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TELECOM TOWERS IN INDIA - ENERGY SUSTAINABILITY ASPECTS

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Abstract

Energy consumption and over-dependence on conventional energy sources for telecom operations are becoming significant concerns for countries. With climate change and global warming taking center stage globally, it is desirable that energy consumption is reduced and sincere efforts are made to transition towards renewable energy sources. India is taking proactive steps in this direction, implementing actions at both policy and operational levels to reduce emissions from its telecom sector significantly. Given that telecom towers consume substantial energy for signal transmission, this article discusses the necessary actions to reduce energy consumption by energy-efficient technologies and products, minimising resources used in telecommunication, improvement of the intelligence of the network through trade-offs between energy consumption and traffic leads and shifting towards renewable energy sources, with a key focus on policy and operational aspects so that a general framework for green telecom is developed in India. A typical calculation for the energy saving that results from migrating to renewable energy sources is also done using replacement cost and payback period calculations.

Keywords:

Green House Gases, Base Trans-Receiver Systems, Green Telecommunications, 5G Technologies, Radio Access, Renewable Sources of Energy

1. INTRODUCTION

The incidences of severe heatwaves, droughts, and floods have escalated in recent years, leading to significant destruction of homes and livelihoods particularly in small and low-income countries. Extreme weather patterns are largely attributed to ‘climate change’ and the ‘global warming’.

The rise in the Earth’s average temperature compared to the pre-industrial levels is commonly termed as 'Global warming'. The term 'Climate Change' is a broader term. It encompasses a broader spectrum of changes in the climate including that of typhoons, flash floods, iceberg melting, etc. Both phenomena are primarily driven by carbon emissions and Greenhouse gases (GHG) [1].

Climate change is currently the most formidable challenge faced globally, necessitating urgent and coordinated international action. To achieve a sustainable future, all countries must collaborate and contribute to reducing GHG and carbon emissions across the sectors.

The United Nations ‘Conference on Sustainable Development’ was held in Rio de Janeiro in the year 2012, wherein the term ‘Sustainable Development Goals (SDGs)’ was introduced. These goals encompass 17 universal objectives and associated strategies to address critical environmental, political, and economic challenges [2]. Among these, the seventh goal has an emphasis on ‘affordable and clean energy’.

The global initiative to reduce greenhouse gas emissions started with the establishment of the United Nations' 'Kyoto Protocol' in the year 1997. The agreement thereof mandated a 5% reduction in the emissions from year 1990’s levels during the initial commitment period (2008-2012). Later on, the ‘Doha Amendment’ in the year 2012 extended the ‘Kyoto Protocol’ for an extended commitment period from 2013-2020 and thus necessitating participating nations to achieve a minimum 18% reduction in Green House Gas emissions below the levels of the year 1990 the year 2020 [3].

'Copenhagen Summit' of the United Nations was held in the year 2009 wherein climate change was recognised as a significant global challenge. urging nations to limit further temperature rise to below 20^0C. As a participant in the agreement, India has formally committed itself to reducing the intensity of its carbon emissions significantly by 25% by the year 2020[4]. This was later enhanced to 45% by the year 2030, over the base 2005 level. In Paris, an agreement has been set to limit global warming to less than 20^0 C and 1.5^0 C [5].

The Glasgow summit (November 2021) highlighted the need to continue progress towards 'Net-Zero' and to keep global warming below 20C. However, it also projected that current efforts might lead to a temperature rise above 2.40C by the year 2100 if the ‘Nationally Determined Contributions’ (NDC) persist [6].

According to the European Union’s Copernicus Climate Service, from June 2023 to June 2024, average global temperature was the highest on record so far, being 1.64°C higher than the fossil fuel era (1850-1900) [7]. This increase has led to more frequent and intense extreme weather events, emphasizing the need to focus on reducing GHG emissions. A Council for Energy, Environment, and Water report indicates that over 80% of India's population is vulnerable to climate disasters, with low adaptive capacities exacerbating the impact of floods, landslides, and heatwaves. Since 2005, there has been an almost 200% increase in the intensity and frequency of extreme climate events in India [8]. Thus, India needs to make concerted efforts across all sectors to mitigate climate change.

2. GROWTH OF TOWERS AND BASE TRANS-RECEIVER SYSTEMS (BTS) IN THE TELECOM SECTOR

Information and Communication Technologies (ICT) leverage electronics and the internet to perform various tasks, offering potential contributions to clean and green energy solutions in both the ICT/ telecom sector and beyond. The rapid digitalization worldwide has increased energy consumption and associated emissions. According to the International Telecommunication Union (ITU), two-thirds of the global population is currently utilizing the Internet [9]. The ICT sector's proportion of global carbon emissions varies from 1.5% to 4% [10]. Reports from the ITU and the World Bank indicate that a minimum of 1.7% of global emissions arise from the ICT sector [11].

