### 3.2.3 Air Transport Infrastructure

Aeroplanes, helicopters, light aircrafts, hot air balloons, blimps and gliders, drones or UASs (unmanned aircraft systems) are all vehicles of air transport and require certain physical infrastructure to support flight and while not in flight, such as service, maintenance and parking.

Airports are complex transportation hubs and is spatially divided into three: airside, landside and terminal that connects the two. The civil engineer has the responsibility of structurally designing and constructing; the airside layout comprising of runways, taxiways, parking aprons, lighting and signages, navigational and visual aids; the landside facilities, such as parking lots, fuel tank farms, access roads, technical buildings like control towers for ground aid, etc. and passenger and cargo terminals.

Helicopters too have designated bases with fixed operations and services like customs, fuel bunkering and maintenance, called heliports. It is like a small airport specifically for helicopters and other vertical-lift vehicles. Often high-rise buildings, hospitals and other buildings or campus of importance have helipads for landing and take-off only. This infrastructure is of particular importance as helicopters and drones are the preferred mode of transport during natural disasters for rescues and searches, supply as well as surveillance.

Aviation falls under critical infrastructure in India and has been a hot target for attacks, online and offline. The regulatory body for India is the Directorate General Civil Aviation (DGCA), empowered by the **Aircraft Act 1934**, implements standards and recommended practices of the International Civil Aviation Organisation (ICAO), and later further bolstered by the Aircraft Rules 1937, is authorised to specify requirements and compliance procedures through Civil Air Regulations (CAR). It outlines the operations and planning of infrastructure as well. The DGCA also regulates the airspace and in turn, monitors and supports the use and manufacture of UAS, as well as authorises remote pilot training and certifications, to overall ensure National security.

### 3.2.4 Futuristic Transport Infrastructure systems

'Smart' transportation is the vision of the future, with driverless cars, flying taxis, delivery drones and levitating trains being already on the horizon. **Novel concepts** of futuristic transportation, impose the need for reimagining the infrastructure, such as;

***Self-drive Cars or autonomous vehicles (AV),*** a technology that is seemingly possible in the near future, require physical and technological framework to support and enable the operation of autonomous vehicles. The most important element is the need for communication network with real-time data exchange through vehicle-to-infrastructure (V2I) systems, such as sensors in roads or street signs that send signals to AVs, helping them navigate city streets. There are also alternatives like, dedicated short-range communications (DSRC) and cellular vehicle-to-everything (C-V2X) systems. Physical infrastructure is also crucial, such as, parking facilities equipped with autonomous parking capabilities, maintenance stations specifically designed for self-driving cars, and a comprehensive network of charging stations as many self-driving cars operate on electric power, to support uninterrupted operation.

***Maglev***, a technology where magnetic levitation actuated by two sets of opposing electromagnets along the tracks, allows trains to travel at high speeds. Shanghai Transrapid is the presently the world's fastest commercial electric train and goes up to 431 Km/h. Japan began development and construction of SCMaglev under the Central Japanese Railway Company in 1969, and the HSST (Linimo) in 1974. A new maglev line, named the Chuo Shinkansen started in 2014. In 2016, South Korea inaugurated the Incheon Airport Maglev. Currently, all maglev trains are in use in Asia.

***Hyperloop***, "*an ultra-high-speed transportation system in which passengers travel in autonomous electric pods*" futuristic transportation concept. It was first conceptualised by Elon Musk in a white paper in 2013 for intra-city mass transit and envisioned "*a tube, over or under the ground, that contains a special environment*". It consists of low-pressure tube with capsules that are transported at both low and high speeds throughout the length of the tube, such that the capsules are supported on a cushion of air and are accelerated by a magnetic linear accelerator affixed at various stations.

