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# Chapter 6

## Green and Sustainable Infrastructure in India

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### ABSTRACT

*In view of sustainable development goals 2030, establishing safeguards to citizens is the basic parameters focusing the area of infrastructure development. Infrastructure development is the base for a country's financial prosperity and assists in upgrading the standard of comfort of its citizens. Affordable and clean energy is an important goal among all SDGs. With the support of our government, the improved economic condition has driven our country to the top and maintained its position in the top market of renewable energy globally. The renewable sector gives opportunity to the youth of our country a large number of jobs in the current scenario. This chapter recognizes the green and sustainable ecosystem of our country and projects the current scenario in the energy generation and distribution (GD) sector, smart city, global warming, and environment change relief in RE sector and sustainable ecosystem.*

### 1. INTRODUCTION

Infrastructure advancement is the base for nation's financial success and assists in enhancing the lifestyle of the people. Quality infrastructure is very important, fulfilling the need of each and every citizen such as energy, food, water, good health, green environment, sanitation, transport, communication, education, and employment. Superior quality infrastructure always fulfils the SDGs in three domains, referred to as 3Ps: i.e. People, Profit, and Planet [Chandel T.A, 2022]. Infrastructure development on short-term basis, on its journey is expected for fulfilling four objectives; quality transport, high speed communication and connectivity, sustainable mobility, superior quality customer satisfaction and experience. India has focussed on renewable energy generation and distribution. India's goal is to achieve 450 GWatt of energy by all installed renewable energy capacity by 2030 and about 60% i.e. 280 GWatt form solar energy. Green energy is also referred to as Clean Energy as it is free from green gas emission and do not affect the environment. The requirement for enhancing the utility of renewable energy (RE) power

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is because of pollutant free environment and making the power generation sector a significant source of green and clean energy. RE strengthens and boosts the economic development, enhances the ease to access the energy and improved its security. Eco-friendly power can supply 66% of energy interest in our nation and decreases CO<sub>2</sub> emission that is required today and in future years for restricting normal worldwide surface temperature increments less than 2°C. The government of our country has designed many policies to influence foreign investments to set up a megawatt rating grid-connected system in the country in the RE market. The economic condition of our nation has reached on top and has maintained its position in RE market globally. This power area provides surplus jobs opportunity to the youth in the current scenario. Energy contributes a significant role in the financial expansion of our nation. Increasing demand of power in India is growing to fulfil the financial development plan [Charles R.K, 2019; Kumar J., 2020]. India has contributes to approximately 6.65% of total carbon emission and maintain its fourth rank according to World Resource Report 2017 [CESI, 2017; Pappas, 2017] while china is responsible of 26.83%, the USA is 14.36%, and the EU is 9.66% respectively. Climate change is apart of the ecosystem.

## **2.0 SMART AND SUSTAINABLE INFRASTRUCTURE**

Infrastructure is very essential for growth of the country. It enables services to the society to work and develop finance from transport, electricity, hospital, clean water supply and sanitation. Infrastructure involves basic living system and facilities such smart building/cities, transport, communication system, water and power supply. Infrastructure growth is necessary to promote economic development and decline poverty. SDGs under smart and sustainable infrastructure include good health and well-being (SDG-3), clean water and sanitation (SDG-6), affordable and green energy (SDG-7), decent work and economic growth (SDG-8), industry innovation and infrastructure (SDG-9) sustainable cities and communities (SDG-11), responsible consumption and production (SDG-12) and climate action (SDG-13) [Jaskaran S.S, 2021]. The SDGs are the outlines to walk in a superior and sustainable future.

### **2.1 Smart Buildings: Convergence of Green and Intelligent Buildings**

Beyond 17<sup>th</sup> century, the systems were designed for maintaining temperature, controlling the mechanism of mill and regularizing steam engine. Continuous feedback system showed system instability. In early 19th century, development of automotive power steering, servomechanism was initially done for ships and later for autopilot [Prabhat K, 2021]. Till 1970's control industry developed fully automatic control system, giving hot water/steam and air conditioning. Control systems for commercial building such as thermostats, valve, pneumatics and control logics was developed, which was operated by compressed air. In 1980's all mechanical control were converted into electronics control and gradually digital system was overtaking [Prabhat K, 2021]. Computers came into market at late 1980's. From 1980 to 2000, building management system (BMS) controlled the heat/air conditioning, lift, and light systems, municipalities controlled water and waste management's system. Drastic change occurred at the beginning of 2000 till 2020 in regard to high energy cost. This enforced the building owner to look towards the electricity consumption, monitor and controlling the energy consumption. This initiated towards monitoring building performance and giving an entry towards new systems in construction. These new systems involve solar panels for energy, smart metering, climatic control, automatic alarm system, air conditioning and

waste management system, promoting in developing eco-friendly environment in buildings. This was only possible due to advancements in semiconductor technology. Internet and cloud computing enabled advanced applications. Now BMS is called as iBMS where 'i' stands for intelligent and so the building was named as intelligent building.

In 2020 green technology and intelligent building technology merged to form the smart buildings. Revolutions in industries took place and transforming towards industrial control system. Industries and BMS combine to work and developed a self-sustaining livelihood infrastructure with internet connectivity and fulfilling the customer's requirements. Now customers are availing multiple operations at low cost with internet of things (IoTs) and artificial intelligent (AI) tools and constructing smart automated building.

### **2.2 Smart and Sustainable City (SDG-11)**

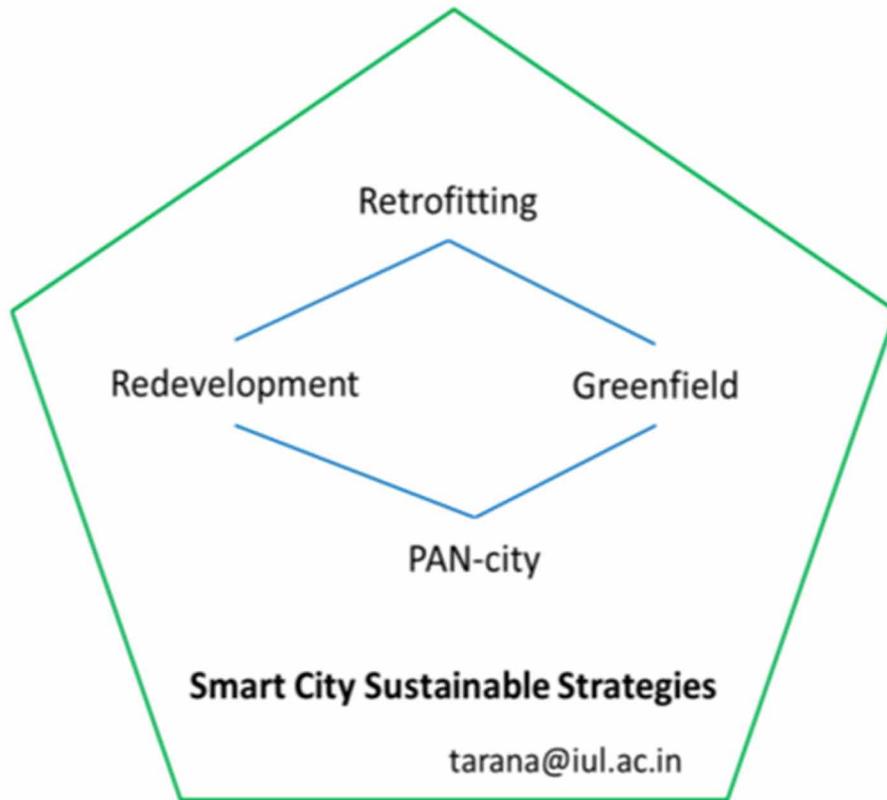
The Indian economy is dependent on the population. The population in urban areas has climbed up from 2001 to 2011 i.e. from 286 to 377 million respectively and will reach 590 million by 2030 [Pranav S. and Suresh R., 2016] as per census report of India. An architecture and finance structure along with new innovation in science and technology shaped the model as the concept of smart growth [Chandel T.A, 2023; Down D, 2005] and exploded the transformation towards smart cities [Jason R and Steve D. B, 2012]. With better expectation for healthy life and attempts to open the gate way of urban civilization, smart cities came into existence. Smart city is an innovation for overcoming the problems related to finance, education, employment, climatic change. In other words smart cities are the backbone of sustainable Indian economy. The idea of intelligent building/city is established on the utility of ICT based technology. OCED defined smart city as the progress towards digital world and upgrading the livelihood of the citizen, providing sustainable services and products, making environment safe [Philip P, 2020]. Taking energy into consideration, smart cities have interrelated systems with 59% sustainability in business, 46% sustainable transport, 43% collaboration between government and private organization [Down D, 2005]. In this regard, at the hindmost of 19<sup>th</sup> century [Hall P, 1988], planning for multi-story tower was done with implantation of software technology and internet of things (IoTs) [Nicos K. and Luca M., 2018] making sustainable and green infrastructure

