ASSESSING INDIA'S ENERGY BASKET

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In the 21st century, energy has become the world's most vital commodity and India is one of its largest consumers. The energy world is rapidly changing and this change is driven by increasing demand, changing growth and demographic patterns, finite resources, environmental concerns, and the transition from hitherto dominant sources of fuel to newer, cleaner sources of energy. This article analyses India's energy basket by exploring the various sources of energy. It also briefly examines the trajectory of the growth of India's power sector, the transformation of its power system, the ministries responsible for the efficient functioning of various energy sources and the growing co-relation between economic growth and energy consumption.

INTRODUCTION

The most substantial transformation seen in the 21st century is the metamorphosis of the global energy landscape. The increasing influence and hold of developing countries in dictating the energy changes have been observed in the last two decades as their energy consumption has nearly doubled.[1] This dramatic increase in energy consumption could be attributed

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1. Philippe Benoit, "Energy and Development in a Changing World: A Framework for the 21st Century", Centre on Global Energy Policy, Columbia SIPA, at https://www.energypolicy.columbia.edu/research/energy-and-development-changing-world-framework-21st-century#_ednref1. Accessed on April 6, 2022.

to increasing amounts of energy being used by over six billion people[2] in the developing world on local consumption of goods and services, and to further economic and social development. This comes as an inherent part of the process of development which is increasing people's standards of living. Contrary to the pattern of consumption prevalent in the previous century which weighed heavily on the developing countries' supply of energy to the developed world through export of material and services, the current pattern of consumption is based on local consumerism, and is driving the need for increased supply. There is a shift in the energy sinks of the world from the developed to the developing world. The latter now faces a two-fold challenge. The first is to ensure the security of supply, and the second is to produce this significantly large amount of energy sustainably. The choices made in these approaches would continue to influence, and have a major impact on, the markets, economy, geopolitics and climate change.

India is a major force in the global energy economy. This primacy could be attributed to two factors: consumption and demand. India has a large population and a fast-growing economy. By 2027, India, which is now second on the list of countries by population, would have surpassed the People's Republic of China (PRC) as the world's most populous nation.[3] India is also the fastest growing economy in the world, according to the Gross Domestic Production (GDP) growth projection by the International Monetary Fund (IMF).[4] In 2020, India's GDP per capita was $6,118.36 when adjusted with the Purchasing Power Parity (PPP) and ranked third in the world, next only

2. UNCTAD Handbook of Statistics- 2017, "World Population 2016", at https://unctad.org/system/files/official-document/tdstat42_FS11_en.pdf. Accessed on June 18, 2022.
3. Special Correspondent, "India to be Most Populous by 2027", *The Hindu*, at https://www.thehindu.com/news/national/india-to-be-most-populous-by-2027-un/article28067167.ece. Accessed on June 18, 2022.
4. "India To Remain The Fastest Growing Major Economy In The World During 2021-21 As Per World Bank, IMF, Says Economic Survey 2022", ANI, at https://www.aninews.in/news/national/general-news/india-to-remain-fastest-growing-major-economy-in-the-world-during-2021-24-as-per-world-bank-imf-says-economic-survey20220201011933/#:~:text=This%20projects%20India%20as%20the,per%20cent%20in%202020%2D21. Accessed on February 1, 2022.

to China and the USA.[5] India uses 6 per cent of the world's primary energy and its energy consumption stands at 1/3rd of the global average.[6] India's urban population is expected to grow by an estimated 270 million people by 2040, which will result in an increase in the energy demand.[7] Considering 2000 as the base year, India has been responsible for a 10 per cent increase in the global energy demand.[8] The last two decades also saw an increase in the per capita energy demand by 60 per cent.[9]

In 2020, India's per capita energy consumption[10] stood at 6,438 kilowatt hours (kWh) which was way less than that of the developed countries like the USA which stood at 73,677 kWh and Canada at 1,00,310 kWh.[11] On an aggregate level, India ranks third in total energy consumption with 908 million tonnes of oil equivalent (mtoe), next only to China and the USA.[12] A discrepancy may be noticed looking at energy consumption from a per capita value and an absolute value. The absolute value looks large and growing while the per capita value seems low by international standards. India is an energy guzzling giant which currently ranks third in the world's primary energy consumption.[13] Increased energy consumption would mean increased energy demand, creating a feedback loop. There is enormous potential for further growth in energy services owing to the forces of industrialisation,

5. Trading Economics, "India GDP Per Capita PPP", at https://tradingeconomics.com/india/gdp-per-capita-ppp. Accessed on June 18, 2022.
6. ET Bureau, "India Needs Quadrupling Per Capita Energy Consumption to Get Into Upper Middle Income Country Club: Economic Survey", *Economic Times*, at https://economictimes.indiatimes.com/industry/energy/power/india-needs-quadrupling-per-capita-energy-consumption-to-get-into-upper-middle-income-country-club-economic-survey/articleshow/70070107.cms?from=mdr. Accessed on May 4, 2022.
7. World Energy Outlook Special Report, "India Energy Outlook 2021".
8. Ibid.
9. Ibid.
10. Per capita 'energy' consumption is different from per capita electricity consumption. Energy consumption refers to primary energy consumption, including electricity consumption.
11. Our World in Data, "Energy Use per Person 2020", at https://ourworldindata.org/grapher/per-capita-energy-use?time=2020. Accessed on June 18, 2022.
12. Enerdata, "World Energy and Climate Statistics 2021", at https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html. Accessed on June 18, 2022.
13. Press Information Bureau, "India has been Ranked Third Largest Primary Energy Consumer in the World; Government has Announced its aim of Achieving 500 GW Installed Capacity from Non-Fossil Fuel Based Capacity by 2030", at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1809204. Accessed on March 24, 2022.

India has one of the largest energy markets in the world, comparable to those of the European Union, Russia, and the US. The largest synchronous national grid in the world is that of India.

urbanisation, growing population, and the economy.[14]

There is an established relation between energy consumption and economic growth, leading to combined and affirmative changes in social spheres, colloquially known as development. Energy is considered to be the primary driving force of economic growth in all economies.[15] The world's most recognisable form of energy is electricity. Primary energy, through several steps, is converted into energy carriers like electricity which is suitable for the end user. Electricity is the primary form of energy and is the most accessible form used in day-to-day life. Electricity is a proxy for all energy forms. The discourse undertaken in this chapter pertaining to energy is considering electricity as the primary source of energy.[16] Apart from being the primary form of energy, it also forms a vital input for socioeconomic and infrastructural development.

ELECTRICITY IN INDIA

India has one of the largest energy markets in the world, comparable to those of the European Union, Russia, and the US. The largest synchronous national grid in the world is that of India.[17] The Indian government has prioritised fulfilling the annual growth in energy demand among millions of people. In the last ten years, India's electricity production has grown

14. Press Information Bureau, "Atmanirbhar India will only be Possible if our Cities Become Productive: Shri Hardeep Puri; Eight-Fold Increase on Urban Development Expenditure over the Last Six Years (2015-2021); Swachh Bharat Mission Becomes a Jan-Andolan and will be Launching SBM 2.0, with an Outlay of Rs. 1.41 Lakh Crores", at https://pib.gov.in/PressReleasePage.aspx?PRID=1754499. Accessed on April 15, 2022.
15. Shaligram Pokharel, "An Econometric Analysis of Energy Consumption in Nepal," Energy Policy, *Elsevier*, vol. 35(1), 2007, pp. 350-361.
16. In considering India's energy basket, the project focusses primarily on energy in terms of electricity.
17. "One Nation- One Grid", at https://www.powergrid.in/one-nation-one-grid, Power Grid Corporation Of India Limited. Accessed on April 18, 2022.

tremendously, with an average annual growth rate of 6 per cent.[18] The industrial and commercial sectors consume the most power, while residential electricity demand is growing at the fastest rate. An estimated three-quarters of all electricity generated in 2021 came from thermal power generation, which has largely satiated the demand growth. Recent years have seen significant development in renewable energy, especially wind and solar, supported by ambitious objectives and legislative measures.

A number of factors have contributed to the growth in the power demand, including growing per capita incomes, increasing levels of industrial expansion, urbanisation and growth.