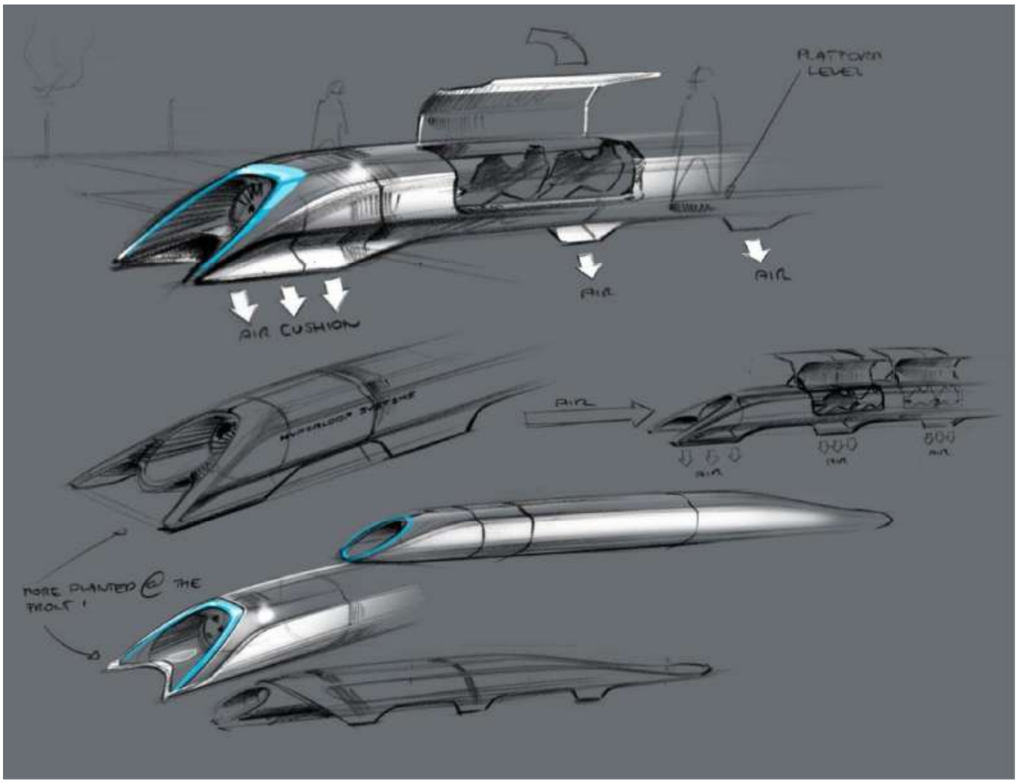


Fig. 3.5 : Hyperloop Alpha concept sketch (source: www.tesla.com)

***Underground tunnel roads*** are another vision of Musk for futuristic transportation where he conceptualises a network of underground tunnels equipped with trolley like platforms to lower the cars from the surface and speedily transport them to their destinations, alleviating congestion. This is much in line with the idea of autonomous vehicles, driverless cars, and flying taxis, which are all well underway in prototyping phase.

*The motivations of these proposed futuristics concepts are; reduction of congestion and greenhouse gas emission, reduce fatalities and prioritise safety, provide access to disadvantaged and to improve on time. 'Quality of life' and low environmental impact are key and in turn, requires to re-imagine the supporting infrastructure for energy, telecom, etc.*

## 3.3 ENERGY

Global energy infrastructure includes delivery systems of oil and natural gas pipelines, power generation facilities and transmission lines, storage facilities, etc. Inclusive economic growth, clean air, climate has necessitated innovations in efficiency gains, new production flows, digitalization, smart grids, etc., requiring infrastructure to become sustainable, resilient, and secure (International Energy Forum). Geopolitical and natural events and accidents may lead to disruption of energy markets, and hence, policy cohesion and regional market integration through cross-border networks are essential to meet SDG, i.e., Ensuring access to clean and affordable energy.

