential buildings through better implementation and enforcement of building standards;
- supporting circular economy approaches by recycling and reusing construction materials and developing more sustainable alternatives to materials like cement and concrete;
- reassessing the strategy for decarbonising residential cooking by looking beyond the current policy preference for PNG- and LPG-based cooking to electrification; and
- working to improve access to, and the reliability of, low-carbon electricity supply to encourage electrification of energy in buildings.

Policies needed to enable the required change:

- Tighten energy and efficiency standards for buildings by making them mandatory for commercial and residential buildings and improving their implementation.
- Update design and material standards as and when new technologies become available.
- Support skills training for the construction sector to enable existing and new workers to implement new technologies and standards.
- Address the lack of information and high upfront costs holding back the use of energy-efficient household appliances, office equipment and lighting by, for example, highlighting the potential energy cost savings and by providing financial support and innovative funding mechanisms to offset upfront costs.
- Overcome behavioural preferences for traditional biomass in residential cooking through awareness programmes that emphasise benefits such as faster cooking, improved taste, reduced need for and less time spent gathering firewood, and the ability to do other tasks while cooking with electricity.

6.5. Agriculture

Direct energy consumption in the agricultural sector, and the resulting greenhouse gas emissions, come from land preparation, irrigation, harvesting and threshing. Land preparation and irrigation are the most energy-intensive areas of agriculture. Improving efficiency and reducing emissions from these operations is likely to require a switch to more efficient agricultural machinery such as pumps, tractors and tillers and to low-carbon energy sources such as distributed solar power and low-carbon electricity; for example, by replacing diesel pumps used for irrigation with distributed solar power and electric pumps, and by electrifying farm vehicles such as tractors used in land preparation.

While policies are in place to support solar power and electrification for agricultural pumps, and electric tractors are gaining in popularity in the lower horsepower segments, heavier vehicles are likely to require biofuel-based or blended diesel to decarbonise.

The scenarios show that this decade India should focus on:

- continuing to drive the adoption of solar-powered and electric irrigation activities and equipment, and the electrification of low-horsepower agricultural vehicles;
- setting out a strategy for decarbonising higher horsepower tractors and tillers, based on a combination of electrification and bio-CNG or biofuel-based or blended diesel, to reduce uncertainty and drive greater use; and
- working to improve access to, and the reliability of, low-carbon electricity supply to encourage electrification of agricultural energy uses.

Policies needed to enable the required change:

- Provide financial support (in the form of subsidies and/or preferential financing) and information on the benefits of energy efficiency (including potential cost savings) of electric compared to diesel vehicles in the lower-horsepower segment.
- Incentivise domestic production and use of lower-carbon energy, such as biodiesel and biomethane, in the higher horsepower segments.
- Introduce energy labelling of irrigation pump sets, provide information on potential savings in energy costs and facilitate low-cost financing for electric pumps to accelerate their adoption.
- Provide fiscal and financial support for distributed solar-based irrigation with battery storage to overcome intermittency and barriers like a mismatch between sunshine and local irrigation timings.
- Mitigate some of the high upfront costs of low-carbon agricultural vehicles to accelerate their uptake (against a backdrop of declining electric vehicle costs this decade).

7

Role for carbon removals

Role for carbon removals

Carbon removals, whether through technology (such as carbon capture and storage or direct air capture) or natural carbon sinks, will be an important part of India's long-term decarbonisation journey. They will be required to address the most expensive and hardest-to-abate emissions, from industry, transport and buildings. Carbon removals will be needed:

- in the transition to net-zero emissions: to offset emissions from high-growth and high energy demand sectors like aviation and heavy industry, and keep the stock of greenhouse gas emissions as close to the 1.5°C budget as possible; and
- in a net-zero emissions world: to reduce temperature overshoot and bring down the stock of greenhouse gas emissions so that global average temperature rise returns to 1.5°C or below by the end of the century.

Across all four India scenarios, carbon removals are required to varying degrees – between 0.5-1.3 gigatonnes of CO_2 equivalent by 2050 – compared to negligible levels today. And while carbon removals are not likely to feature significantly in the period to 2030, policy preparation will be required this decade for them to be deployed at scale in subsequent decades.

