India Energy Security Scenarios, 2047

User guide for

Telecom Sector

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I Overview of the telecom sector

With 951.34 million subscribers as on March 2012[1], Indian telecom market is the second largest and fastest growing telecom sector in the world and is projected to overtake China. The telecom industry has attracted eight per cent of the cumulative foreign direct investment (FDI) over the past two years. Wireless telecommunication has the major share (96.6%)[2] in Indian telecom sector. Over 4,00,000 telecom towers form the backbone of the wireless telecom sector in India. The mobile subscriber base is expected to hit one billion by 2013-14 which would require more than 1,00,000 additionally towers to support this capacity. Operation of these telecom towers requires electrical energy which accounts for a significant share of the operational cost of these towers.

Due to uncertainty of availability of grid electricity, and long power cuts (especially in rural areas), diesel generators are used to ensure continuous power supply. This is not an economical option as the government subsidy on diesel has been aggressively exploited by the telecom sector, given the absence of dual or differential pricing of the fuel by use. This also encourages inefficient consumption of diesel by the telecom sector. The sector annually consumes around 3 billion litres of diesel to power its network towers. This results in an annual loss of around INR 26 billion to the state by way of diesel subsidy. It also has the disadvantage of increasing carbon emission, which has a negative impact on the environment. The diesel generators also emit 6.6 million metric tons of CO^2 annually. Although the share of telecommunications sector to the global carbon emissions is low, compared to other sectors like transportation and construction, but as increasing number of people will become connected by fixed and mobile telecommunications networks, the challenges related to providing electricity to these expanding networks will become greater. Therefore, with increasing energy consumption and rising cost of fossil fuels, it is important that we shift to energy efficient technologies and environment-friendly sources of energy to power the telecom sector.

The Telecommunication sector contributed gross revenue of Rs 49242.99 Crores in the fourth quarter (January-March) of the financial year (2011-12), registering 8.20 per cent change over March 2011.[3] The wireless phones dominate telecommunication market in India and wireline phone segment constitutes only 3 per cent of the total subscriber base (Figure 1). Some studies suggest that mobile phones have a positive impact on GDP.[4] Also, the 3G spectrum auction and bid values for broadband wireless access licenses generated tax revenue of more than Rs 100,000 crore (approximately 1 per cent of the GDP) to the Government in 2010.[5]

India Energy Scenarios, 2047 gives the user an opportunity to explore the energy trends of the telecom sector under four different scenarios (level 1 to level 4), particularly with a view to replace diesel with cleaner fuels.

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[1] 12th Five Year Plan, Economic Sectors, Planning Commission, Government of India, 2012

[2] The telecom sector in India: A decadal profile, Telecom Regulatory Authority of India, 2012

[3] TRAI Annual Report, 2012

[4] McKinsey and Company (2006), Wireless Unbound: The Surprising Economic Value and Untapped Potential of the Mobile Phone, http://ww1.mckinsey.com; and Vodafone (2009),
India: The Impact of Mobile Phones, Vodafone Policy Paper Series No. 9, http://www.vodafone.com

[5] Bhide, S. (2010), *The 3G Auction: What will we do with the extra money?* Macrotrack, National Council of Applied Economic Research, 12(5).

Figure 1: Subscriber Base

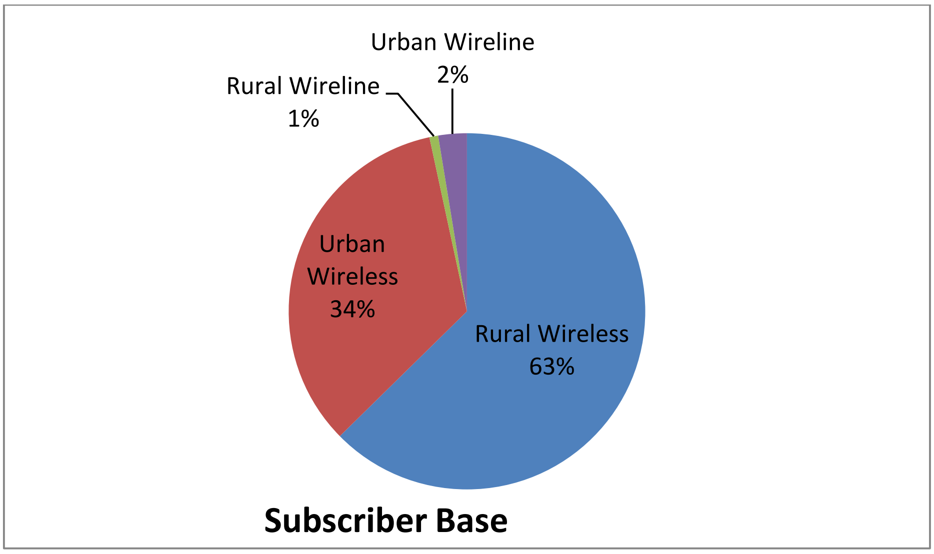


Table 1: Snapshot of Telecom Sector (As on 31st March 2012)[6]

Telecom Subscribers (Wireless + Wireline)	
Total Subscribers	951.34 Million
% change over the previous quarter	2.68%
Urban Subscribers	620.52 Million (65.23%)
Rural Subscribers	330.82 Million (34.77%)
Market share of Private Operators	86.31%
Market share of PSU Operators	13.69%
Teledensity	78.66
Urban Teledensity	169.55
Rural Teledensity	39.22
Wireless Subscribers	
Total Wireless Subscribers	919.17 Million
% change over the previous quarter	2.83%
Urban Subscribers	595.90 Million (64.83%)
Rural Subscribers	323.27 Million (35.17%)
GSM Subscribers	814.06 Million (88.56%)
CDMA Subscribers	105.11 Million (11.44%)
Market share of Private Operators	88.65%
Market share of PSU Operators	11.35%
Teledensity	76.00
Urban Teledensity	162.82
Rural Teledensity	38.33
Wireline Subscribers	
Total Wireline Subscribers	32.17 Million
% change over the previous quarter	-1.57%
Urban Subscribers	24.62 Million (76.54%)