Within the ICT/telecom sector, mobile telephony plays an important role in reducing carbon emissions and GHG through the adoption of green technologies. While the global ICT industry's carbon footprint has a relatively small share, it significantly contributes 9-10% at the national level, necessitating urgent action to mitigate its impact [12].

Mobile services have undergone significant transformations globally, particularly with the advent of 4G and 5G technologies, which have introduced new applications and opportunities. Mobile telephony services and broadband/ internet connectivity are integral to daily life, facilitating communication through calls, videos, SMS, and chats.

Telecom is a key GHG emitting sector for India, which has a high telecom density. With large-scale digitization touching almost every sectors of the economy and majority of the citizens, role of the ICT sector is expected to expand significantly in the coming few years. It also signifies an urgent step to make the growth sustainable.

In line with international agreements and protocols, India has initiated steps to reduce energy consumption and transition to renewable energy sources, impacting sectors such as telecommunications and transportation. These efforts aim to decrease GHG emissions and promote greener technologies.

At Present India has approximately 1.2 billion telecom subscriptions [13], supported by over 800,000 telecom towers nationwide. These towers host around 3 million BTS and antennas for signal transmission and reception [14].

The growth of the trajectory of towers and BTSs over the past six and a half years is detailed in the Fig.1 below:

Fig.1. Telecom Towers in India (Source: Department of Telecom website www.dot.gov.in

The operation of telecom towers needs continuous electricity primarily sourced from grid power for uninterrupted telecom and broadband services. However, many towers in rural and hilly areas face unstable grid power supply, leading to reliance on alternate energy sources like diesel generator sets. With a major share of Indian electricity (75%) being generated using coal, both the grid power and diesel generators contribute to GHG emissions, increasing the carbon footprint and exacerbating global warming and climate change. Additionally, energy consumption by these towers represents a significant operational expenditure for telecom service providers, accounting for about 25% of their operational costs, according to a Global System for Mobile Association (GSMA) white paper [15].

2.1 STAKEHOLDERS IN TELECOM TOWERS BUSINESS

There are several entities involved in the whole value chain for the provisioning of mobile services and wireless broadband /internet services.

- Site owner
- Tower Manufacturer
- Electronics/ equipment manufacturer
- Renewal energy sources (Solar/Wind etc) equipment manufacturer
- Diesel Generator (DG)manufacturer
- Battery manufacturer
- Telecom Service providers (TSPs)
- Installation and operations maintenance persons for towers, Solar, DG, and battery
- Grid power supplier and diesel supplier
- Mobile/ Broadband user

The co-relation amongst these entities(stakeholders) is depicted in the Fig.2 below:

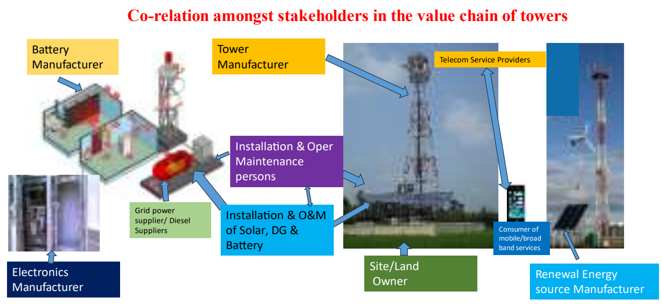

Fig.2. Value chain of Telecom Tower (Authors work based on discussion with experts)

The stakeholders need to take remedial measures coherently to reduce the adverse effects at the ground level.

2.2 TYPICAL CALCULATION OF POWER LOAD AND ENERGY CONSUMPTION OF A TELECOM TOWER

Power load and energy consumption of a telecom tower vary based on factors like type of equipment, number of users, and environmental conditions etc.

India today has the maximum number of 4G subscribers. A ballpoint calculation for power consumption at telecom towers is explained below.

The antenna is rated at 20W. In order to supply output on the eNode-B at the base station, which communicates with the subscriber's mobile via the antenna, it is rated at 150W. An additional 50W is required to power the associated electronics that prepare the signal for transmission. The tower may also necessitate cooling or heating. Furthermore, there are inefficiencies in the power distribution grid, which can lead to an overall power demand of 250–500W for each transceiver (TRX). A typical 4G tower site would encompass 3 sectors, 2x2 MIMO (Multiple-Input Multiple-Output), and 2 carriers, resulting in a total of 12 TRXs.

Hence, the aggregate power requirement at the location falls within the range of 3 kW to 6 kW, derived from the multiplication of 12 TRXs by the power range of 250W to 500W. Assuming uninterrupted functionality, the mean power demand for a location equates to 5 kW, resulting in an energy consumption of 120 kWh (5 Kw x 24 hours) in a day. This culminates in an annual energy consumption of 43.8 MWh (120x365).