"*Energy generation depends on a country's natural resource endowments and technology to harness them*" as per Government of India Budget report 2012-13. India is the world's third largest producer, as well as, consumer of electricity, but this is predicted to increase by 4.5% annually to 2035. Presently, India's energy consumption is 1010kWh per capita against a world average of 3200kWh. Gujrat, Maharashtra, Tamil Nadu, Rajasthan, Karnataka, and Uttar Pradesh are the top power producing states of the country. However, the key issues are poor transmission and distribution grids. India has both non-renewable reserves, of coal, lignite, petroleum, and natural gas, as well as renewable energy resources of hydro, wind solar, biomass, and cogeneration bagasse. But while the non-renewable resources are poor, India is richly endowed with renewable resources, and several policies and initiatives are presently in place to leverage that.

### 3.3.1 Renewable Sources

Renewable energy, popularly referred to as **'clean' energy**, comes from natural sources or processes that have a higher rate of replenishment than its consumption. Their sources are sunlight, wind, water, geothermal and biomass. While large hydroelectricity projects and biomass levy a trade-off on wildlife, biodiversity and climate change, other sources have very little negative impact on the environment and in turn, generate lower emissions.

***Solar technologies*** can also provide heating and cooling solutions, natural lighting, and fuel for cooking. Solar power can be harnessed through mirrors and photovoltaic (PV) panels, that concentrate the solar radiation and converts it into usable fuel or electricity. PV cells are made of silicon and present technology has not only significantly reduced its prices, but extended its life to up to 30 years. Solar farms are fast becoming a large initiative where PV cells are splayed, often aided by mirrors to concentrate the sun light, and in some cases, wastelands, water bodies and wastewater facilities are employed.

***Wind energy*** exploits the kinetic energy of moving air by using large wind turbines situated at on-shore or off-shore locations, as per the average wind speed of the location.

***Geothermal energy*** is garnered through the heat extracted from the earth's interior reservoirs using wells and ducts. Hot fluid of varying temperature is pumped through turbines to generate electricity, and recycling of the used water and steam ensures low emissions.

***Hydropower*** harnesses the energy of falling water from higher to lower elevations and can be generated from reservoirs or flowing rivers. Beyond providing electricity, these sources also provide water for irrigation and drinking, as well as help in flood and drought control, and navigation services. However, rate of precipitation and annual rainfall impacts the functioning of hydropower.

***Tidal and wave energy*** of the ocean is also a potential source of clean energy and is generated through tidal barrages which are dam-like structures located in ocean bays and lagoons, or via devices which are ocean floor-anchored or placed just below the wave surfaces. These interventions may cause adverse effects on the life under water.

***Bioenergy*** is produced from biomass which is the organic remains of various sources, such as, wood, charcoal, dung, manures, reside from agriculture and forestry, and other organic wastes. It is used mostly in rural areas for cooking, lighting, heating. However, in spite of its natural origin, it has detrimental environmental impact as it produces emissions and bioenergy plantations may lead to deforestation and land-use change, making it arguably not a 'clean' energy source.

India is the **third largest producer of renewable energy** and is rich in clean energy sources, such as, solar, wind, and small hydro, with high potential for energy generation. India globally ranked $4^{th}$ in solar power capacity, wind power capacity and overall renewable power installed capacity as of 2021 and ranked $6^{th}$ for hydropower generation in 2019. Today, as of January 2023, India's installed renewable energy capacity, is at 40.9% of the total installed power capacity. Solar (63.3 GW), hydropower (46.85 GW) and wind (41.9 GW) are the largest contributors followed by biomass (10.2 GW), small hydro (4.92 GW) and 'waste to energy' (0.52 GW) as contributors towards the renewable energy capacity.