[6] TRAI Annual report, 2012

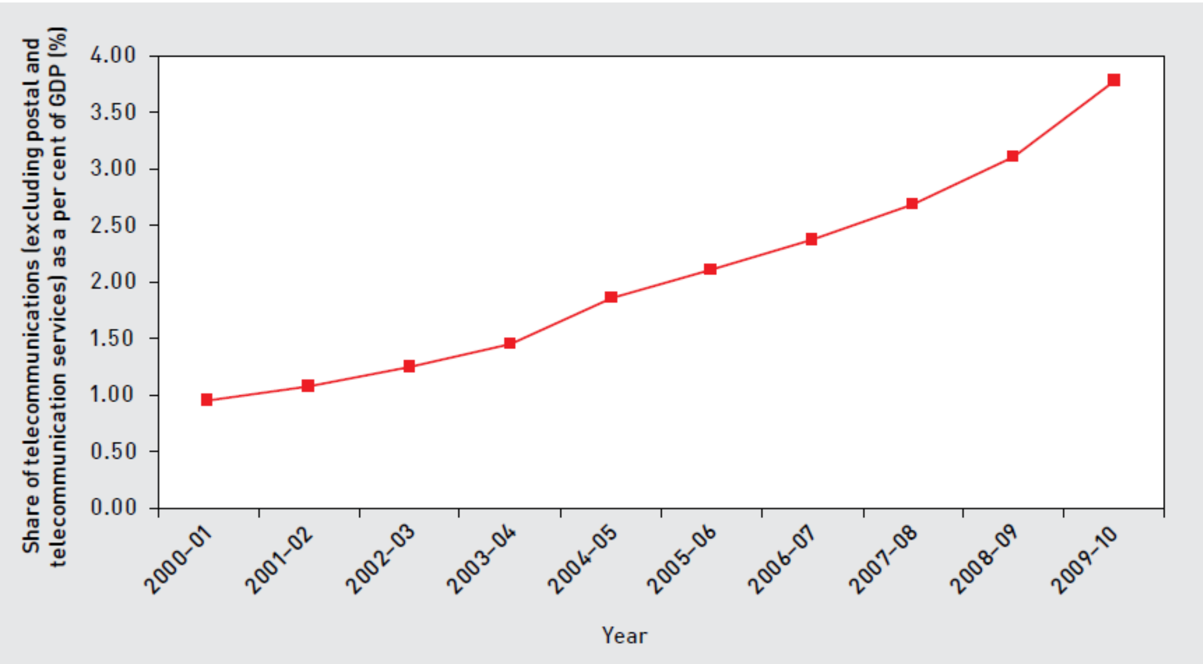
Rural Subscribers	7.55 Million (23.46%)
Market share of Private Operators	19.41%
Market share of PSU Operators	80.59%
Teledensity	2.66
Urban Teledensity	6.73
Rural Teledensity	0.89

Growth in Telecom Sector

Telecom sector in India has witnessed an exponential growth over the past decade. The share of telecom sector as a per cent of GDP has increased from 0.96 per cent in 2000-01 to 3.80 per cent in 2009-10 (Figure 2). Wireless segment is the key contributor to the record growth of total subscribers as well as the overall teledensity of the country.

The annual growth rate of wireless phones has increased over time and peaked at 159.2 per cent in 2003. During the period 2004-2011, it has averaged around 51.8 per cent. In 2011, the growth rate significantly decreased to 18.8 per cent. Mobile phones accounts for nearly 96.6 per cent of the total telecom subscriptions as of March 2012.[7]

Figure 2: Share of telecom sector as a per cent of GDP (%)[8]



[7] The telecom sector in India: A decadal profile, Telecom Regulatory Authority of India, 2012

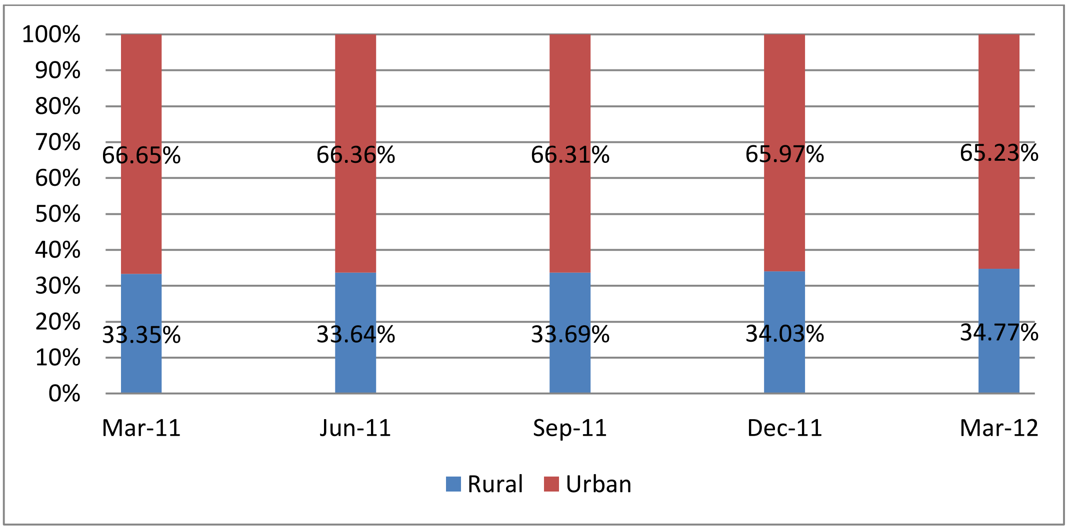
[8] National Accounts Statistics of India (2009) and various issues (NAS); EPW Research Foundation, Mumbai.

The total subscriber base in India has increased from 926.53 million at the end of December 2011 to 951.34 million at the end of March 2012, with a growth of 2.68 per cent over the previous quarter and yearly growth of 12.41 per cent. Subscription in urban areas increased to 620.53 million at the end of March 2012 from 611.19 million at the end of December 2011, increasing the urban teledensity[9] from 167.85 to 169.55. Rural subscription significantly increased from 315.33 million to 330.82 million, and the rural teledensity increased from 37.48 to 39.22. The annual growth rate of rural and urban teledensity between the months March 2011 and March 2012 was 16.08 per cent and 7.78 per cent respectively. Rural subscription has continued to show higher growth rate than urban.[10]

Table 2: Wireless Subscriber Base & Teledensity – Rural & Urban[11]

Quarter Ending	Subscriber Base (million)		Teledensity	
	Rural	Urban	Rural	Urban
March 2011	273.54	538.05	32.75	150.06
June 2011	289.57	262.12	34.58	155.96
September 2011	297.49	576.12	35.44	159.03
December 2011	307.59	586.26	36.56	161.01
March 2012	323.27	595.90	38.33	162.82

Figure 3: Urban and rural teledensity share[12]