#### **2.2.1 Smart City Sustainable Strategic Planning**

Fulfilling basic needs and quality lives are focal points of smart cities. In this perspective, the operation approaches towards digital and ICT, public-private collaboration, framing and implementing new policies to make a change. Smart cities strategies include city modernizing, regeneration and expansion along with Pan-city initiative [Strategy, 2017]. Smart city sustainable strategies are shown in Figure 1.

Retrofitting (modernizing) involve planning in the present areas to accomplish objectives of smart cities and developing it into efficient and livelihood. Redeveloping (regeneration) will result in an eco-friendly environment [Strategy, 2017; SCM, 2016]. Recent example is the Saifee Burhani Upliftment Project in Mumbai (also called the Bhendi Bazaar Project) and the renovation of East Kidwai Nagar, New Delhi was undertaken by the National Building Construction Corporation [Strategy, 2017; SCM, 2016]. Greenfield extension requires more than 250 acres vacant areas. The development authority will do financial and techno planning, implement land construction and provide houses in affordable range especially for under poverty-stricken. Example is the GIFT city in Gujarat [Strategy, 2017;]. Greenfield extension society is under urban development authority (UDA)/ULBs. PAN city implement technolo-

Figure 1. Smart city sustainable strategies  
(Hall P,1988)



gies as internet of things (IoT's), artificial intelligence (AI) in their constructive infrastructure, making services easier and better. these technologies are applied in transportation sectors making intelligent traffics management, reducing conveyance time and money. Another example is waste management system and smart metering [Strategy, 2017].,

### 3.0 ECONOMIC REFORMS AND SUSTAINABLE FINANCING (SDG-8)

The economic reforms were started in India in July 1991 and passed through a diversified structure and governance reforms. In the beginning, crises in payment opened the door of International Monetary Fund (IMF) program, adopting important reforms packages [Arvind P., 2001]. The foreign exchange reserved retrieved with speed and effectively ended the transitory thump of the IMF and World Bank; reforms remained in an intermittent vogue. The plan for enhancing the Indian economy began with the industrial policy, before setting the reforms. Large scale industry was owned by states while others industries were having industrial licencing or reticent for small scale industry. Reforms for freeing the local economy from state monopoly exist no more. State control ended up in all sectors, opening the doors of private sectors. Small scale industry still exists even though it was progressing. Export in apparel opened the

doors to all investors. In 1991, for international trading, import licensing was ubiquitous with products bifurcated into three categories i.e. banned, limited and permissible [Arvind P., 2001]. The international trading was under open general licensing (OGL). This licensing was open to all citizens who wished for international trading with only 30% import [Arvind P., 2001]. Import was allowed with large tariffs and foreign investments were strictly restricted. Industries were not allowed above 40% foreign values until and unless they lie under high-tech sector or export oriented.

During early 1980's telecom sector was also under state and showed congestion in business activities and services. Today telecom sector is under private sector. In 1999, private sector footed into active participant in telecommunication services with new telecom policy and setting the target of distrustful telephone on orders by the end of 2002. Private sectors including foreign investors have opened the door of cellular phones along with fixed services. As the result, the telecom services have reached every nooks and corners of the country and is grooming day by day.

Improvement has been done in many sectors that were prohibited to reforms. Insurance has stepped into business and is open to private, domestic and foreign investors. Fuel prices have jumped the sky. These reforms are the backbone in enhancing Indian economy. An increase in 6% economy integrated with macroeconomics steadiness. Rising income has decline poverty.

### **3.1 Highlights of Indian Economy [Jaskaran S., 2021;.Survey E., 2022-23]**

- Indian economy has undergone wide-spreading structure and governance reforms which has built the fundamental of economy by upgrading its potential during 2014-15.
- After 2014, reforms were made for developing public goods, approving fully trusted governance, collaboration with public-private sectors for development, bettering agricultural production, emphasis was made on improving livelihood and commerce.
- As per the survey, the gross tax revenue growth from April to November 2022 was 15.5% and net tax revenue to the Centre from state was 7.9% on year on year (YoY) basis.
- GST is another source of revenue from central and state government, 24.8% is the total increased GST collection on YoY between April and December 2022.
- Emphasis was made on capital expenditure by the Union Government and has showed continuous increase from 1.7% of GDP (FY 2009 to FY 2020) to 2.5% increase in GDP in FY 2022.
- The central government has encouraged the state government for interest-free loans with increased ceiling limit and emphasised to spend on infrastructure like roads, highways, railways, housing and urban affairs Capex (Capital expenditure). The enhancement in Capex has showed positive involvement towards medium term growth.
- The Capex growth action plan will allow India to maintain the interest rate growth positive leading towards sustainable debt to GDP.
- The reserve bank of India has initiated towards fed increases interest rates in April 2022, leading to enhanced repo rate by 225 bps (basic points), leading towards moderateness of surplus liquidity conditions.
- Central govt. has sanctioned INR 110,055 crores for Indian railroads, with INR 1,07,100 crores for capital expenditure. Furthermore, for metro Projects, the Indian Govt.t has announced to sanction INR 18,998 crores.
- For the coming 5 years, the government has planned to disburse INR 305,984 crores on a revised reform-based and new electricity distribution programme.

- Central government has allocated with INR 1,18,101 crores for development of Highway and road transport sector.
- A 6-year plan to investment of INR 64,180 crores for strengthening the present 'National Health Mission' by regenerating superior healthcare system with basic, secondary, & tertiary care.
- A mission for constructing world-class textile infrastructure led to project named Huge Investment Textiles estate (HITE) and 7 textile estate within 3 years.
- A long term investment plan of INR 820,00,000 cores was proposed by the central government for shipping ports in March 2021.

#### **4. TECHNOLOGICAL INNOVATIONS AND SUSTAINABLE INFRASTRUCTURE (SDG-9)**

Technology is fast growing in each and every aspect of lives i.e. from exchanging information by speaking, writing to education, shopping and in our regular lives and work. The most significant role is played by education in universities, contributing towards country's innovative structure [Jaskaran S., 2021]. For education globalisation, India has impelled topmost institutes to achieve an international space. As per Phil Baty (Chief Global Affairs officer, T.H.E, London), Indian universities are taking part in the international ranking to enhance the globalisation of education [Manash P.G. & Hemali C., 2023]. India stands among top three institutions rated by World University Ranking with a score of 44.9 (i.e. approx. 50 points) in 2020 [S. Priyanka, 2023]. IIT Bombay stands among global top 150 varsities, attaining the ever-top position of 147. The improvement in quality education has enhanced the access to internet from 17% (2015) to 34.45% (2017) [Jaskaran S., 2021]. Access to internet is more than twofold after following SDGs.

