CHAPTER 6

India
Country Report

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1. Background

The world's second-most populous country, with a population of over 1.39 billion, India sits on a land mass of about 3.1 million square kilometres, the seventh-largest country by area (The World Bank, 2021). It is in South Asia and home to arguably the biggest democracy globally. India shares land borders with Pakistan to the west; China, Nepal, and Bhutan to the northeast; and Bangladesh and Myanmar to the east. The Indian Ocean bounds it in the south, the Arabian Sea in the southwest, and the Bay of Bengal in the southeast. India's topography is vast and varied, comprising a wide range of weather conditions. Referencing the Köppen system, the country has six climatic subtypes. Its climate is arid desert in the west, alpine tundra and glaciers in the north, and humid tropical regions supporting rainforests in the southwest and the island territories. Many regions have starkly different microclimates.

India is a leading global economic force. Its economy was nominally worth US$9.3 trillion in 2021 (World Bank, 2022b). It is the fifth largest by market exchange rate and the third largest by purchasing power parity (PPP), at over US$11 trillion (International Monetary Fund, 2022). With its average annual gross domestic product (GDP) growth rate of 8.7% for 2021–2022, India is one of the fastest-growing economies. However, it ranks 142nd for nominal world GDP per capita and 128th for GDP per capita at PPP (The World Bank, 2022a). Despite economic growth in recent decades, India continues to face socio-economic challenges such as poverty and access to modern energy.

Energy consumption has more than doubled since 2000, propelled upwards by a growing population – soon to be the world's largest – and a period of rapid economic growth. Near-universal household access to electricity was achieved in 2019, which means that over 900 million citizens have gained an electrical connection in less than 2 decades (IEA, 2021). Total energy consumption per capita remains about 0.7 tonne of oil equivalent (toe) (2021), half the Asian average (Enerdata, 2022). Despite continued growth, India is still at a comparatively low human development index level of 0.645 in 2019 and a global rank of 131 (UNDP, 2020). It continues to have a large underserved yet aspiring population, indicating that development is the most critical priority. The country faces increasing challenges in meeting growing commercial energy demand sustainably. The concern assumes even greater significance in the context of volatility in global fuel prices and growing global pressure to reduce greenhouse gas (GHG) emissions. Ensuring rapid economic growth and enhancing access to energy and infrastructure in an environmentally sustainable manner with limited resources makes it a complex challenge for India's planners and decision-makers to ensure sustainability and a better living standard.[1]

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[1] The chapter is based on Institute of Energy Economics, Japan model and assumptions.

2. Modelling Assumptions

There is a marked increase in GDP, from US$2.75 trillion (in constant 2015 values) in 2019 to about US$13.45 trillion (in constant 2015 values) in 2050, equivalent to 5.3% average annual growth rate. The population is assumed to grow at an average annual rate of 0.6%, from about 1.37 billion in 2019 to about 1.64 billion in 2050. In the business-as-usual (BAU) scenario, the share of coal in the electricity generation mix slightly decreases over time but remains the dominant source of electricity generation over the modelling timeframe. The shares of hydropower and oil are expected to decrease in the energy mix by 2050, with nuclear power plants and 'others' (renewables) set to increase across the modelling timeframe.

Per the alternative policy scenario (APS), India seeks to attain substantial energy-saving goals by deploying renewable energy power generation and implementing energy efficiency programmes in end-use sectors. Ensuring energy saving in the industry involves improving the efficiency of small plants and highly energy-intensive industries. Efficient end-use technologies and energy management systems can ensure significant savings in the residential and commercial sectors. Improvement in the vehicle fuel economy and effective traffic management is important to increase efficiency in transport.

In the low-carbon energy transition (LCET) scenario, India is expected to achieve its net-zero emission target by 2070. Notable efforts are being made to raise non-fossil fuel energy capacity to 500 gigawatts (GW) and reduce carbon intensity to below 45% by 2030. In addition to energy efficiency programmes in APS, the country deploys significant carbon capture and storage (CCS) technology as well as carbon sequestration through sinks (such as forestry) to significantly lower CO_2 emissions.