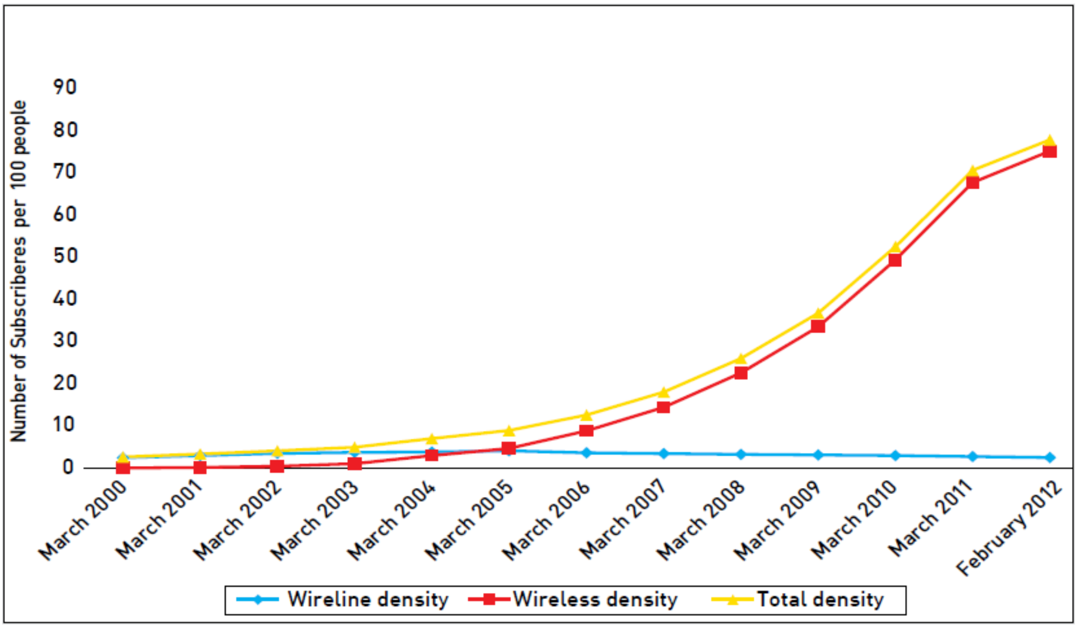


With the increase in the number of telecom subscriptions, the total teledensity has significantly increased from 2.81 in 2000 to 78.66 as on March 2012, registering a CAGR of 31.9 per cent. As the wireline teledensity remains almost steady at the CAGR of 0.19 per cent, this is mainly

[9] Teledensity can be defined as number of telecom subscribers per 100 persons.
[10] TRAI Annual Report, 2012
[11] TRAI Annual Report 2012
[12] TRAI Annual Report, 2012

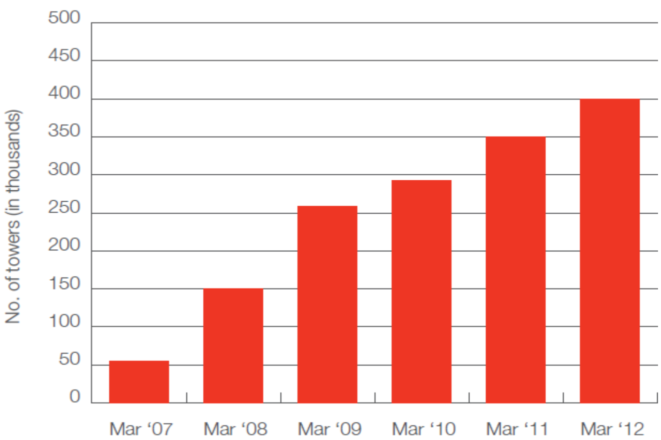
driven by the increase in wireless teledensity. Wireline density was higher than wireless till 2004 and then declined after peaking in 2005.

Figure 4: Teledensity over the period 2001-2012[13]



Due to exponential rise of wireless subscription base and wireless teledensity, number of telecom towers to support the capacity has also increased significantly. With only 50,000 telecom towers in 2007, there are 400,000 telecom towers in the country as on 31st March 2012.

Figure 5: Number of Telecom Towers (in thousands)[14]



[13] Telecom Regulatory Authority of India
[14] Telecom Regulatory Authority of India

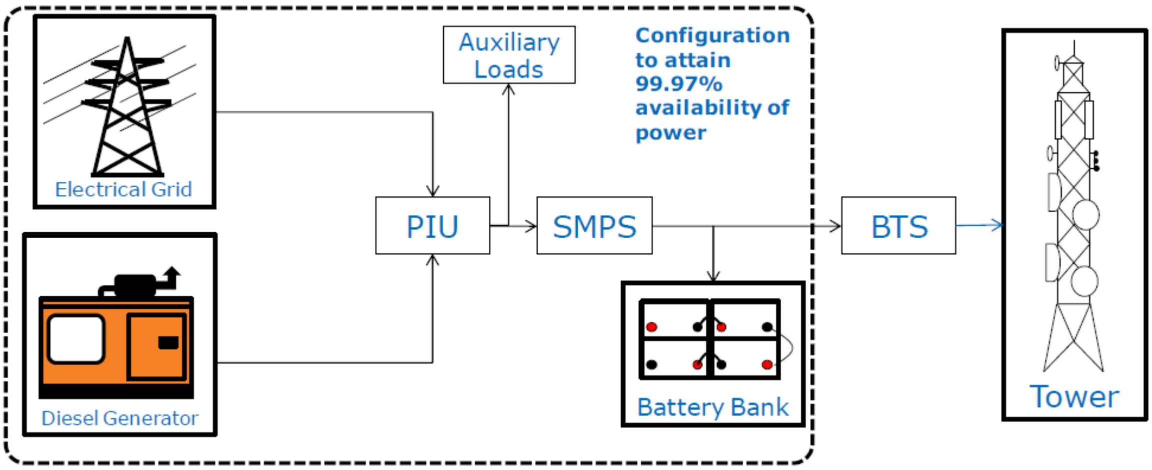
II Energy Requirement by Telecom Sector

The energy requirement for each telecom tower varies owing to several reasons. It depends on various factors such as number of subscribers, air conditioning requirements, efficiency of power instruments, site location, etc. This requirement is either met by grid electricity supply or backup technology such as diesel generator, solar power, wind power, fuel cells etc. Firstly, we discuss the configuration of a typical telecom tower, then the power required for each telecom tower, and lastly the grid supply availability to meet this energy requirement.

Configuration of a Telecom Tower

The power demand of a telecom tower is determined by the configuration of number of Base Transceiver Stations (BTS) in the cell tower. The power requirement of a tower varies from 1 kW to 8.5 kW, where more than 80% of these configurations have a power demand less than 3.5 kW.[15] To ensure 100% power availability to the tower, it is backed up by a combination of batteries and diesel generator to supplement the grid supply. The capacity of diesel and batteries are based on various factors such as geographic location, grid availability, equipment on site, etc. At majority sites, diesel generators of 10kVA to 15kVA capacity supplemented with a battery bank of 300Ahr to 900Ahr capacities is installed.

Figure 6: Schematic of power supply at the telecom tower



The power from electricity grid is fed into the Power Interface Unit (PIU) that selects the best phase of the 3 phase electrical grid and further provides power to the rectifier or switched mode power supply (SMPS). The SMPS converts the 220 VAC to -48 VDC (in some cases to 24 VDC)[16] which provides power to the telecom tower equipment and additionally, charges the batteries. In case of power failure of grid supply, the PIU sends a signal to the diesel generator and the diesel generator supplements the power supply in a few minutes. During the transition of supply from the electricity grid to the diesel generator, the batteries provide the power

[15] Intelligent Energy

[16] Green Solutions for Telecom Towers: Part I, Intelligent Energy Limited, May 2013

required by the telecommunication equipment at the tower and ensure uninterrupted operation of the telecom site.