The government is already starting to consider appropriate policy and financing frameworks to support the development and deployment of carbon capture and storage (CCS). For example, the National Institution for Transforming India's recent report "Carbon Capture Utilization and Storage – Policy Framework and Its Development Mechanism in India" sets out a market-based policy approach.[19] This approach is based on carbon credits and incentives, carbon taxes and financing through a new Carbon Capture Finance Corporation funded by low-cost sovereign or international green funds, carbon bonds and climate funds that are in turn able to bring in private equity and debt for CCS projects.

While there are currently around 196 CCS projects globally at various stages of development, none are planned or in the pipeline in India.[20] While CCS is likely to develop at scale in the early 2030s, the present decade will be important for capacity building and creating an enabling policy and technological environment.

In terms of natural carbon removals and sinks, India launched the Green India Mission as part of the National Action Plan on Climate Change, which aims to increase forest cover by 2.8 million hectares by 2030. The initiative includes activities such as planting trees, rehabilitating degraded forests and conserving wildlife. India has also launched the National Afforestation Programme, which aims to plant almost 2.5 billion trees by 2030 along roadsides, canals and railway tracks, and in degraded forests.

Realising the full potential of natural sinks requires consideration of the full range of terrestrial and aquatic carbon sinks. For example, through recently launched programmes such as MISTI (Mangrove Initiative for Shoreline Habitats and Tangible Income) and 'Amrit Darohar' for wetland management.

The government has also recently released the draft Green Credit Programme Implementation Rules, which includes a new Green Credit Mechanism. This voluntary programme incentivises environmental conservation activities in sectors such as agriculture, forestry, water and energy, thus creating an incentive to invest in a range of natural carbon sinks.

Realising India's full carbon removal potential will require further policy measures this decade – and robust monitoring, reporting and verification mechanisms – to ensure natural carbon removal projects are implemented correctly.

The scenarios show that this decade India should focus on:

- developing a strategy to develop and increase the use of carbon removals based on a sector-by-sector assessment of residual emissions requiring removal;
- building on the experience of voluntary carbon offset markets to establish a systematic and robust policy framework for carbon removals that contribute towards India's nationally determined contribution;[21]
- providing clarity on the balance between potentially competing land uses for agriculture and carbon sinks and addressing other non-financial barriers (such as uncertainty about costs, potential risks and benefits) to private investment in this area; and
- developing CCS-related capabilities (technical, manufacturing and skills) to support private investment in carbon removals.

Policies needed to enable the required change:

- Establish a carbon pricing framework, with a rising carbon price this decade, to create demand and support new business models that incentivise private investment in carbon removals as a business.
- Future-proof investments in energy-intensive industries such as steel, chemicals and cement by requiring new investments to be CCS-ready.
- Provide financial incentives and innovative funding mechanisms for pilot projects (to overcome the large upfront costs of carbon removal technologies) and for CO_2 transport and storage infrastructure.
- Take a holistic approach to carbon removals, creating opportunities for communities as well as private investors covering the full range of natural carbon sinks, in order to achieve both emissions reduction and nature-related Sustainable Development Goals.

8

Investing in the energy transition this decade

Investing in the energy transition this decade

India has a target to achieve net-zero emissions by 2070. Analysis of possible decarbonisation pathways that result in India decarbonising in the second half of the century share several common features this decade.

India has made good progress over the past decade in moving towards a low-carbon energy system, for example by driving energy efficiency and by deploying renewables. Looking across the four scenarios, the country now needs to sustain that effort and ramp up actions in other areas over the course of this decade in order to be on a trajectory to achieve net-zero emissions in the second half of the century (**Table 4**).

In addition, in the two more ambitious scenarios, **Net-zero emissions** and **Sky 2050**, there is a limited yet vital role for carbon removals a combination of both man-made and natural carbon sinks. In a 2030 timeframe, **Sky 2050** includes 20 million tonnes of CO_2 emissions from the industry and power sectors captured and stored annually by 2030 and the opportunity for land use to become a net-carbon sink by the early 2030s.

Across the four scenarios, key areas for accelerated action this decade include:

- Increasing electrification of energy end uses across industry, transport, buildings and agriculture. Electrification increased by a substantial 661 TWh between 2011 and 2021, but this momentum will need to accelerate further this decade, with electricity production doubling or tripling compared with that of the previous decade.