3. Outlook Results

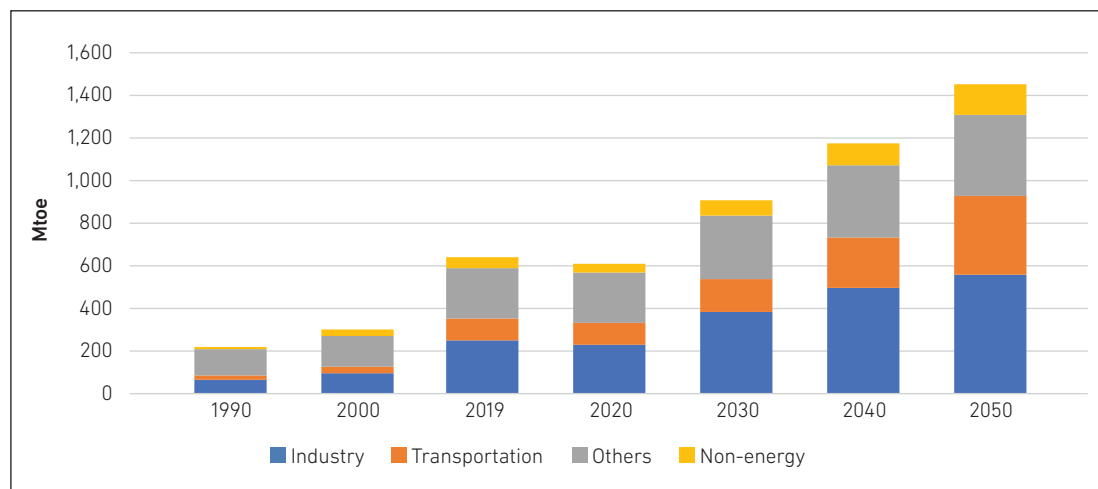## 3.1. Business-as-Usual Scenario

The section describes the current trend of energy production and utilisation based on existing policies, devoid of any other policy intervention, to reduce energy demand or CO_2 emissions.

3.1.1. Final Energy Consumption

BAU assumes strong economic growth and a rising population, resulting in significant projected increase in India's total final energy consumption (TFEC) at an average rate of 2.7% per year, from about 630 million tonnes of oil equivalent (Mtoe) in 2019 to about 1,442 Mtoe in 2050 (Figure 6.1). Projections indicate that the transport end-use sector exhibits marked growth, increasing at an average of 4.1% per year in 2019–2050. The non-energy and industry sectors increase at a projected yearly average rate of 3.3% and 2.7%, respectively. The large share of non-commercial energy in the final energy consumption mixes will result in

a modest growth rate of 'others', including the residential and commercial sectors, by a projected 1.7% per year. Consequently, the energy consumption of commercial and residential sectors in 'others' will increase in value but decrease in share, from about 231 Mtoe (37%) in 2019 to 386 Mtoe (27%) in 2050. Industry is expected to have the highest share of energy demand by 2050, despite its decrease in share from 38% in 2019 to 37% in 2050. Driven by the growing population's high demand for mobility, the share of transport is projected to increase in value and share, from about 17% (105 Mtoe) to 25% (363 Mtoe). The share of the non-energy sector is projected to increase from about 8% (51 Mtoe) to 10% (139 Mtoe).

Figure 6.1 **Total Final Energy Consumption by Sector, Business as Usual (1990–2050)**
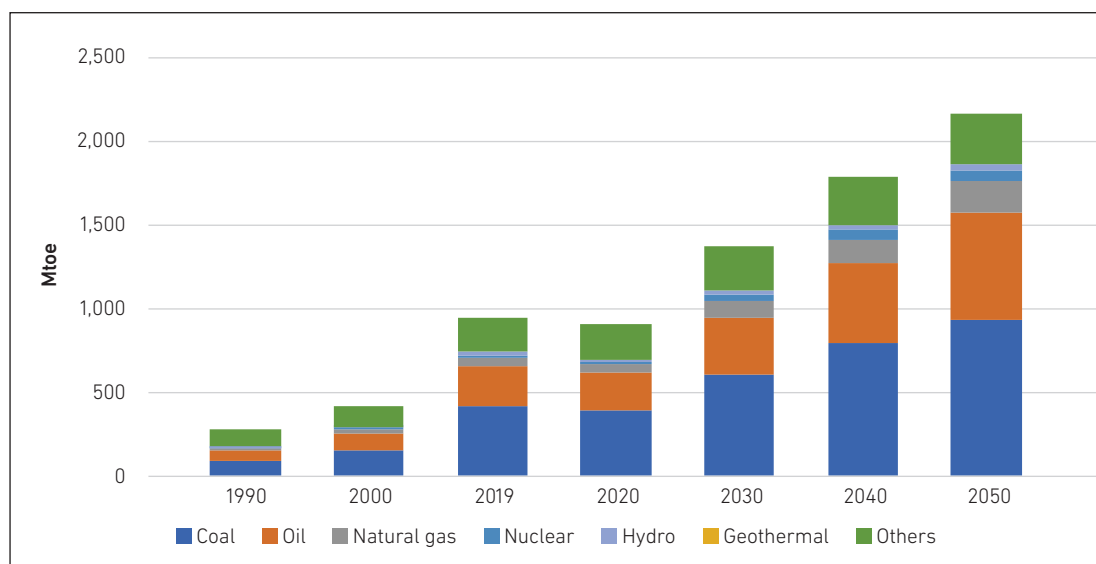

Source: Authors.