Power Requirement

Base Transceiver Stations (BTS) consumes the maximum power in a tower site. BTS configuration varies with sites depending on number of subscribers, area of coverage, data traffic and teledensity of the area. Therefore, generally a 2/2/2 configuration BTS is used in rural areas and 6/6/6 configuration BTS in urban areas. Air conditioners also have a major share in power consumption of a telecom tower, as they are used to cool the shelters in case of BTS overheating. A 2 x 2 x 2 configuration BTS require about 1.3 kW of power supply while the higher capacity versions (4 x 4 x 4 and 6 x 6 x 6) require 2 and 3 kW respectively.[17] With addition of 1.5 ton air conditioners, the power requirement increases to 3-4.7 kW. Since, air conditioners are high consumers of electricity, new BTS with higher operating temperatures helps in minimising energy costs.

Table 3: Power requirement of a typical telecom tower

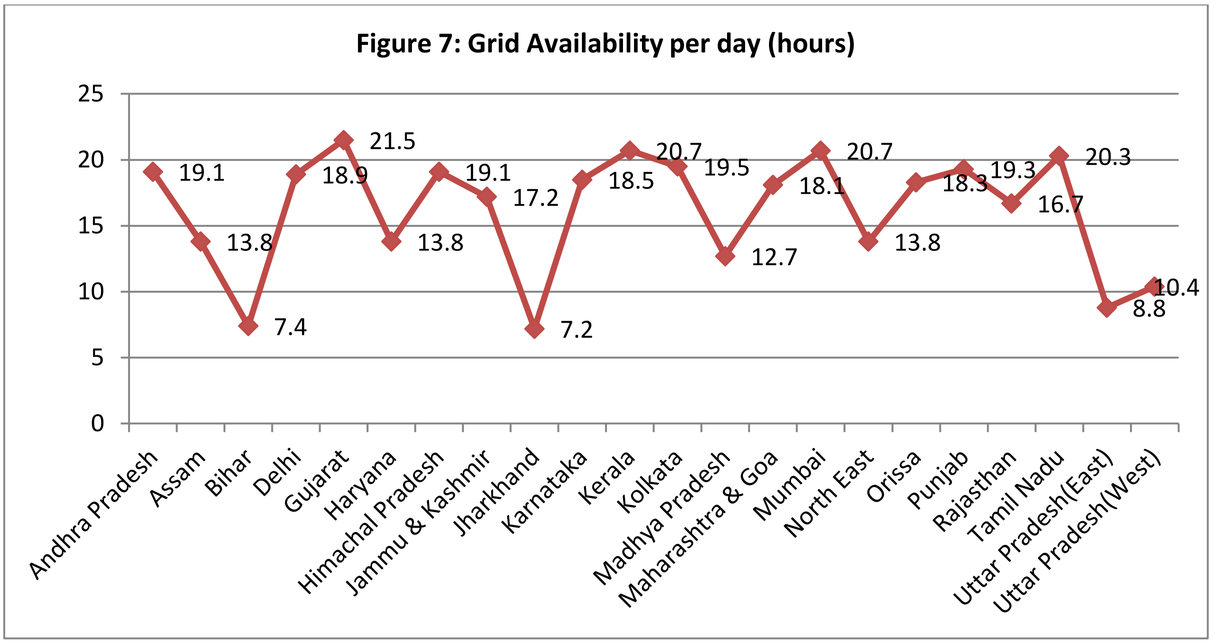
Sl. No	Status	6/6/6 config in W	2/2/2 config in W
1	AC Units only ON	1720.8	999
2	Power Plant Only ON	1631.25	1305
3	Media Equipment only ON (CPE)	1631.25	1305
4	BTS ON but TRXs OFF, Media OFF	1648.53	1310
5	BTS ON, Media OFF	1706.4	1325
6	BTS Power Consumption	2664.45	1647
7	All the Equipments ON	4385.25	2646

Grid Supply Availability

The electricity availability in different states varies from 7 to 21 hours a day in India (Figure 7). Most of the telecom towers are located in rural and semi-urban areas where electricity supply is irregular.

These sites are generally backed up by a 15-25 kVA or 40 kVA diesel generator which runs for long number of hours a day. Therefore, grid supply availability is an important factor in fuel requirement by telecom towers. We assume that over the years, grid supply would improve due to higher electrification rate of the country, increased capacity and better electricity supply.

[17] P.K.Panigrahi report, DoT



[18]

[18] Central Electricity Authority, Ministry of Power, Government of India

III Green Solutions for Telecom

Since the grid electricity supply is unreliable in some areas and even beyond reach in some areas, regular maintenance of diesel generator is a challenge along with rising fossil fuel costs. We should shift our focus to available cost-effective and efficient renewable energy sources which are technically and economically feasible. Since the scope of growth of telecom sector is much higher in rural areas, these solutions become more important as power is a major problem for rural telecommunication. Scope and feasibility of such alternate 'Green' solutions is discussed below:

Solar Photovoltaic Energy

India has a large solar energy potential with 300 days a year of abundant sunshine. Solar energy incidence varies from 4-7 KWh per metre square across different parts of the country which translates to about 4-6 hours of usable solar energy per day.[19]

Since availability of sunshine is limited to only some hours a day, structuring standalone solutions using solar photovoltaic system, is not feasible for high energy requirement telecom towers. But certainly when coupled with appropriate battery banks, the solar photovoltaic backup power system can replace diesel generator. The biggest advantage of solar PV is its scalability. Solar panels are modular and its size can be increased easily with the increasing energy requirements. Significant fall in the solar panel prices (Rs 170/W to Rs 70/W in the year 2011)[20] also makes it a profitable option. The Ministry of New and Renewable Energy (MNRE) supports off-grid solar photovoltaic telecom applications by providing capital subsidy of 30%. India Renewable Energy Development Agency (IREDA) also offers soft loans at 5% interest for renewable energy projects.

Wind Energy

Wind energy is prominent in India in states of Maharashtra, Tamil Nadu, Gujarat, Karnataka, Andhra Pradesh, Madhya Pradesh and in parts of Orissa. The wind speed also varies over the year; it peaks during September and is at its lowest in February. With an annual national average of 5-6 m/sec wind speed and average duration of 4 hours a day, wind power is a potential solution to replace diesel generator. Various regulatory and policy incentives are available for wind power technology. The incentives include 100% foreign direct investment, Generation based incentive upto Rs 10,000,000 per MW and exemption of excise duty. MNRE also offers 30% capital subsidy for telecom applications up to maximum of INR 1,00,000/kW.[21]

Fuel Cells

Fuel cells are evolving as a strong alternative to backup telecom towers. The technology has developed in recent years and has many benefits compared to generators, such as fuel efficiency, climate resistance, reliable start-up etc. Fuel cells operate by converting a fuel, such as hydrogen, into electricity without combustion thus reducing carbon emissions. Fuel cell faces

[19] http://en.wikipedia.org/wiki/Solar_power_in_India
[20] Recommendations on approach towards green telecommunications, TRAI, 2011
[21] Green Solutions for Telecom Towers: Part I, Intelligent Energy Limited, 2013

a challenge in terms of limited availability of hydrogen to certain parts of country only. A comparison between fuel cells and diesel generator is given below.