Table 4: Accelerating the transformation of India's energy system this decade

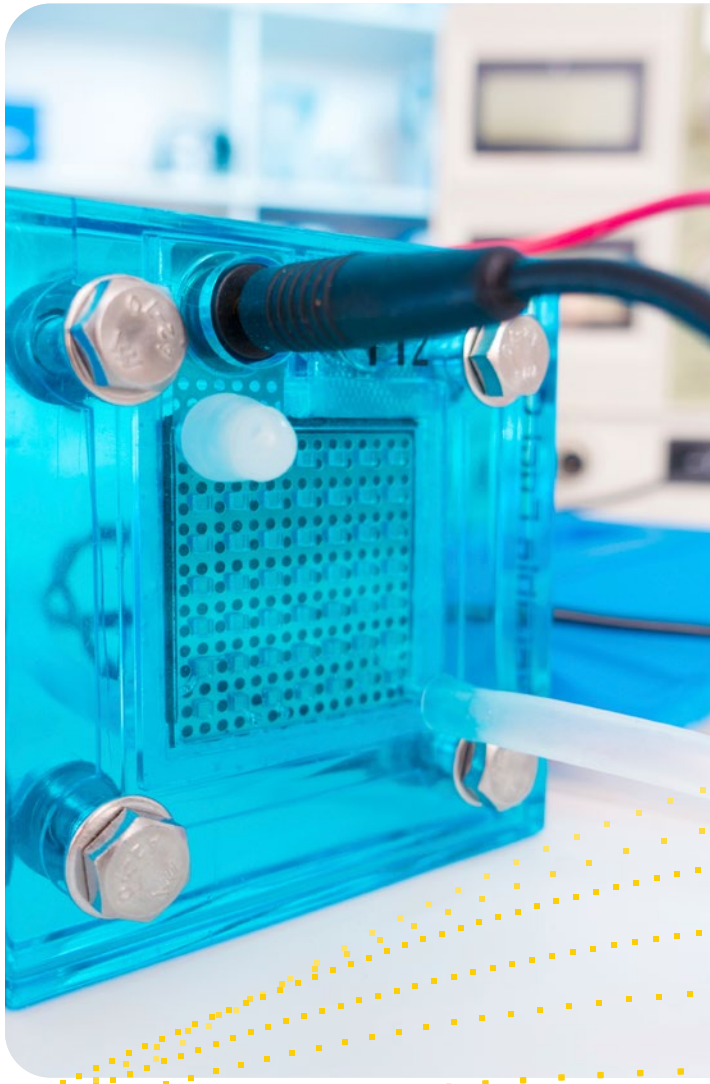
	The previous 10 years (to 2021)	The coming 10 years (to 2031)	
		Low case	High case
Increasing electrification (TWh)	661	1,108	1,878
Increasing non-fossil electricity consumption (TWh)	175	842	2,619
Hydrogen (Mt)	negligible	0.4	1.4
Biofuels (Mtoe)	1	2	27
Declining energy intensity of GDP (total final energy consumption/GDP)	-20%	Further decline of 10-30%	

Source: IEA historical data, **Net-zero emissions**, **Towards net zero**, **Sky 2050**, **Archipelagos**

- Meeting electricity demand increasingly from non-fossil sources, with low-carbon electricity generation accelerating by 5-15 times the pace of the previous decade.
- Developing low-carbon alternatives such as hydrogen and biofuels for hard-to-electrify segments in industry, transport, buildings and agriculture. These fuels will need to become commercially viable this decade, their use rising from negligible levels today, if volumes are to scale up to the substantial levels required in subsequent decades.
- Natural gas still has an important role to play in the energy transition as a lower-carbon alternative to coal in industry, power and residential cooking. However, this will need to be balanced against continued energy import dependency and high and volatile global energy prices.
- Improving energy efficiency and reducing the energy intensity of the economy through the electrification of end uses,[22] by improving energy efficiency in industry and buildings and by deploying digital solutions. India has made substantial gains in energy efficiency over the past decade. Efforts will need to intensify this decade, to make the more difficult energy efficiency improvements, in order to reduce emissions by a further 10-30%.
- Supporting circular economy business models will be important to drive the efficient use of resources and to create a competitive advantage, particularly in the industrial sector.
- Creating an enabling environment for planning, establishing and scaling up carbon removals after 2030 to address the most expensive and hardest-to-abate residual emissions.