The past year has been pivotal for development of renewable energy. The union cabinet approved 2,614 Crore investment in the 382 MW Sunni Dam Hydroproject by SJVN (Satluj Jal

Vidyut Nigam). SVJN also signed an agreement with the Utter Pradesh government to implement 3 solar power project and commissioned a Solar power project (75MW) at Parasan Solar Park near Kanpur, U.P. They further signed up with Tata Power Solar systems to build a 1000MW solar project near Bikaner and announced collaboration with Govt. of Assam for development of hydro and renewable energy projects. National Hydroelectric Power Corporation (NHPC) and Govt. of Himachal Pradesh intend to implement a 500 MW hydroelectricity project in Chamba District, H.P., as well as two project in Nepal. Tata Power Green Energy Limited (TPGEL) commissioned a hybrid power project in Rajasthan and was awarded a solar project in Solapur, Maharashtra. National Thermal Power Corporation (NTPC) announced partial power generation from the floating solar energy plant in Kayamkulam, Kerala, and Jetsar, Rajasthan. Adani Solar and Smart Power India (SPI) signed an MoU to promote usage of solar rooftop panels in rural India. To further promote this the Ministry of New and Renewable Energy has developed a national portal for citizens to directly apply. Several **policies and programs**, such as, '*National programme on High Efficiency Solar PV Modules*', 'smart metre deployment' for National Smart Grid Mission, several electrification schemes and issues of sovereign green bonds and conferring infrastructure status to energy storage systems, are underway to improve India's power sector.

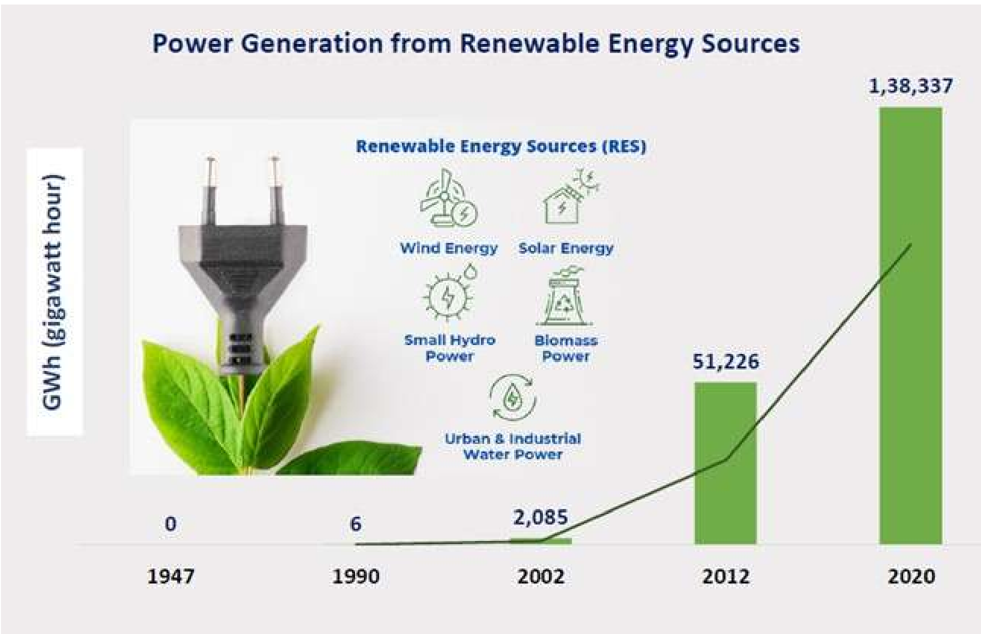


Fig. 3.6 : Power Generation from Renewable Energy Sources (source: Press Information Bureau, GoI)

### 3.3.2 Non-renewable Sources

Non-renewable energy resources are coal, oil or petroleum, natural gas, and nuclear energy, and are those resources that cannot be replenished easily in consideration of the rate of consumption of the same. Fossil fuels are the largest contributors towards global greenhouse gas and $CO_2$ emissions, and accounts for over 80% of the world's global energy production. These fossil fuels were formed over millions of years due to the immense heat and pressure within the earth's crust that converted plant and animal matter into coal, oil, and natural gas. The radioactive elements required to generate nuclear energy, usually uranium, comes from mined ore. However, beyond the issue of limited supply, it is the release of high amounts of $CO_2$ that makes non-renewables an undesired source of energy.