3.1.2. Primary Energy Supply

Energy projections indicate an increase in primary energy supply by an average annual rate of 2.6%, reaching 2,166 Mtoe in 2050 from 938 Mtoe in 2019 (Figure 6.2). With power generation being the major driving force, the consumption of coal is projected to grow by 2.6% per year, from about 418 Mtoe in 2019 to 934 Mtoe in 2050, accounting for the largest share of primary energy supply (43%) in 2050 against 45% in 2019. The supply of oil is projected to increase in value and share due to rapid motorisation; supply will increase at an annual average growth rate of 3.3%, resulting in an increase in value and share from 235 Mtoe (25%) in 2019 to 637 Mtoe (29%) in 2050, representing the second-largest share in the primary energy supply mix. Increasing at a projected 4.1% per year, the share of natural gas will increase by about 3%, from 6% in 2019 to 9% in 2050. In 'others', the share of non-commercial biomass declines significantly from 94% in 2019 to 73% in 2050, resulting in an annual average growth rate (AAGR) of 0.5% per year. Solar photovoltaic (PV) and wind power are expected to increase in value and share, accounting for about 3.8% in 2050 from 1.2% in 2019. Figure 6.2 depicts the projected primary energy supply in 1990–2050.

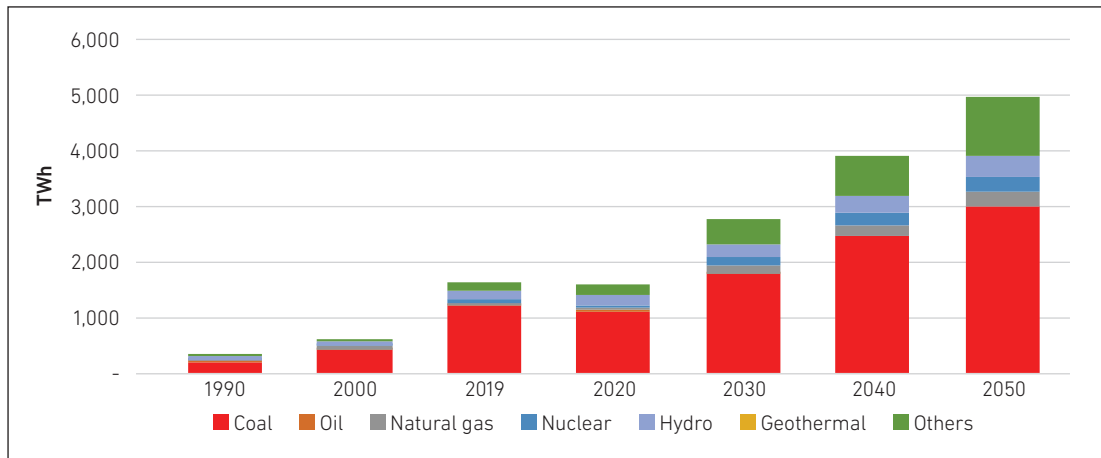**Figure 6.2** India – Total Primary Energy Supply, Business as Usual (1990–2050)

Mtoe = million tonnes of oil equivalent.

Source: Authors.

3.1.3. Power Generation

Power generation stood at 1,623 terawatt-hours (TWh) in 2019. It is projected to increase by 3.7% per year, reaching 4,937 TWh in 2050 (Figure 6.3). Irrespective of its decreased share in power generation output, from 72% in 2019 to 60% in 2050, coal will continue to dominate the power generation mix. The transition to low-carbon fuels will see the share of renewables and alternative energy sources increase over the modelling timeframe. Hydropower will account for the second-largest share in 2050, with about 8% of total energy output, declining from 10% in 2019. In contrast, the share of nuclear energy will increase from about 3% to 5%, at an AAGR of 5.6% per year for the same period. The share of natural gas will reach about 5% by 2050, a slight increase from its 4% value in 2019, equivalent to an average growth rate of 4.7%. The value and share of 'others', comprising wind and solar power, will significantly increase from 202 Mtoe (9.4%) in 2019 to 1,047 Mtoe (21%) in 2050, averaging annual growth of 6.7% a year. Figure 6.3 illustrates the projected power generation output in 1990–2050.