Regardless of the specific year in the second half of the century that India achieves net-zero emissions, significant effort will be required this decade to sow the seeds for future success.

Accelerating the substantial progress India has already made in transforming its energy system will require implementing efficient and innovative polices that minimise costs for business and the economy. It will also require significant additional low-cost financing (from public and private sources) to invest in the supply of low-carbon energy, transform energy demand and build supporting infrastructure. The creation of carbon markets, with international links, will become an increasingly important policy lever to attract investment, promote innovation and drive deployment of low-carbon technologies.



9

An economic growth dividend from the energy transition

An economic growth dividend from the energy transition

While the energy transition requires fundamental changes in how energy is produced, transported and used, the overall macroeconomic cost of transition to a lower-carbon economy is estimated to be relatively modest. For example, organisations like the Intergovernmental Panel on Climate Change and the Energy Transitions Commission estimate that global GDP could be a few percentage points lower mid-century.

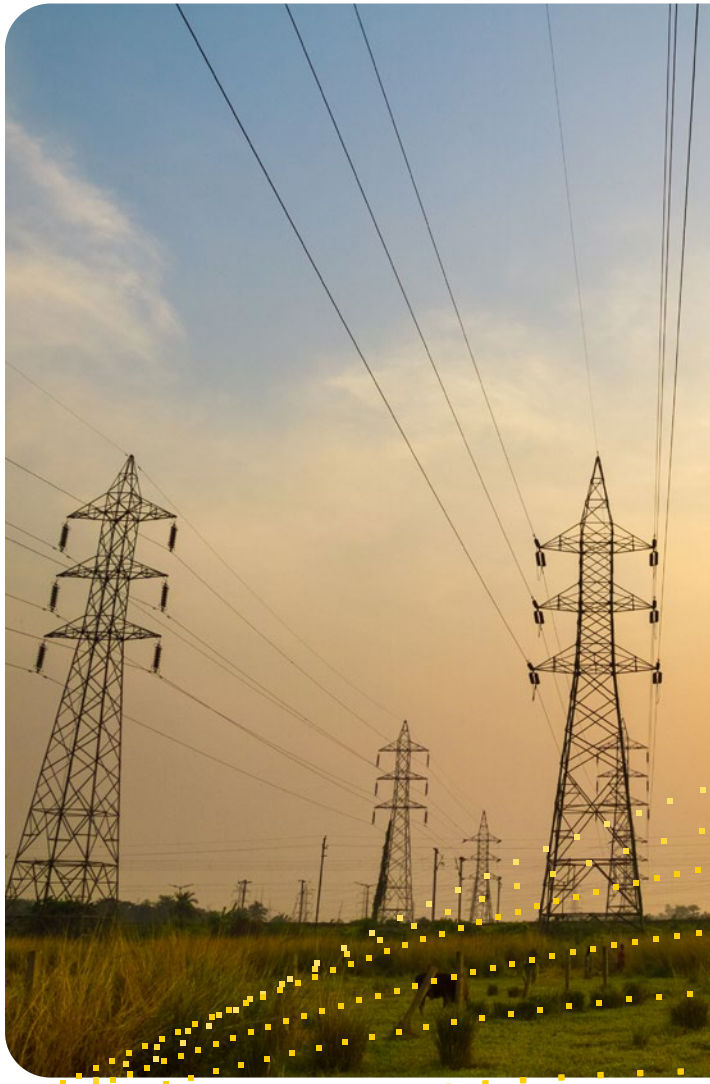
These costs are dwarfed by the potential economic costs of unabated climate change. As the global average temperature rises, India is particularly vulnerable to climate impacts such as extreme heat, unpredictable rainfall patterns, rising sea levels, and increased frequency and intensity of natural disasters like cyclones. Estimates of the economic cost of these climate impacts for a 3°C or higher rise in average temperature range from 10-25% of GDP.[23]

The energy transition also creates new economic and business opportunities, and a chance for India to position itself as a market leader in the expanding global market for low-carbon technologies and solutions.