In Financial Year (FY) 2020-21, electricity generation in India stood at 1,234.44 billion units (BU).[19] The electricity generation recorded a growth of 1.3 per cent Year on Year (YoY) in FY21.[20] A number of factors have contributed to the growth in the power demand, including growing per capita incomes, increasing levels of industrial expansion, urbanisation and growth. India's electricity demand was anticipated to increase to 1,905 terrawatt hours (TWh) by FY22, therefore, this trend is predicted to continue.[21] India's electricity needs are expected to increase to 817 gigawatts (GW) by 2030, according to the Central Electricity Authority (CEA).[22] India's per capita electricity consumption grew at a compound annual growth rate of 4 per cent from 1985 to 2020. It had reached 972 kWh in 2020.[23]

18. "India 2020 Energy Policy Review", International Energy Agency, at https://iea.blob.core.windows.net/assets/2571ae38-c895-430e-8b62-bc19019c6807/India_2020_Energy_Policy_Review.pdf. Accessed on June 18, 2022.
19. Naina Bhardwaj, "Opportunities In The Indian Power Sector For Foreign Players", India Briefing, at https://www.india-briefing.com/news/opportunities-foreign-investors-indian-power-sector-overview-23572.html/. Accessed on May 18, 2022.
20. "Report on Power," IBEF, at https://www.ibef.org/download/Power-October-2021.pdf. Accessed on March 28, 2022.
21. PTI, "Power Demand In India Expected To Grow 6 per cent In FY 22:ICRA", *Live Mint*. at https://www.livemint.com/industry/energy/power-demand-in-india-expected-to-grow-6-in-fy22-icra-11626179693609.html. Accessed on March 18, 2022.
22. Central Electricity Authority, "Report on Optimal Generation Capacity Mix by 2029-30", at https://cea.nic.in/old/reports/others/planning/irp/Optimal_mix_report_2029-30_FINAL.pdf. Accessed on June 18, 2022.
23. n. 7.

The electrification of the Indian energy economy continues apace. With investments across the value chain, India is positioned to become a powerhouse for global manufacturing. The industrial sector accounted for 42 per cent of the total electricity consumption in FY19 which is expected to grow in the times to come.[24] In every scenario mentioned in the World Energy Outlook report, India has the fastest growing global energy consumption, albeit how this demand is supplied depends on the interaction of policies, technologies, and market forces. In view of its increasing importance in the world energy markets, India has the potential to steer the energy discourse and lead the route in efficient energy planning**.**

After years of being a net importer of electricity, India started exporting electricity in 2017. Power commerce between the nation and its South Asian neighbours has increased.[25] In 2018, India sold power to Bangladesh, Myanmar, and Nepal and received power from Bhutan. As part of a larger regional integration effort in South Asia, India has recently established new connections with Nepal and Bangladesh. India wants to purchase excess hydropower from Bhutan and is planning to invest in, and provide, concessional financing for the development of hydropower in both Bhutan and the northern Indian territories.

The service sector and industries are India's main energy users, accounting for about half of the country's Total Final Consumption (TFC). The industries that use the most electricity include iron and steel, chemicals and petrochemicals, and textiles and leather (although nearly half of all industrial electricity consumption is not specified by sector). Agriculture (including a demand for water pumping) and forestry account for half of the industry's demand and are included in this sector. With 25 per cent of

24. "The Future of Indian Electricity Demand", Brookings Institute, at https://www.brookings.edu/wp-content/uploads/2018/10/The-future-of-Indian-electricity-demand.pdf. Accessed on June 18, 2022.
25. "India Becomes net Exporter of Electricity", Press Information Bureau, at https://pib.gov.in/newsite/printrelease.aspx?relid=160105. Accessed on March 29, 2022.

overall demand, the residential sector is the third largest power user. The remainder is used for rail transportation.[26]

India has made considerable progress in delivering universal power access to its populace during the last two decades. Its electrification rate is steadily increasing. After achieving 100 per cent village electrification in 2018, the Government of India announced in March 2019 that all houses have been fully electrified (except those that refused access).[27] By co-funding network renovations and extensions, the government promotes the strengthening of distribution networks and boosting village and home connections.

Evolution Of India's Power Sector

India is the third largest producer of energy and the third largest consumer globally.[28] Its share in global primary energy consumption stands at 6.1 per cent.[29] India's installed capacity at the time of independence stood at a total of 1,362 megawatts (MW).[30] At present, the installed power capacity stands at 3,99,497 MW.[31] India's energy needs are humongous and the capacity additions of the energy sources have to grow in accordance with the growth in demand. This section traces the trajectory of the growth of the power sector in India. The trajectory is divided into four periods: Introductory Phase (before 1956); Nationalisation Stage (1956-91); Liberalisation Era (1991-2002); and Growth Era (post 2003).

Introductory Phase (1956): The construction of a 130 kilowatt (kW) hydroelectric plant in Darjeeling in the 1880s was followed by the establishment of a thermal based power plant in Calcutta in 1897.[32] During this period and

26. World Energy Outlook Special Report, "India Energy outlook 2021", International Energy Agency, at https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf. Accessed on June 18, 2022.
27. Shadab Nazmi, "India Election 2019: Bringing Power To The People", BBC, at https://www.bbc.com/news/world-asia-india-47499917. Accessed on March 26, 2022.
28. n. 13.
29. Ibid.
30. Central Electricity Authority, "All India Installed Capacity Report", at https://cea.nic.in/installed-capacity-report/?lang=en. Accessed on April 14, 2022.
31. Ibid.
32. https://www.cesc.co.in/?page_id=223

Post-independence, the Electricity (Supply) Act 1948 was enacted which established the semi-autonomous State Electricity Boards (SEBs). The SEBs laid the groundwork for the rapid expansion of the country's electricity network

for the next 50 years, until 1947, electricity was confined to urban areas. It was primarily used for lighting purposes and was carried out under private entrepreneurship. For the next two decades, the growth of such small-scale electric power generation was limited to domestic and industrial uses of the growing urban pockets of cities like Calcutta and Bombay. The Indian Electricity Act of 1910, an Act to reform the law pertaining to the supply and use of electrical energy, was the first to establish a legal framework to support and regulate electricity.[33] Post-independence, the Electricity (Supply) Act 1948 was enacted which established the semi-autonomous State Electricity Boards (SEBs).[34] The SEBs laid the groundwork for the rapid expansion of the country's electricity network. The Act also led to the formation of the Central Electricity Authority (CEA) to act under the auspices of the central government.[35]

Nationalisation Stage (1956-91): The Industrial Policy Resolution of 1956 reserved the production of power specifically for the public sector.[36] Since then, it is the public sector that has made all new investments in power production, Transmission and Distribution (T&D). Power generation and distribution came under state control and have remained so. However, the power industry was beset by a slew of issues, including an electricity shortfall, availability of resource, power losses owing to infrastructure bottlenecks, and project management flaws. The expansion of installed generating capacity coincided with an expansion of T&D capacity in the

33. "The Indian Electricity Act 1910", at https://cercind.gov.in/IEA1910.pdf. Accessed on March 18, 2022.
34. "The Electricity (Supply) Act, 1948", at https://cercind.gov.in/ElectSupplyAct1948.pdf. Accessed on March 18, 2022.
35. Ibid.
36. "Industrial Policy Resolution", at https://dpiit.gov.in/sites/default/files/chap001%20%2013.pdf. Accessed on April 30, 2022.

post-independence period. Despite this, the power system has been unable to keep up with demand increases, and the country has always had energy and peaking shortages.

Table 1: India's Installed Generation Capacity and Annual Growth

Installed Capacity as on	Total (MW)	Per cent Growth (on yearly basis)
December 31, 1947	1,362	–
December 31, 1950	1,713	8.59
March 31, 1956	2,886	13.04
March 31, 1961	4,653	12.25
March 31, 1966	9,027	18.80
March 31, 1974	16,664	10.58
March 31, 1979	26,680	12.02
March 31, 1985	42,585	9.94
March 31, 1990	63,636	9.89
March 31, 1997	85,795	4.94
March 31, 2002	105,046	4.49
March 31, 2007	132,329	5.19
March 31, 2012	199,877	9.00
March 31, 2017	326,841	10.31
March 31, 2018	344,002	5.25
March 31, 2019	356,100	3.52
March 31, 2020	370,106	3.93
March 31, 2021	382,151	3.25
March 31, 2022	399,497	4.53

Source: All India installed power capacity, Central Electricity Authority, April 2021.

