A STUDY OF ENERGY CONSERVATION AND CARBON EMISSION IN TELECOMMUNICATIONS SECTOR IN INDIA

By

C. S. AZAD

COLLEGE OF MANAGEMENT AND ECONOMIC STUDIES/ENGINEERING

Submitted

IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

TO

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES, DEHRADUN
March, 2016

Under the Guidance of

Dr. PRASOOM DWIVEDI

Associate Professor & Head Centre for Energy Economic Research

Co-Guide	**External Guide**
Dr. ANKUR MITTAL	**Dr. S. C. BAJPAI**

DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for award of any other degree or diploma of the university or other institutes of higher learning, except where the acknowledgement has been made in the text.

C. S. Azad

THESIS COMPLETION CERTIFICATE

This is to certify that the thesis on **"A Study of Energy Conservation and Carbon Emission in Telecommunications Sector in India"** by **C.S. Azad** in Partial completion of the requirements for the award of the Degree of Doctor of Philosophy (Management) is an original work carried out by him under our joint supervision and guidance.

It is certified that the work has not been submitted anywhere else for the award of any other diploma or degree of this or any other University.

Internal Guide | Co-Guide

Dr. PRASOOM DWIVEDI | **Dr. ANKUR MITTAL**

To whom so ever it may concern

This is to certify that the thesis entitled "**A Study of Energy Conservation and Carbon Emission in Telecommunication Sector in India**" submitted by **Shri C S Azad** to UPES (University of Petroleum and Energy Studies), Deharadun for the award of the degree of Doctor of Philosophy is a bona fide record of the research work carried out by her/him under my (our) supervision and guidance. The content of the thesis, in full or parts have not been submitted to any other Institute or University for the award of any other degree or diploma.

(Dr Prasoom Dwivedi)
Research Supervisor (Internal)

(Dr Suresh C Bajpai)
Research Supervisor (External)

Place:
Date:

Dedicated to
Sweet Memory of
My Father
Late Shri R.C Sharma

ACKNOWLEDGEMENTS

It is with great delight that I acknowledge my debts to those who have contributed to the success of my research work. I am deeply indebted to my research guide Dr. Prasoom Dwivedi for the continuous support of my Ph. D study and related research, for his patience, motivation, and immense knowledge. His guidance helped me in all the time of research .His rich expertise, considerate nature and valuable inputs were a real driving force to my research work. Without his able guidance this work would not be possible.

I express my gratitude to Dr. Anirban Sengupta the Dean, CoEM for his blessings and encouragement. Furthermore, I express my appreciation to my co-guide Dr. Ankur Mittal and external guide Dr. S C Bajpai. I have benefitted a lot from their critical comment, advice and constant support.

I would also like to thank Faculty Research Committee members especially Dr. Tarun Dhingra, Dr. Anil Kumar, Dr. T Bangar Raju, Dr.Neeraj Anand, Dr. Anshuman Gupta, Dr. K K Pandey and Dr. Ashish Tripathi for their insightful comments and encouragement, but also for the hard question which incented me to widen my research from various perspectives.

I am especially thankful to Sh. G K Yadav ADG, DoT, Dr. Geo Jos Fernandez and Dr. Alka Dwivedi of UPES for their continual guidance and support.

I express my gratitude and thanks to Dr. J S Sarma Ex Chair man, TRAI, Sh. P K Panigrahi, Retd. Sr. DDG DoT, Sh. Ram ji Prasad GISFI, Sh. Robert J Ravi Advisor, TRAI, Dr. Gufran Beig Scientist G, IITM ,Sh. Rajan S Mathews, Director General COAI, , Sh. Praveen Varshney Principal Chief Engineer (Electrical) , BSNL, Sh. A S Chandel Ex PGM(EW) BSNL , Sh.Surabh Chaturvedi Director (EW), DoT , Sh. T R Dua , TAIPA, Sh. S Sairam Prasad Ex CTO Bharti Infratel , Sh. Ramesh Babu Guptha Paluri , Head Energy and Opex Optimization Bharti Airtel and Sh. Mrinmoy Chattaraj, Green Peace for giving profound ideas and views about energy conservation and carbon emission in telecom sector.

My sincere thanks also goes to Sh. Parag Varshneya Director TERM Cell , DoT, Sh. Sanjay Agarwal JTO (E), Sanchar Bhawan, Sh. Lenin Ram, Sh. Sathyanarayan SDE(E) Chennai, Sh. Prakash Kumar Samantsinghar M/s Educare, Sh. Govind Bagora , Sh. Naveen Kumar BSNL to help in data collection for this study . A special word of appreciation to the SEEM intern Sh. Sachin Goyal of Delhi Technological University, staff of libraries of TERI, AIMA, UPES and IMT for their support.

I would like to express with special words of thank to Sh. R K Pandit, Ex PGM BSNL , Sh.S K Bhalla ,Director, DoT, Dr. Mohd Naved Khan Associate Professor (Management), AMU, Dr Vijay V Dhabarde, Nagpur and Prof.(Dr.) S Hasan Saeed, HoD, Integral University for inspiration and motivation for this research work .

I am also thankful to Dr. Sudhakar B Reddy, IGIDR, Mumbai, Dr. Bharat Bhushan Verma, IIM, Ahmedabad, Dr. R P S Tomer, Director, IPEM, Ghaziabad and Dr. Priya Gupta, Delhi University for their comments and support.

I am grateful to my officers and project team members specially Sh. G P Gupta and Sh. Rajiv Verma for facilitating to spare time for this arduous research task.

Last but not the least; I would like to thank my family: my parents and my teachers for supporting me spiritually throughout writing this thesis and my life in general.

A special thanks to my family. Words cannot express how grateful I am to, my parents for all of the sacrifices that they’ve made on my behalf. Their prayer for me was what sustained me thus far. I would also like to thank all of my friends who supported me in writing, and incented me to strive towards my goal. At the end I would like express appreciation to my beloved wife Suniti who spent sleepless nights with me and was always my support in the moments when there was no one to answer my queries. She does anything and everything to allow me to devote time for my research journey. I am greatly indebted to my children Pragati and Utkarsh for their support for allowing me to spare time for my research pursuit.

C.S. Azad

Date: 31/03/2016
Place: Dehradun

EXECUTIVE SUMMARY

Energy costs account a significant part of telecom operators' operating expenses, the energy conservation measures are not only good for the environment; they also make commercial sense for operators and support sustainable, profitable business. In view of frequent rise in power tariff and diesel price , controlling the energy cost is a major concern of the telecom operators . In general, adoption of energy efficiency measures result in reduction of carbon footprint and cost saving. Indian telecom sector is growing at an exponential rate. With expansion of the telecom networks in no or poor grid areas, the industry has to use the diesel generators to power the networks. The carbon emission associated with energy use in Indian telecom sector is reported to be high as compared with world. Energy efficiency researches in India are confined to energy intensive industries like Cement, Steel and Fertilizers etc. Researchers did not take notice of the increasing energy requirement of the telecom networks. Research studies have been carried out in various countries to find out the share of telecom networks in national electricity consumption. In India, there is no estimate of electricity demand of telecom networks. In spite of consumption of billions of liters of diesel by the Indian telecom operators, there is no authentic estimation for the same. Moreover, use of diesel by Indian telecom industry is contributing to India's GHG inventory. There is lack of understanding of suitable fuel switching option for telecom sector.

Although the telecom companies are making the efforts to implement energy efficiency measures and using renewable energy, the policy interventions are needed to motivate them.

This study has been conducted to estimate energy requirement of Indian telecom sector. It also develops insight in the energy consumption pattern of telecom operators. This study analyzes existing and potential energy conservation measures in Indian telecom sector. It identifies the critical factors affecting the energy conservation measures in Indian telecom sector.

The whole study is covered under seven chapters which are broadly covering business context, outline of the thesis, overview of Indian telecom sector, research methodology, analysis, findings, conclusion theoretical contribution and references of the study. The brief detail of the chapters is given below:

Chapter One- This chapter outline the background of the study. It explain the availability of grid electricity, forced outage and un-electrified villages in various telecom service areas based on ministry of power, central electricity authority and department of telecommunications data. The business case of the study is discussed with supporting data. The need of the study is outlined in this chapter. A brief structure of the thesis has been provided along with the construct of the research.

Chapter two- Discusses the overview of Indian telecom sector. The chapter provides a snap shot of the Indian telecom sector. The growth of Wireline and wireless telecom subscriber base in India is demonstrated and compound annual growth rate of various telecom services in India has been discussed. It provides the detail about telecom service areas in India and shows telecom service area map.

The roles and responsibilities of key decision making bodies Department of Telecommunications, Telecom Commissions, Statutory Bodies, such as TRAI , TDSAT have been discussed . It also covers important offices, departments like TEC, TERM Cell and public sector undertakings BSNL, MTNL, BBNL etc.

This chapter provides introduction to major telecom service providers in India and their market share. It also traces the role of telecom tower industry with its major players.

This chapter portrays key themes of National Telecom Policy 2012 and explains green telecom, use of renewable energy technologies to reduce carbon foot prints.

Chapter three- Reviews the various literatures available to understand the research area. This chapter gives a back drop of on the energy conservation and has tried to define the term energy conservation and energy efficiency .This chapter discusses the methods of energy conservation and also identifies drivers and barriers to energy conservation. It explains the energy consumption and carbon emission of ICT and telecom networks and identifies the energy conservation and regulatory drivers for the sustainable growth of the telecom sectors. It has also portrayed the energy conservation measures in telecom sector.

Chapter four- Covers the research need, research gap, research problem research questions and research objectives. Discusses the theoretical premise of the study and research methodology adopted in the study. A model for estimation of electricity demand and to estimate the diesel and electricity consumption of Indian telecom sector is developed in the study. Another energy model has been developed of telecom towers in India. To compare the energy cost of Indian telecom operators, two benchmarks "energy cost per subscriber" and "energy cost as percentage of revenue of telecom service providers" have been identified. The study also has identified methodology to calculate the carbon emission of telecom towers. This chapter discusses energy conservation measures adopted by Indian telecom operators and calculation of payback period for fuel switching option based on NPV method. This work has used a questionnaire as research tool to identify the driving forces and barriers to adoption of energy conservation measures in Indian telecom sector.

Chapter five- Showcases the analysis and findings of the study. The estimated annual electricity consumption of Indian telecom networks comes out to be around 35000 million units. This includes the necessary air-conditioning and general lighting requirement of telecom networks. This estimation assumes that there is round the clock availability of the grid electricity to all telecom networks. The share of electricity consumption of Base Transceiver stations (BTS) is about 83.69% in total electricity consumption of the telecom network in India. The annual grid electricity consumption of telecom towers has been estimated as 22194.12 kWh considering daily 4 and 8 hours power breakdown in urban and rural areas respectively. The annual diesel consumption by telecom towers is estimated as 3.3 billion liters.

The chapter portrays the analysis of energy expenditure of five major Indian telecom service providers during last decade. It is evident from the analysis that there is wide difference among the energy cost per subscriber of telecom companies. The energy cost of MTNL for year 2015 is just double of the energy cost of private telecom operators that is below Rs. 200 per subscriber per annum. It demonstrates that energy expenditure has been rising and telecom operators spend a significant percentage of their revenue (5-10%) on energy.

In this chapter, the estimated total annual carbon emission by telecom towers due to energy consumption is 31.69 million ton. Annual carbon emission per subscriber is estimated as 32.67 Kg which is on higher side with TRAI estimation 21 Kg and world average 8 Kg. (TRAI 2011)

There is detailed analysis of existing and potential energy conservation measures including fuel switching options. Payback period for fuel switching at a typical Indian BTS site has been portrayed. Scenario analysis demonstrates that by use of fuel switching option i.e. replacing diesel with hybrid (Renewable Energy + Grid) energy the expected saving in diesel is 1414.05 and 3313.30 million liters respectively for the years 2015 and 2020. The resultant reduction in carbon emission due to fuel switching (diesel to renewable energy) will be 3.81 and 8.95 Mt of CO_2 respectively for the year 2015 and 2020.

Based on factor analysis six drivers has been identified that affect energy conservation in telecommunication sector- Regulation and Competition Oriented Drivers, Organizational Policy Oriented Drivers, Incentive oriented Drivers ,Customer Oriented & Financial Benefits Oriented Drivers and Sustainable Benefit Oriented Drivers

Based on factor analysis eight barriers has been identified that affect energy conservation affecting energy conservation in Indian telecommunication sector - Lack of Benchmarks / Targets and Reporting Barriers, Bounded Rationality Barriers, Customer Awareness Barriers, Precedence and Lack of financial incentives Barriers, Hiding diesel use information Barriers , Lack of Standards of Energy Efficient Products Barriers, Regulatory & Organizational Policy Barriers and Technical Barriers.

Chapter Six- discusses the recommendations of this study. The major recommendations are: Inclusion of Telecommunication Industry under EC Act, Financial Incentives and Subsidy etc. The chapter suggests Layout for Sustainability (Quarterly Energy consumption and resultant CO_2 emissions) Report and for Quarterly Diesel Consumption and Carbon Emission Saving Report for off grid Telecom Tower Sites.

This chapter also covers the further scope of this study and contribution to theory/literature. The limitation of the study also has been discussed.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AC	Air Conditioning
AHU	Air Handling Unit
AMR	Automated Meter Reading
APT	Asia Pacific Tele-community
BBNL	Bharat Broadband Networks Limited
BEE	Bureau of Energy Efficiency
BSC	Base Service Center
BSNL	Bharat Sanchar Nigam Limited
BTS	Base Transceiver Station
CAGR	Compound Annual Growth Rate
C DOT	Centre for Development of Telematics
CEA	Central Electricity Authority
CFL	Compact Florescent Light
CO_2	Carbon Di Oxide
COAI	Cellular Operators Association of India
CPSE	Central Public Sector Enterprise
DCDG	Direct Current Diesel Generators
DG	Diesel Generator
DOT	Department of Telecommunications
EER	Energy Efficiency Ratio
EMF	Electro Magnetic Field
EScerts	Energy Saving Certificates
ETNO	European Telecommunications Network Operators' Association
ETSI	European Telecommunications Standards Institute
FDI	Foreign Direct Investment
FFI	fiscal and financial incentives
FPC	Fuel Policy Committee
GDP	Gross Domestic Product
GHG	Green House Gases
GISFI	Global ICT Standardization Forum of India

GOI	Government of India
GSMA	GSM Association
ICT	Information and Communication Technology
IESS	India Energy Security Scenarios
IMWGEC	Inter-Ministerial Working Group on Energy Conservation
IPCC	Intergovernmental Panel on Climate Change
IPMS	Integrated Power Management Solution
ITI	Indian Telephone Industries
ITL	Indus Towers Limited
ITU	International Telecom Union
KWH	Kilo Watt Hour (Unit of electrical energy)
KJ	Kilo Joule
MJ	Mega Joule
GJ	Giga Joule
TJ	Tera Joule
LBNL	Lawrence Berkeley National Laboratory
LED	Light Emitting Diode
LES	Lighting Energy Savers
KMO	Kaiser Meyer Olkin
MNRE	Ministry of New and Renewable Energy
MOEF	Ministry of Environment and Forests
MOP	Ministry of Power
MSC	Main / Master Switching Centre
MTNL	Mahanagar Telephone Nigam Limited
NAPCC	National Action Plan for Climate Change
NMEEE	National Mission for Enhanced Energy Efficiency
NOC	Network Operating Centre
NTIPRIT	National Telecommunications Institute for Policy Research, Innovation & Training
NTP	National Telecom Policy
PAT	Perform Achieve and Trade
PP	Pricing Policy
PSU	Public Sector Undertaking

QOS	Quality of Service
R&D	Research & Development
RET	Renewable Energy Technologies
RL	Regulation and legislation
RMS	Remote Monitoring Solutions
RRH	Remote Radio Heads
SPV	Solar Photovoltaic Voltage
TAIPA	Tower and Infrastructure Providers Association
T&D	Technical Grid Losses
TDSAT	Telecom Disputes Settlement and Appellate Tribunal
TEC	Telecom Engineering Centre
TERM	Telecom Enforcement, Resource and Monitoring
TRAI	Telecom Regulatory Authority of India
USOF	Universal Service Obligation Fund
UDTDA	United States Trade Development Agency
VFD	Variable Frequency Drives
WEC	World Energy Council
WEEE	Waste Electrical and Electronic Equipment
WMO	Wireless Monitoring Organization

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Telecommunication has become an integral part of our lives. It is difficult to imagine the life without phones now. As on 31st July 2015, India has more than 1 billion telephone subscribers out of which 98.3 crores are mobile subscribers (TRAI 2015). The demand for telephones keeps growing, and it is coming from the rural and such areas of the country where access to electric grids is not always guaranteed. Wherever available, grid power is of poor quality and availability. There is pressure on telecom service providers to provide telecom networks coverage in all areas of the country. While no other essential service, water supply or health care etc. is available round the clock, the telecom network is necessary to be run 24 hours a day. To overcome the electric grid supply constraints, the widely deployed solution is to provide diesel generators to power the telecom infrastructure. This is not an economical option as the subsidized diesel is used by the telecom sector for commercial purpose, as there is no differential pricing mechanism of the diesel by nature of utilization. It also has the disadvantage of rising carbon emission, having a negative impact on the environment. In India, the telecom regulator, Telecom Regulatory Authority of India (TRAI) has estimated green house gases (GHG) emission due to telecommunications services as 1% of the national GHG emission 2011(TRAI 2011).Based on International Telecommunication Union (2007) estimation, the Information and Communication Technology (ICT) contributes 2-2.5 per cent into the worldwide greenhouse gas emissions.

In 2011, TRAI released its recommendations titled '*Approach towards Green Telecommunications'* chalking out the environmentally friendly practices for sustainable benefits to the industry, the consumers as well as to the environment.

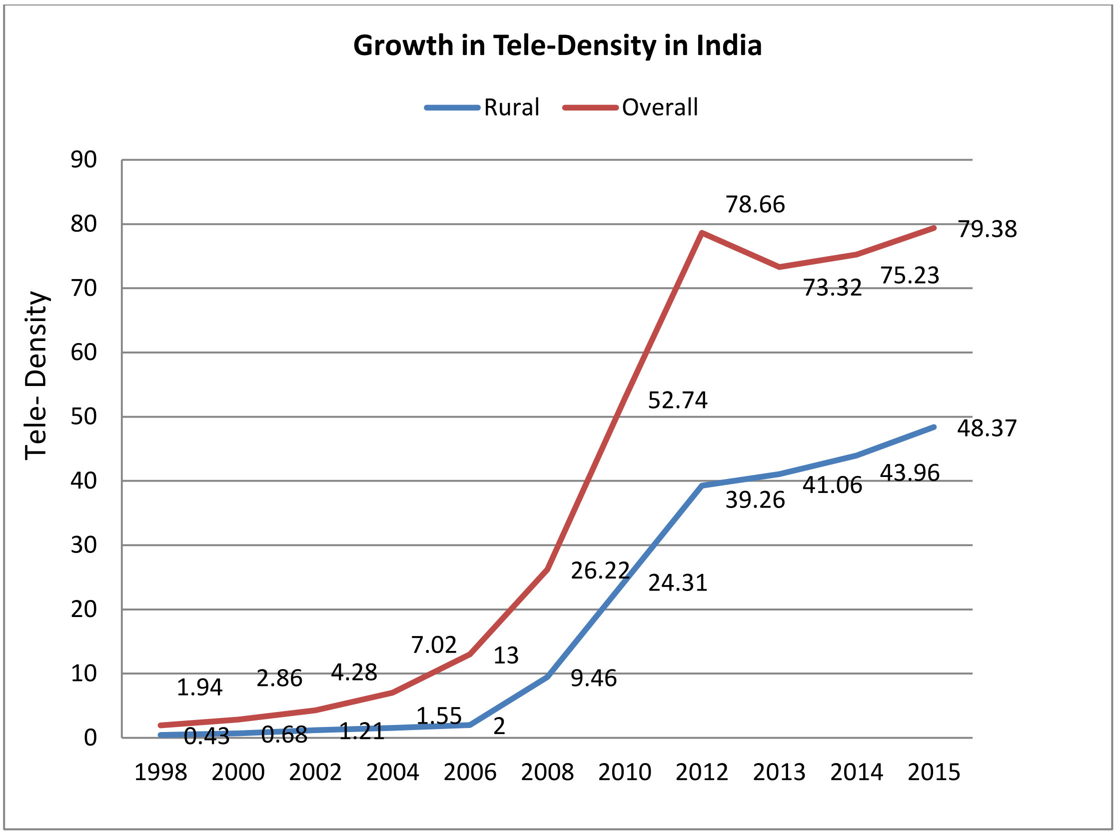
With ever increasing demand for fixed and mobile telecommunications services, the challenges related to power these expanding telecom networks have become more prominent. Therefore, with growing energy consumption and increasing cost of fossil fuels, the adoption of energy conservation measures including switching of fuel in telecom sector is need of the hour.

Given the increasing importance of energy conservation in the national energy policy and growing energy requirement of telecommunication networks, it is highly topical to track energy conservation and carbon emission in Indian telecom sector. Further, it is also worthwhile to probe especially in the context of energy security, climate change and Government of India's recent announcement of reducing emissions intensity of GDP (Gross Domestic Product) by 33%-35% from 2005 level, by 2030.

India's telecom sector has witnessed phenomenal growth during last fifteen years. The country has achieved an overall tele-density of 79.98 (June 2015) vis-à-vis tele-density of 2.86 in 2000(TRAI Annual Reports 2000/2015). While the telecom sector is now seen as central and critical telecommunications infrastructure, it remains far from ubiquitous. There are alarming gaps between the rural and urban areas, and specially the low-income or sparsely populated areas. This is due to the telecom companies viewing poor returns on the expensive investment that is required in setting up the infrastructure. Figure 1.1 shows the wide gap between overall tele-density and rural tele-density.

Saturation in urban market is forcing the telecom companies to look beyond urban areas and present growth of subscribers is mainly is originating from rural areas.

Fig. 1.1: Growth in Tele- Density in India



Source: TRAI and DoT Annual Reports (1998-2015)

This new area of growth generally has no grid or poor grid availability. Even the urban and semi urban areas in India have to face long power cuts. The telecom networks need round the clock power for their operation, therefore diesel generators are used as standby backup to grid or sometimes as main source of power.

Table 1.1 Availability of Grid Electricity in Telecom Service Areas

S. No	Telecom Service Area	Forced Outage as per 2012 (%)	Total No. of Villages as per 2011 census	No. of villages electrified as on 31-3-2015	% of villages electrified as on 31-3-2015	Un-electrified Villages as on 31-3-2015
	Circle A					
1	A.P	4.17	26286	26286	100	0
2	Tamil Nadu	12.76	15049	15049	100	0
3	Karnataka	10.58	27397	27363	99.88	34
4	Maharashtra	13.94	40956	40920	99.91	36
5	Gujarat	25.06	17843	17843	100	0
6	Goa	24.58	320	320	100	0
	Subtotal (Circle A)	Avrage- 15	127851	127781		70
	Circle B					
1	Punjab	6.95	12168	12168	100	0
2	Haryana	15.99	6642	6642	100	0
3	West Bengal	19.93	37463	37461	99.99	2
4	UP	11.27	97813	96515	98.67	1298
5	Rajasthan	11.33	43264	39098	90.37	4166
6	MP	12.34	51929	50471	97.19	1458
7	Kerala	13.75	1017	1017	100.00	0
8	Chhattisgarh	7.89	19567	19124	97.74	443
	Subtotal (Circle B)	12.43	269863	262496		7367
	Circle C					
1	J&K	26.67	6337	6224	98.22	113
2	Bihar	48.76	39073	37316	95.50	1757
3	Orissa	5.14	47677	43799	91.87	3878
4	HP	19.19	17882	17828	99.70	54
5	Uttarakhand		15745	15638	99.32	107
6	Jharkhand	60.3	29492	27363	92.78	2129
7	Assam	66.54	25372	24569	96.84	803
8	Meghalaya		6459	5176	80.14	1283

S. No	Telecom Service Area	Forced Outage as per 2012 (%)	Total No. of Villages as per 2011 census	No. of villages electrified as on 31-3-2015	% of villages electrified as on 31-3-2015	Un-electrified Villages as on 31-3-2015
9	Mizoram		704	659	93.61	45
10	Manipur		2379	2061	86.63	318
11	Nagaland		1400	1271	90.79	129
12	Tripura		863	837	96.99	26
13	Arunachal Pradesh		5258	3694	70.25	1564
14	Sikkim		425	425	100	0
	Subtotal (Circle C)	38	199066	186860		12206
	Total(all circles)	22	596780	577137		19643

Source: Analysis based on data from DoT, CEA, Ministry of Power (2015)

It is evident from the table given above that overall telecom sites excluding metro circles face around 22% forced power outage i.e. grid power interruptions while 19643 villages do not have grid connectivity. This poor grid connectivity, unreliable grid power and higher tariff on telecom sites, force telecom service providers to use diesel generators which increase cost of operation as well as cause carbon emission. As per various estimates, the telecom sector use 2 billion liter or more diesel annually in India which results in about 5 million tons of CO_2 emission (TRAI 2011). As per telecom regulator, TRAI, the per subscriber carbon emission in India is 21 Kg which is well beyond the world average of 8 Kg per subscriber (TRAI 2011).

Moreover, the Indian telecom service sector faces the widest set of challenges in a highly competitive market driven by regulatory challenges and issues. During last five years, telecom operators had to spend huge fund for spectrum allotment through auction and 3G services network rollout. The urban market is highly saturated and rural expansion has challenges of cost effective ways to roll out the network by leveraging available infrastructure.

Indian telecom sector is characterized by cut throat excessive competition affecting the margins, scarcity of spectrum, high regulatory charges and low average revenue per user. The monthly Average Revenue per User (ARPU) in India is approx. Rs. 115 (TRAI 2015). This low ARPU is due to the fact that most of the subscribers are prepaid type.

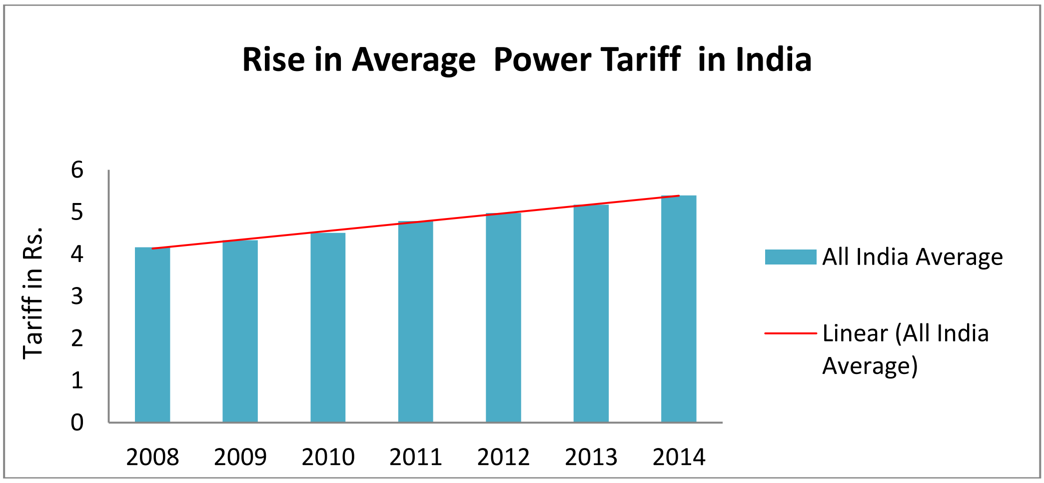
The Indian telecom operators are trying to overcome profit margin pressure by reducing the operating cost through business process outsourcing, infrastructure sharing, IT outsourcing and controlling energy cost.