Over 80% of India's requirement is met by coal, oil and biomass, and in spite of having low per capita energy consumption, **India is the 3rd largest global emitter** of $CO_2$. While the largest domestic source of energy is coal, about 70%, the cumulative domestic fossil fuel production is the lowest among the emerging economies. India relies on crude oil imports as it has only 0.6% and 0.4% of the world's gas and oil reserves respectively. Interestingly however, it is a large net exporter of refined products, amounting to $1.1billion worth to Australia in 2016-17, and has experienced overcapacity in thermal energy. 58.6% of this thermal energy is produced from coal, while the other sources are lignite, diesel, and gas.

### 3.3.3 New sources and technologies

A promising alternative to traditional fossil fuels is **Hydrogen** as a new source of energy. Hydrogen fuel cells are devices that generate electricity by combining hydrogen and oxygen to produce water and heat as by-products, and can be powered by hydrogen produced from renewable energy sources. They are highly efficient, with an energy conversion rate of up to 60%, compared to around 30% for traditional internal combustion engines. They also produce zero greenhouse gas emissions, which can help to mitigate climate change. However, there are several challenges associated with the adoption of hydrogen fuel cells, such as, the infrastructure required for producing, storing, and distributing hydrogen, and the development of a sustainable and scalable hydrogen production system as the production of hydrogen is currently reliant on fossil fuels. The cost is also a barrier to widespread adoption, although research and development are helping to reduce costs.

Another potent technology for energy generation is **nuclear fusion**, which involves combining of light atomic nuclei to form heavier ones and in the process, releasing vast amounts of potential energy. Unlike nuclear fission, which is currently used in nuclear power plants, nuclear fusion does not produce long-lived radioactive waste and has the potential to provide a virtually unlimited source of clean energy. However, there are several challenges associated with developing nuclear fusion as a practical energy source. Firstly, the high temperature and pressure required to initiate and sustain the fusion reaction are difficult to achieve and maintain for extended periods of time, and the magnetic fields required to contain and control the fusion reaction are complex and difficult to engineer. Secondly, since most nuclear fusion research focuses on using deuterium and tritium - two isotopes of hydrogen, as fuel, the development of a sustainable fuel source is a challenge as tritium is radioactive and must be produced artificially. This requires a supply chain that is currently not fully developed and is also expensive. Furthermore, the development and construction of a commercial-scale fusion reactor would require significant investment and infrastructure.

## 3.4 WATER RESOURCE MANAGEMENT

Water resource management is a critical to ensure sustainable and equitable access to water resources for human and ecological needs. In recent years, the issue of water scarcity and the need for effective water resource management has become more pressing due to factors such as population growth, climate change, and increasing water demand from various sectors. The World Bank defines Water Resource Management (WRM) as, "*the process of planning, developing, and managing water resources, in terms of both water quantity and quality, across all water uses. It includes the institutions, infrastructure, incentives, and information systems that support and guide water management.*"

The main challenge in water resource management is the need to mitigate the competing demands of various stakeholders, such as, domestic, industrial, agricultural, and environmental. The traditional approach to water resource management has been to focus on supply-side solutions, such as building dams and reservoirs, to increase the availability of water. However, this approach has been criticized for its negative social and environmental impacts, as well as its limited effectiveness in addressing water scarcity in the long term. Recent approaches emphasize the importance of demand-side management strategies, which aim to reduce water consumption and increase efficiency through measures, such as, water conservation, water pricing, and water reuse, which can be effective in reducing water demand, while also providing economic and environmental benefits. Integration of hydrological modelling and remote sensing technologies is also being employed to improve water management decision-making, as these tools provide valuable information on water availability and usage, as well as help to identify areas of water stress and potential risks to water security. However, the role of institutional and governance arrangements in water resource management is pivotal, as effective governance structures and policies are essential for ensuring equitable access to water resources, as well as promoting sustainable and efficient use of water. Participatory and inclusive decision-making processes, as well as the need for greater collaboration and coordination between different stakeholders are much needed to ensure a holistic solution.