In current scenario, innovations have been playing an important role in digital world, making lives in comfort. The industrial infrastructure is the backbone of Indian economy [Kumar R.2022]. Advancement in technological innovation has made an easy path for the development in the industrial infrastructure. It is resolving difficult challenges and minimizing the losses. Construction sectors which were battling from critical-time target now are dependent on telemetry data (TD) and relay based real time equipment. For example, sensor based embedded system are accessible by computer to a common interface link, gathering information's and data for the working loads and updating the machines and equipment's. The TD and IoTs enables service engineers/ manager a command signal to handle the machine and optimize work in a better way [Srivastava, P., 2023]. Using recent tech-innovation, NHAI of India was capable in setting up Guinness Word Record for constructing the highway of 75 kilometres in Maharashtra, with a ending reported time of 105 hours and 33 minutes [Ajith Athrady, 2022; Gadkari N. 2022]. This project began on 3, June at 7:27 AM and ended on 7 June at 5 PM. This achievement is credited to Rajpath Infracon Pvt Ltd and Jagdish Kadam (Both India) [Gadkari N. 2022; TNND, 2022], deployed approximately 800 workers with 720 workers constructing discrete lane sustained bituminous concrete road on National-Highway-53 lying in-between Amravati and Akola districts, Maharashtra [Ajith Athrady, 2022; Gadkari N. 2022]. Figure of NH-53 is shown in figure 2.

Infrastructure towards interconnectivity are attracting these days. From 2015 till 2019, 84% increase in cargo handling capability in 12 major ports [Jaskaran S., 2021]. This has opened the doors of polished and refined trading, shipping and ramping towards higher level economy. For achieving SDG-9, India has worked for developing business sector, promoting new enterprises and making it easy accessible.

## **Green and Sustainable Infrastructure in India**

*Figure 2. Roadway on National-Highway-53, Maharashtra*



The government of India has adopted commercial reforms for ease of doing business and ranked 63th in doing business according to World Bank Report 2020 [Jaskaran S., 2021]. Thus, it jumped from 142th position in 2015 to 63th position in the world in 2019. Design and production grew side by side. The structural patent doubled from 2015 to 2019. This was due to expansion towards industrial sector. Our country's GDP grew up by 7.2% on average from 2018 to 2019 and predicted to grow 10% in FY 2021-22 [Jaskaran S., 2021]. India not only committed for developing technology, infrastructure and industrialized sector but also making it certain for sustainable and eco-friendly. Consequential development progression in India has helped in achieving SDG 9.

## **5. GLOBAL WARMING AND CLIMATE CHANGE (SDG-13)**

Climatic change because of global warming is one of the major environmental crises tolerated by living being worldwide. The earth's surface temperature is regularly enhancing by using fossil fuel releasing green gas emission in the environment resulting to global warming [Chandel, T. A., 2023; Gilbert Hinge et al, 2020]. According to United Nation Environment Programme (UNEP), the global mean annual temperature globally has increased by 1.1°C from 1850-1900 period [Kumar R, 2022] and 1.59° C [Sinha A., 2023] more than it was during pre-industrial duration i.e. with the option for changing the cruel reality of climatic change to modern era. United Nation Climatic change Conference (COP26) in 2021 presented a report highlighting the role of infrastructure towards climatic change, pointed that it has been overlooked and is responsible of 79% of total carbon emission [Kumar R, 2022]. The Intergovernmental Panel on Climate Change (IPCC) submitted a document on worldwide climate change research finding [Chandel, T. A., 2023; GCCP, 2022] in the Fifth Assessment in 2014, which was same as submitted

in the Fourth Assessment Report, 2007 i.e. to maintain global warming less than 2°C and reduction in release of carbon emission should be 50% by the end of 2050 [Meyer L et al, 2014].

Climatic change refers change in measure of surface temperature, wind, rain extending for future period. Indian government has given a formal consent to Paris agreement in view of its impact and scope. India is far-reaching 2030 International agenda for protecting our planet [Mukherjee M.M, 2015]. It requires effort towards economic sustainability for the future of the environment, fulfilling the objectives of climatic change. The industrial infrastructure is also participating and contributing towards better environment change [Sindhu G., 2022]. India plays a vital role in strengthening the plans of sustainability industrial development (SID) goals as framed by the United Nation. The fiercely flashed flood on 7, February 2021, was a Chamoli disaster in the outer Garhwal Himalayas in Uttarakhand state, India [Sindhu G., 2022; Wikipedia, 2021] shown in figure 3. This disaster left behind 200 killed or missing [Wikipedia, 2021] and became a poignant reminder of aftereffects of climate change and tale-telling for the future.

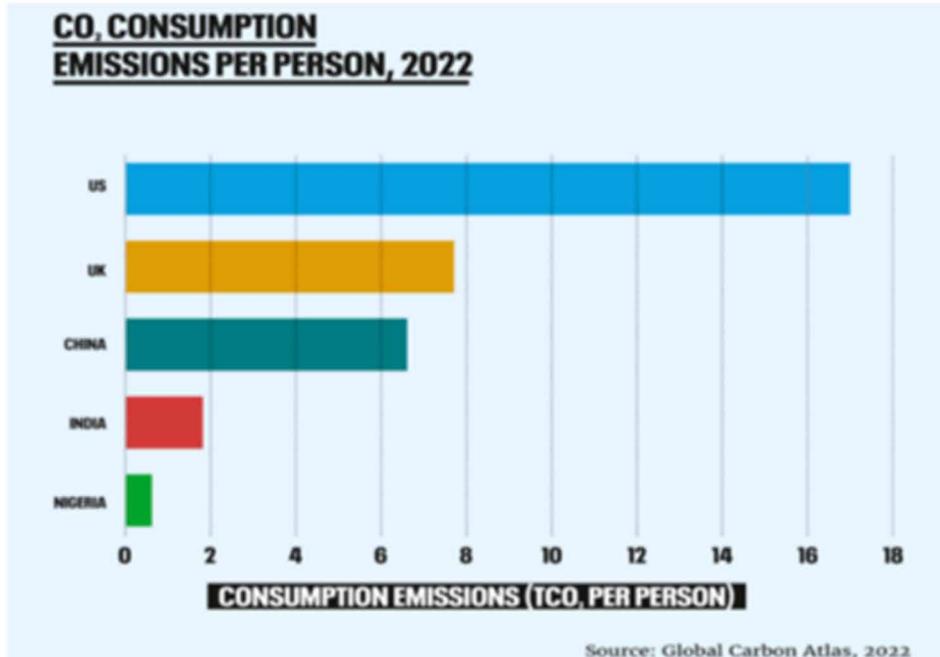
Drastic increase in climatic change-induced natural disasters has focussed the attention of eco-entrepreneurs to take necessary adaptive contribution towards India's sustainability commitments. India is on top fourth position globally in carbon emission following China, US and EU, impact of CO<sub>2</sub> emission per person is shown in Figure 4. This shows that carbon emission is only 1.9 tonnes per person in 2019 as compared to 15.5 tonne /person for US and 12.5 tonnes/ person for Russia in same year [Ajith A., 2022, Sindhu G., 2022].

In 2021 United Nation Climatic Change Conference (COP26), honorable Prime Minister Mr. N. Modi has committed to reduce the green gas emission to net zero by 2070. It is difficult to fulfil this commitment by 2050 as more than 50% of the nation's electricity is based on coal [Sindhu G., 2022]. For fulfilling the commitment of zero carbon emission, Indian government has transformed towards generation of green energy using renewable energy resources.

*Figure 3. Flood in Chamoli, Uttarakhand  
(Sarkar K., 2021)*



*Figure 4. Impact of CO<sub>2</sub> emission per person (UNPF, 2022)*



## 6. AFFORDABLE AND GREEN ENERGY (SDG-7)

As per World Population Review (WPR), India has left behind China in becoming the top most populated nation globally shown in table 1. India’s population in 2022 was 1.417 billion while china’s population was 1.43 billion with the increase in population; India has broken the record of global rank shown in Table 1., with the population of 1.428 billion in 2023 [Population by Country, 2023] leaving behind China with the population of 1.425 billion [world population record, 2023].