To power a telecom tower completely with green energy, a combination of renewable energy sources, storage, and power management systems shall be required. Possible green energy solutions are discussed below:

a) **Solar photovoltaic module-based energy solution**:
b) Energy = No. of panels * Rated Power of each Panel * Sunlight hours/day
c) Assuming a 500 Watt panel, receiving 6 hours of solar insolation, available for 300 Days in a year
d) Total number of solar panels required = 43.8*1000 (KWatt hours)/(500*6*300)=48 Solar panels, equivalent to 24000 watts, or 24 kW capacity.
e) Most telecom sites would have a limitation in terms of space to accommodate this number of modules. Therefore, to have uninterrupted communication through telecom towers, a combination of Solar panels, batteries, DG set and Grid power i.e., a hybrid solution will be practical.
f) **Wind Energy**: Small wind turbines can complement solar PV, especially in windy areas, by providing power when solar generation is low. A hybrid system combining wind and solar is often more reliable for 24/7 operations. However, not all locations are endowed with wind energy, which itself is seasonal in terms of generation (monsoon months).
g) **Battery Storage**: Batteries are crucial for storing excess energy generated during the day or windy periods. A battery system with a storage capacity of around 120-300 kWh can support a telecom tower for 24-48 hours without sunlight or wind. Batteries are very expensive and are often seen as the next resort after Renewal sources and Grid power sources of energy.
h) **Fuel Cells**: In remote or highly critical sites, hydrogen fuel cells can provide backup power, offering higher reliability with lower environmental impact than diesel generators. This is an expensive and unproven technology, currently being experimented across a few telecom tower locations.
i) **Smart Controllers:** Now a days, smart controllers are available. The controller manages multiple available energy sources at the site and optimizes them to the most efficient level. It will try to prioritize solar power as the first source, then it will try to use the grid, which is the most economical source of energy at this moment. Then in the absence of both these sources, the controllers will try to manage the site with the battery power. As a last resort, it will use diesel generators to power the telecom towers.

3. ENERGY SAVING AND COST OF REPLACEMENT & PAYBACK PERIOD

As stated in Section 4, a telecom tower normally consumes 120 KW of power daily (5KW for 24 hrs) and to replace a tower completely with Green Energy a total of 48 panels will be needed. However, for calculation purposes, it is assumed that 75% of energy is from the Grid and 25% from the DG sets. If the commercial electricity rate is Rs8/Unit and Diesel rates are Rs90/Litre. Further, assuming that a 25KVA rating DG set is used at a telecom tower site.

A broad calculation of energy/cost saving calculation is as below. KVA to kW conversion formula is:

$$KW = KVA \times \text{Power Factor (PF)} \tag{1}$$

PS: For a typical DG set, the power factor is around 0.8.

$$KW = 25\ KVA \times 0.8 = 20\ KW \tag{2}$$

3.1 CALCULATION OF OPERATING HOURS TO GENERATE 900 KWH

To determine how many hours the DG set needs to run to produce 900 kWh of electricity:

Operating Hours= Power Output of DG set (KW)/Total Energy Required (KWh)

Operating Hours=900 kWh/20 kW=45 hour

The specific fuel consumption (SFC) of a 25 KVA DG set typically ranges from 0.21 to 0.24 litres per kWh. A PS:-SFC value of 0.22 litre/hr is assumed. The calculation for

Diesel Consumption per Hour=Power Output (kW)×SFC (L/kWh)

= 20*0.22=4.4 litre/hr

For 45 hrs running total diesel will be

=4.4*45=198 litres (Say)=200 Litres

With diesel charges at 90 per litre Total cost will be: 200*90 = Rs 18000

3.2 TOTAL COST OF ENERGY CALCULATION

a. Total Energy Consumption/month =5*24*30=3600KWh
b. Energy from Grid (75%) =0.75x3600=2700 KWh
c. Energy from DG set(25%)=0.25*3600=900 KWh
d. Grid energy charges=2700*8=Rs21600
e. Diesel consumption for 900KWh by a 20KVA DG set will be =200 litres
f. DG sets running charges=200*90=18000
g. Total Cost of Energy=21600+18000=Rs 39600 (Say)= Rs. 40000.

This entire cost of energy can be saved when a telecom tower's conventional sources of energy are replaced with renewable sources of energy.

3.3 REPLACEMENT COSTS CALCULATION WHEN THE GREEN ENERGY IS SUPPLIED BY SOLAR CELLS:

3.3.1 Solar Energy Replacement:

If the entire (100%) of the energy requirement (120 kW daily or 3600 KW monthly) with solar energy, using 48 solar panels(refer section 4 calculations) of 500Watt each.

3.3.2 Power Output of Solar Panels:

a. Total power output of the solar panels:

Total Solar Capacity=48 panels×500 W/panel=24 kW

b. Assuming 6 effective sunlight hours per day(refer section4 assumption),Total daily energy generated by the solar system:

Daily Solar Energy=20 KW×6 hours/day=120 KWh/day

This means that with 48 panels, 120 kWh/day of the total 120 kWh requirement can be met entirely.