### 3.4.1 Water, Sanitation and Hygiene (WASH)

Ensuring access to water and sanitation is one of the critical SDG (goal 6) as safe water, sanitation and hygiene (WASH) is a basic human need. However, contamination and reclaiming of natural water bodies, overuse of ground water and hindering its replenishment, overall poor management and low investments in water infrastructure are some of the key causes of scarce and unsafe water, and inadequate sanitation.

WASH is a collective term that refers to *a set of interventions aimed at improving access to safe water, adequate sanitation, and proper hygiene practices, and is essential for promoting public health, preventing the spread of disease, and reducing poverty*. **'Water'** stands for access to clean drinking water for household and community use, as well as for agriculture, industry, and other economic activities, **'Sanitation'** implies access to safe and hygienic toilet facilities, as well as the safe disposal of human waste, and **'Hygiene'** refers to practices that promote good health, such as handwashing with soap, safe food handling, and proper menstrual hygiene management. WASH interventions can have significant health and social benefits, particularly for vulnerable populations, especially, women and children. For example, access to safe water and sanitation can reduce the incidence of waterborne diseases, such as, diarrhoea, cholera, and typhoid fever. Improved hygiene practices can also reduce the risk of infectious diseases, improve nutritional outcomes, and promote overall well-being. In turn, it is crucial for achieving several other SDGs , particularly those related to health, gender equality, education and economic growth.


Fig. 3.7 : Systemic support required for successful WASH initiatives (source : www.sdgs.un.org)

WASH implementation in India has been a major focus area for the government, NGOs, and international organizations for many years. Some of the **initiatives taken by the Indian government** to improve WASH include:

1. ***Swachh Bharat Abhiyan*** (Clean India Campaign) is a nationwide campaign launched in 2014 to eliminate open defecation, improve solid waste management, and promote hygiene and cleanliness. The campaign has been successful in increasing access to toilets and reducing open defecation.

2. ***Jal Jeevan Mission***, a flagship program launched in 2019 with the aim of providing tap water connections to every rural household by 2024. The program aims to provide safe and adequate drinking water to all households in rural areas.
3. ***National Rural Drinking Water Programme (NRDW)*** launched in 2009 with the aim of providing safe and adequate drinking water to rural areas. The program focuses on creating sustainable drinking water sources, promoting water conservation, and improving water quality.
4. ***National Urban Sanitation Policy (NUSP)*** launched in 2008 with the aim of promoting sanitation and hygiene in urban areas. The policy focuses on creating sustainable sanitation infrastructure, promoting behaviour change, and improving waste management.

### 3.4.2 Strategies for water provisioning and management

Water provisioning and management are undertaken through a combination of policies, regulations, and practices that aim to ensure the sustainable use and distribution of water resources.

Some of the **key strategies** employed are as follows:

1. ***Water conservation and efficiency measures***: These include promoting water-efficient technologies and practices, such as low-flow fixtures, drought-resistant landscaping, and water reuse.
2. ***Water pricing and incentives*****:** Pricing mechanisms and incentives can help to encourage more sustainable water use and conservation practices.
3. ***Investments in water infrastructure****:* Investment in water infrastructure such as dams, reservoirs, and treatment plants can improve access to water and sanitation services.
4. ***Integrated water resources management***: This approach aims to manage water resources in a holistic and integrated manner, taking into account the needs of all stakeholders and balancing social, economic, and environmental considerations.
5. ***Water governance and institutional arrangements***: Effective water governance and institutional arrangements are critical for ensuring the equitable distribution and sustainable management of water resources.
6. ***International cooperation****:* Global collaboration is critical for addressing transboundary water issues and promoting sustainable water management practices worldwide.