Table 4: Comparing Fuel Cells to Diesel Generators[22]

Item	Typical Fuel Cell: 10kW system in enclosure with fuel storage	Diesel Generator: 50kW with ATS and fuel storage	Typical Fuel Cell: 10kW system indoor rack-mount with external fuel storage
Capital Cost			
Equipment Cost	50,000	30,000	45,000
Incentives: Treasury Grant / Federal Tax Credit*	-15,000	0	-13,500
Incentives: States**	varies	0	varies
Permitting/Installation	13,500	18,000	13,500
Total First Cost	48,500	48,000	45,000
Operational Costs			
Annual Maintenance & Fuel	700	5000	700
Lifecycle cost after 10 years	55,500	98,000	52,000
Cost comparison after 5 years	52,000	73,000	48,500
Cost comparison after 1 year	49,200	53,000	45,700
* Federal treasury grant / tax credit is $3/W or 30% of the cost of the fuel cell, whichever is less. In this case, $3/W * 10kW = $30,000; 30% of cost is $15,000 (outdoor) or $13,500 (indoor).			
** State tax credits for fuel cells vary where available. California and New Jersey currently offer the best incentives.			

Biomass

Biomass energy can be obtained from the energy in plants and plant-derived materials, such as food crops, grassy and woody plants, residues from agriculture or forestry and the organic component of municipal and industrial wastes. Biomass seems to be a promising renewable energy solution for conventional diesel generators especially in rural areas. Electricity is generated by burning biomass feedstock to produce steam which runs the turbine to produce electricity. Since biomass absorbs carbon dioxide from atmosphere during its growth, and then emits an equal amount of carbon dioxide when burned, it is a carbon-neutral electric power generation option. There are several incentives, including concessional customs duty on import of machinery and components, excise duty exemption, accelerated depreciation on major components, relief from taxes and capital subsidy for setting up of biomass power projects that are being provided by the government. Biogas power plants are one such feasible solution to power telecom towers.

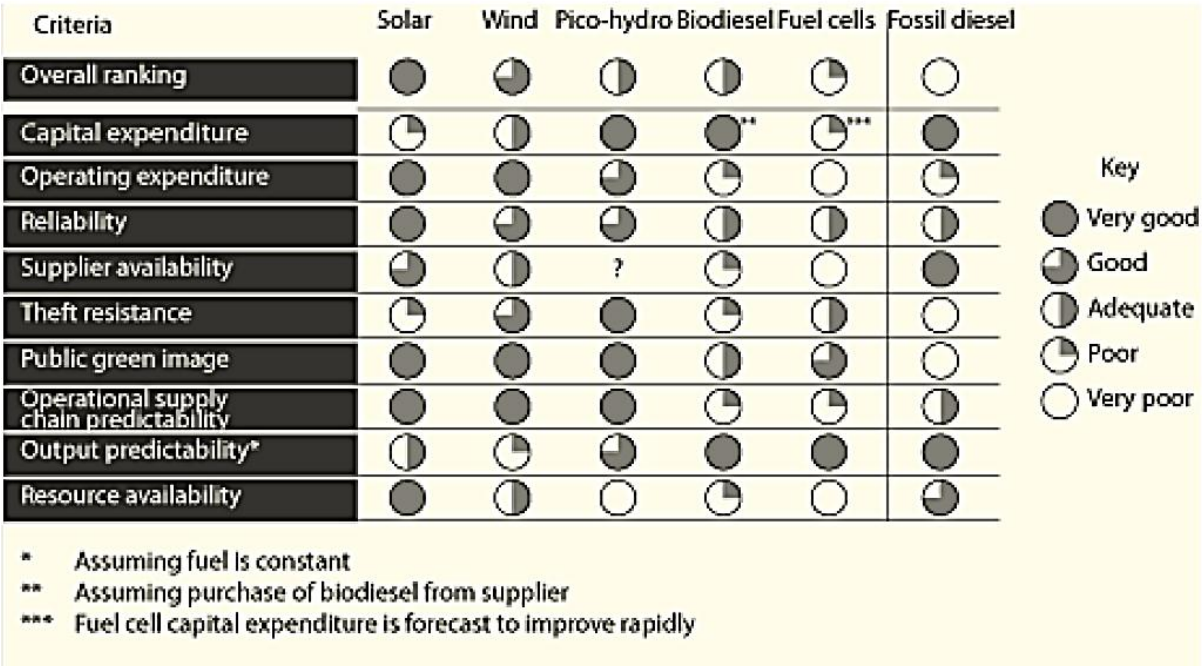
Pico Hydro

Pico-hydro refers to very small hydroelectric power generators that typically produce up to 10kW from the energy derived from streams and rivers. It is a mature technology for other applications such as rural electrification and has one of the lowest capital investment requirements of all. But its feasibility for telecom towers is still under research and

[22]Backup Power for Telecommunication Applications (Reli On Report, 2012)

development. One of the major drawbacks of this solution is its limited availability to certain sites only. Steep flowing streams and rivers provide constant flow paired with low maintenance cost makes it an ideal power solution for telecom sector.

Figure 8: Comparing different energy solutions for telecom towers[23]



As we can clearly see in the comparison chart, off- grid solar has the highest overall ranking among various renewable energy solutions. For India Energy Security Scenarios 2047 Version 2, we have considered Distributed Solar Photovoltaic, Wind, Biogas power plants and Hydrogen as potential solution to replace diesel in telecom sector.

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[23] Source: GSM

IV Government Policies

Several key Government policies and initiatives have helped the telecom sector to adopt energy efficient and renewable power sources available in the economy. Highlights of such policies are discussed below:

1. Under the Solar Photovoltaic Programme of the Jawaharlal Nehru National Solar Mission (JNNSM), the Government provides installation support for 1-10 kWp installed capacity (without distribution networks) and above 10 kWp installed capacity (with distribution networks) stand-alone Solar Photovoltaic (SPV) power plants.

2. As part of the National Action Plan on Climate Change (NAPCC), central financial assistance is provided for rooftop solar photovoltaic systems from 10 kWp to 100 kWp installed generating capacity.

3. A range of subsidies for the developers harnessing power through renewable sources across multiple technologies have been introduced by the Government.

4. To generate power through renewable resources and feed into the grid, State Governments provide low import tariffs for capital equipment, materials and components; and competitive prices under alternate power purchase policies.

5. Ministry of New and Renewable Energy (MNRE) has also extended its support to telecom operators and tower companies in their shift to renewable sources to power network towers. But this support is only limited to 100 network towers per company which is insignificant as compared to more than 400,000 telecom towers presently in existence.

6. The new government's ambition to achieve 100% overall teledensity by 2020 has also been factored into the analysis.

The Telecom Regulatory Authority of India (TRAI) also submitted its recommendation to the Government on 'Green Telecommunication'[24] which will shape the path of renewable energy to power the telecom sector in the following years. Some highlights of the recommendation paper are summarised below:

1. At least 50% of all rural towers and 33% of the urban towers are to be powered by hybrid power (Renewable Energy Technologies (RET) + Grid power) by 2015, while all rural towers and 50% of urban towers are to be hybrid powered by 2020.