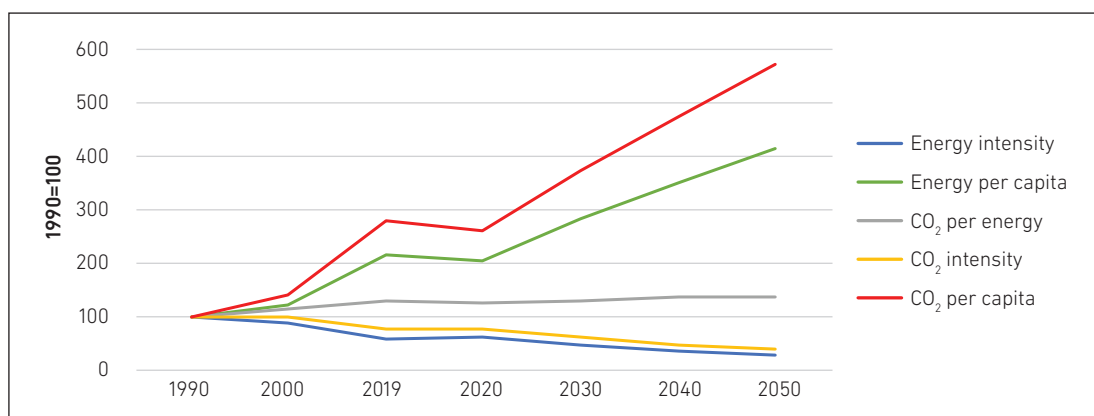**Figure 6.3** India – Electricity Generation, Business as Usual (1990–2050)

TWh = terawatt-hour.

Source: Authors.

3.1.4. Energy Indicators

Based on the socio-economic data projections and energy estimates, Figure 6.4 depicts the changes in various projected energy indicators in 1990 –2050. Owing to the adoption of more energy-conservative measures and more efficient energy technologies, energy intensity will decrease from 590 toe/US$ million (in constant 2015 values) in 2019 to 161 toe/US$ million (in constant 2015 values) in 2050 – an indication of the primary energy supply per unit of GDP – at an average annual growth of −2.4%. Conversely, energy per capita will grow at 2.1% per year, increasing in value from 0.7 toe/person in 2019 to 1.3 toe/person in 2050, indicating marked improvements in energy access across the population. Due to the introduction of renewable energy technology into the energy mix, a significant decrease in CO_2 intensity is observed, to 421 tonnes of carbon (t-C)/US$ million (in constant 2015 values) in 2050, from 840 t-C/US$ million (in constant 2015 values) in 2019, reflecting a notable decrease in CO_2 emissions per unit of GDP, resulting in annual average growth rate of −2.2%. A slight increase in CO_2 emissions per unit of primary energy supply is projected, from about 2.5 t-C/toe in 2019 to 2.6 t-C/toe in 2050, equivalent to an AAGR of 0.2%. Consequently, CO_2 emissions per capita will increase from roughly 1.7 metric tonnes of carbon (Mt-C)/million people in 2019 to 3.5 Mt-C/million people in 2050, corresponding to a growth rate of 2.3% per year, owing to increased CO_2 emissions on the basis of current policies and national energy framework.

Figure 6.4 India – Energy Indicators, Business as Usual (1990–2050)

Source: Authors.

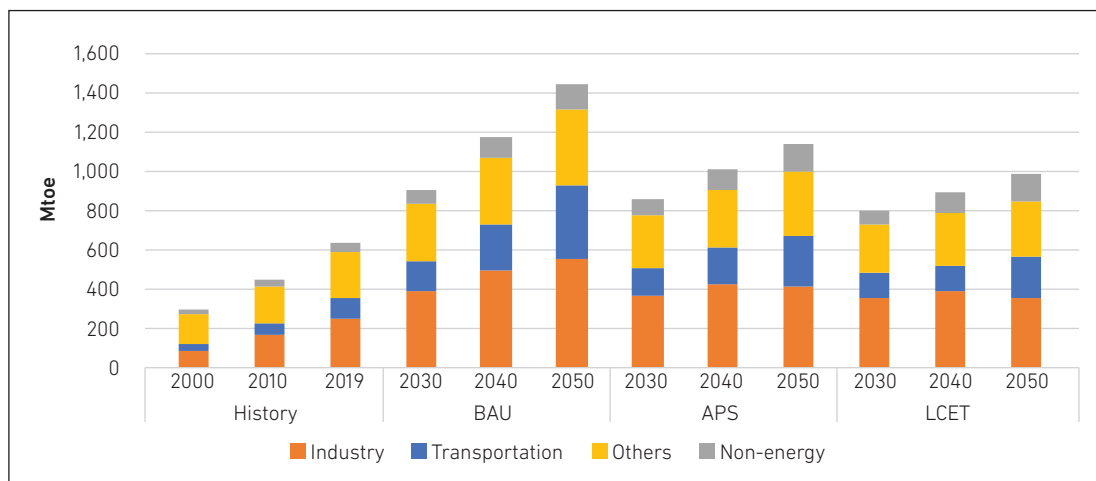## 3.2. Alternative Policy Scenario and Low-Carbon Energy Transition

3.2.1. Final Energy Consumption

TFEC in APS and LCET is expected to be lower, reflecting robust energy-saving targets, improvements in end-use technology, and the introduction of more efficient energy management systems. In APS, TFEC will reach 1,132 Mtoe in 2050, decreasing by 22% (311 Mtoe) relative to BAU (Figure 6.5). TFEC in LCET is projected at 979 Mtoe in 2050, a 32% (464 Mtoe) decrease compared with BAU for the same period.