Although the supply lagged behind the rapidly increasing demand, it, nevertheless, led to the rapid development of the power sector in the post-independence period. The growth of system interconnections gave rise to an electric grid in each state. By the 1960s, coordination and increasing interconnectedness extended the grid system from the state level to the

regional level, and the country was demarcated into five power regions.[37] The interconnections of the supply lines began to increase multi-fold as the states were being financially encouraged by the central government. The interconnections between the states and the regions were strengthened by the setting up of central power generating stations.

Liberalisation Era (1991-2003): The power sector reforms of 1991 coincided with the opening up of the Indian economy with the Liberalisation, Privatisation, Globalisation (LPG) reforms. The reforms were initiated to encourage growth and competition in generation, transmission, and distribution, the three pillars of power supply. A fast-track clearing process for private investment applications was established with the help of essential legislative and policy actions. The Electricity Laws (Amendment) Act of 1998 paved the way for private sector engagement.[38] In order to reorganise the power structure that was hindered by unreasonable retail tariffs, a high level of cross-subsidies, poor planning and operation, insufficient capacity, consumer neglect, lack of private sector skills and resources, and lack of an independent regulatory authority, the Electricity Regulatory Commissions Act (1998) was passed.[39] This Act established the Central Electricity Regulatory Commission (CERC) and the State Electricity Regulatory Commission (SERC) to tackle the aforementioned difficulties.

Growth Era (Post 2003): The Electricity Act enacted in 2003 fast-tracked the privatisation process that had already begun to take place with the power sector reforms in 1991.[40] The electricity industry was virtually restructured by the Electricity Act of 2003. The Indian Electricity Act of 1910, the Electricity (Supply) Act of 1948, and the Electricity Regulatory Commission Act of 1998 were all repealed by the new law. The Act's major goal was to provide a

37. "Evolution of System Operation and Emergence of POSOCO as an Independent Institution in India", Power System Operation Corporation Limited, at https://posoco.in/wp-content/uploads/2021/01/POSOCO-Institution-Building-as-Independent-System-Operator-in-India-1.pdf. Accessed on March 8, 2022.
38. "The Electricity Regulatory Commission Act 1998", at https://cercind.gov.in/electregucommiact1998.pdf. Accessed on March 18, 2022.
39. Ibid.
40. "The Electricity Act, 2003", at https://cercind.gov.in/Act-with-amendment.pdf. Accessed on March 18, 2022.

liberal and progressive framework for the electricity sector's expansion by establishing competition in various areas of production, transmission, and distribution. It eased impediments to private actors entering the industry. The Act implemented a number of consumer protection, pricing control, energy accessibility, and service quality improvement initiatives.[41] The statute entirely delicensed power generating and allowed captive electricity generation without restriction. Newer rules were created over time to meet the changing energy circumstances and to focus on the aims outlined in the Central Electricity Authority's (CEA's) National Energy Policy (NEP).[42] Implementation of newer policies like the Deen Dayal Upadhyay Gram Jyoti Yojana (DDUGJY), Integrated Power Development Scheme for Rural and Urban Areas, and implementation of the Ujwal DISCOM Assurance Yojana (UDAY) signify the smart changes in the growth era post 2003. The Power (Amendment) Act 2018, which is awaiting parliamentary approval, intends to establish supplier competition by separating supply and distribution grid operations, enabling many service providers to distribute electricity to a single distribution region's consumers. This is intended to boost renewable energy while also promoting open access, competition, and market dynamics. It also suggests a new pricing approach for electricity subsidies, including the use of direct benefit transfers (direct distribution of subsidies to users' bank accounts rather than through the power price).

MINISTRIES

India's power industry is governed by the Ministry of Power (MoP), which also houses the Bureau of Energy Efficiency (BEE). The Central Electricity Authority, the Ministry of Power's top adviser, is in charge of technical coordination, programme monitoring, data collection, and distribution, particularly through the five-year National Electricity Plan. Some energy-related departments report to the Prime Minister's Office (PMO) directly. The NITI Aayog, an official think-tank and policy

41. Ibid.
42. The Central Electricity Authority is a statutory body constituted under the electricity (supply) act 1948, which was later replaced by the Electricity Act, 2003.

The Nuclear Power Corporation of India Limited, a central government owned corporation controlled by the DAE, is in charge of nuclear power generation and the operation of India's 22 nuclear reactors.

advisory body of the Indian government, coordinates inter-ministerial activities like India's energy data reform and Electric Vehicle (EV) programme. The Department of Atomic Energy (DAE) is involved in the advancement of nuclear energy technology and the use of other radiation technologies. By implementing domestic and other tested technologies, as well as thorium-based reactors and related fuel cycle facilities, the DAE hopes to enhance nuclear power's share in the electricity market. The Nuclear Power Corporation of India Limited (NPCIL), a central government owned corporation controlled by the DAE, is in charge of nuclear power generation and the operation of India's 22 nuclear reactors. The development of solar, wind, and other renewable energy sources in India is under the supervision of the Ministry of New and Renewable Energy (MNRE). The Indian Renewable Energy Development Agency (IREDA), a non-banking financial organisation that provides finance for renewable energy and energy efficiency projects, the National Institute of Solar Energy (NISE), and the National Institute of Wind Energy (NIWE) are all a part of the MNRE. The Solar Energy Corporation of India (SECI) is in charge of implementing MNRE subsidy programmes, such as the solar park scheme and grid-connected solar rooftop plan.

INDIA'S ENERGY BASKET

India is the world's second fastest growing economy after only China (2021).[43] India's GDP grew at an average yearly pace of 6.8 per cent between 1991 and 2019. The Indian economy has increased roughly nine-fold since

43. Kirtika Suneja, "India to be the Fastest Growing Economy in 2022 TRIPS Waiver Necessary for Vax: UNCTAD", *Economic Times*, at https://economictimes.indiatimes.com/news/economy/indicators/india-to-be-fastest-growing-economy-in-2022-trips-waiver-necessary-for-vax-unctad/articleshow/86233237.cms?from=mdr. Accessed on April 20, 2022.

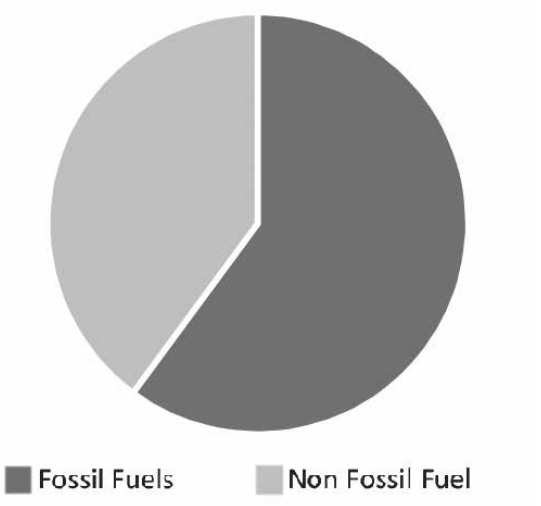
1991, to $2.3 trillion in 2019.[44] In 1991, India's GDP was $266 billion.[45] India's prosperity is inextricably related to its energy industry. Per capita electricity usage has increased by 32 per cent in the previous eight years, from 914 kWh in 2012-13 to 1,208 kWh in 2020.[46] India's per capita consumption is lower than that of other emerging nations like China, Brazil, and South Africa. A slight increase in per capita energy consumption is associated with a higher Human Development Index (HDI) when compared to other human development metrics. According to the Economic Survey 2018-19, India must boost its per capita energy consumption by four times to attain the HDI level of 0.8.[47] With a projected population increase, India's energy consumption is likely to soar. In other words, increasing demand would put pressure on the energy resources which would have to grow at a similar pace. As a result, it is reasonable to assume that India's economic growth would continue to drive its energy consumption, which is expected to increase from 6 per cent to 13 per cent of world energy consumption by 2050.[48] Electricity consumption has increased at a 7.39 per cent Compound Annual Growth Rate (CAGR), and demand is estimated

India's economic growth would continue to drive its energy consumption, which is expected to increase from 6 per cent to 13 per cent of world energy consumption by 2050.