The energy requirement of the telecom industry is growing at a rapid pace as operators implement newer technologies like 3G and 4G, and expand their network coverage in rural areas.

1.2 BUSINESS CASE

The area of concern for the telecom operators is to control the energy expenditure in spite of frequent rise in power tariff and diesel price. Over the years there is manifold increase in annual energy expenditure of telecom operators. Figure 1.2 describes rise in average power tariff in India.

Figure 1.2 Rises in Average Power Tariff in India



Source: CEA (2015)

The power and fuel costs account for a significant share of the operator network cost. The energy expenditure of telecom operators is going to claim a significant share of their hard earned revenue. Table 1.2 shows the trend of energy expenditure of major telecom operators as a percentage of their revenue.

Table 1.2 Energy Expenditure of Indian Telecom Operators

Year	Energy Expenditure as Percentage of Revenue (%)			
	MTNL	**Idea Cellular**	**Bharti Airtel**	**BSNL**
2006	2.8	1.9	2.6	3.7
2007	3.3	2.5	3.5	4.4
2008	4.0	3.3	3.8	4.2
2009	4.1	5.4	5.7	4.9
2010	6.0	8.8	5.2	5.5
2011	5.6	9.1	4.1	7.4
2012	6.3	8.1	4.0	8.7
2013	7.3	8.4	4.3	9.9
2014	7.7	8.6	4.7	10.0
2015	8.3	7.7	4.4	10.7

Source- Annual Reports MTNL (2006-15), Idea Cellular (2006-15), Airtel (2006-15) and BSNL (2006-15)

1.2.1 BUSINESS PROBLEMS STATEMENT

Indian telecom operators facing economic and financial challenges to meet growing energy demand due to increasing telecom network, rising carbon emission and energy expenditure.

1.3 MOTIVATION FOR RESEARCH

The energy issues are used to be associated with energy used for transport, distribution and manufacturing. But the energy consumption related to information and communication technology (ICT) is focus of global attention now. Energy consumption is a significant ingredient in the operation of telecom networks. The major cost centers of the telecom industry are human resource cost, site rental, infrastructure leasing cost and energy cost. While personnel wages and benefits represent a major network operating cost, other high potential areas for cost cutting include site rental and energy costs. Due to cutthroat competition and ever increasing energy tariff, reducing energy cost is now an existential issue in Indian telecom sector. Identification of energy cost as a component of operating costs, recognition of sites with higher-than-normal power consumption and adopting specific measures to reduce it are components of energy conservation programme. The energy conservation measures in India telecom sector include demand side management and use of renewable energy sources. The carbon emissions associated with power consumption of vast telecom network in India is also a matter of concern.

In India, researches on energy efficiency were carried out to study the energy conservation measures in energy intensive sectors like Steel, Aluminum and Fertilizers etc. No study was conducted regarding energy conservation and carbon emission of Indian telecom sector .The present study has been conducted to undertake detailed understanding of energy conservation and carbon emission in Indian telecom sector.

1.4 THESIS STRUCTURE.

The thesis work has been organized in seven chapters including this Introduction chapter.

Chapter 2: Overview of Indian Telecom sector

This chapter presents overview of Telecom sector in India. It discusses the institutional framework of telecom sector in India. The chapter provides an introduction to major telecom service providers in India. The chapter also traces the role played by telecom tower industry and its major players. The key themes of National Telecom Policy 2012 including focus on sustainability and carbon footprint reduction are described in this chapter.

Chapter 3: Literature Review

After the discussion on growing energy demand of telecom networks and need of carbon emission reduction in Chapter 1 and Chapter 2, the Chapter 3 Literature survey discusses the literature related with the research subject under four broad categories as (i) Energy Conservation and Energy Efficiency (ii) Energy Consumption and Carbon Emission of ICT and Telecom Networks (iii) Energy Conservation and Regulatory Drivers for Sustainable Growth of Telecom (iv) Review of Energy Conservation Measures in Telecom Sector

Chapter 4: Research Methodology

The context of research having been established in the previous chapter, this chapter explains the approach and methodology of undertaking the research. It explains the Research Design, Research Gap, the Research Problem, Research Questions, and Research Objectives, the Research Methodology, Sampling Process, Data Collection, variables identified through literature survey and tools used for analyzing the secondary and primary data.

For Estimation of Energy Requirement of Indian telecom sector energy modeling has been carried out. The model is based on "Bottom Up" approach. Energy consumption pattern of Indian telecom service providers has been analyzed based on their annual reports. The methodology for assessing the carbon emission of energy consumption of telecom towers has been discussed. The chapter also discusses the design of survey questionnaire.

Chapter 5: Analysis and Results

This chapter deals with the analysis to find answers to the research questions. Analysis has been done using the methodology highlighted in the previous chapter. An estimation of electricity consumption of telecom networks and carbon emission of network operation (telecom towers) of Indian telecom industry is presented. The existing and potential energy conservation measures in telecom sector have been analyzed. Factor analysis has been used to identify the barriers to implementation of energy conservation measures in

Indian telecom sector. The driving forces for implementation of energy conservation in India telecom sector have been recognized. Payback period with scenario analysis for fuel switching option for telecom towers has been discussed.

Chapter 6: Conclusions and Theoretical Contribution

This chapter gives the conclusions and recommendations of the study. It also highlights the theoretical contribution of the research.

Limitations and Future Research

It covers limitations and future Scope of study.

Chapter 7: Reference

Reference

Appendix (Questionnaires, and Factor Analysis)

The construct of the research is depicted below in Table 1.2:

Table 1.3: Structure of Thesis

Phase 1: Research Context This phase explains context of research and introduces the topics relevant to research	Chapter 1 Introduction
	Chapter 2 Overview of Indian Telecom sector
Phase 2: Research Review Extensive review on journals, Conference proceedings Reports, other relevant literature has been carried out in this phase	Chapter 3 Literature Review
Phase 3: Research problem development and Research Design Based on the Phase 2 Review, research problem/gap has been	Chapter 4 Research Methodology

identified in this phase. The researcher has at this phase drawn insights from the data and defined objective of the research and the methodology to achieve the objective. Model has been developed for estimation of electricity consumption by Indian telecom network. Questionnaires based on Likert scale were developed to identify the critical factors (Drivers and Barriers)	
Phase 4: Data Analysis Estimation of electricity consumption of telecom networks and carbon emission of network operation (telecom towers) of Indian telecom industry has been done based on the developed model. Factor analysis tool has been used to analyz the data collected from the Likert scale based questionnaires. Scenario analysis has been carried out to present reduction in energy consumption and carbon emission of telecom towers by fuel switching.	Chapter 5 Analysis and Results
Phase 4: Discussion and Conclusions Findings of the study are presented and contribution to theory is discussed. Directions for future research are highlighted.	Chapter 6 Conclusion and Theoretical Limitations and Future Research

CHAPTER -2

OVERVIEW OF INDIAN TELECOM SECTOR

2.1 INTRODUCTION

Telecommunication is regarded as a vital infrastructure for socio economic development in modern world .The revolutionary growth of the Indian telecom sector and mobile telephony aroused the attention of the world. The mobile telephones, internet and other telecom services changed the way of communication and information sharing in India.

The Indian telecom sector is among the rapid growing telecom sectors of the world .The Indian telecom network is second largest network only after China. The wireless segment is the driver of the growth of Indian telecom sector. The Indian telecom sector has 996.49 million subscribers as on March 2015 out of which 969.89 million are wireless subscriber (TRAI 2015). Indian telecom sector is a preferred sector for foreign direct investment (FDI) with more than 7% of total FDI received by the country since 2000. 100% FDI is allowed in all telecommunication services. (DoT 2015)

Table 2.1: Snap Shot of Indian Telecom Sector as on 31 March 2015

Telecom Subscribers (Wireless + Wireline)	
Total Subscribers	996.49 Million
Wireless subscriber and share of wireless subscribers	969.89 Million 97.33%
Wireline subscriber and share of Wireline subscribers	26.59 Million 2.67%
Urban Subscribers and Share of urban subscribers	577.18 Million 57.92%

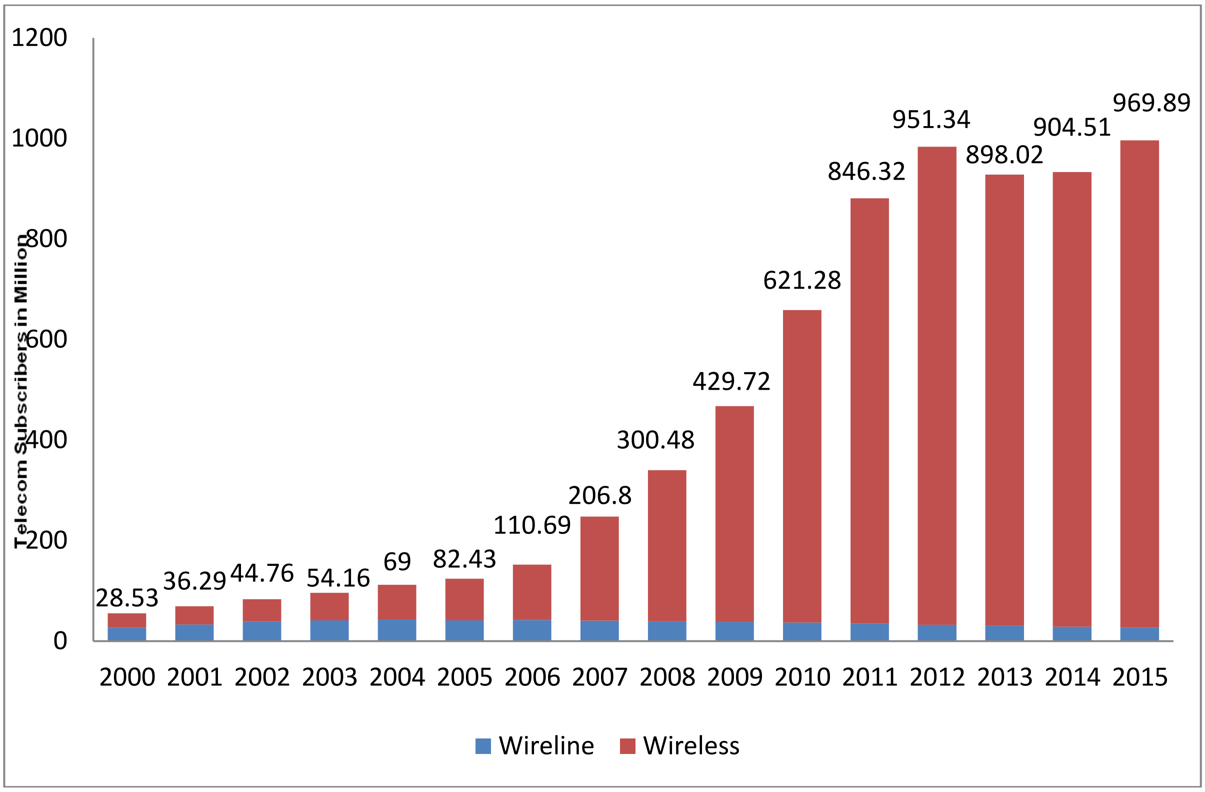
Rural Subscribers and Share of rural subscribers	419.31 Million 42.08%
Tele-density	79.38
Urban Tele-density	148.61
Rural Tele-density	48.37
Market share of Private Operators	89.90%
Market share of PSU Operators	10.10%
Wireless Subscribers	
Total Wireless Subscribers	969.89 Million
Urban Subscribers	555.71Million (57.30%)
Rural Subscribers	414.18Million (42.70%)
Market share of Private Operators	91.68%
Market share of PSU Operators	8.32%
Tele-density	77.27
Urban Tele-density	143.08
Rural Tele-density	47.78
Wireline Subscribers	
Total Wireline Subscribers	26.59 Million
Urban Subscribers	21.47 Million (80.73%)
Rural Subscribers	5.12Million (19.27%)
Market share of Private Operators	24.93%
Market share of PSU Operators	75.07%
Tele-density	2.12
Urban Tele-density	5.53
Rural Tele-density	0.59

Source -TRAI (2015)

From table 2.1 it is evident that the share of Wireline is steadily declining and at present is 2.67%, while the tele-density for wire line is 2.12. Therefore, wireless segment is a major contributor to tele-density in India.

Figure 2.1 depicts the growth of Wireline and wireless telecom subscriber base in India.

Fig. 2.1: Growth of Wireline and Wireless Telecom Subscribers



Source: TRAI Annual Reports (2000-2015)

Table 2.2 illustrates the compound annual growth rate (CAGR) of various telecom services from 2003-2014

Table 2.2: Growth of Telecom Services Subscribers in India

Years		Subscribers' base (in Millions)			
	Wire line	Wireless	Total phones	Internet wired	Broadband
2003	41.33	13.3	54.63	3.64	-
2004	40.92	35.61	76.53	4.55	-
2005	41.42	56.95	98.37	5.55	0.18
2006	41.23	101.86	142.09	7.5	1.32
2007	40.77	165.09	205.87	9.21	2.29
2008	39.41	261.08	300.49	11.05	3.81
2009	37.96	391.76	429.73	13.65	6.22
2010	36.96	584.29	621.25	16.1	8.77
2011	34.73	811.6	864.33	8.77	11.79
2012	32.17	919.17	951.34	22.86	13.79
2013	30.21	867.8	898.01	21.61	15.05
2014	28.49	904.51	933	18.5	60.87
Mean	37.13	426.09	464.64	11.92	12.41
Standard deviation	4.663999	369.4657	366.8517109	6.59444182	17.82049722
Coefficient of variance	12.56013	86.71174	78.95453313	55.3418433	143.6094546
Compound Annual Growth Rate	-3.05	42.14	26.67	14.50	79

Source: Compiled from DoT/ TRAI Annual Reports

It is evident from figure 2.1 and table 2.2 that the demand for wireless services is going unabated. This trend is expected to continue in coming years also with marketing of 4 G and other advance telecom services.

2.2 TELECOM SERVICE AREAS IN INDIA

The country had 23 Telecom Service Areas consisting of 19 Telecom Circle Service and 4 Metro Service Areas to provide telecom services. Later, Chennai metro area was merged with Tamil Nadu telecom service area.

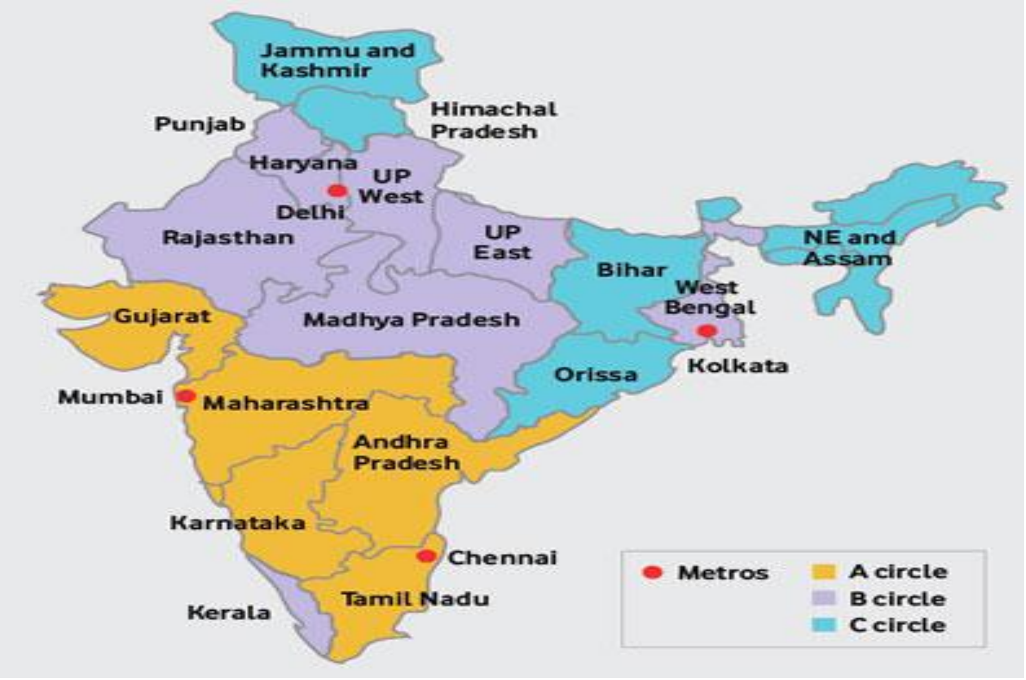
Therefore ,for Access Services, at present there are 22 telecom service level areas consisting of 19 telecom service circles and 3 metro service areas .The telecom service level areas are categorized in to circles namely A, B and C on the basis of the potential of the circle to generate revenue.

Table 2.3: Type of Telecom Circles in India

Telecom Circle Type	Cities / States
Metro	Cities of Delhi, Mumbai and Kolkata
A	States of Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, and Gujarat
B	States of Punjab, Haryana, Uttar Pradesh, Rajasthan Madhya Pradesh and Kerala,
C	States of Jammu & Kashmir ,Himachal Pradesh , Bihar, Orissa, Assam, , Arunachal Pradesh, Meghalaya, Tripura, Nagaland, Mizoram, Manipur and Sikkim

Source: DoT and TRAI

Figure 2.2: Telecom Service Level Area Map of India



Source: DoT and TRAI

The table 2.4 Provides License Service Area wise Number of mobile BTS in India

Table 2.4: License Service Area wise Number of Mobile Base Transceiver Station (BTS)

Sl. No.	License Service Area (LSA)	Total BTSs as on 31.05.2015
1	Andhra Pradesh	73413
2	Assam	17558
3	Bihar	48672
4	Chennai	27014
5	Delhi	43393
6	Gujrat	57498
7	Haryana	21934
8	Himachal Pradesh	8212
9	Jammu & Kashmir	12679
10	Karnataka	66292
11	Kerala	39172

Sl. No.	License Service Area (LSA)	Total BTSs as on 31.05.2015
12	Kolkata	24508
13	Madhya Pradesh	55557
14	Maharashtra (excluding Mumbai)	76700
15	Mumbai	30960
16	North East	10931
17	Odisha	24134
18	Punjab	34431
19	Rajasthan	42682
20	Tamil Nadu (excluding Chennai)	56352
21	Uttar Pradesh (East)	56197
22	Uttar Pradesh (West)	44871
23	West Bengal (excluding Kolkata)	35193
	Grand Total	908353

Source: Lok Sabha Starred Question NO.122 Dated 29th July, 2015

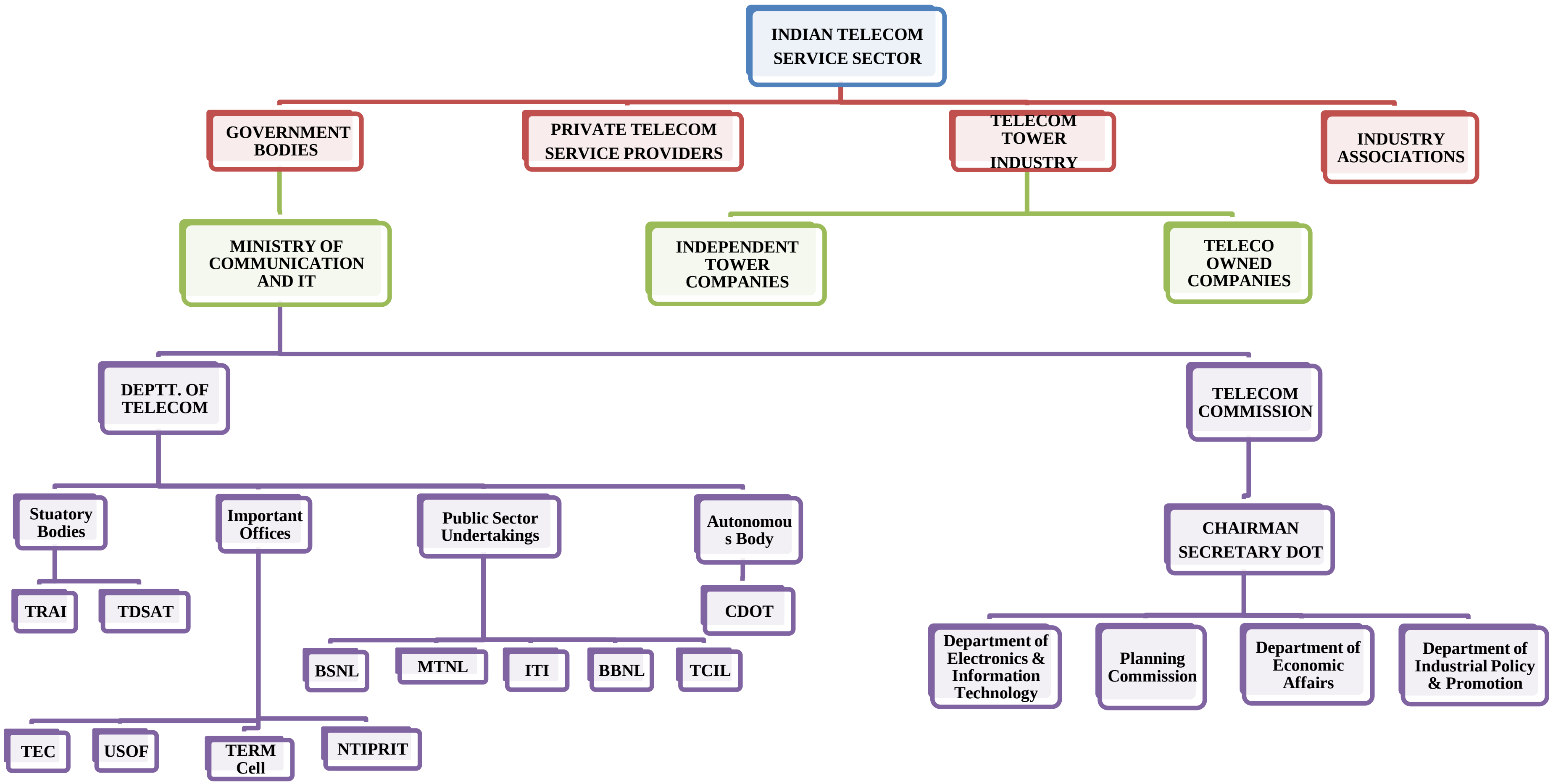
2.3 INSTITUTIONAL FRAMEWORK OF INDIAN TELECOM SECTOR

The Indian telecom service sector comprises decision making government bodies, PSUs, private telecom service providers and telecom infrastructure providers key decision making bodies in Indian telecom sector. The framework has been depicted in figure 2.3.

The roles and responsibilities of various statutory bodies responsible for taking policy decisions in the field of telecommunications in India is as follows :-

The Telecom Commission and the Department of Telecommunications are two key decision making bodies for policy formulation, licensing, wireless spectrum management, administrative monitoring of public sector undertakings (PSUs), research and development and standardization/validation of equipment etc.

Figure 2.3: Institutional Framework of Indian Telecom Sector



2.3.1 KEY DECISION MAKING GOVERNMENT BODIES IN TELECOM SECTOR

- **Telecom Commission**

The Telecom Commission deal with various aspects of telecommunications. It was set up by the Government of India in 1989.The Commission has a Chairman and Four Full Time Members, who are ex-officio secretaries to the Government of India in the Department of Telecommunications. The commission is headed by Secretary, Department of Telecom. It also comprises four part time members. Secretaries to the Government of India from the following departments are involved as part time members.

1. Department of Electronics and Information Technology,
2. Planning Commission,
3. Department of Economic Affairs and
4. Department of Industrial Policy and Promotion

The key functions of the Telecom Commission are summarized as below:

- Formulation of the telecom policy for approval of the Government;
- Preparation of the annual budget of the DoT for approval of the Government; and
- Execution of Government's strategy in all areas pertaining to Telecommunications.

- **Department of Telecommunications**

The Department of Telecommunications (DoT) is responsible for allocation of frequency and managing radio communications in India. It also deals with policy formulation, performance review, monitoring, international cooperation and Research & Development. The department is also in charge for enforcement of wireless regulatory measures and monitoring the wireless transmission. DoT is administrator of the Universal Service Obligation (USO) Fund for the purpose of implementation of universal service support policy. The main functions assigned to the DoT are:

i. Policy framing on telecommunication services in the country.
ii. Issuing license for telecommunications services
iii. Framing of rules, related to security of telecom networks and coordination with security agencies.
iv. Allocation and management of spectrum.
v. Collaboration with International telecommunications organizations..
vi. Coordination with other ministries and departments in the matters related with telecommunications.
vii. Encouragement of Research and Development activities in Telecommunications. Financial assistance to R&D and capacity building .
viii. Promotion of standardization and manufacturing, of Telecommunications equipments.
ix. Encouragement of private investment in Telecommunications.
x. Administration of laws in the matters related with Telecommunications.

2.4 STATUTORY BODIES UNDER DEPARTMENT OF TELECOMMUNICATIONS

The statutory bodies in the field of telecommunications are:-

2.4.1 TELECOM REGULATORY AUTHORITY OF INDIA (TRAI)

The Telecom Regulatory Authority of India (TRAI) was created to provide the level playing field to all telecom operators under the TRAI Act, 1997. The TRAI is mandated of protection of the interests of consumers and nurturing conditions for growth of telecommunications, broadcasting and cable services. It is responsible to ensure compliance of the terms and conditions of license lay down the standards of quality of telecom services and ensure the compliance of quality of services (QoS) standards, specify tariff policy and recommend conditions for entry of new service providers as well as terms and conditions of license to a service provider.

2.4.2 TELECOM DISPUTES SETTLEMENTS & APPELLATE TRIBUNAL (TDSAT)

The world over the disputes in telecom and broadcasting sector are resolved by the regulator or normal courts. However, in India the unique institution in the form of TDSAT exists for speedy settlement and adjudication of disputes on telecom and broadcasting sector dispute resolution in India is outside the purview of the telecom regulator.

It is a statutory body established under “The Telecom Regulatory Authority of India (TRAI) Act, 1997 (as amended)”.The responsibility of Telecom Disputes Settlement and Appellate Tribunal (TDSAT) is to regulate the telecommunication services, adjudicate disputes, dispose of appeals and to protect the interests of service provides and consumers of the telecom sector in order to promote and ensure orderly grown of the telecom sector and for matters connected therewith or incidental thereto(TDSAT 2015).