3.3.3 Cost of Solar Energy:

The major cost for solar energy is upfront installation. Once installed, the operating costs are very low (almost negligible compared to diesel and grid energy). For simplicity, we assume no operational costs for solar power after installation.

- **Monthly Savings calculation**: By replacing grid and DG set energy with solar energy, the monthly savings would be:

Monthly Savings=Total Monthly Cost Without Solar=Rs40,000

- **Payback Period for Solar Investment**: The payback period depends on the cost of the solar installation. Assuming the cost of a solar installation is Rs5Lper 10kW, the total solar cost for a 24 KW system would be: =24KW×Rs5L/10kW=Rs12L

Payback period=Solar Installation Cost/Monthly Saving

=Rs12,00,000/Rs40000≈30 months

Therefore, the estimated monthly cost savings by switching from grid and diesel generator energy to solar energy would be ~Rs40000 and the solar system would pay for itself in approximately 30 months (assuming current energy rates and system costs) or in about two and a half years. To promote the Telecom service providers to switch over to Green energy-based systems efforts will have to be made both at the Policy and Operations level.

4. POLICY AND OPERATIONS-LEVEL SUSTAINABLE INITIATIVES IN INDIA

4.1 POLICY LEVEL INITIATIVES

- **Government Policies**: The Indian government is implementing policies to encourage telecom and internet service providers to utilize more green energy sources.

4.2 POLICY LEVEL INITIATIVES: EVOLUTION AND IMPACT

Over the last decade, there has been significant policy evolution for energy sustainability in India's telecom sector.

4.2.1 Extant Policies:

a) 2011: Telecom Regulatory Authority of India (TRAI)'s 'Green Telecommunications' Initiatives:

- In the year 2011, TRAI came out with a public consultation paper on "Green Telecommunications" wherein key policy issues including carbon footprint estimation, infrastructure sharing, and renewable energy adoption were raised [16].
- After extensive public consultations, TRAI made its recommendations to the Department of Telecommunications(DoT), Government of India. Some of the salient recommendations are as below:
  i. **Hybrid Power**: By 2015, TRAI expected that 50% of rural telecom towers and 33% of urban telecom towers will be powered by hybrid power, utilizing both Grid power and Renewable Energy Technologies. By 2020, the aim is for all rural towers to be powered by this method, with 50% of urban-located towers.
  ii. **Green Passport Certification**: It recommended that by 2015 the telecom products, equipment, and services should be certified 'Green Passport' for energy efficiency.
  iii. **Carbon Footprint Declaration**: TRAI mandated that Service providers are required to disclose the carbon footprint of their network operations to TRAI on an annual basis.
  iv. **Voluntary Code of Practice**: To enhance sustainability and efficiency, it is imperative for service providers to implement energy-efficient network planning, engage in active infrastructure sharing, and integrate renewable energy technology.
  v. **Emission Reduction Targets**: Aiming 8% reduction in carbon emissions by 2012-13, 12% by 2014-15, 17% by 2016-17, and 25% by 2018-19.

The Department of Telecom, Govt of India, accepted most of these recommendations and accordingly issued directions to the telecom operators during the year 2012 [18] to comply with the targets as has been enumerated in the TRAI's recommendations.

4.2.2 2012: National Telecom Policy (NTP-2012):

The goal of NTP-2012 was to further the implementation of environmentally friendly policies within the telecommunications sector and to promote the utilization of renewable energy sources to ensure long-term sustainability [19].

4.2.3 2013: Renewable Energy Technology (RET) Committee Formation:

The telecom service providers through their Industry association, the Association of Indian Chambers of Commerce (ASSOCHAM) opposed the directions issued by DoT, terming them as unrealistic and illogical since these directions ignored the ground realities and technical constraints [20]. As a result, the targets set by DoT were not met despite efforts made by TRAI and DoT. In 2013, the DoT established a Renewable Energy Technology (RET) committee to develop a comprehensive roadmap and secure funding for the deployment of renewable energy technology within the telecom sector. This initiative aimed to address the industry's concerns. The committee gave its report in 2014. These recommendations underwent scrutiny by an inter-ministerial committee, which later resolved to request TRAI's recommendations, inclusive of the implementation of renewable energy technology in the telecommunications sector.

4.2.4 2017: TRAI's Consultation on Sustainable Telecommunications and its recommendations:

Pursuant to the DoT’s reference seeking TRAI’s recommendations on the subject, TRAI held another round of stakeholder consultation, vide its consultation paper titled ‘Approaches toward Sustainable Telecommunications’ dated 16th January 2017 [21]. In the consultation paper, TRAI raised several issues like the types of renewable energy sources available that can be used to provide power to the telecom sector and the methodology for fixing targets for the use of renewable energy. Following extensive public consultation, the TRAI submitted recommendations to the DoT, proposing, among other measures, that the revised targets for reduction in carbon emissions be established at 30% by the fiscal year 2019-20, using 2011-12 as the base year, and 40% by the fiscal year 2022-23 [22].