2. 'Green Passport' certification utilising the ECR's Rating and the Energy 'passport' to be mandatory by the year 2015 for all telecom products, equipment and services in the telecom network.

3. All service providers to declare the carbon footprint of their network operations twice a year to TRAI.

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[24] Recommendations on approach towards green telecommunications, TRAI, 2011

4. Energy efficient radio networks that reduce overall power and energy consumption should be designed by the network operators.

5. The total power consumption of each BTS should not exceed 500W by the year 2020.

6. Sharing of the infrastructure using passive as well active methodologies should be done to minimize the eventuality of locating new sites within the vicinity of existing towers. [Say within 200m, in urban areas & within 2 Km, in rural areas]. Service providers should plan to have at least 10% of their sites actively shared by the year 2014.

7. Carbon emission reduction targets for the mobile network are defined at 8% by the year 2012-2013, 12% by the year 2014-2015, 17% by the year 2016-2017 and 25% by the year 2018-2019.

V Assumptions

The present analysis estimates the reduction in diesel demand by its substitution by solar power. This is supported by improved supply of grid connected power. We make the following common assumptions for all 4 Levels to define different scenarios for power and energy demand by the Telecom towers.

- 60% of total telecom towers are situated in rural areas whereas 40% in urban areas. This ratio remains constant throughout all the levels.
- The growth rate of telecom tower is assumed to be linked with the GDP growth rate.[25]
- For simpler cost calculations, only solar photovoltaic panels are considered as the backup solution for telecom towers.
- We assume that TRAI regulations, cheaper off-grid renewables and Carbon-credit policies for telecom sector will promote use of renewables in telecom towers. Therefore, penetration of solar photovoltaic plants to backup telecom is increased over the years and in subsequent levels.
- The base load capacity of each tower is assumed to be 3KW for rural areas. For urban areas, 5KW is assumed due to BTS configuration (2/2/2 in rural areas and 6/6/6 in urban areas)[26]. The capacity is assumed more due to higher teledensity, higher mobile internet usage, air-conditioning, which increase the base load of the telecom tower.
- Asset life of a BTS is assumed to be 20 years.
- The telecom tower runs on diesel generator for 4 hours per day in urban areas and 12 hours per day in rural areas in 2012, which gradually decreases to 2 hours a day for urban areas and 8 hours a day in rural areas in 2047, over the years due to higher electrification rate and better grid supply.

Table 5: Electricity grid supply in rural and urban areas (hours per day)

	2012	2047
Rural	10	16
Urban	18	22

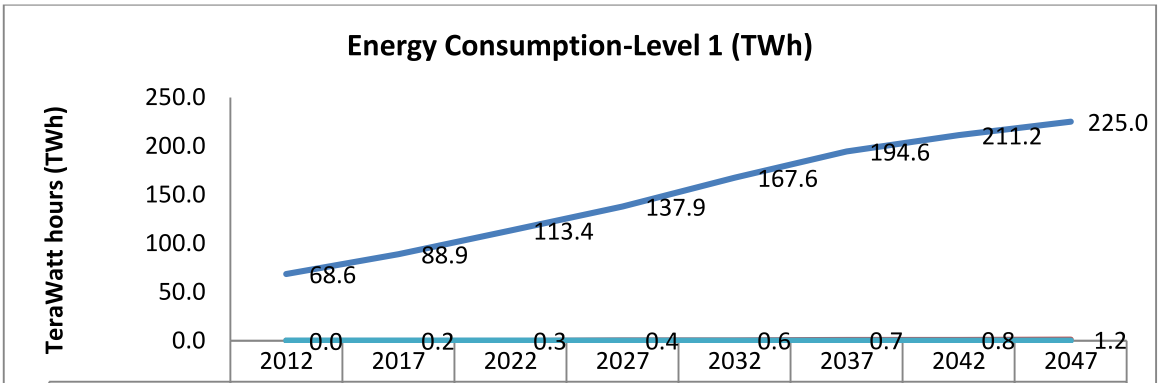
[25] Please visit www.indiaenergy.gov.in for more information
[26] See section II: Power requirement by telecom sector for details

VI Trajectories

We create different scenarios for energy requirement by telecom sector for different penetration rate of Distributed Solar PV, Wind, Bioenergy power plant and Hydrogen to replace diesel. We play on the percentage of telecom towers to be clean energy over the years (2007-2047).

Level 1

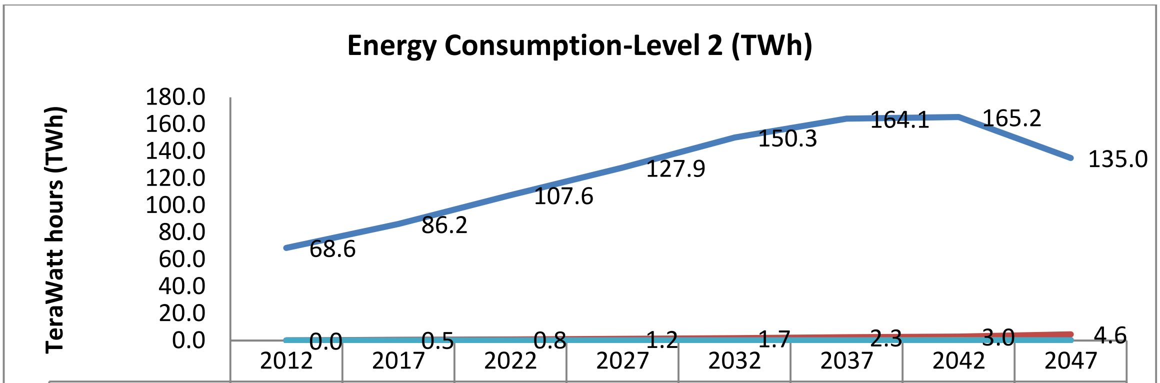
This is a 'Least Effort' scenario where we assume that no regulations have been enforced and the present energy consumption scenario continues. Only solar solutions are considered feasible in this scenario. The percentage of diesel operated telecom towers replaced by off-grid solar in 2047 is assumed to be 10% in rural areas and urban areas.