In APS, savings in energy consumption are estimated at 145 Mtoe in industry, 105 Mtoe in transport, and 60 Mtoe in 'others' in 2050, equivalent to 26%, 29%, and 16% consumption savings, respectively. For the non-energy end-use sector, no change in TFEC is observed under either scenario as energy projection values remain unchanged.

In LCET, TFEC is projected to decrease by significantly more than in BAU, decreasing by 34% and corresponding to energy savings of 464 Mtoe in 2050. Industry, transport, and 'others' will decrease by 199 Mtoe, 157 Mtoe, and 107 Mtoe, respectively, in 2050, corresponding to energy savings of 36%, 43%, and 28%, respectively. The non-energy sector will reach 139 Mtoe in LCET in 2050.

Figure 6.5 India – Total Final Energy Consumption, Alternative Policy Scenario and Low-carbon Energy Transition (2000–2050)

APS = alternative policy scenario, BAU = business as usual, LCET = low-carbon energy transition, Mtoe = million tonnes of oil equivalent.
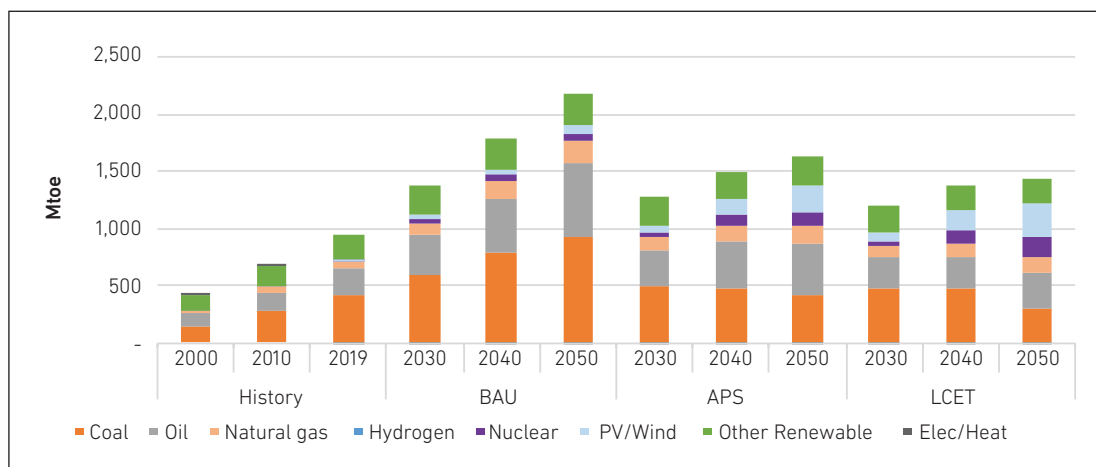Source: Authors.

3.2.2. Primary Energy Supply

In APS, primary energy supply is projected to grow at a slower pace, increasing at an average annual growth rate of 1.8% and reaching 1,624 Mtoe in 2050, a 25% (542 Mtoe) supply savings relative to BAU (Figure 6.6). It will increase by an average of 1.4% per year, reaching 1,430 Mtoe in LCET in 2050, equivalent to 34% (737 Mtoe) energy savings. The observed decreases in consumption can be attributed to a more robust approach to adopting and utilising more efficient low-carbon technologies and the visible incorporation of strong energy-saving targets.

'Others' will account for the second-largest share of TPES in APS and the largest share in LCET, increasing at 2.5% and 2.6% per year, respectively, in 2019–2050. Their overall share will increase, accounting for 27% and 31% in APS and LCET, respectively, by 2050. The share of biomass is observed to decrease to 43% in APS and 37% in LCET. Conversely, the consumption of solar and wind energy will increase in value and share, accounting for 63% and 52%, respectively, of TPES in 2050, at growth rates of 10.9% and 10.1% per year in APS and LCET, respectively. Nuclear energy and hydropower will see notable growth, increasing by 7.9% and 3.1%, respectively, per year in APS, with 9.2% and 3.7% increase, respectively, in LCET.