Pursuant to the recommendations put forth by the TRAI, the DoT has unveiled revised voluntary measures aimed at fostering sustainable telecom practices. These measures underscore the voluntary nature of RET targets, set a target of up to 40% reduction in carbon emissions by the conclusion of 2022, necessitate the submission of mandatory reports on carbon footprint per user, and introduce a Carbon Credit Policy that mandates a 50% reduction in carbon footprint in rural areas and a 66% reduction in urban areas [23].

4.2.5 2018: National Digital Communication Policy (NDCP-2018):

NDCP-2018 envisaged for the adoption of alternative energy sources, such as fuel cells and Li-ion batteries widely, and prioritizes research and development efforts aimed at the identification and exploration of new energy sources. Additionally, the policy underscores the importance of undertaking research and development initiatives to further explore and harness these alternative energy sources [24].

4.2.6 Other Government Initiatives:

- **NITI Aayog’s Energy Storage Roadmap (2019-32)**: Emphasizes the importance of energy storage for integrating renewable energy into India’s power system. It has been determined that India possesses an estimated potential of 900 GW (Giga-Watt) for electricity generation from renewable sources [25].
- **International Energy Agency Report (2020)**: Highlights India’s ambitious renewable energy targets, including 175 GW by 2022 and 450 GW in the future. It noted that under its Nationally Determined Contributions (NDC), India has set itself a target of non-fossil-based capacity in the electricity mix of more than 40% by 2030. Additionally, India aims to reduce the emissions intensity of its GDP by 33-35% by 2030, in comparison to the levels recorded in 2005 [26].
- **Green Energy Open Access**: In the policy the threshold for open access transactions has been lowered from 1 MW to 100 kW for green energy, thus empowering small consumers to actively purchase renewable power through the open access channels.

4.2.7 Operational Level Interventions:

- **Energy Consumption Reduction**: This objective can be realized through the development of environmentally sustainable electronics and the implementation of strategic network planning. The architectural design of facilities accommodating these electronics can be tailored to be environmentally conscious, thereby minimizing power consumption.
- **Renewable Energy Migration**: Transitioning towards renewable energy sources to mitigate the effects of global warming.

5. ENERGY CONSUMPTION REDUCTION

This can be achieved in the following manner-

5.1 5G TECHNOLOGIES:

- 5G technology addresses energy efficiency from the design stage, offering a twentyfold improvement over Long-Term Evolution (LTE) or 4G technology. It allows for efficient resource allocation and power management at the equipment level, reducing power requirements and the need for air conditioning. 5G technology also allows flexible use of the available spectrum which is an essential element for wireless communications and has a direct effect on energy consumption.
- With massive MIMO(Multiple-Input Multiple Output) antenna technologies, which use beamforming to direct the signals more precisely to users results in reduced power needed and thus increased overall energy efficiency.

5.2 EFFICIENT NETWORK OPERATIONS:

- Traditional mobile networks allocate only a small portion of their power (15-20%) to actual data transmission [28]. The majority of power is dissipated as a result of heat loss in power amplifiers, the continuous operation of equipment during idle periods, and the inefficiencies of rectifiers, cooling systems, and battery units. Emerging strategies are being pursued to mitigate and eliminate this inefficiency:
  1. **Cell Switch-off Techniques**: The reduction of base station energy consumption by up to 40% can be achieved through the deactivation of radio-frequency (RF) chains when the base station is not in use. Activation of the base station occurs solely in response to the detection of a signal [29].
  2. **Artificial Intelligence (AI) and Machine Learning (ML)-Driven Smart Shutdowns**: Using AI to reduce power consumption across multiple sites and networks [30]. AI and ML can optimize network performance by predicting user demand and dynamically managing network resources. For example, during off-peak hours, certain network parts can be powered down, or capacity can be scaled based on real-time demand.

iii. **Single Radio Access Network (RAN) Platforms**: Combining multiple technologies in a single base station can reduce power consumption.

iv. **Sunsetting Older Technologies**: Phasing out 2G and 3G systems which consume more power than 4G&5G networks.

v. **Dynamic Spectrum Sharing (DSS)**: Allowing new technologies to share older networks' spectrum dynamically. DSS technologies minimises power usage during low traffic periods by allocating fewer resources to 4G/5G when it is not in high demand thus reducing overall network power consumption.

vi. **IoT Sensors:** IoT sensors can do real-time monitoring of energy usage, network infrastructure, detect inefficiencies, and adjust power usage dynamically. This allows optimisation of energy consumption based on actual demand and thus reducing unnecessary power usages during off-peak hours. In addition, IoT sensors can be integrated with AI systems to reduce power consumption, cooling of the equipment, remote site management, battery operations optimisation etc

vii. **Self-Organizing Networks (SON)**: By utilizing AI in real-time network optimization, SON enables more intelligent and automated management of telecom networks, leading to reduced power consumption by dynamically optimizing the network's use of energy-intensive components. SON optimises power usage by optimising resource allocation, energy-efficient handover, traffic load balancing and dynamic network configuration.