The top most countries with maximum population in the world is shown in Table 1 [Safalta, 2023; Worldmeter, 2023]. Till 2022, India hold second position in world having the population of 1.368 billion as on January 2019 [world meter, 2019], 1.960 billion as on 2020 [Population by Country, 2023] and 1.398 billion as 12, July 2021 [India Population, 2021] and 1.417 billion in 2022 [Aaron O’Neill, 2023; Population by Country, 2023] in world highest population according to datum provided by United Nations Population Division (UNPD). The analysis was done by Dr. Yiming He and showed that population size affects energy consumption [Yiming He, 2019]. His analysis says that if population size increases 20% then energy consumption also increases by 43.6% and if population size decreases 20% then demand for energy also decreases by 44.6% [Yiming He, 2019]. This relation is given by equation 1.1

Therefore,

$$E_D \propto P_s \tag{1.1}$$

Where

Table 1. Most populated countries in the world

#	Country (or dependency)	Population (2023)	Yearly Change	Net Change	Density (P/Km <sup>2</sup> )	Land Area (Km <sup>2</sup> )	Migrants (net)	Fert. Rate	Med. Age	Urban Pop %	World Share
1	India	1,428,627,663	0.81 %	11,454,490	481	2,973,190	-486,136	2.0	28	36 %	17.76 %
2	China	1,425,671,352	-0.02 %	-215,985	152	9,388,211	-310,220	1.2	39	65 %	17.72 %
3	United States	339,996,563	0.50 %	1,706,706	37	9,147,420	999,700	1.7	38	83 %	4.23 %
4	Indonesia	277,534,122	0.74 %	2,032,783	153	1,811,570	-49,997	2.1	30	59 %	3.45 %
5	Pakistan	240,485,658	1.98 %	4,660,796	312	770,880	-165,988	3.3	21	35 %	2.99 %
6	Nigeria	223,804,632	2.41 %	5,263,420	246	910,770	-59,996	5.1	17	54 %	2.78 %
7	Brazil	216,422,446	0.52 %	1,108,948	26	8,358,140	6,000	1.6	34	88 %	2.69 %
8	Bangladesh	172,954,319	1.03 %	1,767,947	1,329	130,170	-309,977	1.9	27	41 %	2.15 %
9	Russia	144,444,359	-0.19 %	-268,955	9	16,376,870	-136,414	1.5	39	75 %	1.80 %
10	Mexico	128,455,567	0.75 %	951,442	66	1,943,950	-50,239	1.8	30	88 %	1.60 %

Source: Safalta, 2023; Worldmeter, 2023

$E_D$  = Energy Demand

$P_S$  = Population size

This was the quotes of Dr. Yiming He of China regrading energy with increasing population size:

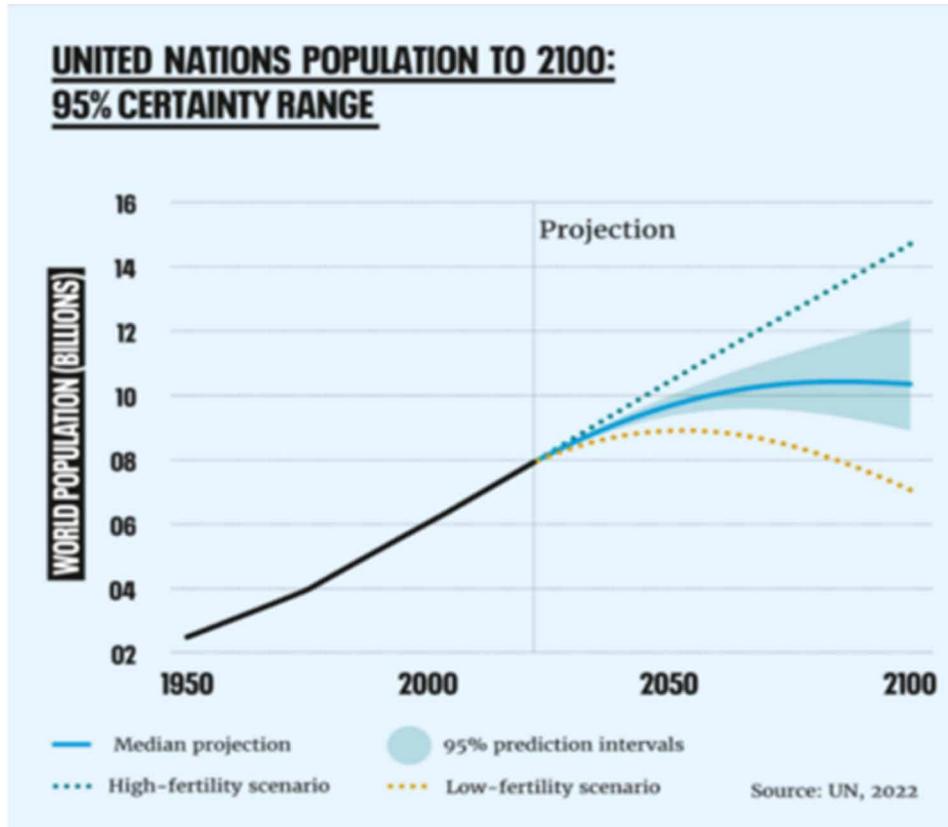
*“In the long-running duration, large-scale population augmentation diminishes the self-sustenance energy of the area”.*

Fast growth in community has caused major obstruction in achieving the sustainable development goals in eliminating poverty and hunger, upgrading education and health. Forecasting the total population by 2050 and 2100 will be 9.7-9.8 billion and 10.4-11.2 billion [Newsletter: population matters, 2022; UN: [Department of Economic and Social Affairs, 2023](#)] respectively as shown in Figure 5.

## 6.1 Energy Demand in India Today

Energy consumption has doubled since 2000 due to increased population size [Kumar. J and Majid, 2020; NEP, 2016; IEA (IEO), 2021; GER, 2021]. It will very soon become the world’s highest energy buyer and enter in an era of rapid economic growth. Majority of household women have access to electricity, to achieve their requirement in 2019 [IEA (IEO), 2021]. Within two decades, more than 900 million Indian citizens have acquired an electricity connection. With a constant effort towards industrialisation and urbanisation, India will make its place in energy sector and policy makers. The reliable and inex-

Figure 5. Forecasting of population by 2030, 2050, and 2100  
(Newsletter: population matters, 2022)

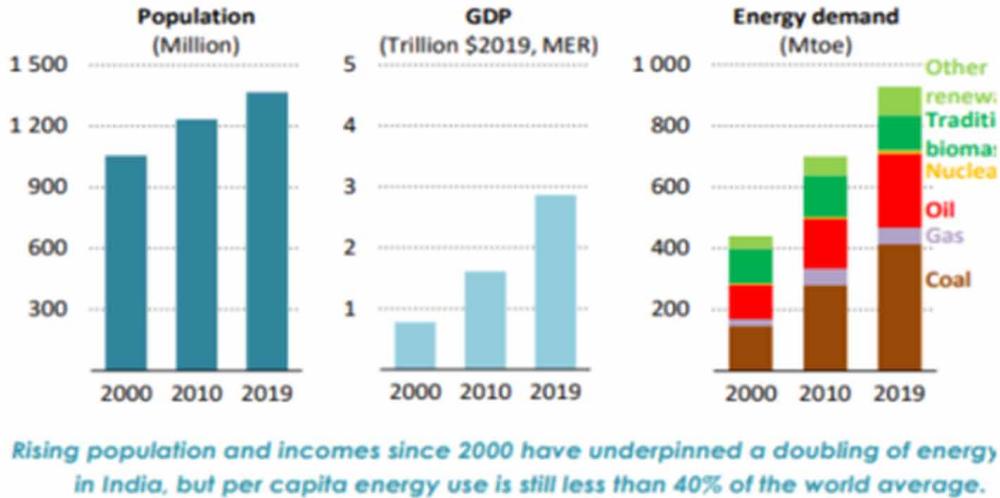


pensive accessibility of energy are major issues for Indian buyer. The corona virus pandemic has thrown the utilization of power into disorder and falls by 5% in our country due to lockdown and restrictions [IEA (IEO), 2021] and 4% globally [GER,2021; BPEO,2019] which is the largest decline ever since World War II. Due to pandemic, an energy sector had financial loss of 15% in 2020, specially the energy distribution companies in India. Figure 6 give a clear picture about the increasing population and incomes and energy demand since 2000. It reflects; though the energy use in India has doubled then too proportionately energy utilization is less than 40% of world average [GER, 2021].