A significant decrease is projected in the share of coal in APS and LCET. By 2050, coal will account for 26% and 22% share in the primary energy supply, equivalent to growth rates of 0.1% and −0.1%, in APS and LCET, respectively, from a 45% share in 2019. The growth rate of oil is expected to be lower in BAU, increasing at about 2.1% and 0.8% per year for APS and LCET, respectively. The AAGR of natural gas is projected at roughly 3.2% in APS (9% of TPES) and 2.95% in LCET (10% of TPES). Consumption of fossil fuels such as coal and natural gas will be mitigated owing to energy efficiency measures. Figure 6.6 shows projected primary energy supply for APS and LCET in 1990–2050.

Figure 6.6 India – Total Primary Energy Supply, Business as Usual, Alternative Policy Scenario, and Low-carbon Energy Transition (2000–2050)

APS = alternative policy scenario, BAU = business as usual, LCET = low-carbon energy transition, Mtoe = million tonnes of oil equivalent.
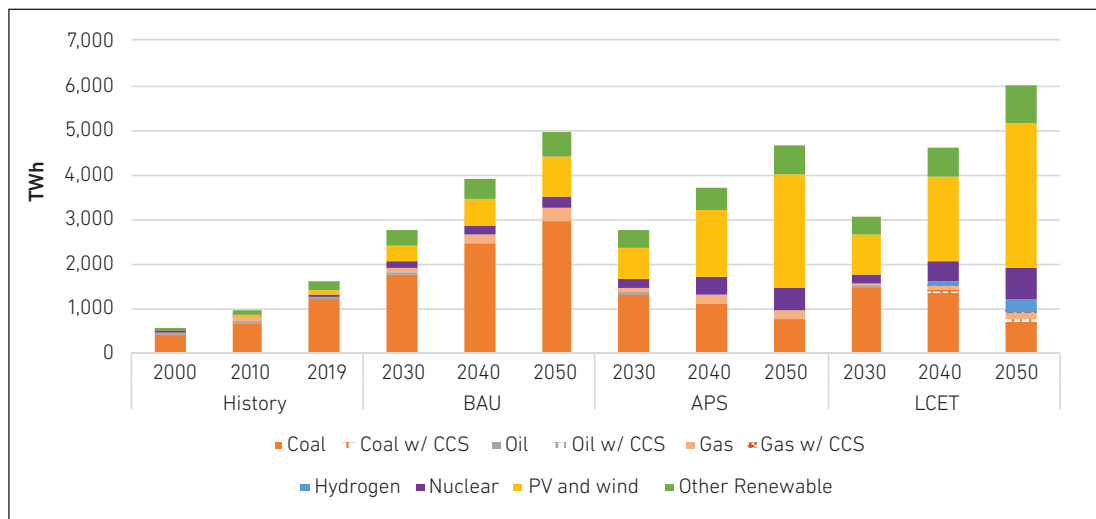Source: Authors.

3.2.3. Power Generation

In APS, power generation output will decrease by 6%, an energy saving of 280 TWh in 2050 (Figure 6.7). 'Others', mainly solar PV and wind power, will account for the largest share (60%) in the power generation mix, increasing by 1,732 TWh (165%) at an AAGR of 9.8% within the same period. Nuclear energy and hydropower are expected to increase by 98% (243 TWh) and 11% (44 TWh), respectively, in 2050 because of the integration of renewable energy technologies and alternative fuels into the power generation mix, with a resultant decline in the use of fossil fuels.

Coal-based power is projected to decrease by about 75%, saving 2,222 TWh in energy by 2050, reflected in its growth rate of −1.5% per year. Demand for oil and natural gas in power generation will decrease subsequently; oil consumption will become obsolete whilst natural gas power generation will decrease by 29% (77 TWh) in 2050.

The scenario is different in LCET. Total power generation output is expected to increase by 21% due to the increased share of renewables and the introduction of CCS technology into the electricity mix. Coal-based power generation is projected to decrease by 77%, saving 2,278 TWh in energy in 2050. Oil will be phased out of the electricity mix, with natural gas–based generation decreasing by 35%, corresponding to saving of 94.33 TWh. Demand for nuclear energy and hydropower is expected to increase by 189% and 34%, respectively, with demand for 'others' increasing at an average growth rate of 11.3% per year. The introduction of CCS technology into coal-, gas-, and hydrogen and ammonia–fuelled power plants will significantly reduce CO_2 emissions in power generation output.