5.3 END-TO-END INTELLIGENT POWER SYSTEMS:

- Integration of cloud infrastructure and artificial intelligence (AI) yields fully intelligent power systems capable of coordinating equipment across multiple layers, thereby enhancing operational efficiency. A cloud-based system facilitates the coordination of base tran-receiver stations, power supplies, edge infrastructure, backhaul units, and other equipment across various layers and domains, resulting in the optimization of power supplies and efficiencies throughout the network. AI-driven intelligent energy allocation enables the provision of varying power levels based on the time of day or specific applications.

6. RENEWABLE ENERGY MIGRATION

Telecommunication towers are substantial consumers of energy. Transitioning to renewable energy sources, particularly solar power, has the potential to significantly mitigate the environmental footprint associated with their operation. It is pertinent to note that India has secured the fourth position globally in wind and solar power capacity as of 2023. India is also ranked fourth in terms of installed renewable energy capacity. India has witnessed a sharp increase in installed renewable power generation capacity in recent years, achieving a compound annual growth rate (CAGR) of 15.4% between the financial year 2016 and the Financial Year 2023. As of July 2024, India's renewable energy capacity stands at 150.2 GW, as depicted in Figures 3 and 4. India emerges as the fastest-growing market for renewable electricity, with projections indicating a doubling of new capacity additions by 2026 [31]. It is also the first G20 nation that has achieved its renewal energy capacity target.

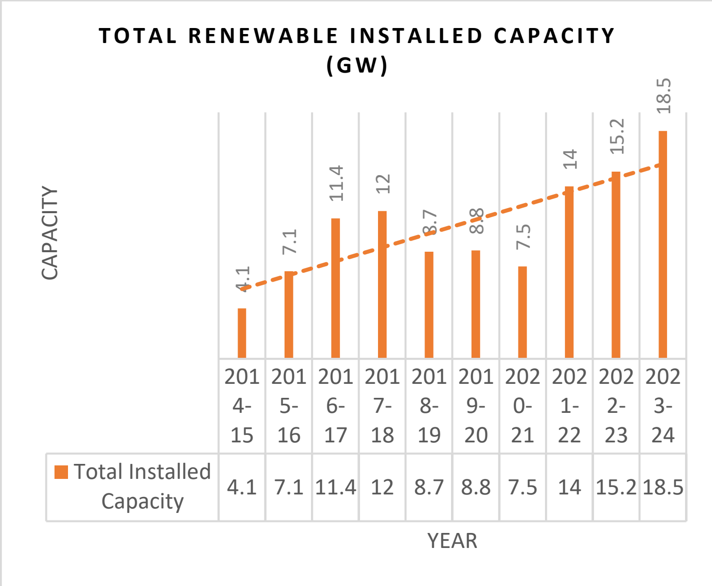

Fig.3. Renewable Capacity India (Authors work using data from government ministry)

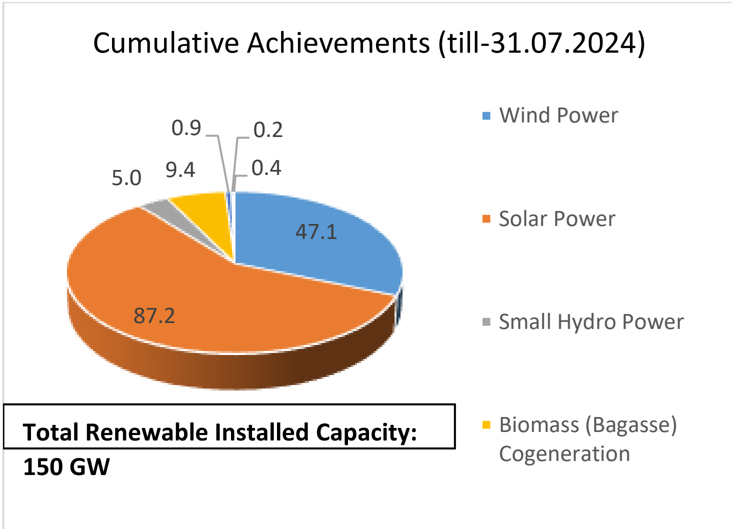

Fig.4. Renewable Installed Capacity (Authors work using data from government ministry)

7. RENEWABLE SOURCES OF ENERGY FOR TELECOM TOWERS

The following renewable energy sources can be utilized to power telecom towers:

7.1 SOLAR POWER

India, positioned within the solar belt between 40° S to 40° N, is a significant beneficiary of solar energy. The solar power capacity in India has increased significantly by more than 18-

times between March 2014 where it was 2.63 GW to 49.3 GW by the end of of 2021. As it is known that in contrast to diesel, solar electricity presents a sustainable, cost-effective, and environmentally friendly power source for the expanding telecommunication sector. Hybrid models, which combine power from the grid and solar cells, are increasingly used in telecom towers to reduce dependence solely on grid and diesel generators. The Fig.5 depicts a solar-powered telecom tower located in India.