44. Amit Mudgill, "Since 1991, Budget Size Grew 19 Times, Economy 9 Times, Your Income 5 Times", *Economic Times*, at https://economictimes.indiatimes.com/markets/stocks/news/since-1991-budget-size-grew-19-times-economy-9-times-your-income-5-times/articleshow/62735382.cms. Accessed on February 19, 2022.
45. Ibid.
46. Report by the Central Electricity Authority, Ministry of Power, "Growth of Electricity Sector in India from 1947- 2020" (Government of India), at https://cea.nic.in/wp-content/uploads/pdm/2020/12/growth_2020.pdf. Accessed on April 29, 2020.
47. Union Budget, "Economic Survey of India 2018-2019", Government of India, pp. 163-164, at https://www.indiabudget.gov.in/budget2019-20/economicsurvey/. Accessed on February 19, 2022.
48. Bp Outlooks, "Country Insight: India", at https://www.bp.com/en/global/corporate/energy-economics/energy-outlook/country-and-regional-insights/india-insights.html. Accessed on March 14, 2022.

to reach 1894.7 TWh in 2022.[49] Approximately 14,500 TWh of energy will be needed annually in India in 2050, with a moderate CAGR of 6.7 per cent up to that point.[50]

Fig 1: India's Total Installed Capacity



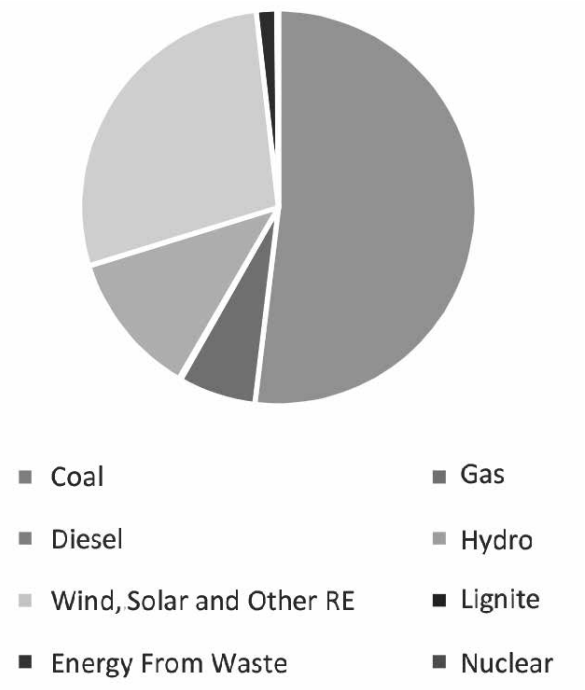
Source: "Power at a Glance", Ministry of Power.

When looking at India's energy basket in terms of Installed Generation Capacity (IGC), fossil fuels account for the majority of the contribution, accounting for 58.6 per cent of the total generation capacity.[51] Coal accounts for 50.7 per cent of total generation capacity, with natural gas coming in second at 6.2 per cent in the fossil fuel category.[52] Renewable energy accounts for the majority of the remaining 41.4 per cent, accounting for a 39.7 per cent

49. India Brand Equity Foundation, "Power Sector in India", at https://www.ibef.org/industry/power-sector-india. Accessed on April 17, 2022.
50. Sambit Nayak, Ankit Gupta and Trideep Kumar Roy, "Future of Energy: India in 2050", Intellecap, at https://www.intellecap.com/future-of-energy-india-in-2050/#:~:text=The%20energy%20supply%20spectrum%20largely,followed%20by%20transportation%20and%20buildings. Accessed on May 17, 2017.
51. Ministry of Power, "Power Sector at a Glance All India", at https://powermin.gov.in/en/content/power-sector-glance-all-india. Accessed on February 19, 2022.
52. Ibid.

contribution.[53] Surprisingly, nuclear energy, which is one of the cleanest sources of energy and is baseload energy, accounts for only 1.7 per cent of the entire IGC.

Fig 2: Installed Generation Capacity



Source: "Power at a Glance", Ministry of Power.

Given its present reliance on fossil fuels, India's energy future is pointing towards unsustainability. India's economic growth has been reliant on coal imports. However, India will ultimately run out of coal and we do not have much time till this happens. The Reserve to Production (R/P) ratio, which is the ratio of existing reserves to current rate of production, gives a clear view of the scenario. Given the current R/P ratio, the globe will run out

53. Ibid.

India's energy demand might double by 2040 if current policies continue, with electricity demand potentially doubling as a result of increased appliance ownership and cooling demands.

of coal in another 70 years or more.[54] India's debilitating reliance on coal as the main energy source, along with threats of negative environmental consequences, necessitate a greater contribution of non-fossil fuels to take a larger share in India's energy basket.

Between 2000 and 2019, almost 900 million individuals in India acquired access to electricity,[55] indicating robust and successful policy execution. India's energy demand might double by 2040 if current policies continue, with electricity demand potentially doubling as a result of increased appliance ownership and cooling demands. Despite this, India uses 30 per cent less energy per person than the worldwide average [0.44 tonnes of oil equivalent (toe) per capita versus the global average of 1.29 toe and the International Energy Agency (IEA) average of 2.9].[56] For FY21, conventional energy generation totalled 1,234.44 billion units (BU), with thermal energy accounting for 1,032.39 BU, hydro energy for 150.30 BU, and nuclear energy for 42.94 BU.[57] The following section examines the various sources of India's energy basket.

Coal

After the People's Republic of China, India is the world's second largest coal producer.[58] Since the 1970s, coal's proportion in the energy and power mix of India has risen, with coal accounting for 74 per cent of electricity

54. MAHB Admin, "When Fossil Fuels Run Out, What Then?" at https://mahb.stanford.edu/library-item/fossil-fuels-run/. Accessed on May 23, 2019.
55. n. 7.
56. P. Kumar, M.O. Dioha and S. Endo, "India Country Report", in P. Han, and S. Kimura, eds., *Energy Outlook and Energy Saving Potential in East Asia 2020* (Jakarta: ERIA, January 2021), pp. 87-101.
57. "Indian Power Sector Analysis Industry Report", IBEF, at https://www.ibef.org/archives/industry/indian-power-industry-analysis-reports/indian-power-industry-analysis-presentation
58. Nicole Wagner, "Major Coal Producing Countries", Encyclopaedia of Geology, at https://www.sciencedirect.com/topics/earth-and-planetary-sciences/coal-production

output in 2022.[59] According to the press release by the Ministry of Coal, India's total coal production increased by 6.74 per cent from December 2019 to December 2021;[60] Although coal is India's most plentiful fossil fuel, the coal available in India is of poor quality, with a low calorific value and an ash content of up to 45 per cent, compared to good quality coal which has an ash content of 5-10 per cent.[61] Coal India Limited (CIL) was established as a monopoly to market coal and manage coal mines when India's coal sector was nationalised in 1975. After the first oil shock, this choice represented the necessity for energy for economic expansion as well as a newfound awareness for energy security.

Because of its high ash concentration and primary application in the production of thermal energy, Indian coking coal is unsuitable for the manufacturing of metallurgical coke.