	2012	2017	2022	2027	2032	2037	2042	2047
Diesel	68.6	88.9	113.4	137.9	167.6	194.6	211.2	225.0
Solar	0.0	0.2	0.3	0.4	0.6	0.7	0.8	1.2
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bioenergy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Level 2

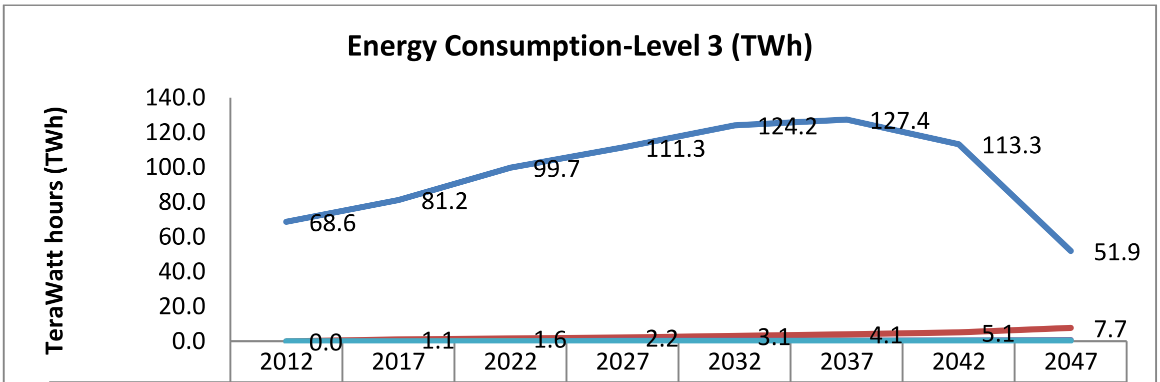
In this 'Determined Effort' scenario, higher solar penetration rate i.e. 40% in rural areas and urban areas is assumed by 2047. Higher electrification rate and penetration of renewables helps to reduce diesel consumption. Wind power solutions replace 3% of telecom towers running on diesel generators in both rural areas and urban areas. Bioenergy solutions contribute to replacement of 3% in rural and urban telecom towers and Hydrogen fuel cell is not considered a commercially feasible option.



	2012	2017	2022	2027	2032	2037	2042	2047
Diesel	68.6	86.2	107.6	127.9	150.3	164.1	165.2	135.0
Solar	0.0	0.5	0.8	1.2	1.7	2.3	3.0	4.6
Wind	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3
Bioenergy	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Level 3

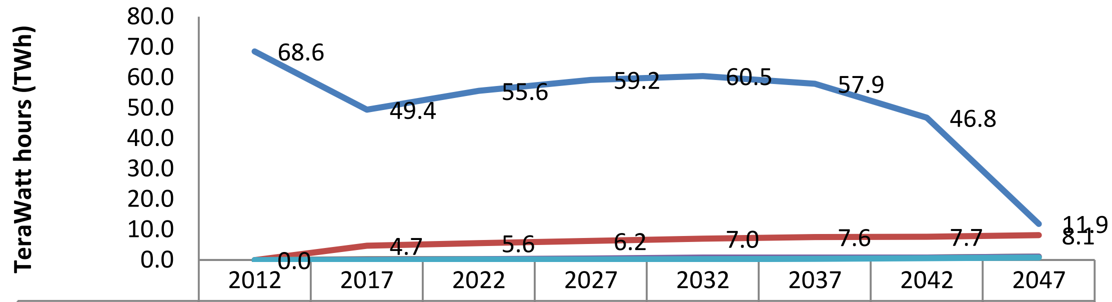
In the ‘Aggressive Effort’ scenario, the penetration rate of off-grid solar plants is assumed to increase to 70% in rural areas and 50% in urban areas in 2047, whereas Wind power solutions replace 10% in rural areas and 7% in urban areas. Bioenergy solutions contribute to replacement of 6% in rural and 5% in urban telecom towers and Hydrogen kicks in after 2022 replacing 3% rural and urban telecom towers.



	2012	2017	2022	2027	2032	2037	2042	2047
Diesel	68.6	81.2	99.7	111.3	124.2	127.4	113.3	51.9
Solar	0.0	1.1	1.6	2.2	3.1	4.1	5.1	7.7
Wind	0.0	0.1	0.1	0.1	0.2	0.3	0.4	0.6
Bioenergy	0.0	0.0	0.0	0.2	0.3	0.4	0.5	0.7
Hydrogen	0.0	0.0	0.0	0.1	0.2	0.2	0.3	0.3

Level 4

This is the ‘Heroic Effort’ scenario where all government regulations are met, and satisfactory quality of electricity supply is assumed for the country. Telecom towers run on grid supply and clean energy solutions, both in urban and rural areas. The percentage of diesel operated telecom towers replaced by off-grid solar in 2047 is assumed to be 75% in rural areas and 50% in urban areas; whereas Wind power solutions replaces 10% in rural areas and 7% in urban areas. Bioenergy solutions contribute to replacement of 10% in rural and 7% in urban telecom towers and Hydrogen replaces 5% in rural and 15% in urban telecom towers.



	2012	2017	2022	2027	2032	2037	2042	2047
Diesel	68.6	49.4	55.6	59.2	60.5	57.9	46.8	11.9
Solar	0.0	4.7	5.6	6.2	7.0	7.6	7.7	8.1
Wind	0.0	0.2	0.3	0.4	0.5	0.7	0.8	1.1
Bioenergy	0.0	0.1	0.3	0.5	0.8	0.8	0.8	1.1
Hydrogen	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8

Levels	Clean Energy Solutions Penetration in 2047 (Rural)			
	Solar	Wind	Bioenergy	Hydrogen
Level 1	10%	0%	0%	0%
Level 2	40%	3%	3%	0%
Level 3	70%	5%	6%	3%
Level 4	75%	10%	10%	5%

Levels	Clean Energy Solutions Penetration in 2047 (Urban)			
	Solar	Wind	Bioenergy	Hydrogen
Level 1	10%	0%	0%	0%
Level 2	40%	3%	3%	0%
Level 3	50%	5%	5%	3%
Level 4	50%	7%	7%	15%

Table 6: Energy demand by telecom towers in 2047 (TWh)

Levels	Diesel	Distributed Solar PV	Wind Energy	Bioenergy	Hydrogen Fuel Cells
Level 1	225	1.2	0	0	0
Level 2	135	4.6	0.3	0.3	0
Level 3	51.9	7.7	0.6	0.7	0.3
Level 4	11.9	8.1	1.1	1.1	0.8

Figure 9 Rural Energy Demand by Telecom Towers in 2047 (TWh)