### 6.1.1 Primary Energy Consumption in India

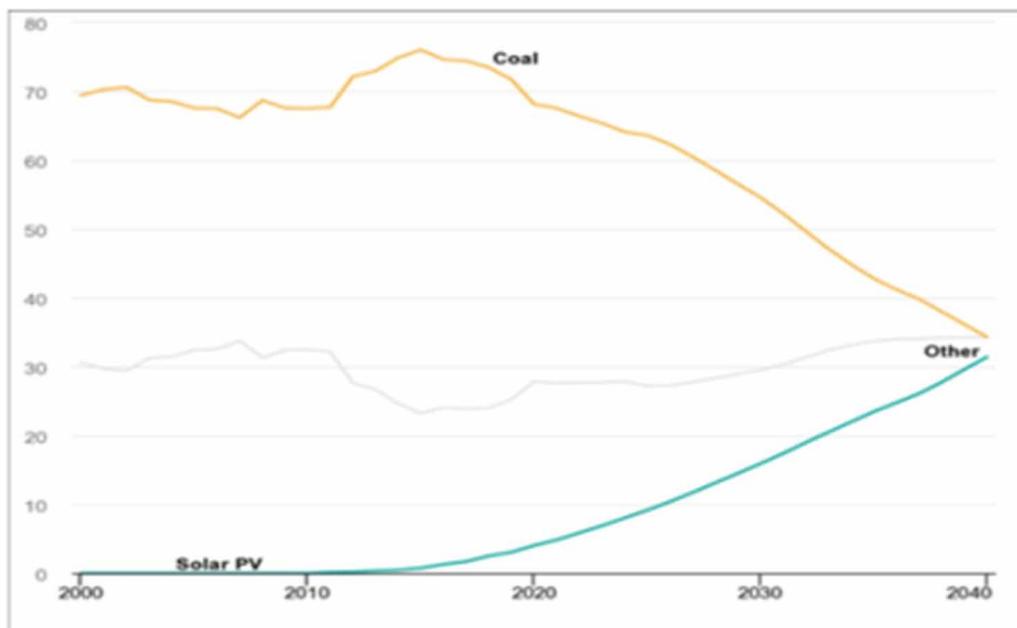
Coal, Oil and biomass are the basic source of energy in India. However, coal fulfils 80% of energy requirement in India since 1990 [IEA (IEO), 2021]. Demand of coal is three times between 2000 and 2019. Coal has an important role in the growth of India's economic development. Traditional biomass i.e. cow dung and fuel-wood became next largest source of energy after 2000. After 2000, contribution of coal as energy source became one-fourth of all primary sources. With gradual decrease in biomass energy by 12%, LPG showed an improvement to modern cooking fuels [Spencer Dale, 2022]. With the increase in household appliances, energy demand has increased three times the past two decades. This

Figure 6. Population, income, and energy demand for the 2000, 2010 and 2019 in India (IEA (IEO), 2021)



increase in energy demand was due to electric motor used in home appliances and in industries. Coal was the dominant source of energy in power sectors. In 2019 generation of power from coal is 70%, while solar PV and wind combine to generate approximately 18% [Spencer Dale, 2022]. Figure 7 shows the change in power generation from 2000 to 2040 [India Energy Outlook, 2021]

Figure 7. Change in power generation from 2000 to 2040 (India Energy Outlook, 2021)



## **6.2 Renewable Energy Sources**

Solar, wind, geothermal, waves, tides and waste energy is abundant. We have plenty of ways to use renewable energy and now days we are using it. Some of the renewable energy resources are discussed in next section.

### **6.2.1. Hydropower**

Electricity generated from Earth's water cycle is known as hydropower. India has approximately 100 hydropower plants generating electricity above 25MW [Iha, 2022]. In 2019, India surpassed Japan and became fifth largest potential hydropower capacity in the world [Iha, 2022]. Figure 8, shows 510 MW hydro-power station known as *Teesta-V power station which is owned and operated by NHPC Limited* [Iha, 2022].

Hydropower plants do not produce any contaminated air emission but affecting the river water quality and also wildlife [DOE, 2021]. This demerit is taken into consideration and hydropower station is now designed and operated taking care to enhance the quality of the river water [DOE, 2021]. In India, the hydropower plant installation capacity at different river bank [EIA, 2017] is shown in Table 2. The total hydropower station installed capacity is India is 148.7 GW. Apart of it, India has 56 storage pump projects with the installation capacity of 94.000 GW. Capacity Small and micro schemes are 6.782 GW in 1512 sites [EIA, 2017]. Compiling all, the overall installation capacity of hydropower in India is 250 GW [EIA, 2017].

*Figure 8. 510 MW Teesta-V power station in Sikkim (Iha, 2022)*



Table 2. Installed capacity of hydropower station (GW) in India

Hydropower Installed Capacity in India (Giga Watt)	
Indus Basin	33.832
Ganga Basin	20.711
Central Indian River system	4.152
Western Flowing Rivers of southern India	9.430
Eastern Flowing Rivers of southern India	14.511
Brahmaputra Basin	66.065
Total	148.701

Source: ELA, 2017

### 6.2.2. Bioenergy

Energy generated from organic materials [DOE,2021] such as plants and trees [DOE,2021; Thomas B.J., 2012; J.Beurskens,2012], forestry by-products [Thomas B.J., 2012; WC Turkenburg ], agricultural residues [DOE,2021; Johansson T.B., 2012 W.C. Turkenburg], is known as bioenergy. While burning wood we get bioenergy. It is not necessary that we get all bio-energies from trees and plants only. We also get bioenergy from the residue of agricultural products i.e. residual biomass which is also a source of bioenergy. Efforts are made to replace fossil fuels with bioenergy [Energy Outlook, 2020; Richie Mittal] and promoting green and clean energy [Phebe A.O. & Samuel S., 2016]. Bio-fuel plays a vital role in decarbonizing (remove carbon emission) from aviation and marine [Energy Outlook, 2020], creating awareness and influencing CO<sub>2</sub>, NO<sub>x</sub> and chlorofluorocarbons (CFC) emissions [Abdeen Omer, 2020] promoting interest in eco-friendly environment.

### 6.2.3. Geothermal Energy

Energy produced from heat present inside the earth core, 4000 miles [Phebe A.O. & Samuel S., 2016] below the surface of earth having a temperature of 9000° F [Phebe A.O. & Samuel S., 2016] is known as geothermal energy. Hot air or hot spring is collected using GTP (Geothermal heat pumps). These pumps pass on the energy and are collected in the reservoir for further process of electricity generation. These geothermal pumps include water to air, water to spring heat pump connected with a long pipes passing deep inside the earth's surface. This collected hot water and steam is used for generating electric power. Ten major geothermal energy plants in different regions of India [Sakhare, V.V, 2020] are listed below:

- **Himalayan Region**
  - Puga Geothermal Field & Chhumathang Geothermal Field, Ladakh
  - Manikaran Geothermal Field, Himachal Pradesh
  - Tapoban Geothermal Field, Uttarakhand
- **Peninsular Region**
  - Tattapani Geothermal Field, Chattisgarh
  - Manuguru Geothermal Field, Telangana
  - West Coast Geothermal Field, Maharashtra

## **Green and Sustainable Infrastructure in India**

- Surajkund Hot Spring & Tantaloi Hot Spring, Jharkhand
- Bakreshwar Hot Spring, West Bengal

### **6.2.4. Solar Energy**

Energy produced by the Sun's heat and radiation via the solar cell is known as solar energy. The advantage of solar energy over conventional energy is the generation of power without carbon dioxide (CO<sub>2</sub>) emission. The solar irradiance in the atmosphere is 342Wm<sup>-2</sup> [Ehsanul Kabir, 2017], 30% of the solar radiation is reflected back or scattered in the space and only 70% of radiation reached the earth surface for harvesting and supplying electric power. The installed solar energy capacity in India has increased by 24.4 times in the last 9 years and stands at 67.07 GW as of July 2023[Manohar A, 2023]

## **6.3 Renewable Energy Integration in India**

India stands third in energy consumption worldwide. India has progressed a lot in RE sector, providing electricity for its residential users. According per-capita consumption of electricity across its 28 states and 8 union territories, India still stand third of world average consumption [IEA, 2021; Chandel, T.A, 2022]. Government policy is to enhance energy efficiency with LED light and electric power rail-route kilometres from 40% to 77% by 2022 [Sahil Ali, 2018]. In India electricity demand boosted up till 2019 but shows a significant fall in 2020 due to lockdown all over country due to wide spread of Covid-19 pandemic.