For example:

- developing new industries, such as the manufacture of solar panels, wind turbines, batteries and hydrogen electrolysers;
- transforming industry through low-carbon industrial processes like the use of hydrogen and bioenergy and the application of carbon capture, so that India can decarbonise as its industries grow;
- generating supplies of – and supply chains for – low-carbon energies, such as hydrogen and advanced bioenergy, to meet future domestic demand and put India at the centre of low-carbon supply chains; and
- developing low-carbon and digital consumer and business solutions so that India can leapfrog to technologies and solutions that are more energy and emissions efficient. This will put the country on a less greenhouse gas-intensive development path than the advanced economies of today and create new business opportunities to provide these solutions on the global market.

The Indian manufacturing sector is well placed to take advantage of the opportunities, based on India's large, young and skilled population, and complemented by the country's existing technical knowledge base and capabilities.



[23] ODI working paper, Capital Economics

The International Energy Agency estimates that India will need to invest $160 billion a year in its energy transition between now and 2030.[24] Another estimate points to significantly larger investments, around $12 trillion in green investments between today and 2050, to be on a trajectory consistent with achieving net-zero emissions in 2070.[25]

These investments could create new employment. With forward planning in areas such as education and reskilling, these jobs could help to mitigate some of the loss of existing jobs and provide new opportunities for India's expanding and changing labour force (as labour moves from rural to urban areas and from agriculture to secondary and tertiary industry jobs).

Setting a clear strategic direction through industrial policy, supported by measures to create a business friendly environment, has the potential to generate significant economic growth by attracting foreign investment and skills, creating new jobs and making India a global leader in low-carbon manufacturing.

India is already taking steps in this direction – for example, through the National Mission on Advanced and High-Impact Research – to identify emerging technologies in the power sector and develop them domestically, at scale, for deployment within and outside India.[26] The National Mission focuses on facilitating domestic research, development and demonstration of the latest technologies in the power sector, using them as a future driver of economic growth and to position India as a global manufacturing hub for these technologies.[27]

Finally, accelerating the transition to low-carbon energy can reduce reliance on energy imports (mainly fossil fuels). The 2020s are likely to be a decade of global energy price volatility. As the traditional fossil-based energy system is phased down and the low-carbon energy system grows (with limited overlap between the two), energy supply is likely to go through a period of inflexibility. Consequently, any disruptions or change in market conditions is will be reflected in relatively large price fluctuations. Given India's significant exposure to energy imports – and its knock-on effects on the economy – a transition to domestic low-carbon energy would serve as a buffer against any large fluctuations in global energy prices.

10

Imperative for a just transition

Imperative for a just transition

Tackling climate change – by reducing greenhouse gas emissions and investing in climate resilience – will be important for India to achieve its sustainable development objectives. As the Intergovernmental Panel on Climate Change's 1.5°C report highlights,[28] there are significant synergies between climate action and the United Nation's Sustainable Development Goals.

Taking a more integrated policy approach to climate change and sustainable development is, therefore, necessary for India to deliver on both agendas simultaneously. India can do this by, for example, investing in natural coastal flood defences that protect lives and livelihoods while also acting as a sink for carbon emissions; focusing skills and educational programmes to meet future labour demand in new low-carbon industries; and supporting the use of more efficient low-carbon energy in agriculture (for agricultural vehicles and machinery) that enhance the viability of the sector while also reducing emissions.

However, it is important to bear in mind that while the overall macroeconomic costs of the energy transition are likely to be relatively modest, its distributional consequences during the transition could be significant.

Managing the phase-down of coal

India is the second largest coal producer in the world, with much of the coal used domestically. The coal industry is a significant source of employment, not just directly but also indirectly across the entire coal value chain and its associated industries and businesses. These industries are also regionally concentrated, making up a significant share of the economy in various eastern states.