Figure 6.7 India – Power Generation Output, Business as Usual, Alternative Policy Scenario, and Low-carbon Energy Transition (2000–2050)

APS = alternative policy scenario, BAU = business as usual, CCS = carbon capture and storage, LCET = low-carbon energy transition, PV = photovoltaic, TWh = terawatt-hour.
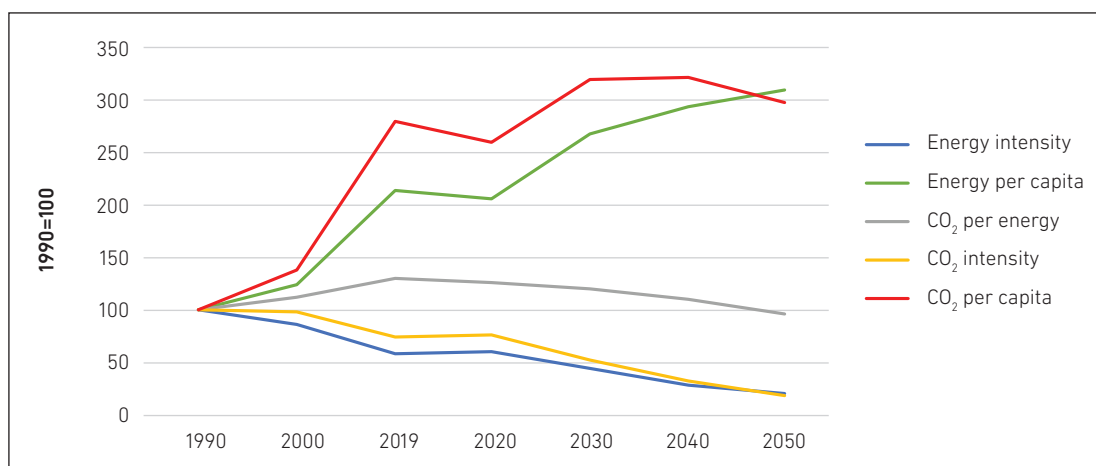
Source: Authors.

3.2.4. Energy Indicators

Due to the vigorous implementation of energy-saving technologies and targets, energy intensity – defined as primary energy supply per unit of GDP – is projected to decrease by 25% (55 toe/US$ million in constant 2015 values) and 34% (40 toe/US$ million in constant 2015 values), in APS and LCET, respectively, in 2050 (Figure 6.8 and Figure 6.9), with individual growth rates of –3.3% and –3.7% per year. CO_2 intensity is expected to decrease by 48% (202 t-C/US$ million in 2015 constant values) and 69% (292 t-C/Us$ million in constant 2015 values) in APS and LCET, respectively, because of significant reductions in CO_2 emissions resulting from the projected decrease in consumption of coal in industrial power plants. The transition from consumption of oil products (mainly gasoline and diesel) in transport and notable reductions in natural gas consumption are expected to considerably lower CO_2 emissions.
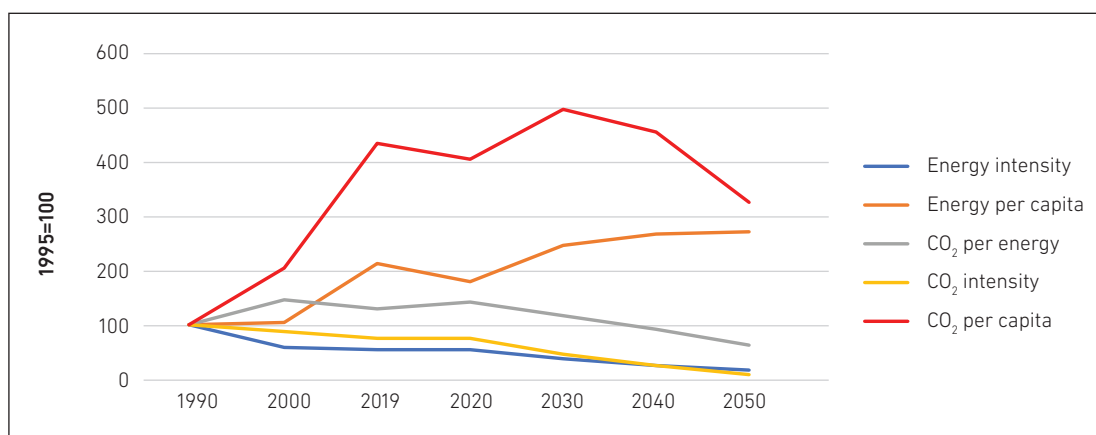
In APS, CO_2 emissions per unit of primary energy supply will reach 1.81 t-C/toe in 2050, decreasing by 31% relative to BAU. In LCET, CO_2 emissions per unit of primary energy supply will decrease to 1.21 t-C/toe in the same year, a 54% decrease compared with BAU.

Figure 6.8 India – Energy Indicators, Alternative Policy Scenario (1990–2050)

Source: Authors.