It was established in 2000 to settle and adjudicate disputes involving licensor licensee, and a group of consumers. In January, 2004 the broadcasting and cable services besides telecommunication services were included in jurisdiction of TDSAT.

The jurisdiction of TDSAT is exclusive. The orders of TDSAT can be challenged before apex court on points of law only. The interim orders of TDSAT cannot be challenged. TDSAT is an expert body and comprises of a Chairperson and two Members. The Chairperson is a former Judge of the Supreme Court of India while two Members are experts in the field of administration or telecommunications (TDAST 2015).

2.5 MAIN OFFICES UNDER DEPARTMENT OF TELECOMMUNICATIONS

Following sections provide the detail of main offices under department of telecommunications

2.5.1 TELECOMMUNICATIONS ENGINEERING CENTRE (TEC)

Telecommunications Engineering Centre (TEC) is the technical wing of the Department of Telecommunications (DoT). The responsibilities of TEC, include the following:

a. Preparation of standards and specifications for Indian telecom network and services. Assessment of new services and technical advice to DoT for their introduction in the Indian telecom network.
b. Evaluation of equipment and services. According approvals for equipment, technology and services.
c. Technical support for DoT. Technical advice to TRAI, TDSAT, USOF, BSNL and MTNL, on request of DoT. Coordination with C-DoT.
d. Interaction with multilateral agencies like APT, ETSI and ITU through DoT and facilitating the objectives of mutual recognition assessment.
e. Facilitating Develop necessary expertise to imbibe the latest technologies and results of R & D.

2.5.2 NATIONAL TELECOMMUNICATIONS INSTITUTE FOR POLICY RESEARCH, INNOVATION & TRAINING (NTIPRIT)

NTIPRIT was established in 2010 as National Telecom Academy, the telecom training Institute of Department of Telecommunications. The National Telecom Policy -2012 envisages NTIPRIT as an institute of world repute, for capacity building and enabling research in India centric technologies and policies in telecommunications field (NTIPRIT 2015).

2.5.3 TELECOM ENFORCEMENT, RESOURCE AND MONITORING (TERM) CELLS

The need for presence of telegraph authority in the field at all the License Service Areas (LSA) and large telecom districts of the country was felt in view of growing number of telecom operators and telecom traffic with illegal / clandestine telecom operations. TERM cells have been assigned the job of vigilance, enforcement and monitoring the adherence of license conditions by telecom operators and network security issues. TERM cells are also responsible for compliance to Electro Magnetic Field (EMF) radiation norms of telecom towers.

2.6 CENTRAL PUBLIC SECTOR UNDERTAKINGS IN TELECOMMUNICATIONS DOMAIN

The Central Public Sector Undertakings (CPSUs) working under Department of Telecommunications are as follows:-

(i) Bharat Sanchar Nigam Limited (BSNL)
(ii) Mahanagar Telephone Nigam Limited (MTNL)
(iii) Telecommunications Consultants India Limited (TCIL)
(iv) Indian Telephone Industries (ITI)
(v) Bharat Broadband Networks Limited (BBNL)

2.6.1 BHARAT SANCHAR NIGAM LIMITED (BSNL)

Bharat Sanchar Nigam Limited (BSNL) is a public sector telecom service provider. It came in to existence on 1st October 2000 as a result of corporatization of the erstwhile Department of Telecom operation & Department Telecom Services. The company is responsible for provision of telecom services across the length and breadth of the country excluding Delhi and Mumbai. It is a 100% Govt. of India owned Public Sector Undertaking (PSU).

BSNL provides all types of telecom services namely telephone services on wireline, WLL and Mobile, Broadband, Internet, leased circuits and long distance telecom Service. The vast nationwide telecom network of BSNL covers almost all the nook and corners of the country (BSNL 2015).

2.6.2 MAHANAGAR TELEPHONE NIGAM LIMITED (MTNL)

Mahanagar Telephone Nigam Limited (MTNL) is responsible for the control, management, operation of the telecommunications networks in Delhi and

Mumbai. It was established in 1986 as central government owned enterprise. MTNL is the principal provider of fixed-line telecommunication service in two metropolitan cities of Delhi and Mumbai. The company provides GSM Mobile services in Delhi NCR (four peripheral towns Noida, Gurgaon, Faridabad & Ghaziabad along with Delhi city) and the areas falling under the Mumbai Municipal Corporation, New Mumbai Corporation and Thane Municipal Corporation along with Mumbai city.

Further, MTNL also provides dial up internet services, broadband service in Delhi and Mumbai. MTNL launched 3G mobile services in 2008.

The authorized capital of the Company is $ 800 crores. At present, 56.25% equity shares are held by Government and remaining 43.75% shares are held by FIIs, financial institutions, banks, mutual funds and others including individual investors(MTNL 2015).

2.6.3 ITI LIMITED

Indian Telephone Industries (ITI) Limited a public sector company is India's pioneer venture in the field of telecommunications. It was started with Bangalore in 1948, operations of ITI further extended to other areas by setting up the manufacturing plants at Srinagar (1968), Naini (1971), Rae Bareli (1973) and Mankapur (1984) and Palakkad (1976). Apart from the manufacturing Plants, ITI has a dedicated Network Systems Unit for execution of turnkey projects and installation and maintenance support of all supplied products. ITI has three separate Project Divisions at Mumbai, Pune and Bangalore for deployment of GSM equipments of BSNL and MTNL.

The Company is a central public sector unit in medium and light engineering sector with 90% share holding by the central Government. The headquarter of ITI Ltd. is located at Bangalore (ITI 2015).

2.6.4 TELECOMMUNICATIONS CONSULTANTS INDIA LIMITED (TCIL)

Telecommunications Consultants India (TCIL) is a consultancy organization. It came in to existence on March 10, 1978.

TCIL is a Schedule-A Miniratna CPSE in Technical Consultancy Service sector with 100% shareholding by the Government of India. Its registered and corporate office is at New Delhi. TCIL undertakes turnkey projects in all fields of Telecommunications & IT in India and abroad. The core competence of the company is in core and access network projects, Telecom Software, Switching and Transmission Systems, Cellular Services, Rural Telecommunications, Optical Fibre based Backbone Transmission System, IT and Networking solutions, E-governance, Civil and Architectural Consultancy for Cyber Cities, Telecom Complex etc.

2.6.5 BHARAT BROADBAND NETWORK LIMITED (BBNL)

Bharat Broadband Network Limited (BBNL) is the new CPSU under Department of Telecommunications. It was incorporated in 2012.BBNL has been given task to provide broadband connectivity in 2,45,748 Gram Panchayats (GPs).

2.7 TELECOM SERVICE PROVIDERS IN INDIA

The telephony segment in India is controlled by private-sector and two PSUs BSNL and MTNL. The telecom sector is biggest beneficiary of economic liberalization policy of Government of India as almost all private telecom companies were formed with liberalized foreign direct investment in telecom sector. India as a fast expanding and vibrant telecom market attracted global companies like Vodafone and Telenor. Government of India has allowed up to 100% Foreign Direct Investment in telecom sector.

2.7.1 TOP MOBILE OPERATORS IN INDIA

Table 2.5 shows a list of top mobile operators of India as on 31 st Oct. 2015

Table 2.5: Top Mobile Telecom Operators in India

Rank	Telecom Operator's Name	Market Share in Percentage	Subscribers in Millions
1.	Airtel India	23.72	237.97
2.	Vodafone India	18.88	189.48
3.	Idea Cellular Ltd.	16.6	167.29
4.	Reliance Communications Ltd.	11.10	111.42
5.	Aircel	8.43	84.61
6.	BSNL	8.03	80.42
7.	Tata Docomoco	6.06	60.85
8.	Telenor India	4.85	48.72
9.	MTS India Acquired by Relianc Communications	0.82	8.26
10.	Videocon	0.78	7.85
11.	MTNL	0.36	3.6
	Total		1003.48

Source: TRAI (2015)

The mobile telephone market in India is dominated by private sector companies which have 91.75% market share as compared to 8.25 % of Government held companies. Table 2.6 shows Telecom service Providers (TSP) wise number of mobile BTS set up in the country.

Table 2.6: Telecom Service Providers (TSP)-wise

Number of mobile Base Transceiver Station (BTS)

S. No.	TSP	Total BTSs as on 31.05.2015
1	Aircel /Dishnet	58169
2	Airtel/BHL	201804
3	BSNL	116856
4	ETISALAT/Allianz	1366
5	Idea/ABTL	143655
6	Loop	129
7	MTNL	3341
8	QTL/HFCL	2240
9	Reliance	76502
10	Reliance Jio	37937
11	Spice Telecom	2299
12	SSTL (MTS)	8235
13	TTSL/TTML	67401
14	Uninor	24773
15	Videocon	5202
16	Vodafone	158444
	Grand Total	908353

Source-Lok Sabha Starred Question No.122 Dated 29th July, 2015

2.7.2 Top Wired Line Operators in India

List of top wired line operators of India as on 31 st Oct. 2015 is as in table 2.7.

Table 2.7: Top Wired Line Operators in India

Rank	Telecom Operator's Name	Market Share	Subscribers in Millions
1.	BSNL	60.05%	15.52
2.	Bharti Airtel	13.74%	3.55
3.	MTNL	13.64%	3.52
4.	Tata	6.59%	1.70
5.	Reliance Communication	4.50%	1.16
6.	Others (Quadrant, Vodafone, and Sistema	1.48%	0.40
	Total		25.85

Source: TRAI (2015)

Following are the main private telecom service providers in India:-

- **Bharti Airtel Limited.**

Bharti Airtel Limited is the leading telecom operator in India. It was started in July 1995. It is amongst the top 4 mobile service providers of the world. Airtel run operations in 20 countries across Asia and Africa. Its headquarter is in New Delhi. The company offers 2G, 3G and 4G wireless services, mobile commerce, fixed line services, broadband and other telecom services in India. Bharti Airtel has more than 243 million mobile telecom customers in India as on 31st Dec. 2015(Bharti Airtel 2015).

- **Vodafone India Ltd.**

Vodafone India Ltd. is second largest wireless network operator in India. It is a 100% subsidiary of Vodafone group. The company came in to existence in 2007 when Vodafone acquired the telecom business of Hutchisson Essar. The company offers 2G, 3G wireless services. Vodafone India provides services on basis of 900 MHz and 1800 MHz digital GSM technology. It has 193.6 million mobile subscribers in India as on 31 st Dec. 2015. The head office of Vodafone India is in Mumbai (Vodafone 2015).

- **Idea Cellular Ltd.**

The third largest mobile service operator in India is Idea Cellular Ltd. It was established in 1995. It provides 2G, 3G and 4G mobile services and has its own NLD and ILD operations. Its headquarter is in Mumbai. Idea has 171.9 million mobile subscribers as on Dec. 31, 2015 (Idea Cellular 2015).

- **Reliance Communication Ltd.**

Reliance Communications Ltd provides a range of telecom services covering wired and wireless telephony, broadband; national and international long distance services. It was established in 2002. Its headquarter is in Mumbai. It is fourth largest telecom operator in India. It has 100.89 million wireless subscribers as on Dec. 31 , 2015 (RCL 2015).

- **Tata Teleservices Limited**

It was incorporated in 1996. It is a pioneer in CDMA technology based wireless services in India. It started 2G and 3G GSM services in 2008 and 2010 respectively. Its headquarter is in Mumbai. The company has 60.72 million wireless subscribers as on Dec. 31, 2015(TTSL 2015)

2.8 INDIAN TELECOM TOWER INDUSTRIES

Telecom towers are required by mobile telecom industry for last mile connectivity to subscribers. Telecom towers are the vital element of wireless networks. In recent years the telecom tower industry has rapidly grown.

Indian wireless telecom operators made huge investments in active and passive infrastructure for expansion of network coverage. The large debt burden of this investment caused the strain on their funds. Under this situation, the telecom companies decided to reduce costs and focus on their core operations. Formation of separate tower companies by hiving off their tower assets was the crucial step to improve their capital structure and lower operating expenditure. It also increased the potential of monetization of tower portfolio. Moreover, these separate tower companies increased the prospects of passive infrastructure sharing. The tower companies created by hiving off of tower assets added an additional revenue stream for the Telecom companies. This has led to emergence of “telecom towers” as a separate industry. Government’s emphasis on popularizing the sharing of passive infrastructure has also played a major role in the growth of telecom towers industry.

The telecom operators as a tenant can use passive infrastructure and services provided by the tower Infrastructure Company. In passive infrastructure sharing the tower company provide and maintain passive infrastructure i.e. physical sites, buildings, shelters, towers / masts, power supply, battery backup etc..

A tower infrastructure company has to perform following activities:

- Acquisition of tower sites, as well as long-term agreements with land owners
- Liaison with agencies for necessary regulatory approvals
- Installation and commissioning of tower and allied equipment
- Provision, Operation and maintenance of support services such as generators, air-conditioners, lighting and security etc.

In addition of above, the tower companies may provide turnkey solutions to telecom companies such as sourcing of equipment, testing, and maintenance.

Infrastructure sharing can save capital and operational costs. It is quiet useful for entry in to new areas and in the long run to build more cost-effective and competitive services. Passive infrastructure sharing can save 15-20% capital cost and 20-30% operational expenditure of a telecom operator. Telecom towers are capable of hosting multiple technologies such as 2G / 3G / 4G LTE. The growth of the tower industry is coupled with the expansion of wireless network.

2.8.1 TYPE OF TELECOM TOWER COMPANIES

1. Telecom Operators Owned Tower Companies: These companies have been formed by hiving off the tower asset of telecom operators into subsidiaries. Most of telecom operator-owned companies are owned by a single operator. Indus Towers Limited (ITL) is a joint venture the shareholding in which is held by three operators: Bharti Airtel Limited, the Vodafone India , and the Idea Cellular . Telecom operators owned tower companies own and manage over 80% of the telecom towers in the country.

2. Independent Telecom Tower Companies: These companies are owned or managed by independent companies. The business model of these companies is to build, own and lease telecom towers to telecom operators. GTL Infrastructure Ltd, ATC and . There are number of small companies in this segment.

3. Towers owned by PSU operators BSNL and MTNL: State run PSUs also have sizable number of telecom towers which are available for other telecom operators on sharing basis .

2.8.2 MAJOR TELECOM TOWER COMPANIES

Major Telecom Tower Companies in India are:-

- Bharti Infratel Ltd.
- Indus Towers Ltd.
- Viom Networks Ltd.
- GTL Infrastructure Ltd.

- **Bharti Infratel Limited**

Bharti Infratel Ltd. was created in July 2007 by hiving off the tower portfolio of Bharti Airtel .It has 42% share in Indus Towers, a Joint Venture of Bharti Infratel ,Vodafone India and Idea Cellular . Over 35,000 towers owned by Baharti Infratel are, spread over 18 states, and 11 Telecom circles (Bharti Infratel 2015).

- **Indus Towers Ltd.**

It was formed in November 2007 to provide passive infrastructure services to telecom operators. It is a joint venture of Bharti Infratel, Vodafone and Idea. Vodafone and Bharti Infratel has shareholding of 42% each while Idea has 16% share .With more than 118,000 towers spread over 15 telecom circles, Indus Tower is the largest telecom tower company of the India (Indus Towers 2015).

- **Viom Networks Ltd.**

Viom Networks Ltd. was established in 2009 by merger of Quippo Telecom Infrastructure Limited (QTIL) and passive infrastructure business of Tata Teleservices Ltd. (TTSL). It also acquired the tower portfolio of Tata Teleservices (Maharashtra) Ltd. Its headquarter is in Gurgaon. Viom has 42000 telecom towers spread across all over the country. (Viom Networks 2015)

- **GTL Infrastructure Ltd.**

This company is an independent tower infrastructure company .It was incorporated in 2004. Its head office is in Mumbai. The Company has 27,839 towers spread across all the 22 telecom Circles in India (GTL 2015).

2.9 NATIONAL TELECOM POLICY 2012

The key themes for National Telecom Policy 2012 are -

- To provide reliable and affordable broadband access to all citizens
- To ensure inclusive and equitable growth leveraging telecom
- To develop indigenous R&D and manufacturing capability
- To optimize spectrum allocation and licensing

- To develop a balanced licensing regime towards sustainable convergence and VAS model
- To promote robust, sustainable and secure state of the art telecommunications network
- To facilitate skill development for the telecom sector
- To address Quality of Service (QoS) issues and protection of consumer interests
- To address financial concern of players in the telecom ecosystem

In new telecom policy 2012 there is emphasis on sustainability. The new policy promotes the use of energy efficient equipment and renewable energy technologies in telecom networks. The policy focus on adoption of measures for the reduction of carbon footprint in the telecom sector.

The New Telecom Policy 2012 envisages the use of renewable energy sources for the powering the telecom networks. (DoT 2012)

The working group in Telecommunications set up by planning commission stipulated the thrust on green telecom and use of renewable energy sources in telecom sector.

2.9.1 GREEN TELECOM, USE OF WIND, SOLAR & HYBRID TECHNOLOGIES FOR REDUCING CARBON FOOTPRINTS

Telecom services in rural India face problems due to miserable situation of rural electrification.

The problem of unavailability and poor quality of grid power is a major challenge for extension of telecom services in rural areas. In case of failure of grid power battery is able to provide power back up for certain number of hours. Diesel generators are the only viable solution for powering the telecomm networks in case of long power cuts. The supply, storage, cost of diesel and the resulting pollution (noise and environmental) are major challenges in using diesel generator sets.

The mobile BTS towers in the country have 15-20 KVA diesel generators as power backup. As per TRAI's recommendation on green telecommunications more than two billion liters of diesel is consumed every year, generating 5.4 million tons of carbon. Average per subscriber CO_2 emission is around 22 kg in India as compared to the international average of 8 kg of CO_2 emission per subscriber. One liter diesel emits 2.68 kg of CO_2 and 1 KWh of grid power consumed emits around 0.84 kg of CO_2 . (TRAI 2011)

The primary reason for this CO_2 emission is these diesel generators powering of the telecom towers and efforts are required to be taken for reduction of carbon footprint in the telecom industry. (Planning Commission Working Group 2012)

One of the approaches suggested by the working group in telecommunications is to design and develop low energy consuming and low radio emission telecom systems. Due to limited wired line network in India, wireless broadband Internet services are becoming popular. The mobile telecom sector will need more spectrum to provide services and technologies with better spectral efficiency (number of bit per Hz per tower). It is crucial that, as the amount of spectrum usage increases and the number of bits transmitted per Hz goes up, the amount of energy used per bit considerably goes down. (Planning Commission Working Group 2012)

The telecom sector in India must take note of its energy use as well as the increasing carbon emission. There is need of research and development in architecture and technologies to reduce energy consumption per bit and power transmitted per bit.

The working group in telecommunications further suggested reducing energy consumption required for cooling of BTS sites. The air conditioners installed to cool the chambers housing base stations, power converters and batteries in the summer heat consume much of the power. The outdoor base stations and alternate cooling solutions such as "free cooling" can avoid the air conditioners required to cool the chambers housing base stations. In some areas, running hours of the air conditioners can be curtailed using “free cooling”.

The working group (Planning Commission Working Group 2012) also considered the use of alternative energy sources for telecom and found Solar Photovoltaic Cells & Wind Turbine Generator as attractive options due to suitability for decentralized applications and their environment friendly nature. The alternative energy sources can satisfy power needs of BTS sites as well as cut down harmful greenhouse gases. Reliability and cost of these technologies is an issue.

With growth of telecom networks and increasing energy requirements, the critical areas identified by working group during 12 th five year plan are as follows:

a. The energy consumption in telecom sector is to be reduced to ten percent.
b. Product development and research in low emission building wireless system is to be encouraged.
c. Research and product development in decentralised, renewable and hybrid energy sources for telecom applications is to be given priority.
d. Efforts are to be targeted for innovative products in the field of energy storage and energy saving .
e. Internationally acknowledged benchmarks are to be used for evaluation of energy efficiency of Indian telecom Networks.
f. Targets are to be set up to reduce carbon emission of mobile network by 8% by the year 2012-2013, 12% by the year 2014-2015, 17% by the year 2016-2017 and 25% by the year 2018-19.
g. There should be target to power 50% of all rural telecom towers and 33% of the urban telecom towers by hybrid power (Renewable Energy Technologies (RET) + Grid power) in the next five years. Further, all

rural towers and 50% of urban towers are to be powered by hybrid energy by the year 2020.

h. The total power consumption of each BTS is to be brought down to 500W by the year 2020.

Conclusion

This chapter show-cases the growth of Indian Telecom Sector since 2000. The role played by wireless telephony in fast development of Indian telecom sector has been explained. This chapter has introduced the key decision making bodies and Government's offices in the telecom domain of the country. Emergence of telecom tower industry has been explained. Finally the chapter concludes with discussion on National Telecom Policy2012 and recommendation of working group on Telecom regarding energy saving measures in telecom operation.

CHAPTER 3

LITERATURE SURVEY

Discussion in previous chapter reveals that the telecom services have grown significantly in India but without climate concerns have not been given due importance. Mostly, these services have been running with conventional energy generation methods. There is significant potential for energy conservation in Indian telecom sector. The discussion has also emphasized the significance of policy and regulatory interventions for promotion of energy efficiency and carbon emission reduction in telecom sector.

Literature survey has been done under the broad categories as follows: (i) Energy Conservation and Energy Efficiency (ii) Energy Consumption and Carbon Emission of ICT and Telecom Networks (iii) Energy Conservation and Regulatory Drivers for Sustainable Growth of Telecom Sector (iv)Review of Energy Conservation Measures in Telecom Sector

3.1 ENERGY CONSERVATION AND ENERGY EFFICIENCY

3.1.1 ENERGY CONSERVATION

Energy conservation is another name for more efficient utilization of the energy resources. Energy Conservation mean that a given amount of energy inputs would produce larger amounts of output than what it did previously .In a macro settings, it would imply that nation's energy consumption would be reduced without hampering the process of economic growth .Energy conservation is rationalization of use and reduction of losses . (Diwan & Dwivedi, 2009)

Energy resource conservation is one of the most effective strategies for managing our energy problems. The following factors serve to highlight the role of energy conservation as an important "energy resource", one that, in addition, poses no pollution problems:

- The realization of the severely finite nature of the terrestrial fossil fuel resources.
- The need to preserve the environment. The concerns regarding the long-term radiation hazards associated with nuclear energy.
- The uncertain future relating to alternative renewable energy technologies

Both energy and environmental considerations point to the desirability of employing energy conservation as a strategy for tackling these twin problems. It is often found that energy conservation efforts require the least investment in relation to the accruing benefits. (Natarajan, and Henham 1992) Cook (1976) and Chaturvedi (1997) noted the role of Government in reduction society's demand for goods and services requiring the expenditure of energy resources. They also took note of contribution of engineering fraternity in supplying this reduced demand at maximum possible efficiency. The Inter-Ministerial Working Group on Energy Conservation (IMWGEC) has explained “Energy Conservation’ from an operational viewpoint, as per the group definition “Energy conservation requires smaller energy inputs for the same level of economic development. An increase in energy productivity is the characteristic of energy conservation. Energy conservation also include the replacement of costly imported energy by cheap energy; the nurturing of renewable energy resources to complement conventional resources etc.” (Inter-Ministerial Working Group on Energy Conservation (IMWGEC), 1983)

Energy conservation has a potential to contribute to sustainable development both by reducing the energy resources consumption and by a corresponding decrees in release of pollutants (Shukla, 1993)

Kablan (2004) notes that "An effective energy conservation program in any country should encourage the different enterprises, utilities and individuals to employ energy efficient processes, technologies, equipment, and materials. Governments use different mechanisms or policy instruments such as pricing policy (PP), regulation and legislation (RL), training and education, fiscal and financial incentives (FFI), and R&D to promote energy conservation. Effective implementation of energy conservation policies requires prioritization of the different available policy instruments" (Kablan, 2004).

According to Bureau of Energy Efficiency (BEE) to achieve "Energy Conservation" the growth of energy consumption is reduced, measured in physical terms. Energy conservation is the result of several processes or developments, such as productivity increase or technological progress. (Bureau of Energy Efficiency, 2002). BEE (2002) points out "Energy conservation and Energy Efficiency are separate, but related concepts"

3.1.2 ENERGY EFFICIENCY

The term "Energy Efficiency" has been defined by various researchers in various ways depending up on area of study and context of literature. In industrial sense, the energy efficiency can be defined as, "it is the amount of energy consumption per unit of product/output" (McKenna, 2009).According to World Energy Council [WEC] energy efficiency is defined as: "Energy Efficiency is the reduction in the energy used for a given energy service of a level or activity. These reductions in energy consumption can change with better organization and management or improved economic efficiency in the sector rather than being just a result of technical change" (WEC, 2004)

According to UN energy report, energy efficiency is the most cost-effective, least-polluting, and readily-available energy "resource" available in all end-use sectors in all countries. (UN Energy Report 2006)

Researchers have observed that, energy efficiency has assumed more significance now because of being the most cost-effective and reliable means of mitigating the global climate change though it has been in practice ever since the first oil crisis in 1973. More efforts are needed to put in “Energy Efficiency” improvements for the control of carbon emissions. While “Energy Efficiency” focuses on cutting on energy cost to make products or services more competitive, it does not tackle the exigent problem of reducing the total supply and demand of conventional energy by fuel switching. It has been pointed out that compared to “Energy Efficiency”, the term ‘Energy Conservation’, enjoys a much wider scope. Energy Efficiency can be considered as a short term strategy, for long term approach for sustainable energy production and consumption ‘energy conservation measures’ are employed (Dey 2009).

A number of studies have quoted the advantages of increased energy efficiency such as reduction in atmospheric pollution, boosting up of industrial competitiveness, generation of employment and better business opportunities, enhancing the productivity, increasing the security of supply and contribution to poverty alleviation along with other aspects (IAC 2007) (Jakob M. 2006) (Jochem 2000) (Laponche, Jamet, Colombier, & Attali 1997) (Leaman & Bordass 1999) (Levine, Metz, Davidson, Bosch, & Dave 2007).

3.1.3 INITIATIVES TAKEN BY THE GOVERNMENT FOR ENERGY CONSERVATION AND ENERGY EFFICIENCY

Various policy initiatives / institutional efforts were taken by the government of India for energy conservation and energy efficiency. Various studies underlined the approach of Government of India to meet the energy demand of the nation while ensuring minimum growth in CO_2 emissions to avoid an irreversible damage to the earth system. Government is promoting greater use of renewable in the energy mix mainly through solar and wind and also shifting towards supercritical technologies for coal based power plants .Efforts are made for saving the energy through demand side management. The Energy Conservation Act 2001 provides legal framework to energy efficiency. The Electricity Act 2003 also emphasized efficient and environment friendly policies. The Electricity Act directs efficiency in electricity generation, transmission and distribution. (MoP 2015) (BEE 2015) (Vasudevan et al 2011) (Dey 2009).