The transition from coal requires careful management and long-term planning. Other countries such as Germany, Poland, the UK and USA have grappled with the issue, with varying degrees of success. Based on their experience, successfully managing the coal transition will require:

- building a social contract to facilitate the labour market transition, retraining and reskilling workers for new jobs and livelihoods in growth sectors;
- planning early for closures at the industry and company level to manage the potentially large volume of redundancies and displaced workers and to create community support and buy-in for the energy transition;
- diversifying coal-dependent regional economies wherever possible to other industries such as renewables or advanced bioenergy; and
- establishing comprehensive policy frameworks, funds and a regulatory authority to facilitate a just transition, including funds to oversee, develop and implement coal transition programmes.

Planning for the shift away from coal is a key just transition consideration for this decade. Phasing down coal from the energy mix is crucial from an emissions reduction perspective, but moving away from coal use has wider economic and social implications beyond the energy system.

India has started to take a more strategic approach, for example, through the Just Transition Worker Support Facility (with the Asian Development Bank) in few districts and states. This facility aims to integrate existing resources across skilling and reskilling, entrepreneurship, livelihood development and relevant social protection initiatives to provide bespoke assistance in making the transition away from coal.

Climate resilience and adaptation are another key dimension of delivering a just transition. The country remains exposed to climate impacts, with significant variation in their societal and geographical effects. For example, rising sea levels will affect the lives and livelihoods of coastal fishing communities and unpredictable rainfall patterns will affect the viability of smaller landholders and rural farming communities. And the increasing frequency and intensity of natural disasters will tend to have a disproportionate impact on the poorest and most vulnerable.

Investing in climate resilience, alongside investments to reduce emissions, will be an important pillar of delivering a just and equitable transition. The Reserve Bank of India estimates that the cumulative total expenditure in 2030 for adapting to climate change is around $1.05 trillion. Investing these resources to enhance the resilience of the economy, of communities and livelihoods, and of the natural ecosystem and environment, will be essential for India's sustainable development.

The synergies between the energy transition and sustainable development highlight the opportunity to make the shift to low-carbon energy a just transition. Seizing the opportunity will require integrated policies and long-term planning, starting this decade, to ensure that energy transition benefits and costs are shared equitably, to support economic development, higher standards of living and a better quality of life for all India's citizens.

11

Call to action

Call to action

India has made substantial progress in transforming its energy system towards low-carbon. This progress cannot be underestimated as it comes against the backdrop of rising energy demand as India's economy grows and standards of living rise. India has even gone beyond some of its original 2030 targets, updating its nationally determined contribution in 2022 to reflect more ambitious targets.

India achieved its earlier target of 40% installed electricity capacity from non-fossil energy sources in 2021, nine years earlier than planned (42% non-fossil electricity was reached in 2022). The 2030 target has since been increased to 50% installed electricity capacity from non-fossil energy sources. The country has also achieved its original commitment to reduce the emissions intensity of the economy by 33-35% compared to 2005 levels (34% lower emissions intensity was achieved in 2021), and has since increased its energy intensity reduction target to 45% by 2030 compared to 2005 levels.

However, as this analysis shows, India will need to intensify its efforts and accelerate the energy transition this decade to meet its 2070 net-zero emissions target. The more ambitious scenarios considered in this analysis highlight pathways that could allow India to position itself as a leader in the energy transition – not just in tackling climate change, but also as a global hub and provider of low-carbon technologies and solutions – and reach net zero earlier than planned.

To fully realise India's ambition and potential to be a climate change-maker will require policy and investment action in 10 key areas this decade:

1. Harness the co-benefits of the energy transition to drive broader sustainable development goals.
2. Develop a vibrant low-carbon manufacturing industry.
3. Expand electricity transmission and distribution networks.
4. Ramp up investment in energy storage and renewables integration.
5. Increase the use of hydrogen and bioenergy to decarbonise hard-to-abate sectors.
6. Establish a robust policy framework for investing in natural carbon sinks.
7. Implement a strategic road map for carbon capture and storage and incentivise investments in carbon removal.
8. Introduce carbon pricing measures to drive low-carbon business and consumer choices.
9. Foster sectoral collaborations and coalitions to accelerate action.
10. Take the opportunity to deliver a just transition by equitably sharing costs and benefits.

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Glossary

Article 6 of the Paris Agreement

Article 6 of the Paris Agreement was established to allow cross-border cooperation between countries attempting to fulfil their nationally determined contributions (NDCs). Parties to the agreement are crafting the details of Article 6 to create a foundation for trade in carbon units.