Coal was designated as the backbone of India's energy supply since it is the most plentiful fossil fuel. India has proven coal reserves of 148.79 gigatonnes (Gt) and total coal resources of 319.02 Gt, according to the most recent Geological Survey of India report dated April 2018.[62] There are 6.54 Gt of proved lignite reserves, and 45.66 Gt of total lignite resources.[63] With a tiny quantity of sub-bituminous reserves, the majority of India's hard coal deposits are bituminous. Because of its high ash concentration and primary application in the production of thermal energy, Indian coking coal is unsuitable for the manufacturing of metallurgical coke. More than two-thirds of coal is used in the production of iron and steel (nearly 20 per cent),

59. n. 7.
60. "India's Total Coal Production Increased by 6.74 per cent to 74.78 million tonne (MT) during December 2021, as compared to the same period in 2019", Press Information Bureau, at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1787667. Accessed on March 5, 2022.
61. Prachi Lokhande, "Nuclear Energy Could be the Answer to India's Energy Woes", *Liberal Studies Journal*, vol 6, issue 2, at https://sls.pdpu.ac.in/downloads/Liberal%20Studies%20Jouranl,%20Vol.%206,%20Issue%202%20%20%20July%20-%20December%20%202021%2029-7-22.pdf. Accessed on April 17, 2022.
62. "Coal Reserves", Ministry of Coal, at https://coal.gov.in/en/major-statistics/coal-reserves. Accessed on February 19, 2022.
63. Ibid.

cement (about 5 per cent), and other products such as fertilisers, pulp and paper, non-ferrous metals, and chemicals. The largest consumer of coal is power generation. During the last decade, coal power output has increased at an extraordinary pace of 8 per cent per year, outpacing the robust rise of 6.5 per cent in power consumption, which was aided by the Electricity Sector Reform of 2003. India has coastal (31 GW) and interior (159 GW) power plants, which are typically placed near mines. There are 18 GW of power plants in India that are intended to run only on imported coal. A mix of indigenous and imported coal is used in power plants with a combined capacity of 32 GW. The overall capacity of plants using just domestic coal is 140 GW.

Imports have been increasing for two decades to meet the rising coal demand amid supply limitations, reaching 173.32 metric tonnes (Mt) in 2020-21.[64] The majority of India's metallurgical coal imports comes from Australia. Thermal coal is imported mostly from Indonesia and South Africa.[65] Imports are influenced by a variety of factors in addition to the consumption-production difference. To begin with, India's low-ash coking coal constraint necessitates imports in order to manufacture metallurgic coal for expanding the iron and steel output. Second, many coal-fired power facilities near the coast are built to use imported coal, and, hence, the quality of domestic coal is insufficient for such plants. Third, to increase quality, efficiency, and reduce pollution emissions, some plants combine domestic and foreign coal. Fourth, imports are necessary when Coal India Limited (CIL) is unable to satisfy the additional demand for coal due to logistical challenges or price disparities.

In India, there are roughly 55 GW of coal-fired power plants, many of which are state-owned and whose tariff revenues routinely fall short of their

64. Express News Service, "India Imports 173.32 Million Tonnes Of Coal in 2021-22; Plans To Cut Down", *New Indian Express*, at https://www.newindianexpress.com/business/2022/mar/19/india-imports-17332-million-tonnes-of-coalin-2021-22-plans-to-cut-down-2431831.html. Accessed on March 19, 2022.
65. Clyde Russel, "India's Coal Imports Are Shifting, Thermal More Than Coking", at https://www.reuters.com/business/energy/indias-coal-imports-are-shifting-thermal-more-than-coking-russell-2022-04-21/. Accessed on April 21, 2022.

generating costs. When supplies are less than for five days for pithead plants and less than for seven days for non-pithead plants, the Central Electricity Authority (CEA) in India, which monitors the stocks at 114 coal power plants, classifies the situation as critical. Supercritical means stockpiles are less than four days' worth of consumption for non-pithead facilities, and three days' worth for pithead plants.[66] In March 2019, the CEA stated that no plants are experiencing critical or supercritical stock levels. But, by October 2020, India was suffering from a major power shortage. May 2022 saw the worst power crisis that India had faced in the last six years. As a result of the rapid increase in output, several power plants ran out of fuel, with average coal supplies stored by utilities at their lowest for this time of year in at least nine years.[67]

The majority of coal used in India is domestically produced, and a sizeable percentage of it is transported throughout the country, frequently over great distances. This has inextricably tied up the railway system with the transportation of coal over long distances, increasing the overall cost of coal. As coal availability is limited, the government regulates coal allocation to guarantee supply which is prioritised while lowering transportation and logistical costs. India's coal dependency is unlikely to diminish in the future, thus, policy-makers and industry must mitigate its negative effects by employing cutting-edge technology in a cost-effective manner. The Ministry of Coal (MoC) is in charge of formulating policies and plans for the exploration and development of coal and lignite deposits in order to ensure that they are available to fulfil the country's demand. This involves the approval of high-value projects as well as the resolution of any connected concerns. The correlation between coal power plants and carbon emissions is a well-known fact. Continued reliance on coal as the primary source of energy could be detrimental to the environment in the long term. A

66. Ministry of Power, Central Electricity Authority, "New Methodology For Monitoring Of Coal Stock At Coal-Based Power Plants", at https://cea.nic.in/wp-content/uploads/2020/04/guidelines_dcr.pdf. Accessed on March 15, 2022.
67. Sudarshan Varadhan, "Why is India Facing Its Worst Power Crisis Over Six Years", Reuters, at https://www.reuters.com/world/india/why-is-india-facing-its-worst-power-crisis-over-six-years-2022-05-19/. Accessed on May 19, 2022.

Just over half of India's gas is produced domestically. The rest is imported as Liquefied Natural Gas (LNG), which has expanded dramatically in recent years as worldwide gas costs have fallen.

fundamental aim of the MoC, in collaboration with the Ministry of Environment, Forestry and Climate Change (MoEFCC), is to guarantee that the coal industry develops in an ecologically responsible and sustainable manner. There are two implications for the economics of existing coal power plants as the amount of variable renewable electricity in India's power grid rapidly rises. On the one hand, this means that less energy will be generated by these plants, putting additional economic and financial strain on many companies. On the other hand, the power system's flexibility requirements will increase. Many coal plants in India were built to generate baseload electricity rather than load following. The Government of India is now selecting plants that can give this flexibility.

Oil

Oil as an energy source is usually consumed as an end user product in the form of diesel. Diesel forms a small part of the thermal power generation of India's energy basket. According to the data provided by the MoP, diesel accounts for 510 MW of the total generated capacity which is 0.1 per cent of the share in total.[68] Diesel is primarily used in the agriculture industry on farms as a secondary source of power, in generators in household usage, and in the aviation, and petrochemical industries. Crude oil and its subsidiaries take up a major part in India's total primary energy consumption through their use in transportation and allied industries.

Natural Gas

Natural gas use in India is minor but growing. Most of the gas is utilised in industry and electricity generation. Although domestic gas consumption is low, India is quickly building its gas distribution networks, an area where

68. n. 51.

significant development is projected. Just over half of India's gas is produced domestically. The rest is imported as Liquefied Natural Gas (LNG), which has expanded dramatically in recent years as worldwide gas costs have fallen. The number of new LNG terminals being built is rapidly increasing. India's domestic gas price was tied to a basket of worldwide LNG prices in 2014. Under the present contractual import costs, gas use for power generation struggles to compete with cheap coal and renewables since local gas output has lagged behind projections. The Hydrocarbon Exploration and Licensing Policy (HELP), which offered new gas producers price and marketing independence, was adopted by the Government of India (GoI) in order to encourage increased domestic oil and gas production. As part of a gas trading centre, India wants to expand contribution of natural gas in the energy mix to 15 per cent by 2030, implying a doubling of present demand and infrastructure requirements.[69] This will necessitate the availability of transportation infrastructure throughout India, allowing all market participants to access LNG supply.

As part of a gas trading centre, India wants to expand contribution of natural gas in the energy mix to 15 per cent by 2030, implying a doubling of present demand and infrastructure requirements.

The Petroleum and Natural Gas Regulatory Board (PNGRB) has authorised roughly 33,764 km of the natural gas pipeline network across the country as of March 31, 2021, with the goal of creating a countrywide gas grid. The National Gas Grid would link all of India's key demand and supply centres. This would assure simple access to natural gas in all locations while also potentially assisting in the attainment of uniform economic and social improvement. As of March 31, 2021, there are 19,998 km of natural gas pipelines in operation, with 15,369 km in different phases of development.[70]

69. Petroleum and Natural Gas Regulatory Board, "Vision 2030",Natural Gas Infrastructure in India, at https://www.pngrb.gov.in/Hindi-Website/pdf/vision-NGPV-2030-06092013.pdf. Accessed on February 19, 2022.
70. Government of India, "Economic Survey 2021-2022", at https://www.indiabudget.gov.in/economicsurvey/ebook_es2022/index.html. Accessed on February 19, 2022.