Annual production of electricity (Solar and Wind) is 29%, 20%, 18% and 14% in Karnataka, Tamil Nadu, Rajasthan and Gujarat respectively for the financial year 2020/21[IEA, 2021]. The energy consumption by the year 2030 can be 35-45 TWh [Sahil Ali, 2018; Diya Dasgupta, 2021]. Figure 9 shows renewable energy system integration, 2019.

As per IRENA, 25% of energy requirement in India can be fulfilled by RE. The contribution of renewable power energy generation by the end of 2030 will be one-third of total generation [Kumar. J & Majid, 2020; IRENA, 2017] and to the overall power requirement in India by the year 2021-22 is 203 GW and by 2026-27, it shall be 242 GW [Sahil Ali, 2018].The IEA World Energy Outlook 2021 scenarios shows the changing era from coal to RE in India from 2030 to 2040 [Kumar. J & Majid, 2020; IEA, 2021; Energy outlook, 2021The energy demand growth in India form 2019 till the end of 2040 is shown in Figure 10.

The percentage of annual GDP growth in India in-between, 2019-2040 is shown in Figure 11.

### **6.3.1 Status of India in Renewable Energy World**

In 2021, India stands 3rd in the world in 57<sup>th</sup> and 58<sup>th</sup> Renewable Energy Country Attractive Index (RE-CAI), creating a sustainable world in 2021 and 2022[RECAI, 2022]. India has set to achieve a target of 175 GW by the end of 2022 [Invest India, 2022] and will expand to 450GW till the end of 2030 [Invest India, 2022], making the world's highest expansion plan in RE. On 15 August 2021 our honourable Prime Minister has set a target of making India energy-independent by the end of 2047 [TET, 2021] as Atmanirbhar Bharat.

Figure 9. Renewable energy system integration, 2019  
(IEA, 2021)

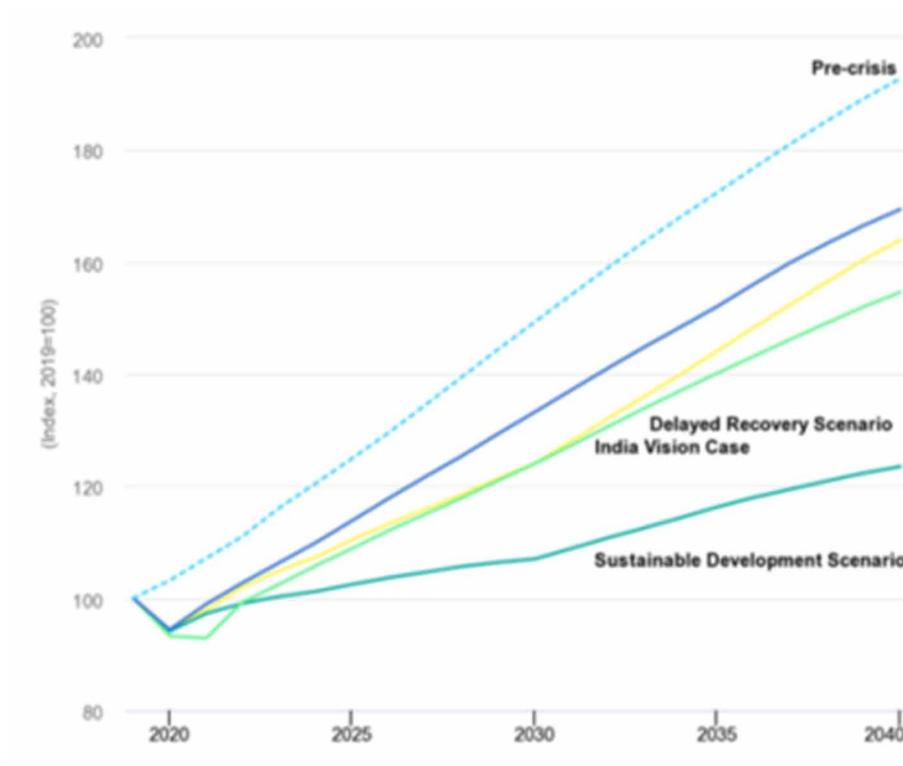
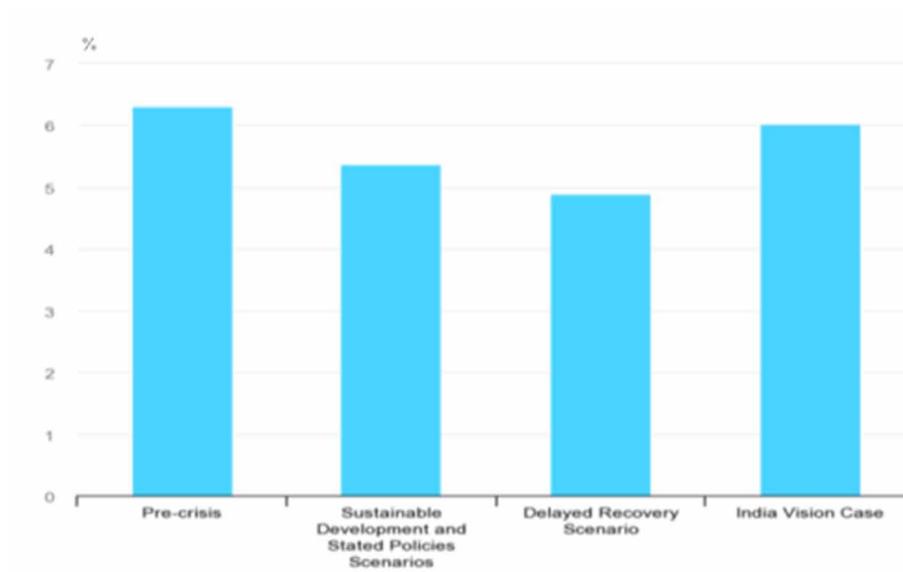
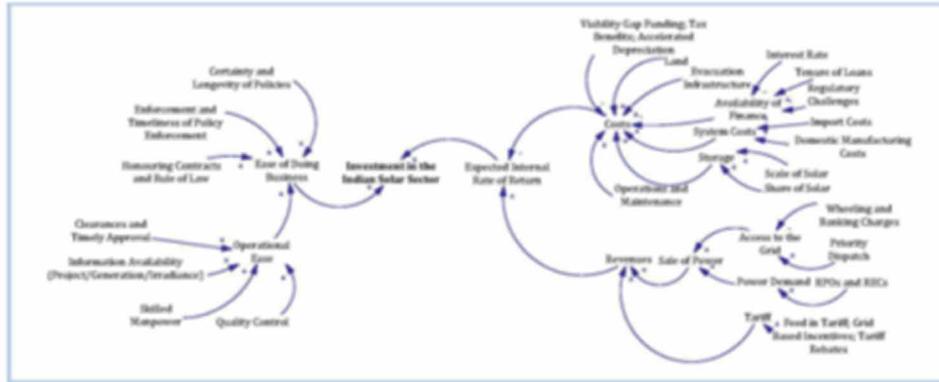


Figure 10. Energy growth in India from 2019 till 2040  
(Aarushi Koundal, 2022)



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Figure 11. Average annual GDP growth in India in-between, 2019-2040  
(Aarushi Koundal, 2022)



### 6.3.2 Industry

In the Indian power industry, installed capacity of RE is 96.95 GW as on 31, June 2021 [Invest India, 2022; WEC, 2013] which include 39.44 GW Wind power, 41.09 GW Solar Power, 10.34 GW Bio Power, 4.79 GW Small Hydro Power. From the Financial Year (FY) 2016-17 to FY 2020-21, capacity of wind energy has increased by 2.2 times. Furthermore government is taking initiative to enhance the capacity of RE to 450 GW by the end of 2030. These are as follow

- 42 solar parks with the capacity of 23,499 MW
- 2GW solar power in Pavagada, 1GW in Kurnool, 648MW in Bhadla-II which include 5 top solar park operations with the capacity of 7GW in India.
- World's largest hybrid (wind-solar) project of 30GW in Gujarat.