India intends to lower the emission intensity of Gross Domestic Products (GDP) by 33% to 35% by 2030 to below 2005 level. The National Action Plan for Climate Change (NAPCC) was launched in 2008 aiming for GHG reduction. One of the eight missions under the National Action Plan on Climate Change (NAPCC) is National Mission for Enhanced Energy Efficiency (NMEEE). NMEEE is an included approach to climate change mitigation by means of energy efficiency actions .The main objective of NMEEE is to have a market based approach for unlocking the energy efficiency opportunities by creating beneficial regulatory system and policies. (BEE 2015)(MoEF 2015)

The Perform Achieve and Trade (PAT) scheme is introduced under this scheme with the aim to improve energy efficiency in energy intensive industry through market- based, cost-effective mechanism. It was included in the amendment to the 2001 Act in 2010 along with the introduction of the energy saving certificate for companies. The PAT scheme would see energy intensive company generating benefit through trading in Energy Saving Certificate (EScerts). In case of failure to meet the energy reduction target at the end of PAT cycle of three years, companies can avoid the penalty by purchasing EScerts from the compliant units. The scheme will be similar to carbon trading and will pave way for creation of national market for energy efficiency. This way, it will be helpful to reduce overall energy consumption. (BEE 2015)

3.1.4 METHODS OF ENERGY CONSERVATION

There are various methods for energy conservation which could be broadly classified into:

- Technological measures
- Social or behavioral measures

- Policy related measures

i) Technological Measures

Langley (1984) classified the technological measures in to following categories:-

- Installation of new process/equipment
- Replacement of existing process/equipment
- Upgrading of existing process/equipment

Industries implement technological measures, as the new technologies tend to efficiently use the energy (Worrell, Laitner, Ruth, & Finman, 2003) (von Weizsäcker, Lovins, & Lovins, 1997)

ii) Social or behavioral measures

Various studies (Wedge, 2003) (Dahle & Neumayer, 2001) (Bertoldi, Ricci, & Almeida, 2001) suggest that the behavioural approach measures are an effective way for improving energy efficiency. It's been suggested that these measures have to be implemented before any other measure is implemented as the capital required for this is low (Wedge, 2003) (Dahle & Neumayer, 2001) (Bertoldi, Ricci, & Almeida, 2001). Ross and Williams (1981) pointed out towards the low adoption rate of even the cost effective energy saving technologies. sThe social-psychological aspects of conservation must be given more attention to address the human side of energy conservation (Costanzo et al 1986).

iii) Policy related measures

The third method of energy conservation is policy related that is due to the change in legislation, resulting in social/behavioral change measures or implementation of technical measures. to improve the energy efficiency is by policy formulation. This has the potential to reduce the energy consumption by legal compliance. In India, the government has taken serious efforts in terms of setting up various institutional efforts and policies on energy efficiency and its conservation; let it be setting up of Fuel Policy Committee [FPC] in the year 1970 or the enactment of Energy Conservation Act 2001 [EC Act] in 2001.

3.1.5 DRIVERS AND BARRIERS TO ENERGY CONSERVATION

Even though organizations benefits greatly by conserving energy, various studies indicate that the recommended conservation procedures are often not implemented due to certain practical drawbacks, such as:

- Cash flow problems.
- Pay-back period longer than about two years.
- Resistance to change on the part of management and labour.
- Lack of commitment in the top management.
- Energy cost being a small fraction of total cost. (Cook ,1976)

Researchers (SPRU 2000)(Hirst and Andersson 1993)(Jaffe & Stavins 1994)(Sanstad and Howarth, 1994) (Stern and Aronsson, 1984)(Stern 1992)(Velthuijsen, 1995) (Weber 1997)(Brown, 1990) analysed this 'energy-efficiency gap'. They discussed the impact of barriers to energy efficiency responsible for 'energy-efficiency gap'.

These barriers depend on sector and regional specific conditions .Ramirez et al., (2005) note that sector and area specific studies are required to investigate these barriers and implement successful energy policies.

Researchers (Hasanbeigi, Menke, & du Pont, 2010) (Thollander & Ottossom, 2008) (Rohdin & Thollander, 2006a) (Rohdin, Thollander, & Solding, 2006b) have identified certain factors that drive the organizations to implement the energy conservation and energy efficiency.

3.2 ENERGY CONSUMPTION AND CARBON EMISSION OF ICT AND TELECOM NETWORKS

3.2.1 INFORMATION AND COMMUNICATION TECHNOLOGIES

Information and Communication Technologies (ICTs**)** can be defined as the interlinking technologies that provide access to information through telecommunications. Generally it is considered as extended synonym for information technology (IT), but here focus is on telecommunications. UNESCO (2002) defines the ICT as "the combination of information technology with other, related technologies specifically communication technology" (UNESCO 2002)

3.2.2 CARBON EMISSION OF ICT AND TELECOM NETWORKS

Literature review under this category reveals that the contribution of ICT sector (excluding the radio communication sector) to the global Green House Gases (GHG) emissions is between 2-2.5 percent (ITU 2008). In this estimate, impact of computers, printers, office communication, wired and wireless telephone devices, servers and cooling equipment are included. Estimates given by the researchers for GHG contribution of ICT industry may vary with definition of the industry and its energy consumption. Kumar R. and Mieritz, L.(2007) estimated that excluding broadcasting the contribution of ICT equipment was 2 to 2.5 percent of the global greenhouse gas emissions . The major contribution to it i.e. 40 percent is made by the energy consumption of the computers and monitors while other contributors are wired and wireless telecommunications (24%), data centers (23%) and printers (6%) (Kumar R. and Mieritz, L 2007) . Another researcher employed life cycle assessment to determine the impact of ICTs and out comes were largely similar (Malmodin 2009) .

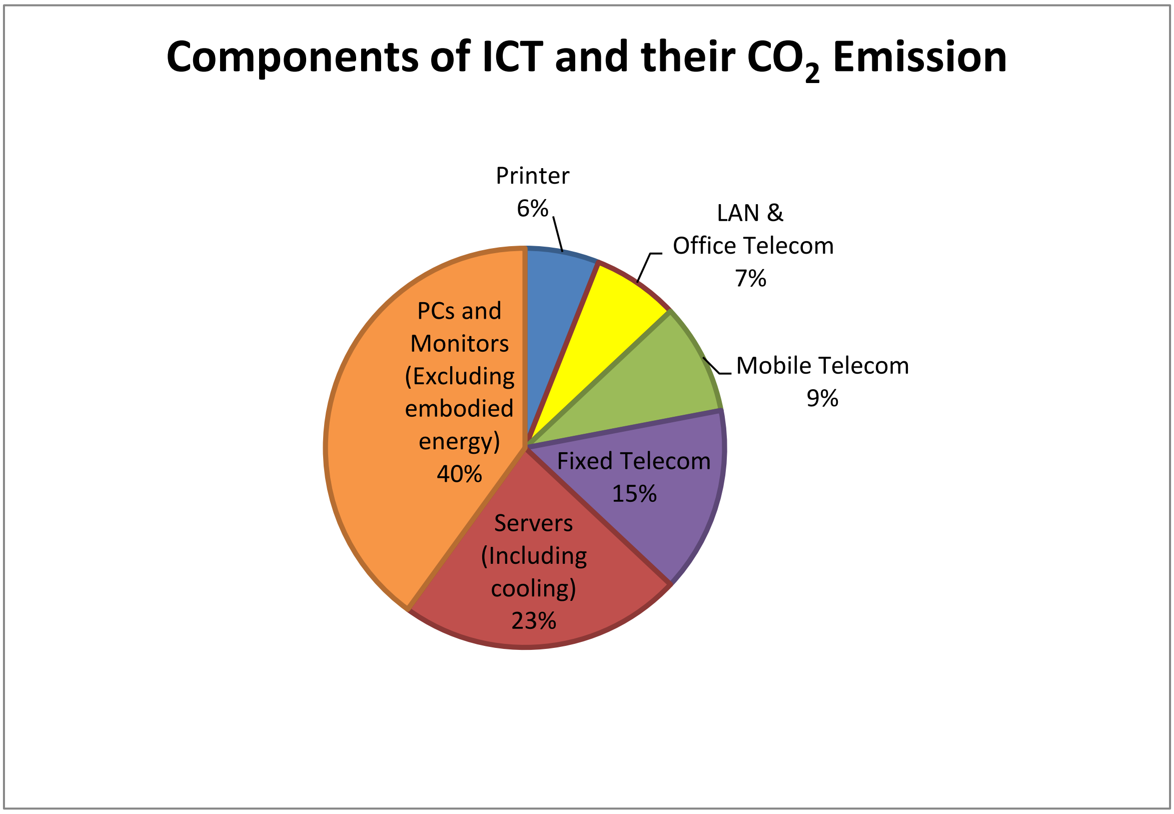
Sutherland (2011) quoted the estimates of the overall contribution of the ICT sector to global emission.

The estimates are as follows:-

- Gartner Group 2007: ICT sector c.2.5 per cent of global emissions;
- KTH Royal Institute of Technology 2007:ICT sector 1.3% of global emissions (3.9% of global ns (3.2% of global electricity use);

Figure 3.1 shows components of ICT and their CO_2 emission.

Fig.3.1: Components of ICT and their CO_2 emission

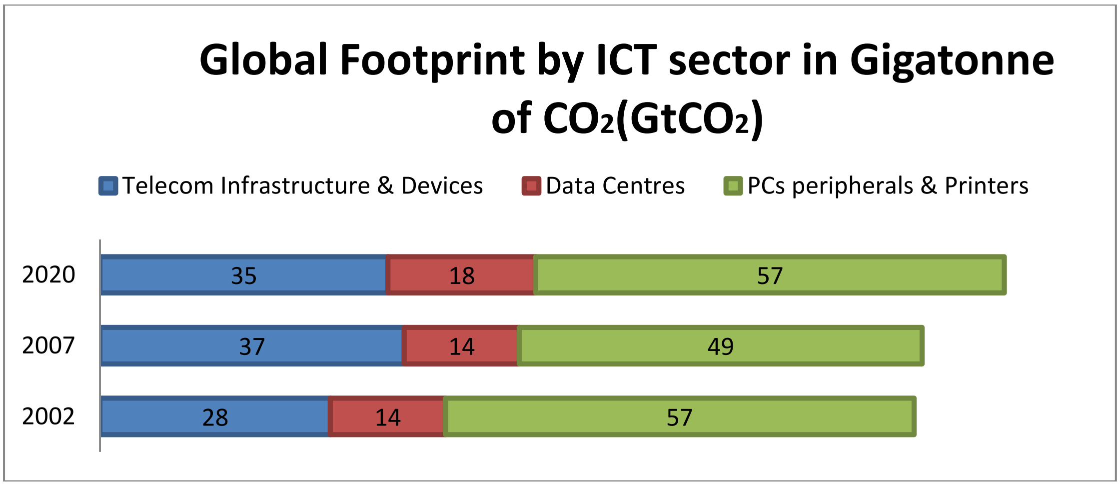


Source: Gartner Group (2007)

Koomey (2007) focused on data centres and estimated that worldwide electricity use for servers doubled between 2000 and 2005, and further he suggested that consumption would increase by a further 40% by 2010. Plepys (2002) observed that computer networks require more of other power demanding equipment, such as servers, amplifiers, routers, filters, storage devices, and communication lines. Additional energy is also required for climate control of the network facilities. Lange C et al (2011) observed "The energy consumption of telecommunication networks is expected to grow significantly over the considered time period of approximately a decade. It became obvious that home networks particularly consume the largest part of energy. They have a high number of elements and are very heterogeneous in terms of used equipment. In the network segments under the responsibility of the network operator, the heaviest energy-consumption increases are estimated in IP/MPLS core networks as well as data centers. The access networks fixed and mobile radio consume largest shares of the overall energy consumption of telecommunication networks owing to lots of active network elements that are widely distributed throughout the field".

Fig. 3.2 depicts the detail of projection of carbon emission by ICT sector by 2020.

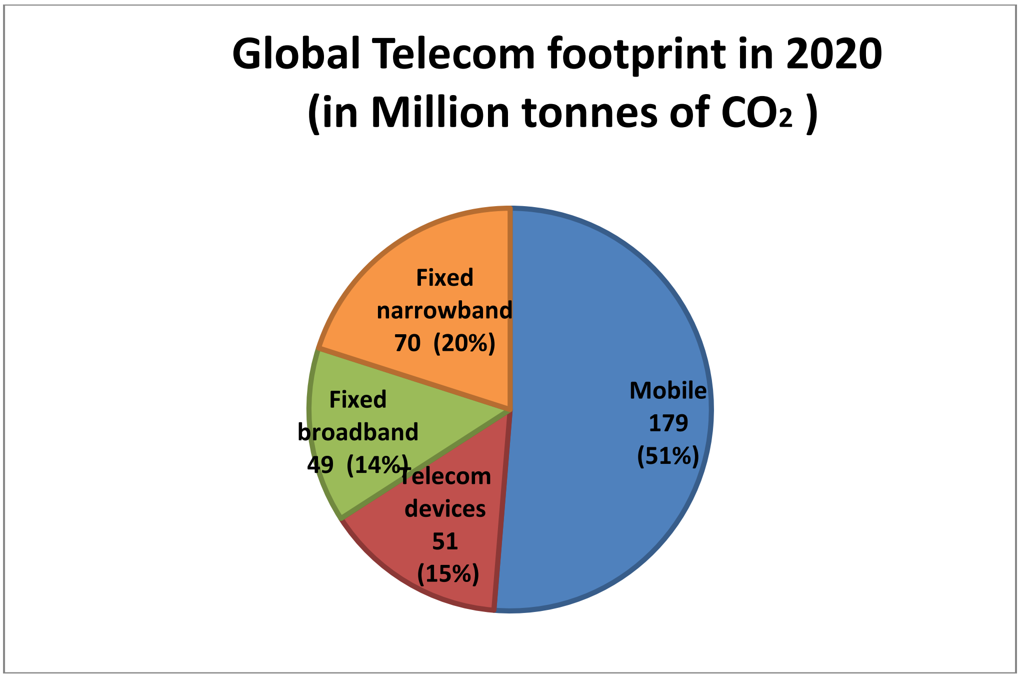
Fig 3.2: Projection for Carbon Footprint of ICT Sector



Source: TRAI (2011)

Telecom networks and services are expanding at an exponential scale all over the world . Figure 2.3 demonstrates the projection of CO_2 footprint due to various telecom services in year 2020.

Fig: 3.3: Global Telecom Footprint in 2020

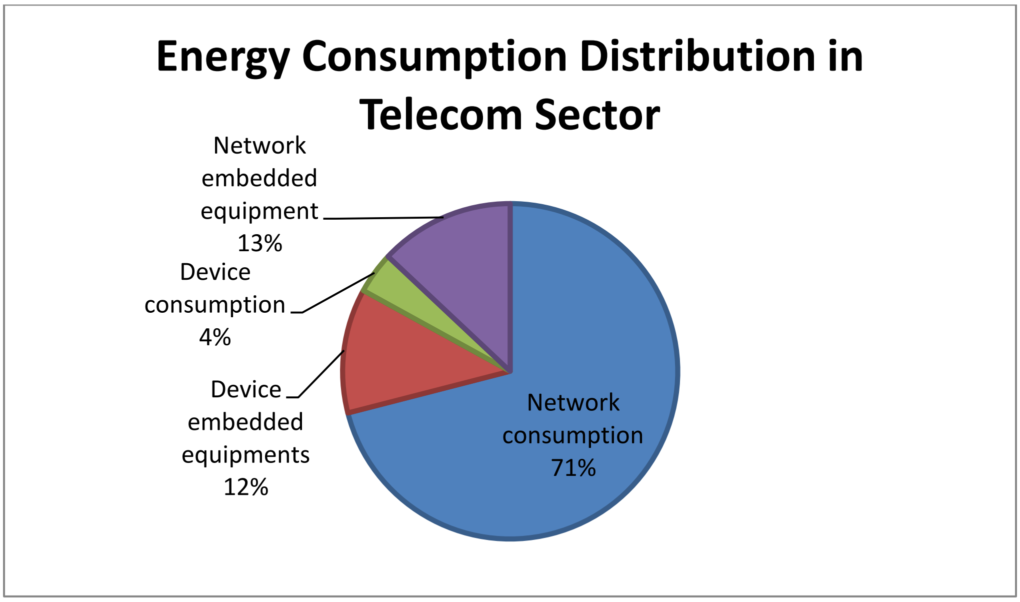


Source: TRAI (2011)

Gerhard Fettweis & Ernesto Zimmermann (2008) estimated that currently, the telecommunications networks (wired and wireless) and data centers are accountable for around three percent of the global electricity consumption. In case of continuation of present growth rate, this consumption may rise and become thirty times in twenty three years. Further, the energy consumption of backhaul networks and base stations of mobile communication networks was referred as approx. 60 billion kwh per year corresponding to 0.33% of global electricity consumption. (Fettweis and Zimmermann 2008)

Researchers all over the world are working in determination of energy consumption and carbon emission in respective countries. Schafer et al (2001) estimated the energy usage of mobile phone services in Germany. Matthews et al(2003)calculated electricity use of wired and Wireless telecommunications networks in the United States. Roeth et al (2005) estimated energy consumption by telecommunications and office apparatus in commercial buildings in USA while Kommey et al (2007) in LBNL study projected total power utilized by servers in U.S. and globally. Yu et al (2010) estimated the energy utilization of mobile phones for China. Paiano et al (2011) projected energy consumption in the Italian cellular phone sector. In Indian context an analysis was carried out by Krisnan et al (2011) regarding energy use and carbon emissions of the Indian mobile telecom sector. Telecom regulator TRAI in its recommendations estimated that carbon emission from the ICT sector in India is around 4% of the GHG emissions that is approximately 80 million tons of CO_2 emission annually. The telecom sector is accountable for about 25% of this emission i.e. 1% of the GHG emissions. Thus, Indian telecom sector contributes around 20 million tons of CO_2 per year (TRAI 2011). As per GSMA and TRAI, 71% energy is required for telecom network operation. Figure 3.4 shows the distribution of energy consumption in telecom sector.

Fig.3.4: Energy Consumption Distribution in Telecom Sector



Source: TRAI (2011)

The rising concentrations of greenhouse gas (GHG) in the international atmosphere were first time reported in 1990 by The Intergovernmental Panel on Climate Change (IPCC, 1990). This was attributed to the human activities, mainly due to burning of fossil-fuels. GHGs are primarily responsible for climate change. The major greenhouse gases are: carbon dioxide, methane, and nitrous oxide etc. Increased concentration of GHGs may cause adverse impacts on environment, ecology, human, animals and plants (Sarkar 2010).

There is a substantial literature about the impacts of climate change (Cline1992b; Fankhauser 1995; Mendelsohn et al. 2000; Nordhaus 1991;Tol 2002a) . Various researchers have identified the linkage between energy consumption and carbon emission (Soytas et al. 2007, Jalil and Mahmud 2009, Soytas and Sari 2009, Zhang and Cheng 2009, , Akbostanci et al. 2009, Ozturk and Acaravci 2010, Apergis and Payne 2010, Acaravci and Ozturk 2010, Alam et al. 2011, Pao and Tsai 2011, Jafari et al. 2012 and Farhani 2013). The greenhouse effect can be mitigated by using preventative measures. According to Cline (1992), preventative measures that can be used to address climate change are as follows:

a. Reducing the level of economic activities responsible for emissions of greenhouse gases,
b. Adopting more energy efficient technologies that allows the same level of economic activity but at a lower level of CO_2 emissions

The National Action Plan on Climate Change (NAPCC) released in 2008, outlines the policies and programs to mitigate and adapt to climate change. The NAPCC enunciates eight key National Missions .The NAPCC also include energy efficiency as one of the measure to fight climate change (NAPCC 2008).

The telecom sector in India is one of the highest emergent sectors. From a subscriber base of 28.93 million in year 2000 to subscriber base of millions in 1002.05 Million at the end of May 2015, the energy demand of the sector is growing.

The energy consumption of telecom networks is the main cause of carbon emission from the telecom networks. The majority of this CO_2 emission is caused by the utilization of the telecom network equipments (TRAI 2011).

3.3 ENERGY CONSERVATION AND REGULATORY DRIVERS FOR SUSTAINABLE GROWTH OF TELECOM SECTOR

The Indian telecom sector is growing at a very fast pace. With the growing numbers of mobile subscribers and internet users the energy requirement of the sector are increasing day by day. The telecom sector comprises telecom buildings and telecom towers .The telecom buildings house wired line exchanges, main switching centers telecommunication switching, networking equipments and billing centers while telecom towers are used for mobile telephony. The telephone exchange buildings are highly energy intensive buildings operating round the clock. On the other hand the growing need of wireless telecommunication requires round the clock operation of telecom towers sites. According to TRAI (2011) estimates, the annual electricity consumption of 400,000 telecom towers spread over the country is around 11169 million kWh (TRAI 2011) .The India telecom industry uses about 2 billion litres of diesel (USD 1.15 billion). This creates 5 million tonnes of CO_2 emissions (approx.) annually. (Vasudevan etal 2013). (TRAI 2011) (Greenpeace 2011). The Niti Ayog in its report on India Energy Security Scenarios 2047 estimated energy demand and CO_2 emissions of telecom towers as 83TWh per year and 19 million tonnes of CO_2 emissions for the base year 2012. (IESS 2015)

Telephone Exchange buildings consume energy in Lighting, Air-conditioning and Power plant (AC-DC Rectifier) 48 V DC for Exchange Equipment. A careful observation of nation energy conservation award winning case studies of telecom buildings point out to huge energy saving potential in telecom buildings.(BEE 2014) Various studies of energy management and energy conservation in telecom buildings such as Azad (2004),Varshneya (2002),Gupta(2000) established the need of energy conservation in telecom sector .

A no. of studies were carried out regarding use of renewable sources of energy in telecom sector.

Ribeiro et al(2009) , Pande (2009),Nema and Ragnekar (2010), Lubritto (2010) ,Prasad (2010), Nema (2011), Odadzic et al (2011), Panigrahi (2012), Faruk et al (2012)and Pachauri et al(2014) are some of the researchers who worked in the area of renewable energy solutions and GHG emissions at the telecommunication sites.

The glorious growth in telecom sector has created many adverse effects on environment like emission of green house gases and carbon dioxide into atmosphere. Use of enormous amount of fuel has resulted into paucity of energy resources. This growth however has and continues to be at the cost of climate powered by an unsustainable and inefficient model of energy usages. Simultaneously this growth has also come at significant and growing loss to the state exchequer raising fundamental questions on the future business and operation model of the telecom sector .(Chhaya 2013)

3.4 REVIEW OF ENERGY CONSERVATION AND CARBON EMISSION REDUCTION MEASURES IN TELECOM SECTOR

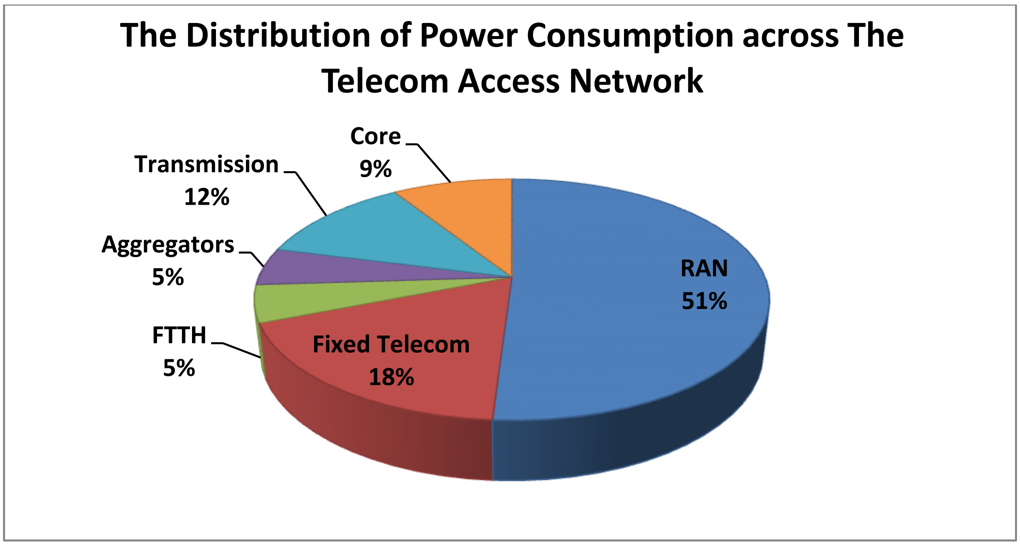
It is evident from the figure 3.4 that telecom network consumption is responsible for 71% of total telecom energy consumption. The mobile network is expanding very fast while the fixed network is almost at saturation level. Figure 3.3 demonstrates that by year 2020 mobile network will be accountable for more than half of telecom energy consumption as well as carbon emission.

TRAI (2011) has attributed 80% energy use by telecom operator for network operation and 20% for remaining activities. Of the energy used for network operation 90% is used for radio network and 10% for the core network. The base stations consume the largest amount of energy (TRAI 2011).

The figure 3.5 shows the breakup of the power consumption across the telecom access network. It is visible from the figure that Radio Access Network (RAN) i.e. BTS sites are accountable for more than 50 % of power consumption followed by fixed telecom network .Therefore , energy conservation measures in wireless telecom segment are expected to yield more results .

Fig, 3.5: Distribution of Power Consumption

Across Telecom Access Network



Source: TRAI (2011)

This section focuses on the various technological measures that can reduce the energy consumption in telecom sector. These measures can be categorized as:

i) Energy Conservation in Wireless Segment
   a) Improving energy efficiency in passive infrastructure equipment
   b) Demand side management by reduction of equipment load
   c) Demand side management of active infrastructure at BTS sites

ii) Energy Conservation in Wire Line Telecom and Office Buildings

3.4.1 ENERGY CONSERVATION IN WIRELESS SEGMENT:-

A number of energy conservation measures can be employed in passive infrastructure equipment i.e. generator, battery etc. at telecom towers. Table 3.1 list some of such measures with technical characteristics and economic impact.