Gas power generation increased from 87 TWh in 2008 to around 116 TWh between 2009 and 2011, then fell to about 60 TWh in 2013, which is consistent with a decline in domestic gas output. In 2017, the generation of gas power climbed slightly to 71 TWh. Natural gas output in 2020-21 was 28.67 billion cubic metres (BCM), down from 31.18 BCM in 2019-20 and 85.4 per cent below the forecast of 33.57 BCM for 2020-21,[71] but India still has a lot of gas power potential that isn't being used. The supply of natural gas has been expanding at a slower rate than overall energy demand. As a result, the proportion of natural gas in Total Primary Energy Supply (TPES) has decreased during the last decade. The proportion of gas in power generation is decreasing, and newly constructed gas power capacity remains underutilised.

A share of the relatively inexpensive domestic gas production, which the government had set aside for power generation, was expected to expand, prompting the development of gas-fired power generation capacity. In the beginning, this was set at 75 per cent of gas output to fulfil demand in the power sector, but because domestic production did not materialise sufficiently, some power plants were left stranded and unable to afford more expensive imported gas. The Standing Committee on Energy of the Ministry of Power found in January 2019 that repeated policy revisions on domestic gas allocations, along with dismal domestic output, had rendered the financial case for gas-based capacity unsustainable which needed to be rectified.

Renewable Energy

For the short to medium term, the Government of India has set aggressive renewable power objectives. The country plans to have 175 GW of installed renewable energy capacity by 2022.[72] The Government of India declared an expanded goal of 227 GW renewable capacity by 2022[73] and 275 GW

71. Ibid.
72. United Nations Department of Economic and Social Affairs, "India Plans to Produce 175 GW of Renewable Energy by 2022", at https://sustainabledevelopment.un.org/partnership/?p=34566
73. ET Energy World, "India Will Have 227 GW Of Renewable Capacity In The World By 2022:Vice President", *Economic Times*, at https://energy.economictimes.indiatimes.com/

by 2027 in 2018.[74] By March 2022, the government aims to generate 175 GW of grid-connected renewable electricity, of which 100 GW will come from solar energy, 60 GW from wind energy, 10 GW from biomass, and 5 GW from hydropower. The MNRE also plans to reach 1 GW of geothermal capacity by 2022. According to the 2018 National Electricity Plan, 275 GW of renewable energy sources should be available by 2027, increasing their participation to a projected 44 per cent of power capacity and 24 per cent of electricity generation.[75] On September 23, 2019, during the United Nations Climate Summit in New York, India's prime minister declared a new aim of 450 GW of renewable power capacity, without naming a deadline although the country is nearing its previously set goal of 175 GW of renewable energy by 2022.[76]

Solar power had a share of 13.5 per cent in the installed generation capacity as of March 2022.[77] Solar Photovoltaic (PV) usage has become popular in recent years. India has implemented countrywide competitive auctions for solar PV to stimulate investment in renewable power in a cost-effective manner. When deciding the procurement price for solar-generated power, auctions were determined to be better than the tariffs established by the regulator.[78] This was observed in the rapid switch from feed-in tariffs (fixed prices) to centrally administered reverse auctions (sellers bid below each other for a fixed quantity policy) under the renewables assistance system adopted by the government. Other policy initiatives at the state and local levels, such as the renewable purchase obligations and increased assistance

news/renewable/india-will-have-227-gigawatt-of-renewable-energy-capacity-by-2022-vice-president/68887932. Accessed on April 15, 2022.

74. IBEF, "Renewable Energy", at https://www.ibef.org/download/Renewable-Energy-September-2020.pdf. Accessed on May 15, 2022.
75. Ministry of Power, "National Electricity Plan. Volume II- (Transmission)", at https://powermin.gov.in/en/content/national-electricity-plan-0. Accessed on February 19, 2022.
76. Our Bureau, "India Nears Goal of 175 GW of Renewable Power", at https://www.thehindubusinessline.com/news/national/india-nears-goal-of-175-gw-renewable-power/article34833792.ece. Accessed on May 15, 2022.
77. n. 51.
78. "Feed Tarrifs vs Reverse Auctions: Setting the Right Subsidy Rate for Solar", Development Asia, at https://development.asia/printpdf/insight/feed-tariffs-vs-reverse-auctions-setting-right-subsidy-rates-solar. Accessed on May 28, 2022.

Wind power has evolved at a significantly slower rate than solar PV, according to current auction volumes, and has a share of 10.1 per cent in the IGC. India has the fourth highest wind installed capacity in the world.

for rooftop PV installations, supplement the auctions. The 2022 target and auctions for new PV installations have only recently helped solar power gain traction. The average annual increase in solar power generation from 2013 to 2017 was 64 per cent.[79]

Wind power has evolved at a significantly slower rate than solar PV, according to current auction volumes, and has a share of 10.1 per cent in the IGC. Wind power generation has increased at a Compound Annual Growth Rate (CAGR) of 21 per cent from 2000.[80] India has the fourth highest wind installed capacity in the world.[81] The government is encouraging private sector investment in wind power projects across the entire nation by offering a variety of tax and financial advantages, such as the Accelerated Depreciation Benefit (ADB) and a reduced customs duty exemption on specific parts of wind energy generators.

In India, hydropower has traditionally dominated as a source of renewable electricity. Hydropower projects are separated into large and small hydro projects based on their sizes: 10 MW to 50 MW is the size range for small hydropower plants, and different nations have different size classification rules. Small hydro projects in India refer to hydroelectric power projects with a capacity of 25 MW or less. Micro (100 MW or less), mini (101 kW-2 MW), and small hydro (2–25 MW) segments are further subdivided into these units. Prior to 1989, the State Electricity Boards mostly assisted the

79. "Performance of Solar Power Plants In India, Submitted to the Central Electricity Regulatory Commission", at https://cercind.gov.in/2011/Whats-New/PERFORMANCE%20OF%20SOLAR%20POWER%20PLANTS.pdf. Accessed on May 15, 2022.
80. International Renewable Energy Agency, "Future of Wind-Deployment, Investment, Technology, Grid Integration and Socio-Economic Aspect", at https://www.irena.org/-/media/files/irena/agency/publication/2019/oct/irena_future_of_wind_2019.pdf. Accessed on May 15, 2022.
81. Ministry of New and Renewable Energy, "Overview: Wind Energy", at https://mnre.gov.in/wind/current-status/.

Ministry of Power in managing hydropower. By itself, hydropower contributed about 40 per cent of the electricity generated in the late 1970s.[82] Even as the supply of hydropower has grown considerably, its share in the generation mix accounts for 11.6 per cent with small hydro power contributing 1.2 per cent.

The proportion of bioenergy in the mix of electricity generation is rising. The main source is cogeneration plants that use bagasse waste from India's sugar industry.

The proportion of bioenergy in the mix of electricity generation is rising. The main source is cogeneration plants that use bagasse waste from India's sugar industry. Compared to the conventional use in households, using biomass for power generation is a more sustainable use of bioenergy resources. Energy from Waste (EfW) initiatives that use industrial, municipal, and agricultural wastes and leftovers provide a small portion of the total supply. EfW can benefit India's waste management industry by supplying electricity where it is needed. This is a meagre 0.1 per cent of the entire installed generation capacity. Cities have urgent waste management difficulties as a result of rising urbanisation and economic development, and there is, therefore, room for additional expansion in the EfW industry.

Auction design, grid connections, and the financial health of electricity distribution firms are key factors for change to assure continuing progress in the rise of renewables. In recent years, the country has quickly increased its usage of renewable energy sources. Despite rising power demand, this has maintained a steady percentage of renewables in electricity generation at roughly 39 per cent.[83] India has been very keen on furthering the case of renewable energy although its assessment is necessary to understand its merit.

82. Subhash Kumar, "Renewable Energy in India", Green Initiative and Sustainable Development, pp. 259-267, 2019, at https://www.researchgate.net/publication/354527294_RENEWABLE_ENERGY_IN_INDIA. Accessed on May 15, 2022.
83. n. 51.