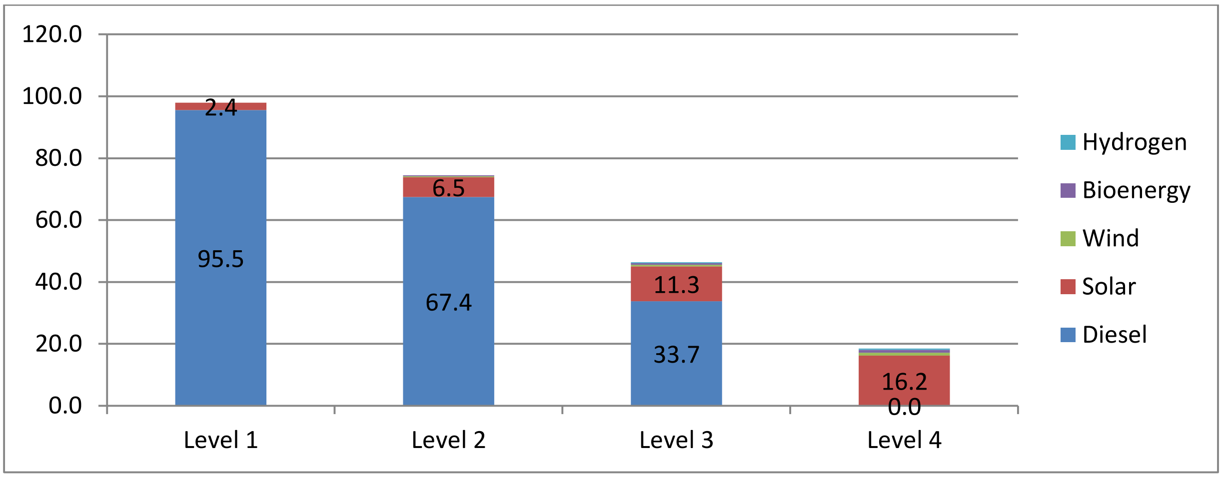
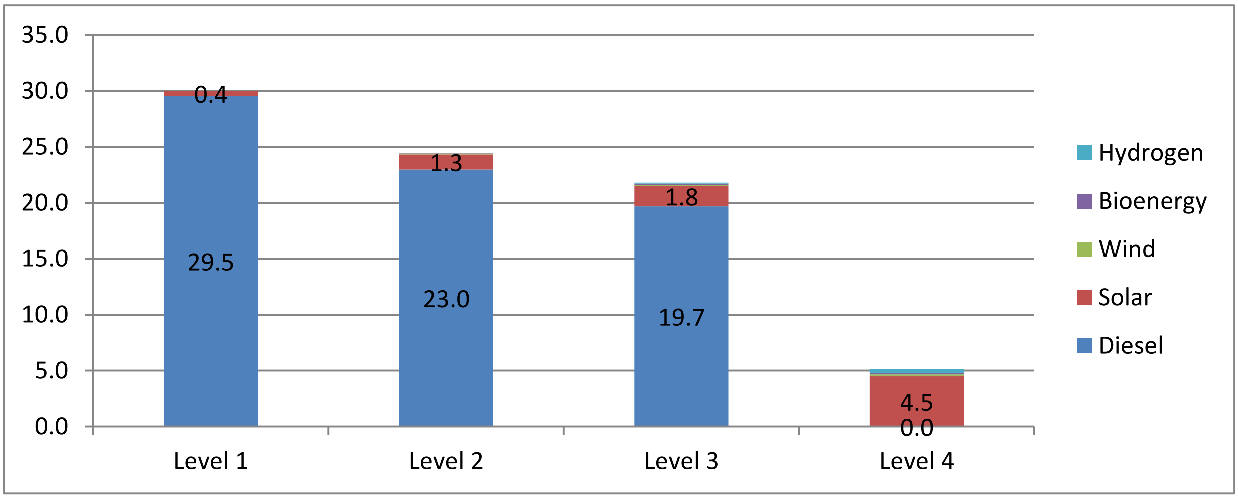


Figure 10 Urban Energy Demand by Telecom Towers in 2047 (TWh)



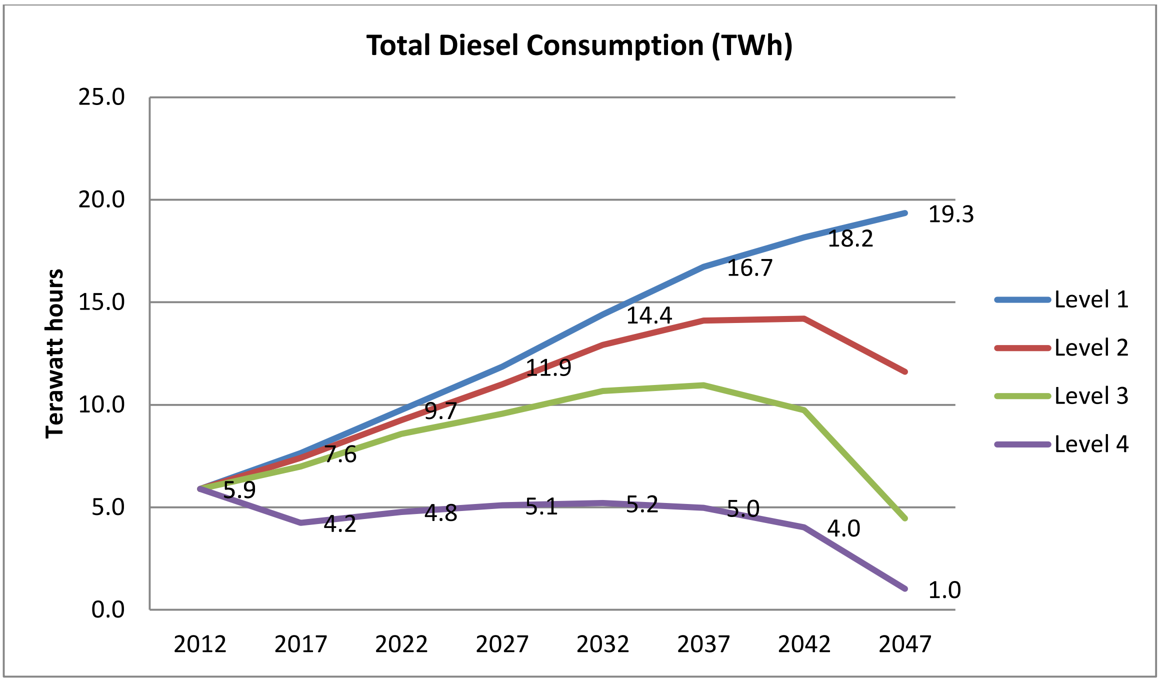


Figure 11: Total Diesel Consumption by Telecom Towers

VII Costs

The costs calculated here represent the cost to economy for migration from Diesel generators to Clean Energy solutions for telecom towers. There are three components of the costs: Capital cost, Operating cost and Fuel cost. For the purpose of this estimation, it is assumed that:

1. All costs are computed annually per BTS.
2. Real prices have been considered for estimation
3. Asset life of a BTS is assumed to be 20 years. Also, asset life of wind turbine, biogas plant and hydrogen cell is assumed to be 20 years. Hence, $1/20^{th}$ of current stock retires every year
4. Fuel costs are captured on the supply side of the IESS 2047 model.

There are three estimates for each, Capital costs and Operating costs: High estimate, Point Estimate and Low estimate. High cost is assumed to be present day prices and remain constant till 2047. Low cost is assumed to decline linearly by 30% till 2047. Point cost estimate is the average of High cost and Low cost. Due to lack of relevant literature, operating costs are assumed to be 5% of the capital costs and the Low estimate is assumed to linearly decline by 20% till 2047.

Annualised capital cost of Telecom Energy Solutions[27]

Energy solution	Capital cost (INR)
Diesel Generator	144000
Solar Panels	223530
Wind Turbine	197059
Biogas Power plant	160000
Hydrogen Fuel cell	66880

Cost of energy saved due to increase in energy efficiency of BTS and also migration to clean energy. For the calculations, kindly refer to the India Energy Security Scenarios 2047 Version 2 Excel Model.

[27] http://www.intelligent-energy.com/media/uploads/green_solutions_for_telecom_towers_part_1.pdf

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