Bioenergy

Bioenergy is one of many diverse resources available to help meet demand for energy. It is a form of renewable energy that is derived from recently living organic materials known as biomass, such as agriculture crops, animal and plant waste, algae or wood. It can be used to produce transport fuels, heat, electricity and other products and includes solid biomass, biofuels and biogases.

Nationally Determined Contribution (NDC)

The proposed actions countries will take to reduce greenhouse gas emissions under the Paris Agreement over a future five or ten-year period.

Endnotes

1. Intergovernmental Panel on Climate Change, AR6 Synthesis Report: Climate Change, 2023.
2. World Meteorological Organization, Global Annual to Decadal Climate Update, 2023.
3. Government of India, India's Updated First Nationally Determined Contribution Under Paris Agreement (2021-2030), 2022.
4. Shell Scenarios Sketch, India: Transforming to a net-zero emissions energy system, 2021.
5. Shell International, The Energy Security Scenarios, 2023.
6. **Sky 2050** is a normative scenario, i.e. it assumes that the world reaches net-zero emissions by 2050 and sets out a possible pathway for how that might be achieved.
7. Perform Achieve and Trade is a market-based approach for driving energy efficiency improvements, with the participants in the scheme able to trade any energy savings above their targets in the form of energy saving certificates.
8. Shell Scenarios Sketch, India: Transforming to a net-zero emissions energy system, 2021.
9. Shell Scenarios Sketch, India: Transforming to a net-zero emissions energy system, 2021.
10. Shell International, The Energy Security Scenarios, 2023.
11. Shell International, The Energy Security Scenarios, 2023.
12. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1777364 Ministry of New and Renewable Energy, 2021.
13. Consumers and businesses increase, decrease or shift their electricity use – for instance, in response to a price signal from the energy supplier – to help balance electricity supply and demand.
14. International Energy Agency, Global EV Outlook 2023: Catching up with climate ambitions, 2023.
15. Invest India, India's EV economy: The future of automotive transportation, 2023.
16. Interoperability means drivers can use EV charging stations belonging to different networks.
17. Ellen MacArthur Foundation, Fixing the economy to fix climate change, (no date).
18. Ministry of Power, 2023.
19. National Institution for Transforming India, Carbon Capture Utilization and Storage (CCUS): Policy Framework and Its Development Mechanism in India, 2022.
20. Global CCS Institute, Carbon Capture and Storage Experiencing Record Growth as Countries Strive to Meet Global Climate Goals, 2022.
21. Based on the global consensus on implementation of Article 6 of the Paris Agreement that carbon credits generated by negative emission technologies could be used not just for compliance with domestic climate targets, but any additional credits could be traded internationally, for instance to provide compliance units for other national trading systems.
22. For example, electric vehicles are more efficient than internal combustion engines in passenger vehicles, electric pump sets are more efficient than diesel pumps for irrigation, and cooking efficiency is higher with induction cooktops. Therefore, electrification can also act as an enabler of sectoral efficiency gains.
23. Overseas Development Institute working paper, 2021.
24. International Energy Agency, India's clean energy transition is rapidly underway, benefiting the entire world, 2022.
25. McKinsey Sustainability, Decarbonising India: Charting a pathway for sustainable growth, 2022.
26. Ministry of Power, Mission on Advanced and High-Impact Research, 2023.
27. Ministry of Power, Mission on Advanced and High-Impact Research (MAHIR) launched to leverage Emerging Technologies in Power Sector, 2023.
28. Intergovernmental Panel on Climate Change, Global Warming of 1.5°C.

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In developing this scenario sketch, Shell and TERI have considered four decarbonisation scenarios for India: two based on the recent Shell published Energy Security Scenarios (namely **Sky 2050** and **Archipelagos**) and two based on previously published Shell-TERI scenarios for India (namely Net-Zero and Towards net zero in the **Shell Scenarios Sketch: India: Transforming to a net-zero emissions energy system**, 2021). There are other possible paths for India to take towards a net-zero energy system, which depend on the technologies and policies the country prioritises. Shell believes different countries and sectors will move towards net-zero emissions at different pace, and all should move as fast as possible for society to achieve the goal of the Paris Agreement.

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