Generating renewable energy is land intensive. With the current rate of growth, it is estimated that in 2050, solar energy will be produced on around 50,000-75,000 sq km of land, and wind energy will be produced on another 15,000-20,000 sq km of land. A typical 1,000-MW nuclear plant requires somewhat more than one square mile to run. According to the Nuclear Energy Institute (NEI), solar photovoltaic plants need 75 times more space than wind farms and 360 times more land to produce the same amount of electricity. Imports have been a crucial factor in the exponential rise of solar and wind energy over the last ten years. In the first nine months of 2021, imports of solar cells and modules rose by 448 per cent. The cost of raw materials used in batteries and transmission technologies has increased, which could put additional strain on the Indian exchequer, according to the Asia Europe Clean Energy Solar Advisory (AECEA). India is, thus, exposed to the shifting winds of the global environment due to the import-based growth of renewable energy. Capacity factors of an energy source play a really important role when it comes to looking upon it as a reliable source of power. Renewable energy capacity factors are frequently seen on the lower sides of the records. To put it unambiguously, the sun does not always shine nor does the wind blow daily. The inefficiencies in these phenomena make it difficult for power generators to operate effectively. The storage of generated electricity is another drawback for solar and wind energy. Due to an irregular supply and storage incompetency, it is unable to function as a baseload of electricity

Nuclear

Nuclear power has the potential to become a major contributor to India's energy basket in the future. It is the world's second largest source for low carbon power and contributes to 10 per cent of the world's total electricity generation.[84] At present, it accounts for a meagre 1.7 per cent of India's

84. Worldnuclear.org, "Nuclear Power in the World Today," at https://world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx. Accessed on May 15, 2022.

installed generation capacity and 3 per cent of the total power generation.[85] India's installed nuclear power capacity has grown substantially. It grew 40 per cent in the last seven years itself.[86]

Twenty-two nuclear power stations with a combined installed capacity of 6,780 MW have been designed, built, commissioned and, are operated by the state-owned Nuclear Power Corporation of India Limited (NPCIL).

Twenty-two nuclear power stations with a combined installed capacity of 6,780 MW have been designed, built, commissioned and, are operated by the state-owned Nuclear Power Corporation of India Limited (NPCIL). In 1969, two small GE Boiling Water Reactors (BWRs) were commissioned (160 MW each) at the Tarapur Atomic Power Station, Maharashtra. In 1972, one AECL Pressurised Heavy Water Reactor (PHWR) constructed in Canada was commissioned (100 MW) at the Rajasthan Atomic Power Station. By 2017, two huge Russian-built Pressurised Water Reactors (PWRs) of 1,000 MW each were put into service at the Kudankulam Nuclear Power Station, Tamil Nadu.[87]

Table 2: India's Nuclear Power Plants

Plant	Unit	Type	Capacity (MWe)	Date of Commercial Operation
Tarapur Atomic Power Station (TAPS), Maharashtra	1	BWR	160	October 28, 1969
Tarapur Atomic Power Station (TAPS), Maharashtra	2	BWR	160	October 28, 1969

85. n. 51.
86. Press Trust of India, "Installed Nuclear Power Capacity Grew By Over 40 per cent In The Last 7 Years: Govt", *Business Standard*, at https://www.business-standard.com/article/economy-policy/installed-nuclear-power-capacity-grew-by-over-40-in-last-7-years-govt-121121500653_1.html. Accessed on March 28, 2022.
87. Nuclear Power Corporation of India Limited, "Plants Under Operation", at https://www.npcil.nic.in/content/302_1_AllPlants.aspx. Accessed on May 15, 2022.

Tarapur Atomic Power Station (TAPS), Maharashtra	3	PHWR	540	August 18, 2006
Tarapur Atomic Power Station (TAPS), Maharashtra	4	PHWR	540	September 12, 2005
Rajasthan Atomic Power Station (RAPS), Rajasthan	1	PHWR	100	December 16, 1973
Rajasthan Atomic Power Station (RAPS), Rajasthan	2	PHWR	200	April 1, 1981
Rajasthan Atomic Power Station (RAPS), Rajasthan	3	PHWR	220	June 1, 2000
Rajasthan Atomic Power Station (RAPS), Rajasthan	4	PHWR	220	December 23, 2000
Rajasthan Atomic Power Station (RAPS), Rajasthan	5	PHWR	220	February 4, 2010
Rajasthan Atomic Power Station (RAPS), Rajasthan	6	PHWR	220	March 31, 2010
Madras Atomic Power Station (MAPS), Tamil Nadu	1	PHWR	220	January 27,1984
Madras Atomic Power Station (MAPS), Tamil Nadu	2	PHWR	220	March 21, 1986
Kaiga Generating Station (KGS), Karnataka	1	PHWR	220	November 16, 2000
Kaiga Generating Station (KGS), Karnataka	2	PHWR	220	March 16, 2000
Kaiga Generating Station (KGS), Karnataka	3	PHWR	220	May 6, 2007
Kaiga Generating Station (KGS), Karnataka	4	PHWR	220	January 20, 2011
Kudankulam Nuclear Power Station (KKNPS), Tamil Nadu	1	VVER -1000 (PWR)	1000	December 31, 2014
Kudankulam Nuclear Power Station (KKNPS), Tamil Nadu	2	VVER -1000 (PWR)	1000	March 31, 2017

Narora Atomic Power Station (NAPS), Uttar Pradesh	1	PHWR	220	January 1,1991
Narora Atomic Power Station (NAPS), Uttar Pradesh	2	PHWR	220	July 1,1992
Kakrapar Atomic Power Station (KAPS), Gujarat	1	PHWR	220	May 6, 1993
Kakrapar Atomic Power Station (KAPS), Gujarat	2	PHWR	220	September 1,1995

Source: https://www.npcil.nic.in/content/302_1_AllPlants.aspx

The Government of India has set ambitious aims to develop India's nuclear capacity.[88] The country's 12th Five-Year Plan in 2010 aimed for total built nuclear capacity of 63 GW equivalent by 2032.[89] India also expects to have 10 per cent of its energy sourced from nuclear energy by 2030.[90] India is currently building seven nuclear reactors, comprising four indigenous 2,800 MW PHWRs, two Russian-built 1,000 MW PWRs, and one 500 MW indigenous Fast Breeder Reactor (FBR).[91] The Department of Atomic Energy informed India's Parliament that 21 more reactors with a combined installed capacity of 15,700 MW are anticipated to be built by 2031.[92] Additionally, India would start the construction of 10 nuclear plants in fleet mode from 2023.[93]

India's nuclear power programme is mostly self-contained. India has developed a nuclear fuel cycle to use its thorium deposits due to past trade

88. United Nations, Nationally Determined Contributions Registry, "India's Intended Nationally Determined Contributions", at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/India%20First/INDIA%20INDC%20TO%20UNFCCC.pdf. Accessed on May 15, 2022.
89. Pooran Chandra Pandey, "India Expects to have 10 per cent of Its Energy Sourced to Nuclear Power in 10 Years", Climate Score Card, at https://www.climatescorecard.org/2021/08/india-expects-to-have-10-of-its-energy-sourced-to-nuclear-power-in-10-years/. Accessed on March 28, 2022.
90. Ibid.
91. Press Release, "Nuclear Power Plants", Press Information Bureau, at https://pib.gov.in/PressReleseDetail.aspx?PRID=1605939. Accessed on March 11, 2022.
92. Press Information Bureau, "Generation of Nuclear Power," at https://pib.gov.in/PressReleasePage.aspx?PRID=1808681. Accessed on March 23, 2022.
93. Worldnuclear.org, "2023 Construction Start for Indian Reactor Fleet," at https://www.world-nuclear-news.org/Articles/2023-construction-start-for-Indian-reactor-fleet. Accessed on March 28, 2022.