Table3.1: Improving Energy Efficiency of Tower Passive Infrastructure Equipments

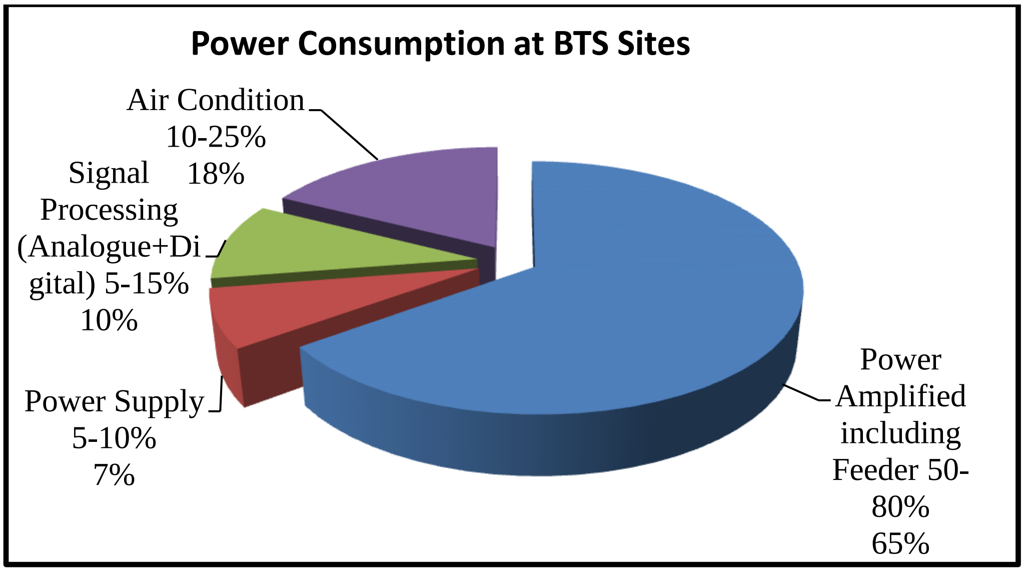
Sl. No.	Measure	Characteristics	Economic Impact
1.	Use of Variable Speed DC Diesel Generators (Prasad S 2011)	Telecom loads are highly variable. It depends on traffic and temperature. The fuel consumption of constant speed AC Diesel Generators does not vary much with load. Therefore conventional AC DG becomes inefficient under low-load conditions. For the telecom requirements, the load is in form of a battery bank which needs to be charged. The variable speed DC generator automatically adjusts its speed to the load requirements thus results in significant savings in the fuel consumption. The speed of the DCDG decreases with increasing battery charge level thereby saving fuel.	Up to 60% saving in fuel consumption is possible with the use of variable speed DCDG. Bharti Infratel saves 10.18 million liters diesel per year by implementation of DCDG at 2000 sites .
2.	Fuel Catalyst (Prasad S 2011)	Fuel Catalyst contains rare earths and metals in a steel barrel form. It is attached in the fuel line. It reformulates the diesel causing the reformulated fuel to burn efficiently. Fuel Oxidation catalyst increases combustion efficiency. It reduces particulates, soot and wax etc. It result in reduction in fuel consumption and better exhaust emission.	Bharti Infratel has planned fuel catalyst installation for 4800 sites. It will result reduction in diesel consumption by 6-9% per year. The estimated revenue savings will be Rs.168 Million per year.

Sl. No.	Measure	Characteristics	Economic Impact
3.	IPMS: Integrated Power Management System (Prasad S 2011)	It provides a complete single point control to manage the power requirements for telecom base stations. It is designed to seamlessly switch between AC and DC power intelligently and maximize power utilization. IPMS results in maximizing usage of grid power and reducing DG run-hours at telecom sites.	Bharti Infratel has planned for 4658 sites and estimated resultant revenue savings of Rs.180 Million per year.
4.	Battery Bank Hybrid Solutions (Balshe W2011)	The solution is meant for increasing battery bank charging rate and providing additional battery banks. This results in enhanced battery backup and thereby, helps to reduce DG run hours and diesel consumption.	Reduced DG run hours results reduction in diesel consumption.
5.	Use of Lithium Ion batteries (McDowell J 2002)	Lithium Ion batteries are charged faster than conventional VRLA Batteries	Saving in electricity required for battery charging. Reduction in diesel consumption if DG is used to charge the batteries.

Figure 3.6 explain the breakup of power consumption at a typical BTS site.

From this figure it is understood that major power consumption takes place in power amplifier and air conditioning . Energy saving measures focus on these two areas.

Fig. 3.6: Power Consumption at BTS Sites



Source: Huwei (2009)

The demand side management energy conservation measures along with their techno-economic analysis are explained in Table 3.2.

Table 3.2: Demand Side Management (Reduction of Equipment Load/T

Sl. No.	Measure	Characteristics	Economic Impact
1.	DC Free Cooling Unit (DCFCU) (Prasad S 2011)	A DCFCU operates on DC power whereas an Air-Conditioner requires a 230 V AC supply. So, in case of a grid Power failure, a DCFCU can run on power available in the battery and reduce the usage of DG by maintaining the temperature. The power consumed by a DC Free Cooling Unit (DCFCU) is only 208 watts as against 1350 watts consumed by a 0.9 ton air-conditioner. Further,	Bharti Infratel has planned for 6318 sites and estimated resultant revenue savings of Rs. 250 million per year.

Sl. No.	**Measure**	**Characteristics**	**Economic Impact**
2.	Soft Start Inverter (Prasad S 2011)	It coverts DC power to AC power, and has the functionality of a soft starter. This is useful at indoor cell sites. This allows running of air-conditioner from battery source during grid unavailability thus avoiding DG usage.	Bharti Infratel has planned installation of soft start inverter at 3534 sites. The estimated resultant revenue savings will be Rs.250 million per year.
3.	Free cooling Units(FCU) (Roy SN 2008)	Free Cooling Units use the outside ambient air for cooling the BTS shelter and avoids the use of air conditioners. .	FCUs consume less power as compared to air conditioners and thus, help reduce energy consumption.
4.	The free cooling system with roof turbo air ventilator system (Roy SN 2008)	Wind energy is used to run roof turbo air ventilator. The centrifugal force caused by the spinning vanes creates a region of low-pressure area, which draws air out through the turbine exhaust. Air drawn out by the turbine exhaust is continuously replaced by fresh air from the outside.	There is no operating cost as it run on wind energy
5.	Remote monitoring of site health parameters through NOC (Network Operations Centre) (Malhotra R 2010)	Better monitoring and management of remote sites	3-5% Energy Saving
6.	Indoor to Outdoor conversion (Prasad S 2011)	Indoor Base station can withstand higher temperatures till 55 °C. The indoor to outdoor conversion can reduce load	Tata Teleservices installed for 4843 sites and estimated resultant revenue savings of Rs 37 Millions per year.

Sl. No.	Measure	Characteristics	Economic Impact
		as it eliminates the requirement of air-conditioning.	with estimated lifetime savings (6 years) of Rs 222 Millions at the investment of Rs 47.3 Millions
7.	Passive Cooling (Roy SN 200)	PCM freezes overnight to absorb heat during day.	Energy saving up to 25% (NSN)
8.	Variable TRX capacity as per traffic (Prasad S 2011)	Load of the radio site vary as per TRX capacity.	Energy is saved.
9.	Installation of High Efficiency Rectifiers with wide input voltage range SMPS (Balshe W 2011)	Installation of High Efficiency Rectifiers with wide input voltage range SMPS with minimum derating at lower input voltages	

Table 3.3 provides the energy saving measures in active infrastructure at mobile BTS sites

Table 3.3 Demand Side Management of Active Infrastructure at Mobile BTS sites

Sl. No.	Measure	Characteristics	Economic Impact
1	Distributed antenna systems(DAS) (Roy SN 2008)	DAS is a network of spatially separated antenna nodes connected to a common source via a transport medium that provides wireless service within a geographic area or structure. A single antenna radiating at high power is replaced by a group of low-power antennas to cover the	Less power is wasted in overcoming penetration and shadowing losses. As a line-of-sight channel is present more frequently, it leads to reduced fade depths and reduced delay spread.

		same area.	
2	Sleep mode BTS (Morosi S 2013)	Sleep mode BTS can turn power Off when the call traffic is low. This capability can be simply added to the site with minor software modifications in BTS technology.	This technology has the potential to reduce power consumption by more than 40% under low traffic conditions and more than 10-15% on an overall level.
3	In-Building Cellular Enhancement Systems (Roy SN 2008)	An in-building cellular enhancement system is a telecommunications solution which is used to extend and distribute the cellular signal of a given mobile network operators	Energy is saved

3.4.2 ENERGY CONSERVATION IN WIRE LINE TELECOM AND OFFICE BUILDINGS

In case of wired line telecom buildings the major electrical loads are telecom equipment load , air conditioning and lighting . In literature, the connected load in telecom buildings is specified as per switching technology. Table 3.4 provides the detail of electrical load in wired line buildings. Telecom office buildings are basically commercial buildings where the major load is air conditioning computers and lighting.

Table 3.4 Electrical Load Details of Wiredline Telecom Buildings

Type of Exchanges(Wired lines)	**Connected Load in Watt (Approx. Percentage of total load)**				
	Light and fans	**Telecom Equipments**	**Air Conditioning**	**Pumps and Others**	**Total**
256+256 Lines Without A/c	1140 (17%)	5556 (83%)	Nil	Nil	6696
256+256 Lines With A/C	1140 (13%)	5556 (62%)	2200 (25%)	Nil	8896
512 to 1.4K Lines (CDOT)	2230 (11%)	11112 (56%)	6600(33%)	Nil	19942
1K Lines to 2K	2880(10%)	16668 (57%)	8800(30%)	750(3%)	3000

Type of Exchanges(Wired lines)	Connected Load in Watt (Approx. Percentage of total load)				
	Light and fans	Telecom Equipments	Air Conditioning	Pumps and Others	Total
Lines RLU/RSU					
2K Lines to 5K Lines RLU/RSU	3820(11%)	22222(59%)	11000(29%)	750(2%)	37792
2K Lines to 5K Lines CDOT Main	6650(10%)	33334(50%)	25800(38%)	1500(2%)	67284
5K to 10K Lines Main CDOT/New Technology)	9560(12%)	33334(41%)	36500(45%)	1500(2%)	80894

Source: Azad (2006)

A number of energy conservation measures can be employed in telecom buildings. Table 3.5 illustrates some of the energy saving measures applicable to wireline telecom buildings, data centers and telecom office buildings.

Table 3.5: Supply Side and Demand side Energy Management in Wire line telecom exchanges and Telecom Office Buildings

Supply Side Management	Characteristics	Economic Impact
Power quality improvement by installing harmonic filters (BEE2010)	Nonlinear loads such as UPS, SMPS, and rectifiers, which are predominantly used in telecom exchanges, lead to harmonic distortion. Excessive harmonic currents can overload wiring and transformers, leading to additional losses.	The implementation of active harmonics filters resulted for a major telecom company result an annual savings achieved of Rs 3.3 million. The investment made for this project was Rs 4 million. The pay back period is 15 months
Energy Efficient Cabling / Bus bars (BEE 2010)	Selecting Cables / Bus-bars with proven lesser impedance-drops per meter of its length helps a lot in reducing transmission losses and contributes appreciably in Energy Efficient System.	By selecting Cables “One-Size-Up” which means by going for higher sized cable one may ensure lesser drop and therefore, higher distribution efficiency.

Demand Side Management

Sl. No.	Measure	Characteristics	Economic Impact
1.	Optimizing the loading on the UPS (BEE 2010)	The efficiency of the UPS system varies with loading. Typically, an UPS system has maximum efficiency at 75-80% loading. At loading of less than 40-45%, the efficiency reduces drastically .An Energy Optimizer is a device which senses the load demand continuously and controls the operation of the number of UPSs at any point of time, and also maintains optimum loading on all UPS.	The efficiency of the UPS system is improved and result in a reduction in demand consumption.
2.	Installation of occupancy Motion sensor (Tyagi A K 2003)	Installation of motion / occupancy sensors is identified as one of the primary Energy saving proposals in cabins/ washrooms / passage area / conference rooms since such places are not monitored for switching off lights when not required.	The PIR Sensor senses the motion of a human body by the change in surrounding ambient temperature when a human body passes through. It turns on the lighting load/ fan to which is connected. The lighting load fan will remain ON until it senses motion. Once the motion is seized it switches OFF the lighting load.
3.	Installation of LED Lights (Tyagi A K 2003)	Reduction in lighting power consumption by 73% and Increase in lifetime up to 3 times	In an Indian company the annual savings achieved was Rs 0.54 million. The investment made for this project was Rs 1 million which is paid back in 22 months. Energy saving : Payback Period<2 years
4.	Replacement of 40 W tubes with 28W T5	Reduction in lighting power	Energy saving :45%

Sl. No.	Measure	Characteristics	Economic Impact
	lights (Tyagi A K 2003)	consumption	Payback Period<2 years
5.	Installation of electronic ballasts for fluorescent lamps (Tyagi A K 2003)	Reduction in lighting power consumption	Energy saving :25% Payback Period<2 years
6.	Installation of automatic lighting controls (Tyagi A K 2000)	Reduction in lighting power consumption	Energy saving :2-50% Payback Period:2-5 years
7.	Localized lighting to supplement general lighting (Tyagi A K 2003)	Reduction in lighting power consumption	Energy saving: 60-80%.Payback Period:4-8 year
8.	Introduction of Intelligent controller for multiple Computer Room Air-conditioner (CRAC) unit System (Tyagi A K 2003)	Reduction in AC power consumption	There is a substantial reduction in power consumption of ACs.
9.	Installation of cooling system economizer (Tyagi A K 2003)	Reduction in AC power consumption	There is a substantial reduction in power consumption of chiller and HVAC
10.	Increase the Chilled Water Supply Temperature (CHWST) Set point (Tyagi A K 2003)	Chiller efficiency improves by 1% for every 1OF raise in the temperature of water leaving the evaporator with all other factors held constant	There is net reduction in overall energy Consumption
11.	Installation of high efficiency pumps (Tyagi A K 2003)	Appropriate high-efficiency pumps can be selected by matching their duty point to operating parameter values such as maximum head and flow requirements in the pumping system	High efficiency pumps provide considerable reduction in power consumption

A number of wired line buildings and telecom office buildings have employed the above mentioned measures and received the National Energy Conservation Award under office building category.

3.4.3 FUEL SWITCHING OPTION FOR TELECOM TOWERS

It has been discussed in section 3.3 that various researches have been carried out for use of alternative energy sources in telecom sector. As BTS sites have become more energy efficient it is more economically and technically feasible to use the alternative energy sources. TRAI (2011) has identified the following alternative energy solutions that can be used singly or in combination at BTS sites in India:

A. Solar energy
B. Wind energy
C. Biomass energy
D. Fuel cell energy

Table 3.6 illustrates the comparative features of these fuel switching options

Table 3.6: Comparative Analysis of Fuel Switching Options for Telecom Towers

Energy source	**Solar Energy**	**Wind Energy**	**Biomass**	**Fuel Cell**
Principle of Operation	Photovoltaic energy generating systems convert sun's energy into electricity	The kinetic energy of wind is converted to mechanical energy and then into electrical energy	Waste matter composed of parts from living or recently dead organisms are used to produce alternative fuels for producing energy	Chemical energy in hydrogen is converted to electricity, water vapour and heat
Efficiency	6.2-19.7%	20%	20%	40-60%
Carbon Foot Print	Zero at point of use	Zero at point of use	Minimal	Zero at point of use
Limitations	1. Dependent on sunshine availability 2. Requires equivalent storage capacity hence needing additional investment 3. large area required for installation	1. Dependent on the quality of wind speed and duration of wind availability requirement 2. Requires equivalent storage capacity needing additional investment	1. Load uptake cannot be limited to telecom, hence need load aggregation from the other source	1.Underdeveloped hydrogen logistics as of date
Maintenance	Minimal maintenance	Minimal maintenance	Biomass fuel cost and plant maintenance	Hydrogen fuel cost and system maintenance

Source: Intelligent Energy (2013)

Literature survey done in this chapter was centered on the theme of research. It has widened the understanding of the concept of "Energy Conservation", the difference between energy conservation and energy efficiency, methods of energy conservation and drivers/barriers to energy conservation.

Detailed literature survey was undertaken to understand the energy consumption and carbon emission of telecom networks. Survey of energy consumption of ICT & telecom networks in various countries provided the perspective of energy modeling and highlighted the absence of estimate of energy demand of telecom sector in India. Moreover, the survey pointed out to the missing links of assessment of carbon emission of telecom towers based on Indian site conditions.

The survey further explored the energy conservation and regulatory drivers for the sustainable growth of the telecom sector. In-depth study of energy conservation and carbon emission reduction measures including fuel switching was done. Understanding was developed regarding various energy conservation measures applicable to wireless networks and telecom buildings.

Enlightened by the literature survey on all above aspects, Research Problem and Research Questions were framed in next chapter and analysis has been made in chapter 5.

CHAPTER 4

RESEARCH METHODOLOGY

Literature survey done in the previous chapter has widened the understanding about energy conservation and carbon emission of telecommunication sector. This chapter discusses the research methodology used for analysis of the issues revealed by the literature survey.

4.1 RESEARCH NEED

Energy consumption is a significant ingredient in the operation of telecom networks. The major cost centers of the telecom industry are human resource cost, site rental, infrastructure leasing cost and energy cost. While personnel wages and benefits represent a major network operating cost, other high potential areas for cost cutting include site rental and energy costs. Due to cutthroat competition and ever increasing energy tariff, reducing energy cost is now an existential issue in Indian telecom sector. In terms of energy operating costs, identification of sites with higher-than-normal power consumption and adopting specific measures to reduce it are components of energy conservation programme. The energy conservation measures in India telecom sector include demand side management and use of renewable energy sources. The carbon emissions associated with power consumption of vast telecom network in India is also a matter of concern.

In India, researches on energy efficiency were carried out to study the energy conservation measures in energy intensive sectors like steel, aluminum, fertilizers etc. No study was conducted regarding energy conservation and carbon emission of Indian telecom sector. The present study has been conducted to undertake detailed understanding of energy conservation and carbon emission in Indian telecom sector.

4.2 RESEARCH GAP

Literature survey and the information available in the public domain reveal primarily the growth of telecom sector in India and technological energy efficiency measures.

The following specific gaps are revealed from literature review:

1. Literature does not provide understanding on energy demand of telecom sector in India. Energy consumption and carbon emission estimation of telecom towers by taking in to account the availability of grid power, use of diesel and sharing of telecom towers is not known.
2. Lacks of understanding on interactions of energy demand, energy cost, and carbon emission with energy efficiency demand side management and fuel switching in the sector.
3. Identification of critical factors for effective energy conservation in telecom sector in Indian context in also not available.

4.3 RESEARCH PROBLEM

In the light of the above discussion, **s**tudies have to be conducted to assess the energy consumption, resultant carbon emission of Indian telecom network and to understand energy cost of Indian telecom operators. The studies also have to be conducted to identify the energy conservation measures, economics of fuel switching options and critical factors affecting the energy conservation in Indian telecom network.

4.3.1 RESEARCH PROBLEM STATEMENT

Analyzing interactions of energy demand, energy cost, carbon emission based on energy conservation premise in Indian Telecom sector**.**

4.4 RESEARCH QUESTIONS

The research questions arising out of above discussion are as follows:

- What is energy requirement of Indian telecom sector?
- What is the carbon emission of telecommunication network operation (telecom towers) in India?
- What are the practices to save energy cost and reduce carbon emission in Indian telecommunication sector?
- What are the critical factors affecting implementation of energy conservation measures in Indian telecommunication sector?

4.5 RESEARCH OBJECTIVES

The objectives of the research are as under:

- To estimate energy requirement of Indian telecom sector and develop insight in the energy consumption pattern of telecom operators
- To assess carbon emission of network operation(telecom towers) of Indian telecom industry
- To analyze existing and potential energy conservation measures in Indian telecom sector
- To identify the critical factors affecting the energy conservation measures in Indian telecom sector

4.6 THEORETICAL UNDERPINNING:

Due to rising energy cost, K.E. Boulding, in 1956, developed new production function known as KLEM model, (Capital, Labor, Energy and Management) in which he identified energy as a separate factor of production. With this theory, of Energy Conservation came in to being which suggests that one unit of energy saved is equal to 1.5 unit of energy generated. This theory has also categorized energy conservation efforts into technical measures, behavioral and structural measures of energy conservation. Based on energy conservation premise, the researcher has studied the interactions of energy demand, energy cost, and carbon emission with energy conservation measures in Indian Telecom sector.

4.6.1 THEORETICAL PREMISE:-

Energy conservation can help to reduce the energy cost and carbon emission of the telecom sector in India.

4.7 RESEARCH METHODOLOGY

4.7.1 RESEARCH OBJECTIVE 1

Research objective 1 comprises two parts

a) Estimation of Energy Requirement of Indian telecom sector
b) Developing insight in to energy consumption pattern of Indian telecom operators

- **Research Objective 1a) Estimation of Energy Requirement of Indian telecom sector**

- **Energy Modeling**

Telecom sector need electricity for round the clock operation of telecom networks, diesel generators are used as secondary source or back up supply source when grid power is absent**.** The energy used for network operation also includes the general lighting, cooling requirement of telecom networks. There are two approaches for estimation of electricity demand of telecom sector:-

a. Top -down Approach
b. Bottom -up Approach

In top down approach, the data provided by telecom service providers is used to calculate average electricity consumption and extrapolate it to estimate the demand of telecom networks. This method is based on calculation of the energy usage by analyzing the energy costs of the operators. Data on the energy consumption of single components is not kept by telecom operators, because the metering of energy consumption is only available for locations, not for components. Lambert et al (2012) used top -down approach to estimate the worldwide electricity consumption of telecom networks. The top down approach cannot be applied in the countries like India where record is not available regarding the electricity consumption of the telecom operators. The bottom up estimation approach, based on the component wise annual energy consumption is preferred in such cases. This approach uses data on the stock of the different types of components and the average power consumption of each type. This method allows recalculations when the network is growing.

For estimation of electricity consumption, telecom networks can be divided in following categories:-

i. Mobile and wireless network comprising Base Transceiver Stations(BTS), Base Station Controller (BSC) and Mobile Services Switching Center(MSC)
ii. Exchanges comprising Fixed access Network
iii. Other network elements comprising transmission equipment ,network controllers, core and servers

The annual electricity by the telecom network can be expressed as follows:-

$E^* = E_w + E_f + E_o$

Where:

- E= Electrical energy Consumed by telecom network per year (kWh)
- E_w= Electrical energy Consumed by mobile and wireless network Per Year (kWh)
- E_f= Electrical energy Consumed by wired line exchanges per year (kWh)
- E_o= Electrical energy Consumed by other telecom network (other than wired line and wireless telecom network) per year (kWh)

*This includes the electricity consumed on general lighting and air conditioning requirement of telecom networks

a. Estimation of electricity consumption of telecom networks

i. Mobile and wireless Network

The most important types of wireless network equipment for mobile telephone services are listed below:

- BTS, Base Transceiver Station;
- BSC, Base Station Controller
- MSC, Mobile Services Switching Center;

Base Transceiver Stations (BTS) are needed to communicate with the handsets of the subscribers. Every BTS covers a geographical area or cell and connects all users who are located in the cell to the wireless network. The size of these cells depends on operating frequencies and geographical conditions.

Many cells with a small size are found in cities, whereas only a few cells covering large areas are found in non-urban zones. Base Station Controllers (BSC) are needed to control the operation of several Base Transceiver Stations. The Mobile Services Switching Center (MSC) connects the subscribers to the wireless networks and the wired network. Additional components and software support the operation of the wireless network. The wireless infrastructure is also connected to the infrastructure of wired telephone networks. A call between two subscribers of a mobile network is not only transmitted wirelessly, since the wired network also might be used to transmit data between two BTS. All this network equipment needs electricity to operate. Some of the (mostly digital) components additionally need air-conditioning to operate, leading to additional electricity demand.

The number of components, especially the number of Base Transceiver Stations, is viewed as an indicator of the network quality, since by increasing the number of BTS the coverage of a geographical area is improved. As per Schafer (2001), a Base Service Centre (BSC) control one hundred BTS and a Master Service Centre (MSC) is needed for two BSCs. Generally data regarding number of BTS is available from telecom regulator or Government departments and other sources. Accordingly, stock of elements of wireless system Base Service Centre (BSC) and Master Service Centre (MSC) is calculated and used for estimation of electricity consumption of mobile network.

The annual energy consumption of the mobile telephone network is calculated by multiplying the average power consumption of a type of component and the number of hours of operation per year. After that, the result is multiplied with the stock of that component.

In India, Service level area (SLA) wise stock of BTS is available from Department of Telecommunications.

Assumptions of the electrical load of BTS, BSC and MSC in India were made in line with Schafer (2001), Krisnan et al (2011), Department of Telecommunications report and feedback of the industry.

The element wise assumed load is given in table 4.1:

Table 4.1: The element wise electrical load (kW) of wireless network

Sl. No.	**Element of wireless network**	**Electrical Load (kW) including general lighting and air-conditioning requirement as per Indian conditions**
1.	Base Transceiver Station (BTS) (Rural and Suburban Area) BTS Configuration 2/2 and 4/4	3kW
	Base Transceiver Station (BTS) (Urban Area) BTS Configuration 6/6	5kW
2.	Base Station Controller (BSC)	4kW
3.	Mobile Services Switching Center (MSC)	4kW

$Ew = E_{BTS} + E_{BSC} + E_{MSC}$

Where

Ew = Electrical energy Consumed by mobile and wireless network Per Year (kWh)

E_{BTS} = Electrical energy Consumed by BTS of network Per Year (kWh)

E_{BSC} = Electrical energy Consumed by BSC of network Per Year (kWh)

E_{MSC} = Electrical energy Consumed by MSC of network Per Year (kWh)

E_{BTS}, E_{BSC} and E_{MSC}= Electrical energy Consumed by mobile and wireless network Per Year [kWh per year]= Average power consumption of the element of mobile and wireless network in kW[P] x8760 [h per year] x Stock of the element [n]

ii. Exchanges comprising Fixed access Network

The fixed line telecom network comprises different switching technologies like CDOT switches in rural areas while NGN, EWSD, AXE10 in urban areas. There is wide variation in power and cooling requirements of these fixed access switching technologies.

The electricity power consumption by the fixed telecom network including general lighting and air conditioning requirement can be calculated in following way:-

$E_f = B * W_i$

Where

E_f = Electrical energy Consumed by wired line exchanges per year (kWh)

B = Bench mark for average energy consumption of wired lines (kWh/Line/Annum)

$W_{i=}$ No. of installed wired lines

The numbers of working fixed line and installed capacity is available from Department of Telecommunication in India. Department of Telecommunications established the benchmark of power consumption in telecom buildings based on energy consumption reports of the telecom buildings; according to it the average power consumption ranges from 2.5 to 5 units per line per month.

For estimating electrical power consumption by the fixed telecom network in this study, five units per line per month has been used to estimate the electricity consumption of wired line telecom network. In case of India, B can be considered as 60 kWh per line per year.

Electrical energy Consumed by exchanges Per Year, E_f [kWh per year]

= 60 kWh per line per year X No. of Installed lines

iii. Other telecom networks

The major electricity consumption occurs in radio access network and exchanges having wired line network. For, other telecom network elements like network controller, transmission and the estimation has been made considering electricity consumption as ten percent of electricity consumption of mobile-wireless network and fixed access network.