## 3.5 TELECOMMUNICATION

Telecommunication is defined as the transmission of information – voice, data and multimedia, over electronic media across large distances. It uses various types of transmission technologies, such as, over wire, electromagnetic, radio and optical, and requires infrastructure for radio and television broadcasting, wired and wireless devices, fibre optic cables, satellites, and networks etc. Telecommunication infrastructure is a key driver of economic development, enabling access to information, markets, and resources that can help to spur innovation and growth. The importance of telecommunication infrastructure can be seen in several domains, such as :

1. ***Business and commerce***: Telecommunication infrastructure is essential for conducting business and commerce across distances, facilitating transactions, and enabling access to markets and customers around the world.
2. ***Education and research*:** Telecommunication infrastructure is increasingly important in education and research, enabling distance learning, remote collaboration, and access to online resources.
3. ***Public safety and emergency response***: Telecommunication infrastructure is critical for public safety and emergency response, enabling communication between emergency responders and the public during times of crisis.
4. ***Social connectivity and cultural exchange***: Telecommunication infrastructure provides a means for people to connect with each other, regardless of their location, enabling social connectivity and cultural exchange.

### 3.5.1 *Telecom infrastructure*

Telecommunication infrastructure refers to the physical networks, equipment, and facilities used to transmit voice, data, and multimedia communication over long distances. There are several types of telecommunication infrastructure, broadly for wired and wireless communication. Wired networks use physical cables, such as copper or fibre optic cables, to transmit data over long distances, as in, traditional landline telephone networks, cable television networks, and high-speed internet networks. Whereas Wireless networks use radio waves to transmit data over the air, without the need for physical cables, such as, cellular networks, satellite networks, and Wi-Fi networks.

However, both require physical facilities and equipment, such as;

- **Telecom towers or cell towers** are structures used to facilitate wireless communication between mobile devices and the telecommunications network. These towers are typically tall structures, ranging from 30 meters to over 100 meters in height, and are equipped with antennas, transmitters, and receivers that enable wireless communication. They are typically located in urban and rural areas, along highways and major roads, and in remote areas where coverage is limited, and maybe freestanding or mounted on existing structures, such as buildings or utility poles. They can also be designed to accommodate multiple carriers, allowing different providers to share the same tower and reduce costs. However, the concern of exposure to electromagnetic radiation and its impact on human health is much debated.
- **Cables** can be installed over ground, underground or under seas. Overground cables are typically strung between poles, buildings, or other structures, and are commonly used in urban and suburban areas, where the cost and complexity of underground installation can be prohibitive. Overground cables are typically made of copper or fibre optic materials, and are designed to withstand weather and environmental conditions. Underground

cables are buried beneath the ground either direct-buried or installed in conduits or ducts, and are commonly used in urban areas. While these are more expensive and difficult to install, underground cables are more reliable and secure, however other activities such as road construction or excavations and servicing sewers, etc can lead to damaging of underground cables. Undersea cables are physical cables laid on the ocean floor to connect different continents and regions, in line with underground but the environmental conditions and installation is extremely challenging.

- **Other Transmission equipment** and devices, i.e., the equipment used to transmit and receive signals, such as, antennas, modems, routers, and switches.
- **Internet exchange points (IXPs)** are physical locations where different internet service providers (ISPs) connect their networks to exchange data. IXPs are essential for enabling the flow of data across different networks and supporting the growth of the internet.
- **Data centers** are facilities used to store, manage, and process large amounts of data, particularly in the areas of cloud computing and internet-based services.