Fig.5. Hybrid power supply to telecom towers (Sourced from a telecom tower company)

7.2 WIND POWER

Wind power represents a clean, reliable, and cost-competitive form of renewable energy. When integrated with solar power as a hybrid renewable power source, wind power generation is experiencing growing popularity, leading to increased installation of wind turbines. Key challenges associated with wind power include the cost, the impact of variable resources on the grid, and site location. Nevertheless, recent technological advancements have notably enhanced wind power solutions.

7.3 GEOTHERMAL POWER

Geothermal power harnesses the Earth's natural heat by tapping into underground hot water or steam. Low-temperature geothermal sources can be utilized for heating and cooling through heat pump systems, while high-temperature geothermal sources can generate clean, renewable electrical energy by driving turbines.

7.4 FUEL CELLS

Fuel cells function by combining hydrogen and oxygen to produce heat and electricity. Although they perform optimally with pure hydrogen, they can also utilize reformed fuels such as natural gas, methanol, or gasoline to generate the necessary hydrogen. Unlike batteries, fuel cells have the capabilities to continuously generate electricity as long as they are supplied with fuel, making them a promising technology for ensuring consistent power supply.

7.5 OTHER INNOVATIVE SOLUTIONS

Wave power, tidal power, and ocean currents possess the potential to drive turbines for electricity generation. Ongoing technological advancements aimed at harnessing these forms of energy indicate substantial progress toward commercialization.

8. TECHNICAL EVALUATION OF RENEWAL SOURCES-BASED SOLUTIONS FOR DIFFERENT GEOGRAPHIC REGIONS IN INDIA

India is a geographically and climatically a diverse country. On the one hand, India has regions like Rajasthan and Gujarat where ample sunlight is available and coastal areas where ample wind power is available, on the other hand, it has regions like Meghalaya, Nagaland, Mizoram, J&K etc which are cloudy/low solar regions. These different geographies have different types of challenges. While high solar regions have challenges of high dust levels due to dry weather, and temperature fluctuations the low solar regions require uninterrupted grid or DG supply and high battery backup for sustained operations. Similarly, there are different challenges in rural and urban areas in India. In urban areas finding space for towers both Ground-based towers and roof-top towers is a challenge while in rural areas transportation of material and diesel for DG sets increases operational costs. In the case of wind-energy based systems also there are different challenges in coastal and hilly regions. In coastal regions the maintenance cost is high due to salt-corrosion and storms like Cyclone etc. In the hilly areas, terrain remains mostly uneven and wind speed variability is high.

In order to have optimise solutions to the challenges as have been discussed, it becomes necessary to go for hybrid solutions by integrating two or more systems. As discussed in section 4 of this paper, smart controllers are now available, which can manage multiple available energy sources at the site and optimizes them to the most efficient level. These controllers integrate solar, wind, grid, and DG set-based power sources and manage the supply of power by switching between these sources based on their availability and load requirement. With the availability of net-metering these controllers also help in feeding excess renewal power/energy available at telecom towers into the grid thus reducing energy costs.

8.1 BARRIERS TO RENEWABLE ENERGY IMPLEMENTATION AND REMEDIAL MEASURES

Several policies, regulatory, legal, Financial and techno-economic obstacles need to be overcome for effective implementation of green telecom using renewable energy sources. Some of these barriers/obstacles are possible remedies are discussed below:

- **Policy Level Challenge:** The landscape of policies related to green telecom is undergoing development. It is imperative to establish clear, well-defined, and unambiguous policies. An illustrative example is the recent adjustment in the Green Open Access rules, where the limit of Open Access Transaction has been revised from 1 MW to 100 KW for green energy. This modification aims to facilitate the purchase of renewable power through open access for small-scale consumers. As open-access solar projects rely on state transmission networks, the small-scale consumers have to bear additional charges levied by their respective states. Some states still have to implement these rules and give benefits to consumers including telecom/infrastructure providers.