$Eo=K(E_w + E_f)$

Where

Eo= Electrical energy Consumed by other telecom network (other than wired line and wireless telecom network) per year (KWh)

K= Constant (In percentage)

For India we can assume value of K as 5%.

Electrical energy Consumed by other telecom network Per Year [kWh per year] $\mathbf{E_o}$ =5% of (Electrical energy Consumed by mobile and wireless network Per Year ($\mathbf{E_w}$)+ Electrical energy Consumed by Exchanges Per Year ($\mathbf{E_f}$))

b. Estimation of Energy (Electricity and Diesel) Consumption of Telecom Towers

- **The configuration of telecom tower.**

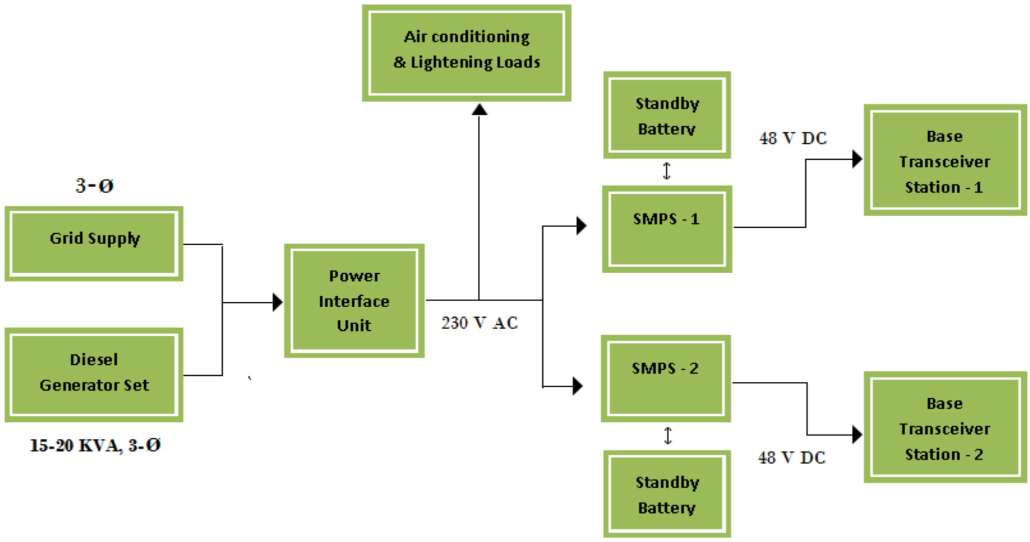
Typically, a telecom tower site has active and passive infrastructure components. Active components include the antennae, base transceivers, feeder cables and microwave radio equipments. Passive components include the underlying land, tower, shelter, air conditioning equipment (AC), diesel generator (DG), battery, electrical supply, technical premises etc.

The electrical energy is required for operation of the telecom towers and due to uncertainty of availability of grid electricity and long power interruptions diesel generators are used.

The power demand of a telecom tower is determined by the configuration of number of Base Transceiver Stations (BTS) in the cell tower. Generally at tower site infrastructure is being shared by multiple operators (telecom service providers). The telecom towers consume the largest amount of energy of the telecom network.

A schematic figure of power supply arrangement at telecom tower is given in figure 4.1. The power from grid is supplied to a Power Interface Unit. The function of power interface unit (PIU) is to check and select the best phase of the three phase grid to feed the Switched Mode Power Supply (SMPS).Air conditioners and other auxiliary load is fed from AC supply from grid. The function of SMPS is to covert 230 V AC to -48 V to power the BTS and other telecom equipments as well as charging the stand by batteries. In case of interruption of grid supply PIU sends a signal to the diesel generator. The diesel generator starts and supplements the power. During the transition period of change of supply from grid to DG set and in case of problem with DG set , the stand by batteries provide the power to the telecom equipment to ensure uninterrupted operation . Each operator has its own SMPS and battery set.

Figure 4.1: Schematic Power Supply Arrangement at Telecom Tower Site



The electrical load of BTS depends on the configuration. Generally BTS of 2/2/2 configuration are used at rural sites while at urban sites BTS of 6/6/6 configuration are used. The electrical load of various configurations of BTS is shown in table 4.2.Table 4.3 shows the operational electrical load detail at BTS sites.

Table 4.2 Configuration wise Electrical Load of Base Transceiver Stations

Type of Base Transceiver Station (BTS)	Average Electrical Load
GSM base station (2/2/2 Configuration)	1.3 kW
GSM base station (4/4/4 Configuration)	2.5 kW
Macro/fiber–4/4/4 base station	1.3–1.7kW
Large WiMaxi base station	1.3–1.6kW
GSM base station (6/6/6)	3.5kW

Source: TRAI (2011)

Table 4.3 Operational Electrical Load detail at BTS Sites

Sl. No.	Status	Electrical Load of 6/6/6 Configuration BTS in Watt	Electrical Load of 2/2/2 Configuration BTS in Watt
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 TRX OFF, Media OFF	1648.53	1510
5.	BTS ON, Media OFF	1706.4	1325
6.	BTS Power Consumption	2664.45	1647
7.	All the Equipments ON	4385.25	2646

Source: P.K. Panigrahi Report, DoT (2008)

In India and other power starved countries, due to frequent power cuts and non-availability of grid electricity diesel generators are used for powering the telecom networks. Telecom service providers share the infrastructure and a telecom tower can have antennas and BTS of more than one telecom service providers. The number of telecom operators sharing a tower depends on a no of factors like location of tower etc. The generator installed at tower side supply the electricity to the all BTS installed at that tower. The annual diesel consumption by the telecom towers can be obtained in following way:-

D= $N * d * H$

Where

D= Annual diesel consumption by telecom towers (Liters)

N = No. of telecom towers

d=Average diesel consumption per hour by the generator installed at telecom tower (Liters per hour)

H=Average annual operating of generators installed at telecom tower (Hours)

In case of non-availability of data of towers the number of towers can be estimated with the help of number of BTS and tenancy ratio.

No. of Towers (n) = Number of BTS/ Tenancy Ratio

In India, the secondary data of BTS is available from Department of telecommunication.. Based on feedback of industry experts tenancy ratio of major Indian tower companies like Bharti Infratel, Indus , ATC and telecom operators owned towers the tenancy ratio (average number of BTS at telecom tower) was assumed as 1.6 to estimate the number of telecom towers in the present study. Each telecom tower has a diesel generator set of 15-25 KVA. As per engine manufacture's M/s Cummins India specification for "Cummins DXP Series generators for 15-25 kVA the diesel consumption ranges from 1.7 liter to 2.5 liter per hour.. The fuel consumption of the diesel generator set was taken as 2.5 liter per hour for this study. As per TRAI's recommendation on green telecommunication (2011), seventy percent of BTS sites are situated in rural and semi-urban areas that have average eight hour power outage on daily basis while average power outage in urban BTS sites is four hours per day. The estimation of consumption of diesel for rural and urban mobile sites was made based on secondary data about no. of mobile telecom sites and diesel consumption per hour.

The assumptions for estimation of diesel consumption by the telecom tower are given in the table 4.4.

Table 4.4: Assumptions for Estimation of Diesel Consumption by Telecom Towers

Tenancy Ratio[1] (Average no. of tenants per tower)	1.6	Grid Availability in Rural Semi Urban Area	16 Hours
Percentage of Towers in Rural and semi urban area	70%	Average BTS load with AC in Rural area	3kW
		Average BTS load with AC in Urban area	5kW
Percentage of Towers in Urban Area	30%	Generator capacity at tower site	15 -25 KVA
Grid Availability in Urban Area	20 Hours	Average fuel consumption of diesel generator	2.5 Liter/hour

- **Methodology Used in the Study for Estimation of Energy Consumption of Telecom Towers:-**

1. Number of Telecom towers in service level areas were calculated as follows:- No. of Towers in Service Level Area = No. of BTS in Service Level Area/Tenancy Ratio i.e. 1.6 (Assumed)
2. The calculated telecom towers were divided in Rural and Urban Category (70% Rural and 30% Rural)
3. Annual grid electricity consumption was calculated considering grid availability in urban area as 20 Hours daily and electrical load of urban BTS as 5kW. For rural area grid availability was taken as 16 Hours and electrical load of BTS as 3kW.
4. Annual Diesel consumption by diesel generators were calculated for urban and rural tower sites taking average fuel consumption as 2.5 liter per hour of run.

Research Objective 1 b)

- **To study energy consumption pattern of telecom service providers**

[1] Tenancy ratio refers to the number of tenants (operators) who have put up their antennae and other active infrastructure on the towers. (GSMA)

Energy consumption and energy cost of Indian telecom operators were studied by reviewing the energy consumption of major telecom service providers based on their annual and sustainability reports for the last decade (Period 2002 -2014) and available literature.

The selected telecom service providers belong to both public and private sector and have major subscriber base in India.

1. Bharat Sanchar Nigam Ltd. (BSNL)
2. Mahanagar Telephone Nigam Ltd.(MTNL)
3. Bharti Airtel
4. Reliance Communication Ltd.
5. Idea Cellular Ltd.

From the annual reports of telecom service providers the annual energy cost is available while subscriber number during the period is also available from telecom service provider's annual reports and TRAI reports. Two benchmarks for comparison of energy cost of Indian telecom operators , "energy cost per subscriber" and "energy cost as percentage of revenue of telecom service providers" were identified based on GSM Association (GSMA), European Telecommunications Network Operators' Association(ETNO) reporting criterion, and ISO 14031 .

Tools used for analysis: Data have been represented through various charts.

4.7.2 RESEARCH METHODOLOGY FOR RESEARCH OBJECTIVE -2

- **Estimation of Carbon Emission**

The carbon emission due to the energy use by the telecom towers can be calculated in following way:-

Emission $_{Tower}$ = Emission due to grid electricity consumption by the BTS (E_E) +Emission due to diesel consumption by the generators installed at the tower sites (E_D)

Where E_E =Grid Electricity Consumption by telecom tower (BTS) in year (in MWh)* Emission factor of the grid serving the location (MWh/ t CO_2)

Grid Electricity Consumption by telecom tower (BTS) in year

$=\sum (n *P *h) / (1-l_y)$

n =No. of BTS

P = Average power consumption of BTS with air conditioning and general lighting

h =Average annual operating hours of BTS with grid electricity

l_y= Average technical grid losses (transmission and distribution) for the year for the grid serving the location where telecom tower is situated, expressed as a fraction

The emission factor for grid electricity in India is available from Central Electricity Authority (CEA) base line data. (CEA2013). The geographical scope of the two electricity grids in India is as follows:-

Table 4.5: Geographical Scope of Electricity Grids in India

NEWNE Grid				Southern Grid
Northern	Eastern	Western	North Eastern	Southern
Chandigarh Delhi Haryana Himachal Pradesh Jammu & Kashmir Punjab Rajasthan Uttar Pradesh Uttarakhand	Bihar Jharkhand Orissa West Bengal Sikkim Andaman Nicobar	Chhattisgarh Daman & Diu Dadar & Nagar Haveli Goa Gujarat Madhya Pradesh Maharashtra	Arunachal Pradesh Assam Manipur Meghalaya Mizoram Nagaland Tripura	Andhra Pradesh Karnataka Kerala Tamil Nadu Puducherry Lakshadweep

Source: CEA (2013)

Average emission factor for grids including inter-grid and cross-border power transfers are given in table 4.6

Table 4.6: Emission Factor for Grid Electricity in India

Grid	Average Emission Factor
NEWNE	0.78
Southern	0.76
India	0.78

Source: CEA (2013)

The average technical grid losses in states and Union Territories are given in Table 4.7.

Table 4.7: Average Technical Grid (T&D) Losses in India

S. No.	State / Union Territories	Average Technical Grid Losses (%)
1.	Andhra Pradesh	16
2.	Assam	26.69
3.	Bihar	42
4.	Chhattisgarh	26.27
5.	Gujarat	18.4
6.	Haryana	23.72
7.	Himachal Pradesh	12.39
8.	Jammu and Kashmir	46.72
9.	Jharkhand	32.58
10.	Karnataka	19.09
11.	Kerala	16.77
12.	Madhya Pradesh	31
13.	Maharashtra	17.56
14.	Meghalaya	28.28
15.	Punjab	16.84
16.	Rajasthan	23

S. No.	State / Union Territories	Average Technical Grid Losses (%)
17.	Tamil Nadu	20
18.	Uttar Pradesh	28.83
19.	Uttarakhand	19
20.	West Bengal	21.09
21.	Total (I)	21.84
22.	Arunachal Pradesh	42.74
23.	Goa	15.92
24.	Manipur	29.42
25.	Mizoram	30.5
26.	Nagaland	40.93
27.	Pondicherry	11.31
28.	Sikkim	16.19
29.	Tripura	22.36

Source: CEA (2013)

The carbon emission due to diesel consumption by telecom towers

E_D = D *Emission Factor of diesel

$= n * d * h$ * Emission Factor of diesel

Where

n = No. of telecom towers

d=Average diesel consumption per hour by the generator installed at telecom tower (Liters per hour)

h=Average annual operating of generators installed at telecom tower (Hours)

The emission factor due to diesel consumption in diesel generator given by United States' Environmental Protection Agency (EPA 2005) is 0.0027 tCO_2/l, Therefore,

CO_2 Emission from Diesel Consumption (t CO_2) = Total Diesel Consumption in Liter x 0.0027 (tCO_2 Per Liter)

- **Methodology Used in the Study for Estimation of Carbon Emission of Energy Consumption of Telecom Towers**

1. Annual grid electricity and diesel consumption estimates carried out in research objective 1 was used for estimation of carbon emission.
2. SLA wise CO_2 emission at tower site was calculated by considering average technical grid loss, grid emission factor, and emission from diesel consumption. The grid emission factor and technical losses depend on geographical location of the tower.
3. The grid emission factor for north east circle has been considered as average of T&D losses of north eastern states.
4. Based on number of wireless subscribers the carbon emission per subscriber was calculated.

4.7.3 RESEARCH METHODOLOGY FOR RESEARCH OBJECTIVE -3

- **To analyze existing and potential energy conservation measures in Indian telecom sector**

Step 1:- Collection of secondary data : Available literature comprising journal articles ,annual reports, conference proceedings , trade journals , websites of International Telecom Union(ITU), Department of Telecommunication(DoT), Bureau of Energy efficiency (BEE) and industry associations e.g. GSMA, Cellular Operators Association of India (COAI), Tower and Infrastructure Providers Association (TAIPA), were surveyed. Study was made in to the various energy conservation measures in telecommunication networks based on technical literature .Energy conservation practices of International telecom service providers China Mobile , NTT group of Japan, Vodafone etc. were studied to examine their applicability to Indian context.

To know the energy conservation practices undertaken in Indian telecommunication sector, information collected from the energy nodes of the annual reports and sustainability reports of the telecom companies. Energy conservation measures applicable to telecommunication buildings housing telecom equipments, administrative offices and billing centers were examined separately apart from cell sites of wireless network. The energy conservation measures undertaken in national energy conservation award winning telephone exchange buildings were also studied.

Detailed study was undertaken in application of alternative energy sources. Techno economic analysis of fuel switching options for telecom towers was carried out by using payback method considering the various price levels of diesel.

Tools used for analysis: Analysis has been carried out using appropriate tools, like Descriptive analysis, Pictorial presentation etc. Considering the findings of Research Objective- 1 (energy consumption of telecom towers) as Business As Usual (BAU) scenario , scenario analysis has been carried out to assess the reduction in energy consumption in compliance with Govt. direction on the use of hybrid energy (Renewable Energy Technologies(RET)+ grid electricity) for the years 2015 and 2020. Saving in diesel consumption and carbon emission was also calculated

Techno economic analysis has been carried out for energy conservation measures undertaken by telecom operators .Cost benefit analysis has been carried out by quantifying the payback period of the initial investment. For calculating payback period Net Payback Value (NPV) method was used.

4.7.4 RESEARCH METHODOLOGY FOR RESEARCH OBJECTIVE 4:

- **To identify the critical factors affecting the energy conservation measures in Indian telecom sector**

To understand the critical factors affecting the variables were identified on the basis of literature and exploratory interviews were carried out with major stake holders to determine their applicability in the context of Indian telecom sector. The stake holders include officers of regulating agency TRAI, administering department DoT, NGOs, managers of telecom service providers tower companies and academicians. It was observed that some variables are acting as a barrier in the implementation of energy conservation measures while the others act as motivating drivers. It was decided to use separate sections one for barriers and other for drivers in the questionnaire.

- **Variable identification:**

The probable variables were identified through primary and secondary source of information for designing the questionnaire. As per the approach of Yeo Karling Catrina (2012), "A systems approach to overcome industrial Energy efficiency barriers" the exploratory interviews were held with stake holders to identify the variables applicable to Indian telecom sector and relevant variables were identified. There are 25 driving forces and 31 barriers variables.

- **Designing the Questionnaire:**

A structured questionnaire was designed based on identification of critical issues through informal interviews with stake holders. This Questionnaire was designed on 5 point Likert scale as given below in Table 4.8:

Table 4.8: Five Point Likert Scale for Questionnaire

Not at all Important (1)	Not very Important (2)	Some What Important (3)	Very Important (4)	Extremely Important (5)

The reliability of questionnaire was verified (Chronbach Alpha) on the responds that was received from a pilot study or a sample of 30 respondents comprising energy managers of telecom service providers and academicians etc.

- **Sampling Plan & Sample Size:**

Method of stratified proportional sampling has been used for collecting the primary data

- While sample has been selected from a finite population size N as different stakeholders and divided into different strata and a proportion drawn from the strata depending upon the population size.

Sample size:

Yamane (1967:886) provides a simplified formula to calculate sample sizes.

$n= N/1+N(e)^2$

The total sample size of 205 (sample size based on Simplified Formula for Proportions provided by Yamane with 7% precision – is 163 out of the population of 800. Here sample size of 205 has been taken) proportionately distributed across different players in the ratio of the total number of stakeholders. Table 4.9 explains the sample population of the survey.

Table 4.9: Overall Sample Size of Survey

Source	**No.**	**% 0f Sample**	**Sample size**
Government Senior Officers (Department of Telecommunications and MNRE) /Individual Experts	100	25%	25
Telecom Regulator TRAI	05	20%	01
Associations of Telecom and internet Operators	10	30%	03
Telecom and internet service providers	600	25%	150
Telecom Tower Companies	80	30%	24
NGOs	10	20%	02
Total	Approx. 800		205

The sample size under telecom and internet service providers category was further distributed across the 2 categories viz. PSU and Private as reflected in Table 4.10

Table 4.10: Distribution of Sample Size in Public and Private Telecom Companies

Telecom Service Providers	No.	% of Sample	Sample size
PSU TSP	510	25	127
Private TSP	80	25	20
Internet Service Providers	10	30	3
Total	600		150

The structured questionnaire was administered to stake holders i.e .the regulating agency TRAI, administering department DoT, NGOs, managers of telecom service providers and tower companies etc. The questionnaire was sent through on line media to 400 respondents out of which 205 response were received. The response rate is 51.25% which in comparison to similar studies considered high .The received responses have been analysed by factor analysis through SPSS 16 software.

- **Statistical Analysis**:

In order to identify the critical factors affecting implementation of energy conservation measures in Indian telecommunication sector researcher used factor analysis. Factor analysis of Barriers and Drivers part was carried out separately. The data need to be reduced to manageable level to achieve the objective of research. As out of the large no. of parameters of the study some are correlated, the best way to reduce data is factor analysis.

The research methodology discussed in this chapter has been used in next chapter for estimation of electricity consumption of telecom networks in India, electricity and diesel consumption of telecom towers, analysis of energy cost of telecom operators and assessment of carbon emission of telecom towers.

Further, the methodology of this chapter has been employed for analysis of energy conservation measures in Indian telecom sector, identification of drivers and barriers to energy conservation in Indian telecom sector.

CHAPTER 5

ANALYSIS AND FINDINGS

The previous chapter discussed the research methods used in the context of the

Research. In this chapter analysis has been carried out to find the answers of the research questions.

5.1 ESTIMATION OF ELECTRICITY CONSUMPTION OF TELECOM NETWORKS IN INDIA

a. Mobile and Wireless Network

There are 908353 BTS in India as on May 31, 2015 (Lok Sabha 2015)

Table 5.1 reflect the estimated stock of various elements of mobile wireless network in India based on assumptions described in section 4.1 of previous chapter.

Table 5.1: Elements of Indian Mobile and Wireless Network

S. No.	Parameter	Name of Element	Stock (Numbers)
1.	n	Base Transceiver Station (BTS)	908353
2.	N_{BSC}	Base Service Centre (BSC) (n/100)	9084
3.	N_{MSC}	Master Service Centre (MSC) (N_{BSC} /2)	4542

- **Electrical Energy Consumed by Base Transceiver Stations (BTS)**

Electrical Energy Consumed by Base Transceiver Stations (BTS)

$E_{BTS} = E_{BTSR} + E_{BTSU}$

Where

$E_{BTS =}$ Electrical energy Consumed by BTS per Year

$E_{BTSR =}$ Electrical energy Consumed by Rural and Suburban BTS per Year

$E_{BTSU=}$ Electrical energy Consumed by Rural and Suburban BTS per Year

Table 5.2 explain the calculation of annual electricity consumption by rural and semi urban BTS

Table 5.2: Annual Electrical Energy Consumed by Rural and Semi Urban BTS

Parameter	Description	Value	Unit
n_r	Base Transceiver Station **(**BTS)(Rural and Suburban Area) BTS Configuration 2/2 and 4/4	547735	Numbers
P_r	Electrical Load (kW) including general lighting and air-conditioning	3	kW
h_r	Average annual operating Hours	8760	Hours
E_{BTSR}	Electrical energy Consumed by Rural and Suburban BTS Per Year (n_{r*} P_{r*} H_r)	$14394*10^6$	kWh

Table 5.2 shows the calculation of annual electricity consumption by rural and semi urban BTS

Table 5.3: Annual Electrical Energy Consumed by Urban BTS

Parameter	Description	Value	Unit
n_u	Base Transceiver Station (BTS) (Urban Area)BTS Configuration 6/6	345145	Numbers
P_u	Electrical Load (kW) including general lighting and air-conditioning	5	kW
h_u	Average annual operating Hours	8760	Hours
E_{BTSU}	Electrical energy Consumed by Urban BTS Per Year ($n_{u*} P_{u*} h_u$)	$15117*10^6$	kWh

- **Annual Electricity Consumption of BSC and MSC**

Table 5.4 and 5.5 demonstrate the calculation of annual electricity consumption of BSC and MSC

Table 5.4: Annual Electrical Energy Consumed by

Base Service Centers (BSC)

Parameter	Description	Value	Unit
N_{BSC}	Base Service Centre (BSC)	9084	Numbers
P_{BSC}	Electrical Load (kW) including general lighting and air-conditioning	4	kW
H_{BSC}	Average annual operating Hours	8760	Hours
E_{BSC}	Elec Electrical energy Consumed by Base Service Centers Per Year ($N_{BSC} * P_{BSC} * H_{BSC}$)	$265*10^6$	kWh

Table 5.5: Electrical Energy Consumed by Master Service Centers (MSC)

Parameter	Description	Value	Unit
N_{MSC}	Master Service Centre (MSC)	4542	Numbers
P_{MSC}	Electri Electrical Load (kW) including general lighting and air-conditioning	4	kW
H_{MSC}	Average annual operating Hours	8760	Hours
E_{MSC}	Elect Electrical energy Consumed by Master Service Centers (MSC) Per Year (N_{MSC} * P_{MSC} * H_{MSC})	$133*10^6$	kWh

Table 5.6 provide the annual electricity consumption of wireless telecom network in India

Table 5.6: Annual Electrical Energy Consumption of

Wireless Telecom Network in India

Parameter	Description	Value	Unit
E_{BTSR}	Electrical energy Consumed by Rural and Suburban BTS Per Year	$14394*10^6$	kWh
E_{BTSU}	Elec Electrical energy Consumed by Urban BTS Per Year	$15117*10^6$	kWh
E_{BTS}	Electrical energy Consumed by Base Transceiver Stations (BTS) Per Year	$29511*10^6$	kWh
E_{BSC}	Electrical energy consumed by Base Service Centers Per Year	$265*10^6$	kWh
E_{MSC}	Elect Electrical energy consumed by Master Service Centers (MSC) Per Year	$133*10^6$	kWh
E_w	Electrical energy consumed by wireless telecom network Per Year $E_w = E_{BTS} + E_{BSC} + E_{MSC}$	$29910*10^6$	kWh

The annual electricity consumption of wireless telecom network in India has been estimated as 29910 million units.

- **Annual Electricity Consumption by Wired Line Network**

Table 5.7 reflects the annual electricity consumption by wired lines in India.

Table 5.7: Annual Electricity Consumption by Fixed Access Network

Parameter	Description	Value	Unit
W_i	Number of Installed Wired Lines	61,177,510	Lines
B	Bench mark for average energy consumption of wired lines	60	kWh/Line/Annum
E_f	Electrical energy Consumed by wired line exchanges per year($B * W_i$)	$3671*10^6$	kWh

- **Annual Electricity Consumption of Indian Telecom Networks**

Table 5.8 demonstrates the estimated annual electricity consumption by Indian telecom networks

Table 5.8: Estimated Annual Electricity Consumption by Indian Telecom Networks

Parameter	Description	Value	Unit
E_f	Electrical energy Consumed by wired line exchanges per year	$3671*10^6$	kWh
E_w	Electrical energy Consumed by mobile and wireless network Per Year	$29910*10^6$	kWh
E_o	Electrical energy Consumed by other telecom network Per Year 5% of ($E_f + E_w$)	$1679*10^6$	kWh
E	Electrical energy Consumed by telecom network per year ($E_w + E_f + E_o$)	$35260*10^6$\	kWh

5.1.1 FINDINGS

The estimated annual electricity consumption of Indian telecom networks comes out to be around 35000 million units. This includes the necessary air-conditioning and general lighting requirement of telecom networks. This estimation assumes that there is round the clock availability of the grid electricity to all telecom networks. The share of electricity consumption of BTS is about 83.69% in total electricity consumption of the telecom network in India.

5.2 ESTIMATION OF ANNUAL ELECTRICITY & DIESEL CONSUMPTION BY TELECOM TOWERS IN INDIA

Table 5.9 and Table 5.10 demonstrate the estimation of consumption of diesel by rural/suburban and urban telecom towers respectively.