### 3.5.2 Present and future Challenges in Telecom

Telecommunication infrastructure faces a range of challenges that can impact its effectiveness and ability to support modern communication needs, some of which are as follows:

1. ***Access and Connectivity gaps:*** Despite significant progress in expanding telecommunication infrastructure, there are still areas around the world that lack access to reliable and high-speed internet connectivity, particularly in rural and remote areas. Addressing these gaps in connectivity requires significant investment and infrastructure development.
2. ***Cybersecurity threats:*** Telecommunication infrastructure is vulnerable to a range of cybersecurity threats, including hacking, data breaches, and cyber-attacks. Ensuring the security of telecommunication networks and devices is critical to protecting sensitive information and maintaining public safety.
3. ***Cost and affordability:*** Telecommunication infrastructure can be expensive to build and maintain, which can impact its availability and affordability, particularly in developing countries. Ensuring that telecommunication services are accessible and affordable to all is essential for supporting economic development and social connectivity.
4. ***Regulation and policy***: Telecommunication infrastructure is subject to a range of regulatory and policy frameworks that can impact its development and implementation. Ensuring that policies and regulations support the growth and effectiveness of telecommunication infrastructure can be challenging, particularly in rapidly changing technology environments.
5. ***Integrating Emerging technologies****:* The telecommunication industry is constantly evolving, with new technologies and integrating these emerging technologies into existing infrastructure can be challenging, requiring significant investment and expertise.

### *The India Story*

India is the second-largest telecommunications market globally, with a consistently growing subscriber base and broadband subscriptions. As of December 2022, the tele-density reached 84.56%, while broadband subscriptions reached 832.2 million. The total subscriber base stood at 1170.38 million. In the first quarter of FY23, the telecom sector's gross revenue was Rs. 76,408 Crores, i.e., US$ 9.3 billion (IBEF).

In June-September 2022, the total number of internet subscribers reached 850.95 million, with the wireless segment contributing 95.4% of the total telephone subscriptions. Among the different data technologies, 2G accounted for 0.16%, 3G for 1.02%, and 4G for 98.81% of the total wireless data usage. The rise in mobile-phone penetration and declining data costs are expected to bring 500 million new internet users to India in the next five years, creating opportunities for new businesses. Government initiatives such as the BharatNet Project Scheme, Telecom Development Plan, Aspirational District Scheme, and Comprehensive Telecom Development Plan (CTDP) in the North-Eastern Region have led to a significant growth of 200% in rural internet subscriptions from 2015 to 2021. The integration of payments on unified payments interface (UPI) enabled higher and easier usage. Department of Telecommunication (DoT) launched '*Tarang Sanchar'* - a web portal sharing information on mobile towers and EMF Emission Compliances.

In the past four years, there has been over 75% increase in internet coverage, from 251 million users to 446 million, and it is estimated that by 2025, India will require approximately 22 million skilled workers in 5G-centric technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), robotics, and cloud computing.

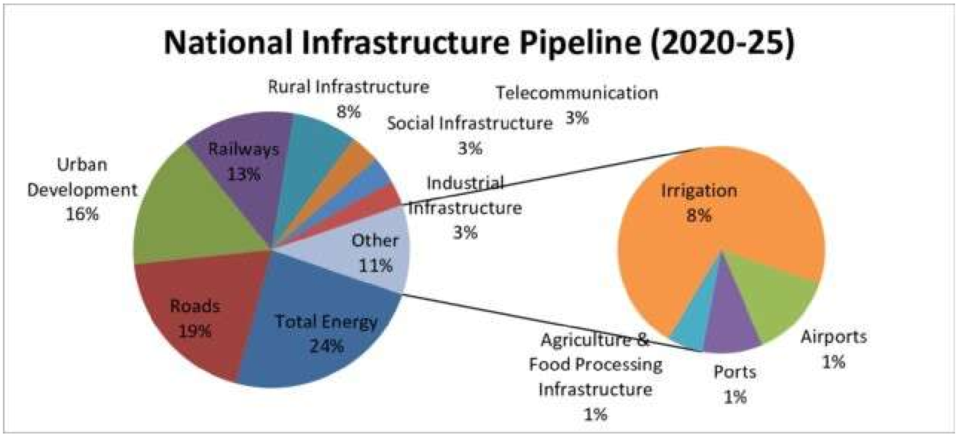


Fig. 3.8: National Infrastructure Pipeline, 2022-25, Sector-wise Fund allocation in % (source : DoEA, MoF, 2019)