Indian investors face difficulties since the operator, rather than the vendor, is responsible for all nuclear safety risks, which makes it challenging to import foreign technology (some bilateral agreements include unique measures to avoid India's liability rules).

limitations and a shortage of indigenous uranium. With a total installed capacity of 4,280 MW, 14 reactors are International Atomic Energy Agency (IAEA)-guaranteed and rely on imported fuel. Indigenous fuel is used in the remaining eight reactors, which have a total installed capacity of 2,400 MW. India and the Nuclear Suppliers Group (NSG) inked an agreement in 2008 that allowed worldwide commerce in nuclear technology and materials to begin. Indian investors face difficulties since the operator, rather than the vendor, is responsible for all nuclear safety risks, which makes it challenging to import foreign technology (some bilateral agreements include unique measures to avoid India's liability rules). With the introduction of the India Nuclear Insurance Pool in 2015, the Government of India claimed that "international and internal concerns" about India's liability rules had been addressed, although suppliers remain unwilling to invest in India.

Despite the benefits of nuclear energy being so pronounced, India's ability to translate this desire into reality has been left unchecked. India needs a long-term strategy towards securing sustainable energy sources. Considering India's long-term goals, nuclear energy checks all the boxes on the list. But this is fraught with difficulties and has its share of setbacks. Overriding costs and a longer period for the return on investment are other challenges India faces in pushing for nuclear energy. Market conditions coupled with strict regulations on maintenance, personnel training and popular opposition have discouraged investors from investing in a growing nuclear market.

An essential component of producing nuclear electricity is managing nuclear wastes. The activities involved in managing these wastes include

their handling, processing, storage, and disposal. A high level of safety is guaranteed in the management of radioactive waste thanks to recent technological advancements in India. At the Near Surface Disposal Facility (NSDF), garbage is disposed of in specially designed engineering modules such as stone-lined pits, reinforced concrete trenches, and tile holes.

It is an absolute necessity for India to start taking its people into confidence when it comes to the propagation of nuclear power plants. In the aftermath of the nuclear disaster at Fukushima Daiichi, there has been a global surge of scepticism over the spread of civil nuclear energy, and India is no exception.

It is an absolute necessity for India to start taking its people into confidence when it comes to the propagation of nuclear power plants. In the aftermath of the nuclear disaster at Fukushima Daiichi, there has been a global surge of scepticism over the spread of civil nuclear energy, and India is no exception. The shock in public faith and downward slump in the nuclear energy discourse in the post Daiichi era enforces this argument. People's uninformed biases that identify nuclear power as "unsafe" are the main cause of their opposition, which is typical in these situations. The majority of the general public is uninformed of the potential energy issues India may face in the future. The government's top priority is to instil trust by making the public aware of the safety precautions it has taken to ensure the safety of its citizens, including the area surrounding the project. People's acceptance must result from a thoughtful evaluation of the dangers and advantages present. Information dissemination, not compulsion, is to be used to win over the populace. To elicit widespread support, the information must gradually spread to the populace. Governmental organisations are primarily responsible for this effort. The task of advancing the agenda may also be aided by regional organisations and Non-Governmental Organisations (NGOs). Nuclear energy could emerge as a strong option against coal in assuring India's energy needs in the next decades, given its large

capacity for development, being emission-free, and the steady nature of its output.

CONCLUSION

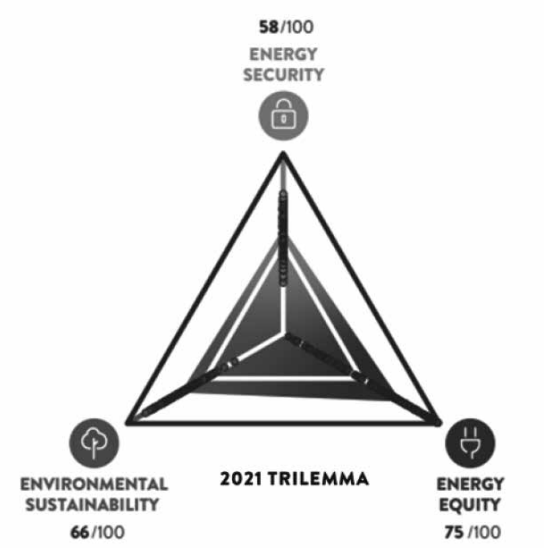
Clean and green have become the terms to stand by in considering India's energy future. The power sector has witnessed substantial transformation owing to an increased demand (universal electrification) and supply (move towards green energy).[94] India's ability to offer inexpensive, dependable, and sustainable energy will determine its economic destiny and prosperity. For a vast country like India, a significant portion of the energy should be produced domestically, yet overall, we do not have many possibilities. Self-sufficiency and development play a significant role in India's strategic aims. Bulk imports and reliance on them are neither financially feasible nor wise from a strategic standpoint. It is imperative to reverse the current trend of over-dependence on coal as quickly as possible, which calls for more effort in other areas. The entire potential of non-conventional and renewable energy sources such as solar, wind, and others must be utilised.

The energy trilemma, a concept in the energy discourse, addresses three conflicting challenges: energy equity, energy security and environment sustainability. The three pillars of the energy trilemma can be thought of as three independent axes with their own weight in the energy discourse. With the trilemma, there is a triple challenge of assuring a secure supply which is affordable and environmentally sustainable. Balancing these axes is a challenge but it forms the foundation for the prosperity and competitiveness of individual countries.[95] The quantification of the energy trilemma is presented via an energy trilemma index released by the World Energy Council every year. The world energy trilemma index follows 133 nations and assigns them a total score, depending on how well they perform

94. n. 61.
95. Worldenergy.org, World Energy Council, "World Energy Trilemma Index 2021", at https://www.worldenergy.org/publications/entry/world-energy-trilemma-index-2021. Accessed on May 15, 2022.

on each of the three axes.[96] It creates a historical index for each dimension with a base year of 2000. The country context focusses on variables that help governments create and implement successful energy policies and meet their energy objectives. India ranks 75th on the world energy trilemma index 2021 which shows a significant improvement from its rank of 109 in 2019.[97] In the latest index report of 2021, India's trilemma score is 53.1 with a significant improvement in the energy security sector.[98] India scored 61.2, 47.1 and 50 in energy security, energy equity, and environment sustainability in that order (the scores are on a scale of 100). India has a balance grade of BDD.[99, 100]

Fig 3: India's Energy Trilemma Index



India's energy security remains a challenge due to the primacy of import dependence in the case of primary energy supply. India's energy equity

96. Ibid.
97. Ibid.
98. Ibid.
99. Ibid.
100. Grade as specified in the report in the order of energy security, energy equity and energy sustainability.

has shown considerable improvement in comparison with its 2000 level. Increasing access to clean cooking fuel and achievement of near universal electrification in 2019 have been major contributors in improving India's energy equity.[101] Although sustainability shows a grade D, India is one of the few countries that is on track to meet its Paris Summit commitments.[102] There has been a 250 per cent increase in renewable energy installations in the past couple of years.[103] India's leading role in global collaboration on solar energy in the form of the creation of the International Solar Alliance (ISA) in 2015 has made it an emerging actor in the renewable energy discourse. Although there have been significant improvements in India's energy scenario, a few key challenges remain. These include the reduction of import dependence of primary energy sources; introduction and integration of cleaner and sustainable fuels like nuclear energy, hydrogen, and biofuels; integration of renewables and non-fossil fuel sources of energy in a phased and reliable manner; and reducing emissions in a bid towards adopting sustainable policies to help towards tackling climate change while attaining specified social and economic goals. Given India's humongous electricity requirement, lack of indigenous fuel sources, its long-term vision for sustainable growth, environmental responsibility and a growing population with an aspirational young demographic,[104] diversifying its energy basket is the key to ensure India's energy security.

101. Debajit Palit, "The Journey Towards Universal Electrification In India", Friends of Europe, at https://www.friendsofeurope.org/insights/the-journey-towards-universal-electrification-in-india/. Accessed on February 23, 2022.
102. It achieved an emission reduction of 24 per cent by 2016 (from 2005 levels) and has more than 38 per cent of its installed capacity as non-fossil capacity.
103. ANI, *Business Standard*, "India's Capacity For Renewable Energy Rose By 250 per cent In 6-7 Years: PM", at https://www.business-standard.com/article/economy-policy/india-s-capacity-for-renewable-energy-rose-by-over-250-in-6-7-years-pm-121060500419_1.html. Accessed on April 5, 2022.
104. Lokhande, n. 61.