Table 5.9: Estimation of Consumption of Diesel by Rural and Suburban Telecom Towers

Parameter	Description	Value	Unit
N_r	Telecom Towers in rural and Suburban area (No. of BTS/ Tenancy Ratio)	342334 (547735/1.6)	Numbers
d	Average diesel consumption per hour by the generator installed at telecom tower	2.5	Liter/Hour
H_r	Average annual operating Hours of diesel generator installed at telecom tower (8*365)	2920	Hours
D_R	AnnD Diesel consumption by rural and suburban telecom towers Per Year ($n_r * d * h_r$)	$2499.04*10^6$	Liter

Table 5.10: Estimation of Consumption of Diesel by Urban Telecom Towers

Parameter	Description	Value	Unit
N_u	Telec Telecom Towers in urban area#	225388	Numbers
d	Average diesel consumption per hour by the generator installed at telecom tower	2.5	Liter/Hour
H_u	Average annual operating hours of diesel generator installed at telecom tower (4*365)	1460	Hours
D_U	Ann Diesel consumption by urban telecom towers Per Year (n* d* h)	$822.67*10^6$	Liter

In metro circles all the towers have been considered as urban towers

Total diesel consumption by telecom towers in India per year =Diesel consumption by rural towers per year + Diesel consumption by Urban telecom towers per year

$= (2499.04+822.67)* 10^6$

$= 3321.71* 10^6$ Liter

~3.3 Billion Liters

The estimate is based on assumption of daily 4 and 8 hours power breakdown in urban and rural areas respectively.

Table 5.11 and 5.12 describes the annual electricity consumption by urban and rural telecom towers in India

Table 5.11: Annual Electricity Consumption by Urban Telecom Towers in India

Parameter	Description	Value	Unit
n_u	Base Transceiver Station (BTS) (Urban Area)BTS Configuration 6/6	345145	Numbers
P_u	Elec Electrical Load (kW) including general lighting and air-conditioning	5	kW
h_u	Aver Average annual operating Hours with grid electricity (20*365)	7300	Hours
E_{BTSU}	Elec Electrical energy Consumed by Urban BTS Per Year(nu*Pu* h_u)	$12597.79*10^6$	kWh

Table 5.12: Electricity Consumption by Rural and Sub urban Telecom Towers

Parameter	Description	Value	Unit
n_r	Base Transceiver Station (BTS)(Rural and Suburban Area) BTS Configuration 2/2 and 4/4	547735	Numbers
P_r	Elect Electrical Load (kW) including general lighting and air-conditioning	3	kW
h_r	Ave Average annual operating Hours with grid electricity (16*365)	5840	Hours
E_{BTSR}	Elect Electrical energy Consumed by Rural and Suburban BTS Per Year (n_{r*} P_{r*} H_r)	$9596.30*10^6$	kWh

Table 5.13 shows the state wise annual electricity and diesel consumption of telecom tower in India.

Table 5.13: Annual Electricity and Diesel Consumption of

Telecom Towers in India

Sl No.	Telecom Service Area	Annual Electricity Consumption of BTS sites(Million Units /Annum)			Annual Diesel Consumption of BTS Sites (Million Liters /Annum)		
		Urban sites	**Rural sites**	**Total**	**Urban sites**	**Rural sites**	**Total**
1.	Andhra Pradesh	803.87	900.34	1704.21	50.24202	234.4628	284.70
2.	Assam	192.26	215.33	407.59	12.01626	56.07586	68.09
3.	Bihar and Jharkhand	532.96	596.91	1129.87	33.3099	155.4462	188.76
4.	Chennai	846.65	0.00	846.65	61.6266	0	61.63
5.	Delhi	1354.04	0.00	1354.04	98.99165	0	98.99
6.	Gujarat and Daman & Diu	629.60	705.16	1334.76	39.35019	183.6342	222.98
7.	Haryana	240.18	269.00	509.18	15.01108	70.05171	85.06
8.	Himachal Pradesh	89.92	100.71	190.63	5.620088	26.22708	31.85
9.	Jammu and Kashmir	138.84	155.50	294.33	8.677191	40.49356	49.17
10.	Karnataka	725.90	813.01	1538.90	45.36859	211.7201	257.09
11.	Kerala and Lakshadweep	428.93	480.41	909.34	26.80834	125.1056	151.91
12.	Kolkata	761.50	0.00	761.50	55.9107	0	55.91

Sl No.	Telecom Service Area	Annual Electricity Consumption of BTS sites(Million Units /Annum)			Annual Diesel Consumption of BTS Sites (Million Liters /Annum)		
		Urban sites	**Rural sites**	**Total**	**Urban sites**	**Rural sites**	**Total**
13.	Madhya Pradesh and Chhattisgarh	839.87	940.65	1780.51	52.49156	244.9606	297.45
14.	Maharashtra & Goa	608.35	681.35	1289.70	38.02182	177.4352	215.46
15.	Mumbai	1067.48	0.00	1067.48	70.6275	0	70.63
16.	North East	119.69	134.06	253.75	7.480903	34.91088	42.39
17.	Orissa	264.27	295.98	560.25	16.51671	77.07796	93.59
18.	Punjab	377.02	422.26	799.28	23.56372	109.964	133.53
19.	Rajasthan	467.37	523.45	990.82	29.21049	136.3156	165.53
20.	Tamil Nadu	617.05	691.10	1308.16	38.5659	179.9742	218.54
21.	UP (East)	615.36	689.20	1304.56	38.45982	179.4792	217.94
22.	UP (West) and Uttarakhand	491.34	550.30	1041.64	30.70859	143.3068	174.02
23.	West Bengal	385.36	431.61	816.97	24.08521	112.3976	136.48
Total		12597.81	9596.31	22194.12	822.6648	2499.039	3321.70

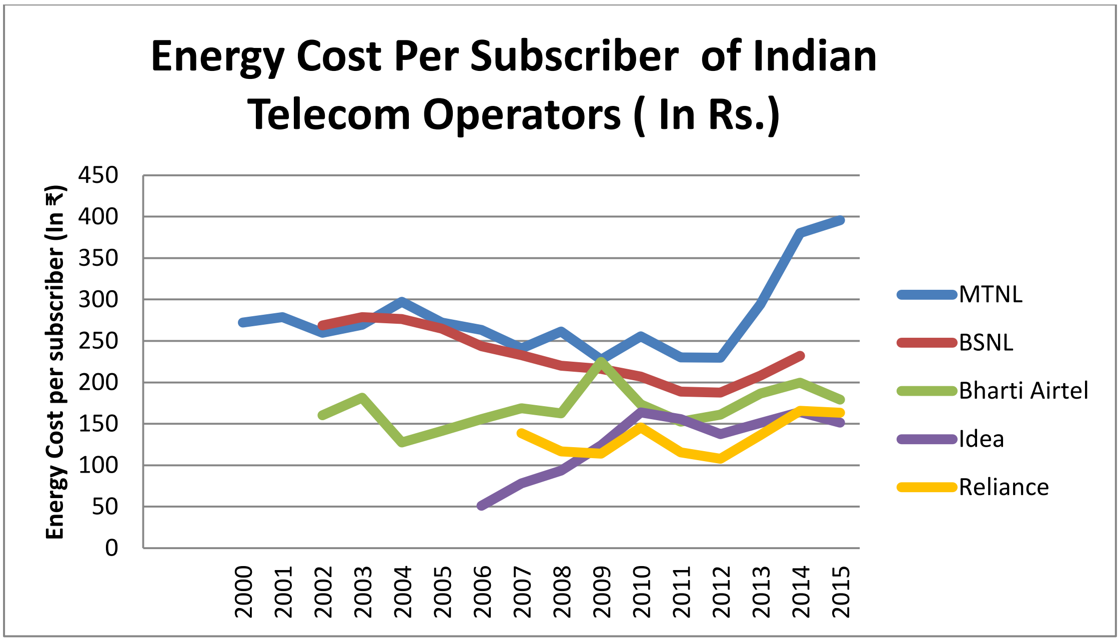
5.2.1 FINDINGS

The annual grid electricity consumption of telecom towers in India has been estimated as 22194.12 kWh considering daily 4 and 8 hours power breakdown in urban and rural areas respectively. The annual diesel consumption by telecom towers has been estimated as 3.3 Billion Liters.

5.3 ANALYSIS OF ENERGY CONSUMPTION OF TELECOM OPERATORS

Energy cost per subscriber for five major telecom operators namely MTNL, BSNL , Bharti Airtel and Idea Cellular has been demonstrated in figure 5.1 from year 2000 to 2015 .

Figure 5.1Analysis of Energy Cost Per Subscriber of Indian Telecom Operators

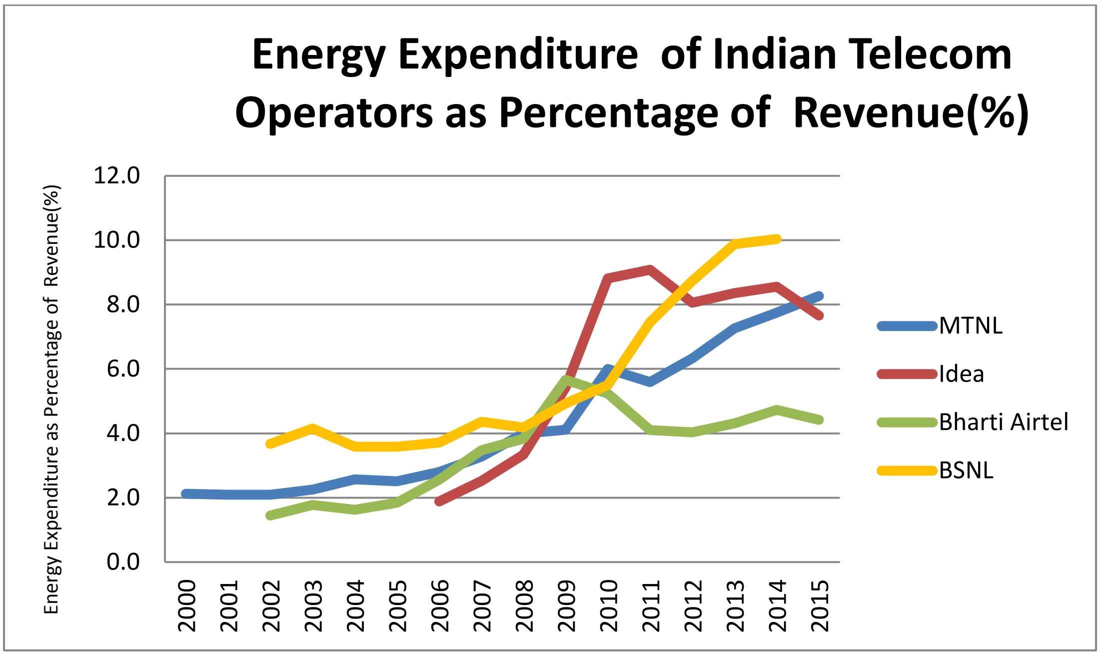


(Source: Analysis Based on Telecom Operators Annual Reports 2000 -2015)

Energy cost per subscriber can aptly describe the energy performance of the telecom operators. Idea cellular and Reliance Communication Ltd. have better control on their energy cost.

Figure 5.2 reflect the energy expenditure of four major telecom operators as a percentage of revenue .

Fig.5.2: Energy Expenditure of Indian Telecom Operators as Percentage of Revenue



5.3.1 FINDINGS

The energy expenditure of five major Indian telecom service providers were analysed based on annual energy expenditures made by them during last decade. Out of these telecom service providers two, BSNL and MTNL belong to public sector while Bharti Airtel, Idea and Reliance are private telecom companies . It is evident from the analysis that there is wide difference among the energy cost per subscriber of telecom companies. The energy cost of MTNL for year 2015 is just double of the energy cost of private telecom operators that is below Rs. 200 per subscriber per annum.

Analysis based on energy expenditure made by telecom operators demonstrate that energy expenditure has rising trend and telecom operators spend a significant percentage of their revenue (5-10%) on energy.

5.4 ESTIMATION OF CARBON EMISSION OF TELECOM TOWERS IN INDIA

Table 5.14 describes the annual carbon emission by diesel consumption of telecom towers in India.

Table 5.14: Carbon Emission by Diesel consumption of Telecom Towers in India

Parameter	Description	Value	Unit
D	Diesel consumption by telecom towers Per Year	$3321.71*10^6$	Liter
EF_D	Emission factor of the diesel	0.0027	tCO_2 Per Liter
E_D	Carbon emission due to diesel consumption by telecom towers ($D*EF_D$)	$8.97*10^6$	tCO_2

Carbon Emission due to grid electricity consumption:-

Carbon emission due to grid electricity consumption=$\sum$ (n *P *h) / (1-l_y)*EF_{GRID}

The 'l_y' technical losses of the grid (T&D Losses) and emission factor 'EF_{GRID} 'depends on the location (telecom circle/SLA) of the telecom tower.

The detailed calculation of telecom circle wise carbon emission is in table 5.15.

Table 5.15: Carbon Emission of Telecom Towers in India

S No.	Telecom Service Area	Carbon Emission (Million Ton/Annum) Urban Telecom Tower sites			Carbon Emission (Million Ton/Annum) Rural Telecom Tower sites			Total Carbon Emission For Telecom Towers
		Electricity	Diesel	Total	Electricity	Diesel	Total	Million Ton/Annum
1.	Andhra Pradesh	0.73	0.14	0.86	0.81	0.63	1.45	2.31
2.	Assam	0.20	0.03	0.24	0.23	0.15	0.38	0.62
3.	Bihar and Jharkhand	0.72	0.09	0.81	0.80	0.42	1.22	2.03
4.	Chennai	0.90	0.17	1.06	0.00	0.00	0.00	1.06
5.	Delhi	1.29	0.27	1.56	0.00	0.00	0.00	1.56
6.	Gujarat and Daman & Diu	0.64	0.11	0.75	0.72	0.50	1.22	1.97
7.	Haryana	0.21	0.04	0.25	0.24	0.19	0.43	0.68
8.	Himachal Pradesh	0.13	0.02	0.15	0.15	0.07	0.22	0.37
9.	Jammu and Kashmir	0.16	0.02	0.18	0.18	0.11	0.29	0.47
10.	Karnataka	0.68	0.12	0.80	0.76	0.57	1.34	2.14
11.	Kerala and Lakshadweep	0.39	0.07	0.46	0.44	0.34	0.78	1.24
12.	Kolkata	0.86	0.15	1.01	0.00	0.00	0.00	1.01

S No.	Telecom Service Area	Carbon Emission (Million Ton/Annum) Urban Telecom Tower sites			Carbon Emission (Million Ton/Annum) Rural Telecom Tower sites			Total Carbon Emission For Telecom Towers
		Electricity	**Diesel**	**Total**	**Electricity**	**Diesel**	**Total**	**Million Ton/Annum**
13.	Madhya Pradesh and Chhattisgarh	0.79	0.14	0.94	0.89	0.66	1.55	2.49
14.	Maharashtra & Goa	0.66	0.10	0.76	0.74	0.48	1.22	1.98
15.	Mumbai	1.00	0.19	1.19	0.00	0.00	0.00	1.19
16.	North East	0.12	0.02	0.14	0.14	0.09	0.23	0.37
17.	Orissa	0.26	0.04	0.30	0.29	0.21	0.50	0.80
18.	Punjab	0.41	0.06	0.48	0.46	0.30	0.76	1.24
19.	Rajasthan	0.45	0.08	0.53	0.50	0.37	0.87	1.40
20.	Tamil Nadu	0.59	0.10	0.70	0.67	0.49	1.15	1.85
21.	UP (East)	0.61	0.10	0.72	0.69	0.48	1.17	1.89
22.	UP (West) and Uttarakhand	0.67	0.08	0.75	0.75	0.39	1.14	1.89
23.	West Bengal	0.36	0.07	0.42	0.40	0.30	0.70	1.13
Total		12.86	2.22	15.08	9.86	6.75	16.61	31.69

Table5.16 reflects the state wise estimated per subscriber carbon emission of telecom towers in India.

Table5.16: Per Subscriber Carbon Emission of Wireless Telecom Network in India

S. No.	Telecom Circle	Carbon Emission of Energy Consumption of Telecom towers in Mt of CO2	Number of Wireless Subscribers as on 31.3.2015	Carbon Emission Per subscriber (in Kg of CO2)
1	Andhra Pradesh	2.31061	71948399	32.11
2	Assam	0.61752	17150891	36.00
3	Bihar	2.02912	69270633	29.29
4	Delhi	1.56158	46174913	33.82
5	Gujrat	1.96691	58563862	33.59
6	Haryana	0.68299	22006037	31.04
7	HP	0.36507	7856087	46.47
8	J&K	0.47328	9312750	50.82
9	Karnatka	2.13965	58035456	36.87
10	Kerala	1.24051	31406080	39.50
11	Kolkata	1.01178	22560818	44.85
12	Maharshtra	2.48774	76942011	32.33
13	MP	1.98436	60720742	32.68
14	Mumbai	1.19194	30645305	38.89
15	North East	0.37151	10390348	35.75
16	Odisha	0.79895	27869427	28.67
17	Punjab	1.23651	30628488	40.37
18	Rajsthan	1.40104	55205832	25.38
19	Tamilnadu and Chennai	2.91203	80318342	36.26
20	UP(E)	1.89032	83398874	22.67
21	UP(W)	1.88876	52023903	36.31
22	West Bengal	1.12640	47464597	23.73
Total		31.68859	969893795	32.67

5.4.1 FINDINGS

- The annual carbon emission due to diesel consumption is 8.97 million ton while 22.72 million ton carbon emission can be attributed to electricity consumption.
- The annual carbon emission of rural telecom towers and urban towers is 16.61 and 15.08 million ton respectively.
- The total annual carbon emission by telecom towers due to energy consumption is 31.69 million ton.
- Per subscriber annual carbon emission has been estimated as 32.67 Kg which is on higher side with TRAI estimation 21 Kg and world average 8 Kg. (TRAI 2011)

5.5 ANALYSIS OF EXISTING AND POTENTIAL ENERGY CONSERVATION MEASURES IN INDIAN TELECOM SECTOR

5.5.1 ENERGY CONSERVATION PRACTICES OF INDIAN TELECOM COMPANIES

Annual reports and sustainability reports of Indian telecom companies were referred to know about the energy conservation measures undertaken by them.

Public sector undertakings BSNL, MTNL etc. did not provide such information in their annual report. The energy conservation measures undertaken by these companies are known by the other sources like BEE information booklet on Energy Conservation Awards, conference proceedings etc. Some telecom companies like Vodafone India and Bharti Airtel published the sustainability reports mentioning energy consumption and energy conservation measures. It was observed that Indian telecom companies do not provide sufficient information regarding their energy consumption. Only one telecom company Vodafone India has disclosed its energy consumption so far. Table 5.17 provides the detail of electricity and diesel consumption of Vodafone India over the last four years.

Table 5.17: Energy Consumption Trend of Indian Telecom Operator (M/s Vodafone India)

Financial Year	Electricity Consumption (in 000 GJ)	Diesel Consumption (in 000 GJ)
2010-11	1346	1856
2011-12	1421	1690
2012-13	1480	1622
2013-14	1516	1424

Source: Vodafone India Sustainability Reports (2012) (2014)

The company has focused on energy saving and trend shows the reduction in its diesel consumption. A number of innovative energy saving measures was taken by the company to reduce its energy consumption.

Table 5.18 provides the summary of the energy conservation measures undertaken by the Indian telecom companies. It is evident that Indian telecom companies are taking up the latest technologies and methods to save energy:-

Table 5.18: Energy Conservation Measures in Indian Telecom Sector

S No.	Energy conservation Measures	Technical Characteristics	Name of company	Year of Introduction
1.	Green Shelter concept for BTS	The shelter has optimum cooling requirement. Reduction of 40% operation cost by minimizing the generator running time.	Bharti Airtel	2009-10
			GTL Infra	2008-09
			Infratel	2008-09
2.	Data Centre Optimization	Reduction of data centers to save space and power	Airtel	2008-09
			Vodafone	2013-14
3.	Solar hybrid towers for BTS	Fuel switching helps to reduce carbon emission	Bharti Airtel	2008-09
			Idea Cellular	2009-10
			GTL Infra	2011-12
4.	Use of alternate fuels to operate DG sets	Fuel switching helps to reduce carbon emission	Bharti Airtel	2008-09
			Idea Cellular	2009-10
			GTL Infra	2007-08
5.	Electronic Billing	It saves paper and power for printing	Airtel	2009-10
			Idea Cellular	2010-11
			RCL	2010-11
6.	Integrated Power Management Solution (IPMS)	It maximizes usage of grid power and reduces DG run-hours at telecom sites	Airtel	2010-11
			Infratel	2010-11
			GTL Infra	2012-13

S No.	Energy conservation Measures	Technical Characteristics	Name of company	Year of Introduction
7.	Variable speed DC Generators (DCDG)	The variable speed DC generator automatically adjusts its speed to the load requirements thus results in significant savings in the fuel consumption.	Airtel	2010-11
			GTL Infra	2011-12
			Infratel	2010-11
8.	Biomass-based electricity generation	Fuel switching helps to reduce carbon emission	Bharti Airtel	2010-11
9.	Green Tower	Green tower works without DG Set. It either have deep discharge batteries or Renewable Energy Sources	Bharti Airtel	2010-11
			Infratel	2009-10
10.	Managed Energy Services and Remote Monitoring	Monitoring the energy consumption pattern of the facility identifying and implementing energy saving measures based on consumption pattern of the facility	Bharti Airtel	2010-11
			GTL Infra	2008-09
11.	Virtualization of servers and cloud based	CPUs and servers are removed leading to power saving	Bharti Airtel	2010-11
12.	Outdoor BTS	Outdoor BTS does not require air conditioning thus saves power.	Bharti Airtel	2011-12
13.	Low power consuming BTS	The power consumption of new BTS is 0.8-1.0 KW	Bharti Airtel	2011-12
			Idea Cellular	2013-14
14.	Auto shutdown of TRX	Traffic load is variable, during non peak period some of TRX can be switch off to reduce power requirement.	Bharti Airtel	2011-12
15.	Infrastructure Sharing	Reduction in carbon emission	Bharti Airtel	2007-08
			Idea Cellular	2006-07

S No.	Energy conservation Measures	Technical Characteristics	Name of company	Year of Introduction
16.	Conversion of Indoor Sites to Outdoor	Saving in power as air conditioning is not required	Bharti Airtel	2013-14
			Tata Teleservices	2012-13
17.	Lithium Ion Batteries	Efficiency of Lithium ion batteries is better to conventional VRLA batteries	Bharti Airtel	2013-14
			GRL Infra	2013-14
18.	Fuel cell	Reduction in carbon emission	Idea Cellular	2009-10
19.	Free Cooling Unit (FCU)	Outside air is used for cooling .Use of air conditioners is avoided.	Idea Cellular	2013-14
			GTL Infra	2007-08
20.	Diesel additives	It result in reduction in fuel consumption and better exhaust emission.	Idea Cellular	2013-14
21.	Additives in air conditioner coolant	Efficiency of air conditioners is improved.	Idea Cellular	2013-14
22.	Wind Turbine	Reduction in carbon emission	GTL Infra	2007-08
23.	Use of Energy efficient and star rated products	Energy Saving	Almost all telecom companies have mentioned about use of energy efficient star rated products	
24.	Power saving and energy efficiency program	Monitoring of Energy Bill, Measures for saving energy	BSNL & MTNL	2000-2001
			Bharti Airtel	2004

It is observed that energy conservation in mobile telecommunications is a relatively new concept in India. Though a lot of case studies are available for energy conservation in telecom buildings, energy efficiency in wireless segment is evolving in last decade. Indian mobile companies and tower companies are following the examples of world companies and trying to be more energy efficient.

5.5.2 FUEL SWITCHING OPTION FOR TELECOM TOWERS

Let us consider the case for the BTS site as follows:-

Table 5.19: Detail of BTS Site for Fuel Switching

BTS Site Type	Outdoor Site
Load	3 kW
Grid Power Availability	16 hrs/day
Diesel consumption per hour	2.5 liters
Output Power Requirement	3*8=24 kWhr/day
Battery Output Voltage	48 volts

Based on the above mentioned case assumptions, the site requires 8 hours or 24 kWh/day equivalent of back-up power.

Diesel Consumption for the Site Considering a 15-20 KVA DG Set

Diesel consumption for 3kW load= 2.5 liters/hour
Diesel consumed in one day= 2.5*8=20 liters
Diesel consumed per annum=20*365= 7300 liters

Case I:-
Let the diesel price be Rs 50/liter
Liters of diesel consumed per annum=7300
Total Diesel cost per annum= 7300*50 =Rs 3,65,000
DG Maintenance Cost: Rs 14.8/hour
DG Replacement Cost: Rs. 14.71/hour
DG Maintenance Cost per annum: 14.8*8*365 : Rs 43,216

DG Replacement Cost per annum: 14.7*8*365 : Rs 42,953

Total diesel cost saving per annum: Rs 4,51,169

Case II

Let the diesel price be Rs 60/liter

Liters of diesel consumed per annum=7300

Net diesel cost per annum= 7300*60 =Rs 438000

DG Maintenance Cost: Rs 14.8/hour

DG Replacement Cost: Rs. 14.71/hour

DG Maintenance Cost per annum: 14.8*8*365 : Rs 43,216

DG Replacement Cost per annum: 14.7*8*365 : Rs 42,953

Total diesel cost saving per annum: Rs 5, 24,169

Case III

Let the diesel price be Rs 70/liter

Liters of diesel consumed per annum=7300

Net diesel cost per annum= 7300*70 =Rs 5,11,000

DG Maintenance Cost: Rs 14.8/hour

DG Replacement Cost: Rs. 14.71/hour

DG Maintenance Cost per annum: 14.8*8*365 : Rs 43,216

DG Replacement Cost per annum: 14.7*8*365 : Rs 42,953

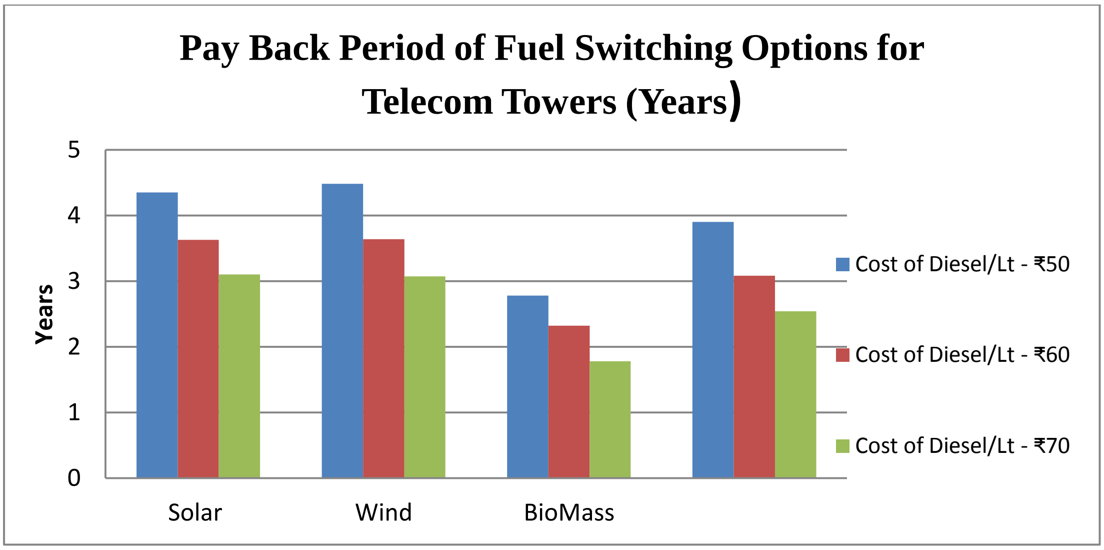
Total diesel cost saving per annum: Rs 5, 97,169

Table 5.20 explains the detail of fuel switching option for Indian BTS sites with capacity and capital cost of the solution. The capital cost is based on market price of SPV, WTG, Biomass Gasifier, Fuel Cell and batteries in India. The operations cost of fuel switching option is not taken in to consideration while determining the payback period by NPV method.