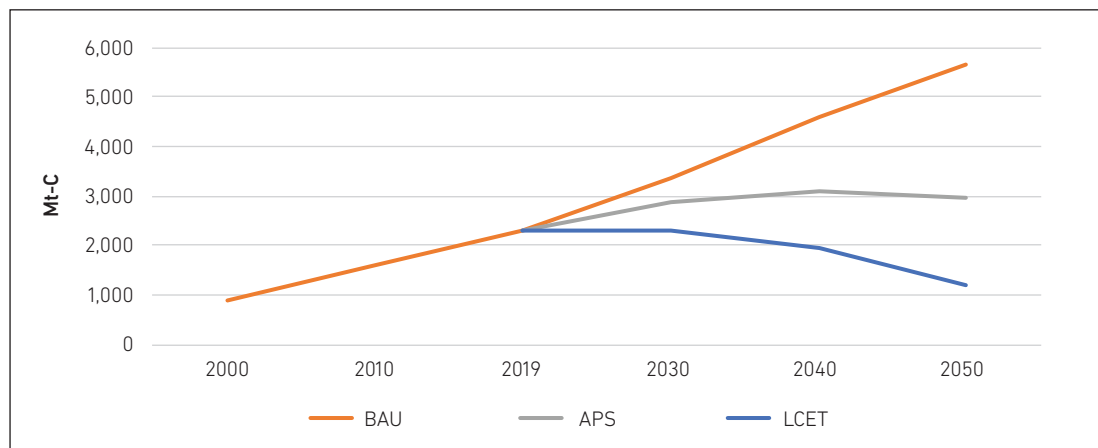**Figure 6.9** India – Energy Indicators, Low-carbon Energy Transition (1990–2050)

Source: Authors.

3.2.5. Saving of Fossil Fuel Consumption and CO_2 Reduction

In BAU, CO_2 emissions from energy consumption are expected to increase by 2.9% per year, reaching 5,658 million tonnes of carbon (Mt-C) in 2050. Coal is the highest emitter of CO_2, accounting for 65% of total emissions, with oil and natural gas each contributing 30% and 5%, respectively. BAU is still marked by the presence of fossil fuels in its energy mix, with negligible effort to implement energy-saving initiatives. However, the case is different in APS and LCET.

By 2050, overall CO_2 emissions in APS and LCET will be 2,946 and 1,730 Mt-C, respectively, equivalent to 48% (2,712 Mt-C) and 69% (3,928 Mt-C) reductions, respectively, compared with BAU (Figure 6.10). The reasons are reduced demand for coal, oil, and natural gas in power generation output, the introduction of more alternative fuel options into end-use subsectors, and robust energy-saving goals (Figure 6.10).

Figure 6.10 India – CO_2 Emissions, Business as Usual, Alternative Policy Scenario, and Low-carbon Energy Transition (2000–2050)

APS = alternative policy scenario, BAU = business as usual, LCET = low-carbon energy transition, Mt-C = metric tonne of carbon.
Source: Authors.

4. Implications and Policy Recommendations

Achieving net-zero emissions requires significantly lowering CO_2 emissions and fostering a swift transition to renewable energy. Pathways to help achieve the targets include the following:

- Developing policies that promote the massive expansion of renewables, strengthen the electricity grid to enhance flexibility, and develop storage technologies.
- Deployment of a substantial amount of carbon-removal projects using CCS technology and encouragement of massive investment in afforestation to sink carbon. The measures will aid in significantly lowering CO_2 emissions by capturing residual emissions from fossil-fuel–generated power plants and hard-to-abate industries, such as cement, and offset emissions from fast-growing sectors.
- Raising the share of hydrogen from its nascent stage today and deploying it mainly as a fuel substitute for heavy-duty transport and industrial applications.
- Considerably improving energy efficiency through robust investment in urban and industrial energy infrastructure, power plants, factories, appliances, and cars to significantly lower energy intensity.
- Transitioning from fossil fuel–generated power output in the electricity mix, primarily from coal, to renewable energy sources such as wind power, solar PV, and hydropower and other alternative energy sources such as nuclear energy and hydrogen.
- Implementing policies that favour the adoption of electric vehicle technology to phase out oil consumption in transport. The measure will serve to not only lower CO_2 emissions and energy intensity but also create significant opportunities for local and foreign investors.

References

Enerdata (2022), *India Energy Information*. https://www.enerdata.net/estore/energy-market/india/

International Energy Agency (2021), *India Energy Outlook.* Paris. https://www.iea.org/reports/india-energy-outlook-2021

International Monetary Fund (2022), *World Economic Outlook Database*. World Economic and Financial Surveys. https://www.imf.org/en/Publications/WEO/weo-database/2022/April/

UNDP (2020), Human Development Report 2020. New York. https://hdr.undp.org/system/files/documents/hdr2020pdf.pdf

World Bank (2021), Land area (sq. km) – India. https://data.worldbank.org/indicator/AG.LND.TOTL.K2?locations=IN

World Bank (2022a), GDP per capita (current US$). https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?most_recent_value_desc=true

The World Bank (2022b), GDP, PPP (constant 2017 international $) – India. https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD?locations=IN