### 6.4 Foreign Direct Investment Policy of India

The investment policies have shown improvement in an Indian economy in 1991. This has made easier in FDI norms across the nation. Today India is among top 100 bodies on Ease of Doing Business (EoDB) [FDI Policy, 2023]. Foreign Investment income in India remained at \$45.15 bn in 2014-15. FDI income grew by 65.3%, for example from \$266.21 bn in 2007-14 to \$440.01bn in 2014-21. India has drawn FDI income of \$76.30 billion during April to March 2021. India has become the fifth biggest beneficiary of economy globally. FDI income in India from April to December 2022 was \$67.54 billion. In the financial year 2020-21, income through FDI was \$58.37 billion, which is 22% higher than the initial eight months of the financial year 2019-20. FDI income got from April to November 2021 is \$43.85 bn which is 37% more contrasted with April - November 2020 (\$32.11 bn) [FDI Policy, 2023]. According to BNEF report, global investment in sustainable power was US\$ 279.8 billion in 2017. The top ten worldwide investments are made by China (126.1 \$BN), the USA (40.5 \$BN), Japan (13.4 \$BN), India (10.9 \$BN), Germany (10.4 \$BN), Australia (8.5 \$BN), UK (7.6 \$BN), Brazil (6.0 \$BN), Mexico (6.0 \$BN), and Sweden (3.7 \$BN) [Angus McCrone, 2018]. This success was only possible to the countries

having equipped policies and strategies for promoting the investments [Charles R. K. and A. Majid, 2019; Angus McCrone, 2018, Allianz climate Institute, 2017].

#### 6.4.1 Investment opportunities in RE in India

In 2018, investment in RE jumped up by 22% comparatively to 2017. Record of Bloomberg New Energy Finance (BNEF) [BNEF, 2018; Rolf W., 2012] shows the investment made by the countries given in Table 3. Our country is on the front position for transforming an eco-friendly power by achieving the target of 175 GW by 2020 [Kumar. J., Majid, 2020]. To accomplish this objective, it has rapidly increased the interest of investors in RE sectors.

#### 6.4.2 Mobilising investment

Investment in RE require motivation for achieving the target by tapping their potentials. Factors crashing the investments are shown in Figure 12. Investments are done on the basis of return of investment (ROI) and the surrounding commercial environment i.e., are a function of the costs involved and the revenue generated.

**India is making great strides towards affordable, secure and cleaner energy [Fatih Birol, 2020]**

### 7. GOOD HEALTH AND WELL-BEING (SDG-3)

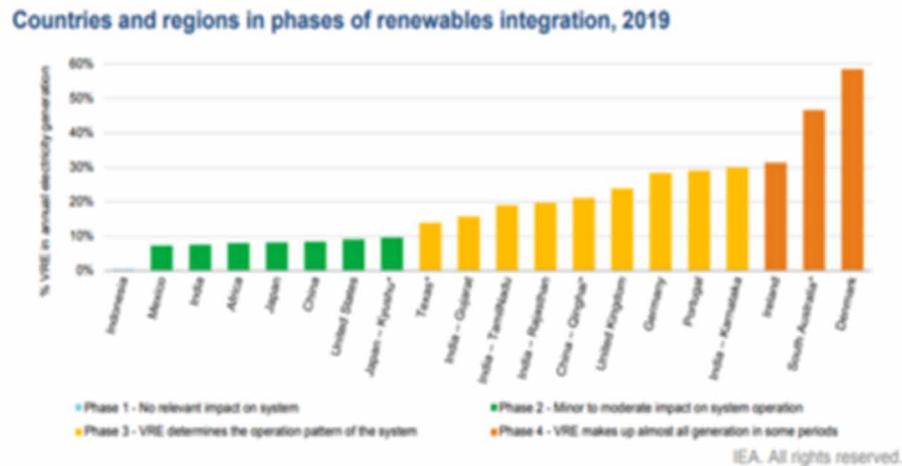
One of the important goals among all UN’s sustainability goals is good health and well-being (SDG-3) [Singh A.P., 2023]. The principal is to maintain healthy living and well-being at all age of human life. In

*Table 3. RE investment trends, 2010-2017*

\$Bn	2010	2011	2012	2013	2014	2015	2016	2017
USA	46.6	62.3	52.9	44.6	52.2	58.4	56.4	56.9
Europe	123.1	137.8	96.4	70.2	78.5	73.8	77.7	57.4
China	45.0	51.5	62.6	66.9	89.6	125.4	107.2	132.6
Brazil	7.5	10.3	8.2	4.4	7.8	6.7	5.7	6.2
Canada	6.6	4.0	5.8	6.7	7.0	3.8	2.3	3.3
Mexico	2.5	4.0	1.6	1.9	2.3	1.8	1.0	6.2
UK	10.8	13.1	11.7	15.1	17.5	25.9	23.4	10.3
Germany	40.3	39.0	27.4	18.8	24.0	18.5	19.8	14.6
France	6.3	10.5	7.0	5.2	7.3	4.1	4.3	5.0
Spain	8.1	10.6	3.0	1.2	0.8	0.1	0.8	1.1
Italy	24.3	32.3	15.6	4.3	1.7	2.1	2.2	2.5
Japan	14.8	18.6	25.0	37.3	44.3	42.6	27.9	23.4
India	9.0	13.8	8.1	6.8	8.5	9.9	13.7	11.0
Australia	5.2	6.2	6.2	4.8	2.2	2.2	3.6	9.0

Source: BNEF, 2018; Rolf W., 2012

*Figure 12. Framework to evaluate investments in RE (IRENA, 2017)*



spite of remarkable development in health and technology, various health issues may cause temporary or permanent destruction to people which affect the function globally. To overcome such issues, emphasis should be done on financing more on health system to improve sanitation and hygiene.

Health care is an act of prevention, medication and controlling of the sickness/disease and the services provided by the health professionals for protecting the mental and physical well-being of human. According to WHO, health care holds all goods and services together with preventive care, healing and palliative care process, whether for mass or individuals?

- Health care sectors in India [A Sheeba and Seilan A., 2020] consist of
  - Primary care provider
  - Diagnostic care centres and laboratory pathology services
  - Pharmaceutical Industry
  - Medical equipment industry
  - Life insurance company
  - Third party services provider such as catering and laundry

### **7.1.1 Health Care Challenges in India**

Health-care plan in India has a wide range of contrasting landscapes. One side of healthcare shows garish and glassy structured with high-tech equipment’s usually in urban area while the other side shows rickety outpost in remote areas of the country, desperately struggling for their survival. Our nation began the health care referred as Indus valley civilization from 5500 to 1300 BCE, mentioned as Arogya as “holistic well-being [Arvind Kasthuri, 2018; Roy S., 1985]. Today’s population of our country is 1,430,145,789 [World population Review 2023] with huge cultural diversity and therefore numerous challenges in health-care sector. This led to focus the theme of WHO in 2018, call for Universal Health

coverage for everyone and everywhere [Arvind Kasthuri, 2018]. Among many challenges, the author has mentioned only five major challenges, which are given below;

- Lack of awareness
- Lack of access
- Lack of man-power
- Lack of affordability cost of healthcare

Major initiatives were taken towards integrated health care in five-year plan. Emphasis was done on family planning, nutrition care services for different groups such as children, pregnant lady, feeder women's [Gupta I. and Patel N., 2020; N S Deodhar, 1982]. The fruitless coordination in nutrition services and lack of national health program results as slower development and interdependency of different zones. Hence it was necessary to upgrade the health infrastructure. Adopting westerly medical culture, emphasis was done on "cure" instead of "care" [Gupta I. and Patel N., 2020]. Emphasis on medical education such as nursing, paramedical has showed improvements in health sector. Community medicine centres were opened for adequate health care services for all, especially for the poor and deprived citizens.