- **Land Acquisition for Green Energy and space constraints:** Acquiring land for clean energy projects like that of Green Energy in India presents challenges, primarily due to the scarcity of suitable lands and the associated and existing connectivity challenges. Similarly, there are space constraints to install renewal energy of power and require efficient space planning particularly in urban areas. Implementing specific measures could rectify these challenges. One potential solution could be to have dedicated land banks tailored for solar projects, ensuring easier access to suitable land parcels for establishing solar and telecom towers both. Further incentivising ‘clean energy projects would increase tower infrastructure provider’s confidence and will ease their financial burdens associated with land acquisitions.
- **Cost:** Many renewable energy technologies continue to be costly due to their higher capital expenses in comparison to conventional energy sources. However, through the widespread proliferation of green towers, economies of scale can be attained in the long term.
- **Initial Investment:** Renewable energy technologies necessitate substantial initial investment and may require long-term support before achieving profitability. Incentives from the governments in terms of easy availability of land and connectivity will reduce the financial burden on the tower infrastructure companies.
- **Consumer Awareness:** Due to a lack of proper awareness, there have been instances where in rural areas solar panels, diesel for DG Sets and batteries of the tower electronics have either been tampered with or stolen in isolated and rural areas. Therefore, there is a need for increased stakeholder awareness regarding the benefits and opportunities of renewable energy. This will reduce tempering with the solar panels as is being observed in rural areas.
- **Availability of semiconductors and electronics:** There have been challenges in the availability of semiconductors and electronics, thus affecting the telecom towers installation and conversion to green telecom. This obstacle can be overcome if India can manufacture Semiconductor chips and associated electronics to cater to its own needs. This will result in reducing the dependency of other countries for the supply of electronics for towers and other mobile services equipment.
- **Maintenance and Reliability:** Solar panels and wind turbines need periodic maintenance to function optimally, especially in harsh weather conditions like extreme heat, cold, or dust storms. This issue can be addressed by having remote monitoring systems and using robust, weather-resistant equipment.
- **Renewal energy production:** In the case of solar energy production the challenges are the variability of solar power. Solar power generation is highly dependent on weather conditions and geographical location. Remote areas may experience long periods of cloud cover, monsoons, or reduced sunlight during winters, leading to fluctuating power output. Further, the energy produced by solar panels depends on several factors, such as the tilt angle of panels, dust accumulation, and shading from nearby structures or terrain. In remote areas, dust and debris may accumulate on solar panels without regular maintenance, reducing efficiency. Similarly in case of Wind energy, the remote areas may not always have the consistent wind speeds required for efficient wind energy production. Wind patterns can vary significantly, and turbines may underperform during periods of low wind. Maintenance of turbines particularly in remote areas becomes challenging. One solution could be to go for hybrid solutions Hybrid systems i.e. combining solar and wind energy. Even though they provide more stable power supply, they still face technical issues related to intermittency. These challenges can be overcome by having energy storage systems for ensuring a continuous power supply in renewable energy-based telecom tower operations, especially in remote areas.
- **Challenges in Energy storage systems:** In telecom tower bases for energy storage Lithium-ion or lead-acid batteries are commonly used. These energy storage systems store renewable energy generated during peak production (daytime for solar panels or windy periods for wind energy). This stored energy can then be used when renewable generation is low or unavailable (e.g., nighttime or cloudy days). Though there can be challenges like the size of storage, life span and efficiency etc. However with the latest development in energy like hydrogen energy etc, it can be expected that these challenges will be overcome in future.
- **Other Challenges**: There are other challenges like Regulatory and Organizational Barriers, load management, Grid integration and environmental challenges etc.

To establish renewable energy technologies and cultivate markets in India, it is imperative to surmount financial, legal, regulatory, and organizational barriers [32].

9. CONCLUSION

9.1 IMPACT OF POLICIES

The implementation of favourable policies and heightened stakeholder awareness, particularly among Infrastructure Providers (IPs) and Telecom Service providers, has resulted in the successful transition of approximately 186,000 tower sites to diesel-free status. Over 40% of India's total telecom tower sites are now classified as Green, as their diesel consumption has been less than 100 liters per week. This achievement has led to an annual reduction of 334 million liters of diesel consumption [33]. Some of the other achievements are:

- **Conversion to Outdoor Sites:** At present, 60% of tower sites have undergone a conversion from indoor to outdoor infrastructure, making use of natural ventilation and free cooling units. Consequently, this transition has effectively obviated the requirement for air conditioning.
- **Use of Piped Natural Gas (PNG) Compressed and Natural GAS (CNG):** Replacing diesel with natural gas of these variants in existing generators, has significantly reduced carbon footprint.
- **Lithium-Ion Batteries:** The industry is undergoing a shift towards lithium-ion batteries as a replacement for lead-acid

batteries, thus offering an extended battery lifespan and increased energy efficiency.

- **Renewable Energy Service Company (RESCO) Model:** Providing sustainable energy to clusters of high-rise structures and distributing surplus power to the surrounding community.
- **Circular Economy and Lifecycle Assessment**: Integration of these principles into procurement processes, as recommended by the Next Generation Mobile Networks (NGMN) Alliance.
- **Global Standards:** In accordance with the objectives outlined in the United Nations Framework Convention on Climate Change as the Paris Agreement, the International Telecommunication Union (ITU) has established standards for evaluating the environmental lifecycle of ICT products, networks, and services.

In conclusion, it is the collective responsibility of all the stakeholders to ensure a sustainable and healthy environment for future generations. There will be substantial savings if all the telecom towers are moved towards green telecommunication towers. Further, Green Telecommunications represents a pivotal stride towards upholding this obligation. Through concerted endeavours, India can potentially be a global frontrunner in green initiatives and technology within the realm of telecommunications.

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