A health insurance schemes i.e. Rashtriya Swasthya Bima Yojan (RSBY) was launched in 2008 for poverty-stricken citizens. Approximately 41 million Indian families got enrolled in RSBY by the end of 2016 [A. Karan, 2017] and 37% of citizens were covered by some or other form of insurance in-between 2017 and 2018 [National Health Profile, 2018]. In March 2018, central government has launched Ayushman Bharat-Pradhan Mantri Arogya Yojan i.e. tax-financed national Health Protection Scheme for deprived people [Modicare, 2018; National Health Profile, 2018; Times of India, 2019]. This scheme will help the poor people of our nation to avail the facility of cashless secondary and tertiary care at private hospitals. This policy has benefited 10.74 crores for poverty-stricken citizens [Ayushman Bharat, 2018].

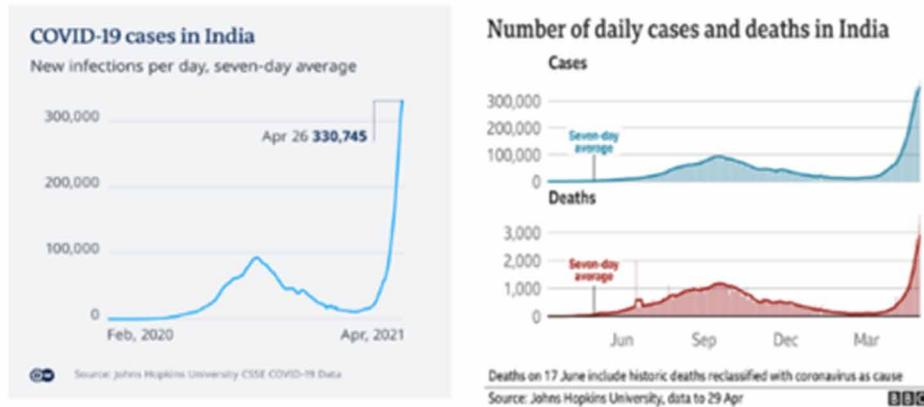
## **8. IMPACT OF COVID-19 IN INDIA**

The coronavirus-2019 outbreak was an awful tragedy for human life. John Hopkins University presented the statistical data of COVID-19 on 28, June 2021 showing 3,923,132 people passed away and 181,102,393 people were infected worldwide [Francesco La, 2022]. Disease was passed to maximum people in United States, India and Brazil and casualties globally [Chandel, T. A., 2023]. Instead of outspread the disease, almost all countries had some or other limitations. Partial or full lockdowns was announced, schools, colleges, universities and work-placed were closed. Employes were advised to work from home. These limitations affected power sectors, transport sectors, commercial sectors, medical units, real estate, catering, entertainments and environment. Foundation of global economy system was almost shattered in the year 2020 and 2021. Figure 13 shows the infected [DW, 2021] and death report of second wave of coronavirus disease (SARS-Cov-2) [BBC News India, 2021].

### **8.1. Impact of COVID-19 on Infrastructure**

Budget related to infrastructure was already on shortfall in some place and COVID-19 stepped at our doors. Lockdown had a great impact on the infrastructure sector, power, transport, employment, environment and economy of the country. In a construction company more than 51 million people are employed

*Figure 13. Infected and death report of SARS-Cov-2*



including engineers, managers, skilled and unskilled labours. Construction system collapsed due to various reasons such as shortage of materials [KPMG, 2020; Das, P., 2020], disturbance in supply chain [Zamani, S.H, 2022], less demand in construction due to financial loss, distance generated within team members and lastly projects were terminated [Gamil, Y., 2020; 109, Hafnidar A. Rani, 2022]. All these factors led towards major economy downfall [Thomas, N, 2021]. At the time of COVID-19 approximated twenty thousand projects were on going and more than eighteen thousand all over the nation were on site as per confederation of real estate developer association of India. Due to first lockdown from 25 March to 17 May 2020 [Hafnidar A. Rani, 2022], migration of people started all over the country, leaving the working place and moving towards their hometown thus leading to shortage of man power. More than 6 Lakh citizens migrated on foot towards their hometown while more than 1 lakh were kept in relief camp in different parts of the country. Resulting, approximately 30% or more, labours never returned to their work place after lockdown. Spontaneous response of government was required toward health related issues, social measures, lockdown emergency, government projects for addressing the COVID-19 pandemic. All these issues significantly affected the public funds, asset, stock market, public and private shareholders, proceeding toward the slowness of the activities. Continuous reduction in government funds at state and national levels hindered the projects activities at short and long term [S & L. Govt. Workforce, 2020]. Apart of it, transport sectors under infrastructure was completely out of demand, collection of money at toll junction were reduced, power metering in commercial sectors dipped by huge level, creating liquidity and credential issues in all sectors. It was a great burden on the government to carry on further projects EPC mode. Nothing was left instead waiting and watching.

## **8.2. Impact of COVID-19 on Power Sector**

Power sector is a strongest source of the global economy, supplying electricity to other countries. COVID-19 had screwed the grip globally and forced many countries to imposed unprecedented lockdowns, which was an impending concern over the livelihoods and economy globally. At this time, power supply was a critical issue for human survival in medical services among other aspects of daily lives. Power was generated by harnessing hydropower. At the same time generation of power was transformed towards RE i.e. solar and wind energy. Due to lockdown, there was drastic declination of power demand in the

manufacturing and commercial sectors. The International Energy Agency (IEA) estimates 2.5% decline electricity demand worldwide during first quarter of 2020, and predicted 5% reduction by the end of the year [IFC, 2020]. The sinking energy demand continued till 15 April 2020 [Chaturvedi A., 2020]. However, some change was observed during mid-April as it was proceeding towards warmer season. Due to lockdown, people were working from home, enhancing the power demand which could partially compensate the declination of energy demand in industries and manufacturing units.

### **8.3. Impact of COVID-19 on Employment**

According to the International Labour Organisation in April 2020, approximately 2.5 crores people became unemployed globally due to the COVID-19 pandemic in 2020 [Kumar, O., & Srivastava S., 2021]. Apart of it, at the same time, more than 40 crores self-employed workers in India were thrown down below poverty level. Unemployment increased to 20.9% in urban areas during the period of April- June quarter of 2020, which is double the previous year under unemployment rate. Mr. Mahesh Vyas, CEO of Center for Monitoring Indian Economy (CMIE), announced the unemployment rate to be 12% during 1<sup>st</sup> wave of corona pandemic and during the second wave of corona pandemic unemployment reached up to 1 crores [Roy, D. K., 2021]. The analysis of after effects of pandemic regarding employment showed that approximately half of formal salaried employee transformed toward informal employments i.e. the percentage ratio for self-employed was 30%, casual wage employee was 10% or informal salaried was 9% during the period of 2019-20, also there was declination in their salary package, 20% of the poorest household became jobless [Roy, D. K., 2021].

## **9. CONCLUSION**

Industries and sustainable infrastructure play an essential role in providing quality life and safe environment. Part of it is achieved through new infrastructure developments such as RE generation, smart metering. To ensure country's sustainable growth, an Indian government has showed its interest towards industry infrastructure by investing \$1.4 trillion in between 2019 to 2023 [Jaskaran S. S., 2020] and \$750 billion on railway infrastructure. India and Japan has signed the partnership contract for building infrastructure in north-east states of the country, forming an Indo-Japan Coordination forum for industrial mega projects and infrastructure in the above said development areas.

The achievement of long lasting and sustainable structure is hypercritical. Even though, if the climatic objective is achieved globally, life is affected by climatic change worldwide. In the limelight of enhanced threat to the environment and communities, strong infrastructure will be censorious in establishing healthy water & sanitation system, RE system and insuring that the communities can survive and get rid of the disasters. Infrastructure is the way of providing services and shelter to sustainable growth.

There was a great impact of COVID-19 on power sector due to lockdown. During this period demand in power supply declined in commercial sector and increased in residential sectors. The study shows energy supply from thermal power plant based on coal reduced by 26% during lockdown, as the result direct reduction in carbon emission. However there was flexibility in renewable variability. The impact of reduction in carbon emission transformed the energy generation towards RE resources.

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