Table 5.20: Fuel Switching Options for BTS Sites in India

S. No.	Fuel Switching Option	Capital Cost in Rs.	Pay Back Period		
			Case 1 Diesel Price @Rs. 50 / Per Liter	Case 1 Diesel Price @Rs. 60 / Per Liter	Case 1 Diesel Price @Rs. 70 / Per Liter
1.	Solar Photovoltaic (SPV) Solution 8kW Solar Panel with Batteries	15.99 Lakhs	4.35 Years	3.63 Years	3.10 years
2.	Wind Turbine Generator WTG 10kW with Batteries	14.32 Lakhs	4.48 Years	3.64 Years	3.07 Years
3.	Biomass Gasifier 10kW	10.18 Lakhs	2.78 Years	2.32 Years	1.98 Years
4.	Hydrogen Fuel Cell 4kW	10.68 Lakhs	3.90 Years	3.08 Years	2.54 Years

Figure 5.3: Pay Back Period of Fuel Switching Options for Telecom Towers

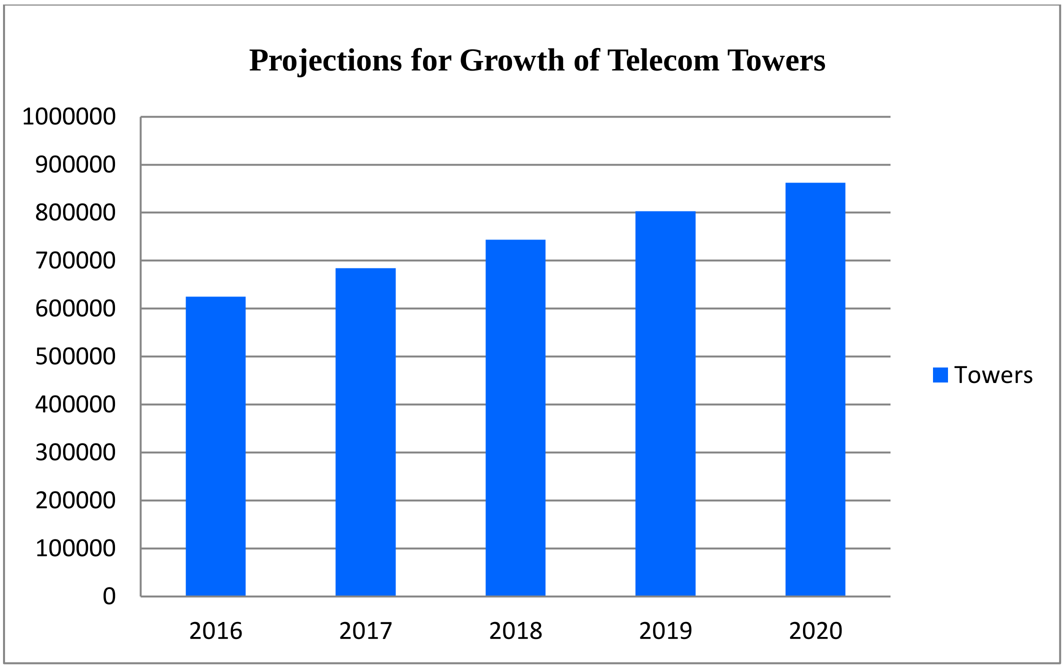


The solution discussed here includes a combination of Solar photovoltaic and batteries, thus replacing the diesel generator at site.

5.5.3 SCENARIO ANALYSIS TO ASSESS IMPACT ON ENERGY CONSUMPTION OF TELECOM TOWERS IN VIEW OF GOVERNMENT DIRECTIVE TO USE HYBRID ENERGY FOR TELECOM TOWERS

The projection for growth of telecom towers in shown in fig. 5.4

Figure5.4: Projection for Growth of Telecom Towers



In view of growing demand of telecom services demand for telecom towers will grow, it is projected to reach 862606 in 2020 from 567722 in 2015.

The present energy consumptions by telecom towers is 206 PJ. With projected growth of 862606 towers in 2020, the energy requirement will be 318 PJ under Business As Usual (BAU) case .The energy requirement of telecom towers from base year 2012 to 2020 under BAU scenario has been depicted in fig. 5.5.

Table 5.21: Annual Energy (Electricity and Diesel) consumption of telecom towers in PJ

Parameter	Description	Value	Unit
E_{BTSR}	Electrical Energy Consumed by Rural and Suburban BTS Per Year in kWh	$9596.30*10^6$	kWh
	Elec Electrical Energy Consumed by Rural and Suburban BTS Per Year in PJ (E_{BTSR} *0.0036/10^6)	35	PJ
E_{BTSU}	Elec Electrical energy Consumed by Urban BTS Per Year in kWh	$12597.79*10^6$	kWh
	Elect Electrical Energy Consumed by Urban BTS Per Year in PJ (E_{BTSR} *0.0036/10^6)	45	PJ
E_{BTS}	Electrical energy Consumed by BTS Per Year (E_{BTSR} + E_{BTSU})	$22194*10^6$	kWh
	Electrical energy Consumed by BTS Per Year in PJ (E_{BTS}*0.0036/10^6)	80	PJ
D_R	AnnD Diesel consumption by rural and suburban telecom towers Per Year	$2499.04*10^6$	Liters
	=D_R*38/10^9	95	PJ
D_U	Diese Diesel consumption by urban telecom towers Per Year	$822.67*10^6$	Liters
	= D_U*38/10^9	31	PJ
D	Diesel consumption by telecom towers Per Year (D_R+ D_U)	$3321.71*10^6$	Liters
	= D*38/10^9	126	PJ

Here following conversion factors have used for conversion of electricity and diesel in PJ

1kWh = $3.6*10^{-9}$ PJ

1 Litre diesel (Industrial diesel fuel) =38MJ= $38 * 10^{-9}$ PJ

(http://www.natural-gas.com.au/about/references.html**)**

Table 5.22: Growth Projection of Telecom Towers in India

S. No.	Year	Urban Towers	Rural Towers	Total Towers
1	2012	158800	241200	400000
2	2013	176665	268335	445000
3	2014	196515	298485	495000
4	2015	225386	342336	567722
5	2016	251528	382043	633571
6	2017	275651	418684	694336
7	2018	299775	455326	755100
8	2019	323899	491967	815865
9	2020	348022	528608	876630

Source – DoT (2015) TRAI (2011)

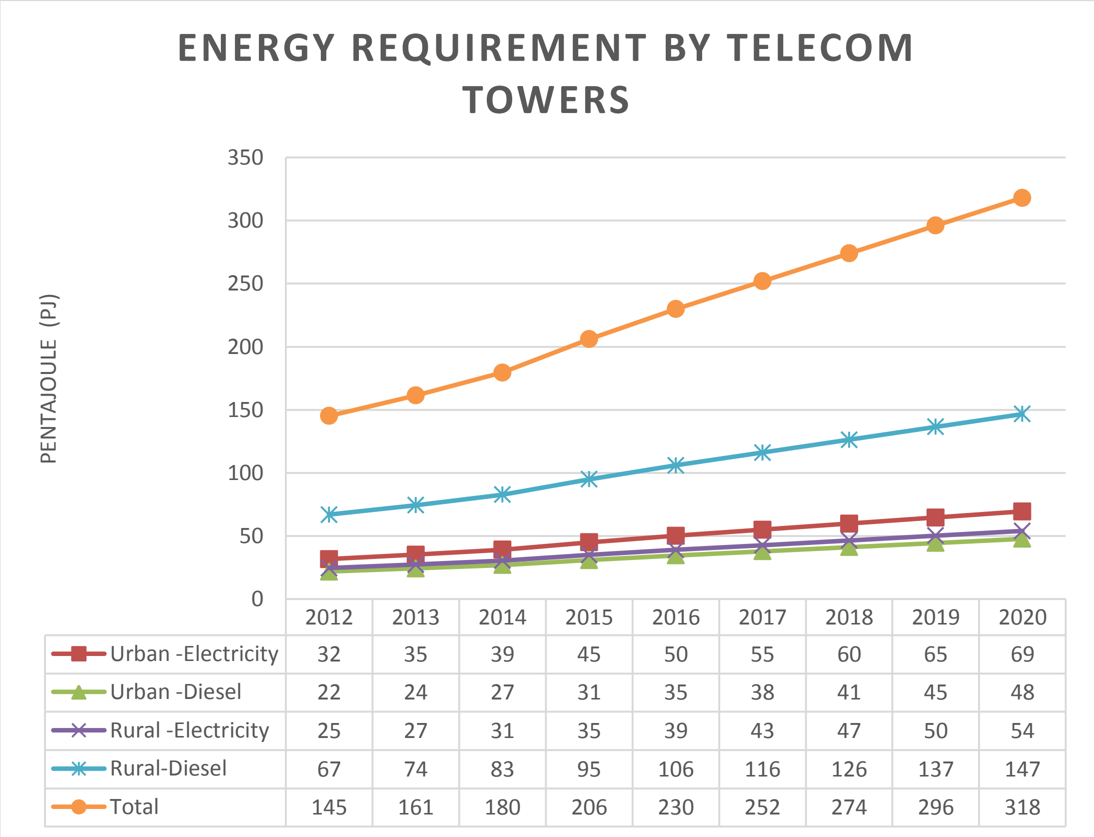
Table 5.23: Projection for Energy Consumption of Telecom Towers

S. No.	Year	Urban Towers Energy Consumption(PJ)		Rural Towers Energy Consumption(PJ)		Total (PJ)
		Electricity	Diesel	Electricity	Diesel	
1	2012	32	22	25	67	145
2	2013	35	24	27	74	161
3	2014	39	27	31	83	180
4	2015	45	31	35	95	206
5	2016	50	35	39	106	230
6	2017	55	38	43	116	252
7	2018	60	41	47	126	274
8	2019	65	45	50	137	296
9	2020	69	48	54	147	318

Table 5.24: Impact on Energy Consumption by fuel switching for Telecom Towers

DoT Directive	Year	Urban Towers Energy Consumption(PJ)		Rural and semi Urban Towers Energy Consumption(PJ)		Total (PJ)
		Electricity	Diesel	Electricity	Diesel	
50% of Rural Towers and 20% of Urban towers are to be powered by hybrid energy (RET+ Grid) by 2015	2015 (BAU)	45	31	35	95	206
	2015 (With fuel switching)	45	25	35	48	153
Hybrid energy (RET+ Grid) for 75% of rural towers and 33% urban towers by 2020.	2020 (BAU	69	48	54	147	318
	2020 (With fuel switching)	69	32	54	37	192

Figure 5.5: Projection for Energy Requirement of Telecom Towers



As per the DOT directive to use renewable energy technology **"**At least 50% of all rural towers and 20% of the urban towers are to be powered by hybrid power (Renewable Energy Technologies (RET +Grid power) by 2015". Figure 5.6 shows the impact on energy and diesel consumption if renewable energy technology is employed for 20% urban and 50% of rural towers. With the use of renewable energy technology the energy requirement is expected to reduce to 153 PJ from the existing 206 PJ. Further DOT directive stipulates to use renewable energy for 75% of rural towers and 33% urban towers by 2020. Figure 5.7 describes the scenario by 2020.The expected reduction in energy requirement is about 40%.

Figure 5.6 Scenario Analysis for Impact of Fuel Switching for Telecom Towers By 2015

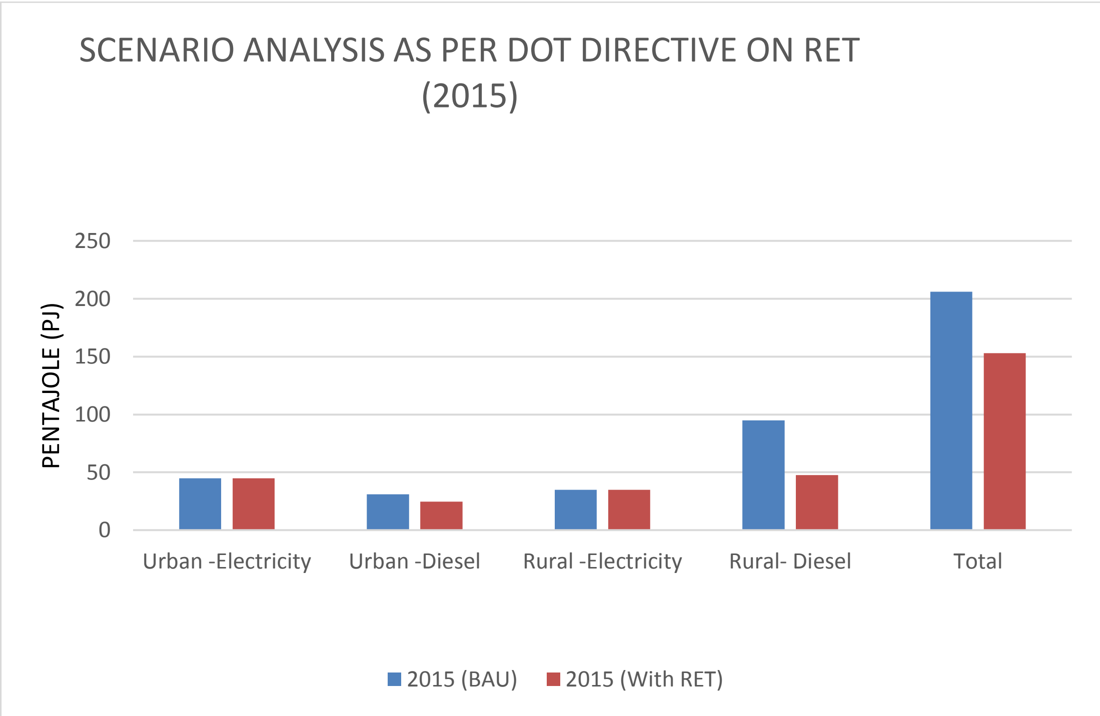
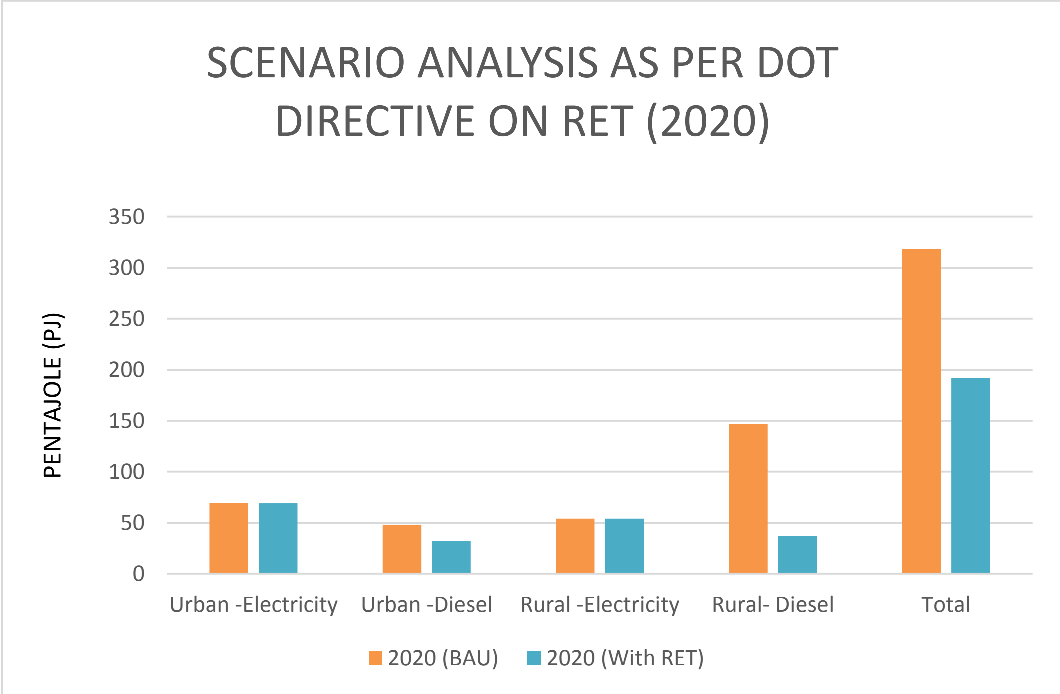


Figure 5.7 Scenario Analysis for Impact of Fuel Switching for Telecom Towers By 2020



Saving in Diesel Consumption & CO_2 Emission by fuel switching for Telecom Towers has been shown in table 5.25 it shows a saving of 3.81 Mt of CO_2, 8.95 Mt of CO_2 respectively by year 2015 and 2020 if hybrid energy employee.

Table 5.25: Saving in Diesel Consumption & CO_2 Emission by fuel switching for Telecom Towers

DoT Directive	Year	Annual Diesel Consumption by Telecom Towers (Million Liters)		CO_2 Emission Due to Diesel Consumption by Telecom Towers (Mt of CO_2)		Annual Saving in Diesel Consumption (Million Liters)	Saving in CO_2 Emission (Mt of CO_2)
		Urban	**Rural**	**Urban**	**Rural**		
50% of Rural Towers and 20% of Urban towers are to be powered by Hybrid Power (RET+ Grid Power) by 2015	2015 (BAU)	822.67	2499.03	2.22	6.75	1414.05	3.81
	2015 (RET)	658.14	1249.51	1.78	3.38		
Hybrid (RET+ Grid) Power for 75% of rural towers and 33% urban towers by 2020.	2020 (BAU	1270.30	3858.80	3.43	10.42	3313.30	8.95
	2020 (With RET)	851.10	964.7	2.30	2.60		

5.5.2 FINDINGS

- A no. of energy conservation opportunities is available in telecom sector. Study has found that telecom companies in India are adopting various measures like Use of Variable Speed DC Diesel Generators, Use of Lithium Ion batteries, Free cooling Units etc. for energy saving.
- Due to vast abundance of natural resources, one more attractive option for the telecom sector is fuel switching. The diesel generators at telecom tower sites can be replaced by renewable energy namely solar, wind , Biomass and fuel cell
- Payback period of biomass option is lowest but logistic problems of feed stock do not make it attractive. Fuel cell though popular at international level is not much used in India due to logistic problem of hydrogen . In Indian conditions solar photo voltaic (SPV) are extensively used as Government also provide subsidy on solar installations .At places having optimum wind velocity , wind turbines in isolation and with SPV units are used . The payback period for solar solution is 4.35 years (Considering diesel price @Rs. 50), under subsidy scheme by MNRE it becomes more attractive.
- The no. of telecom towers is estimated to increase from present 567722 to 876630 in year 2020 if present trend of growth in telecom infrastructure continue . Under Business As Usual (BAU) scenario the energy demand of telecom tower will rise to 318 PJ from present 206 PJ.
- As per the DOT directive to use renewable energy technology "At least 50% of all rural towers and 20% of the urban towers are to be powered by hybrid power (Renewable Energy Technologies (RET +Grid power) by 2015". With the use of renewable energy technology the energy requirement is expected to reduce to 153 PJ from the existing 206 PJ. Further DOT directive stipulates to use renewable energy for 75% of rural towers and 33% urban towers by 2020. The expected reduction in energy requirement is about 40%.

- By use of fuel switching option i.e replacing diesel with renewable energy the expected saving in diesel is 1414.05 and 3313.30 million liters respectively for the years 2015 and 2020.
- The resultant reduction in carbon emission due to fuel switching (diesel to renewable energy) will be 3.81 and 8.95 Mt of CO_2 respectively for the year 2015 and 2020.

5.6 IDENTIFICATION OF CRITICAL FACTORS AFFECTING ENERGY CONSERVATION IN INDIAN TELECOMMUNICATION SECTOR

5.6.1 DRIVERS FOR IMPLEMENTATION OF ENERGY CONSERVATION MEASURES IN INDIAN TELECOMMUNICATION SERVICE SECTOR

Before starting the analysis the reliability of the scale was checked using Cronbach’s Alpha (Statistical Tool). The value greater than 0.7 is considered to be highly reliable. The results achieved by this statistical test are portrayed below:

Table 5.26: Reliability Statistics. Driving Forces

Cronbach's Alpha	N of Items
0.913	25

The scale is highly reliable as the Cronbach’s Alpha value is above 0.7. As the scale was accepted, factor analysis was used to reduce the data by grouping the similar parameters to a few manageable factors.

The Kaiser-Meyer-Olkin (KMO) statistic was used to evaluate whether the sample size used for study was adequate so as to ensure the precision of factor analysis. The value of KMO statistic greater than .6 is considered to be adequate. The results achieved by this statistical test are portrayed below:

Table 5.27: KMO and Bartlett's Test: Driving Forces

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.644
Bartlett's Test of Sphericity	Approx. Chi-Square	7.851E3
	df	300
	Sig.	.000

The value of KMO statistic is greater than 0.6. As such, the sample size is considered to be adequate and the aptness of factor analysis is ensured

The Principle Component Analysis method was used to analyze these 25 parameters. In this Principle Component Analysis Eigen Value Method and Scree Plot Method were used to determine and justify the factors.

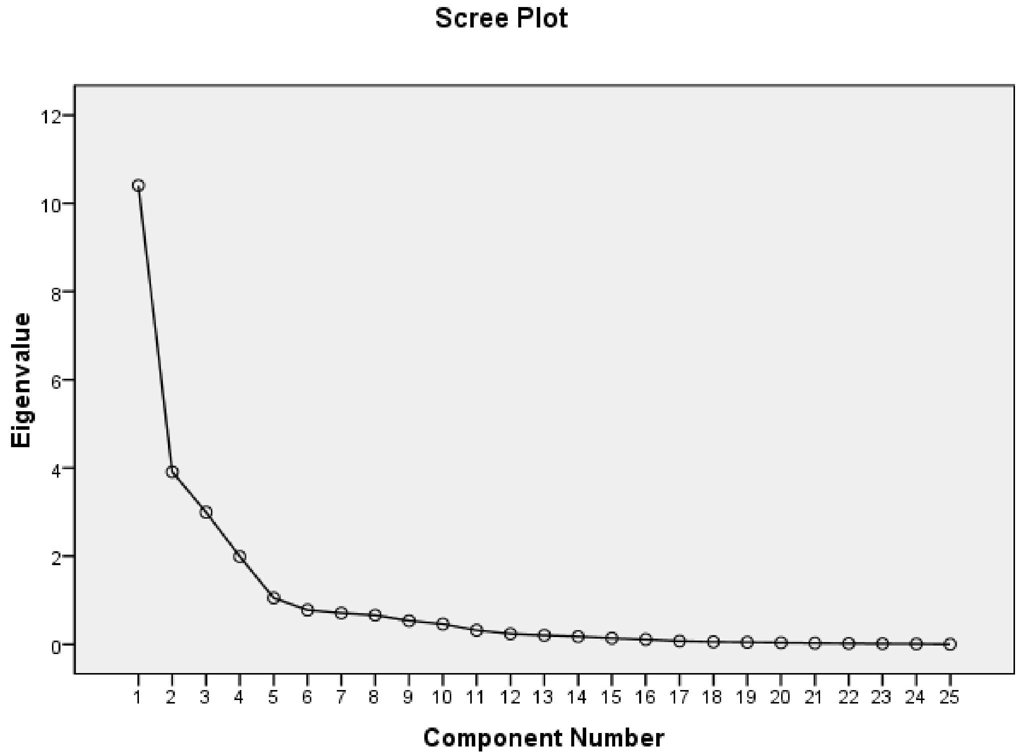
Communality"- Common Factor Variance Communality of each statement refers to the variance being shared or common by other statements.

"Eigen Value": Indicates the amount of variance in the original variables accounted or by each component. The total initial variance in the components will be 25. The extracted 5 factors are contributing 81.431 % of cumulative variance

Driving factors affecting the energy conservation measures in Indian telecom sector

Using Principle Component Analysis, 5 factors were determined whose cumulative percentage of variances is explained by 67.30%..

Figure 5.8: Scree Plot, Driving Forces



After determining the five factors, the factor matrix was prepared which loaded 25 variables on the factors. Thereafter factor rotation matrix was prepared by rotating the factors using Varimax procedure which is an orthogonal method of factor rotation. Cronbach's Alpha of each of 4 factors was calculated to establish the internal consistency and it was found to be 0.969, 0.934., 0.877 and 0.804 respectively for the studied factors and is found to be consistent. For fifth factor, there is only single variable, the computation of chronbach's alfa is not required.

By the application of factor analysis, 25 identified variables were reduced to 5 major factors which act as the driving factors affecting the energy conservation measures in Indian telecom sector.. The significant factor loadings of each identified variable, the total variance explained for each factor and the Cronbach's Alpha for each factor is shown below:

Table 5.28: Driving forces for implementation of energy conservation measures in Indian telecom sector and variables loaded into those factors.

Factors	Factor Interpretation	Factor Loading	Variables Included in Factor
F1	Regulation and Competition Oriented Drivers (Total Variance =37.019%) Chronbach alpha =0.969 N of items =13	0.824	Commitment from Top Management
		0.879	Cost cutting for competitive advantage
		0.947	Cost reduction due to energy conservation
		0.906	Share on energy cost in operation cost
		0.876	Declining Average revenue per unit of service providers
		0.717	Rising of Telecom infrastructure Companies
		0.729	Govt announcement to cut carbon
		0.943	Restriction on use of subsidized diesel for telecom industry
		0.962	Department of Telecommunication directives to use renewable energy technology for telecom towers
		0.806	Availability of energy Efficient telecom network equipments
		0.778	Availability of BEE certified energy auditors / Managers in telecom organizations
		0.592	Reduction in Carbon emission by fuel switching and reduction energy consumption
		0.749	Use of Energy conservation building code for telecom buildings
F2	Organizational policy oriented Drivers (Total Variance =13.422%) Chronbach alpha =0.934 N of items =3	0.904	Long term Energy Strategy
		0.884	Rising energy prices
		0.883	Awareness Workshop seminars on energy conservation

Factors	Factor Interpretation	Factor Loading	Variables Included in Factor
F3	Incentive oriented Drivers (Total Variance =13.325%) Chronbach alpha =0.877 N of items = 4	0.839	Improved Working Condition
		0.860	National Energy Conservation Award for Saving Energy
		0.912	Focus on sustainability
		0.764	Energy Conservation case studies of foreign telecom operators
F4	Customer oriented and Financial Benefits Oriented Drivers (Total Variance =10.914%) Chronbach alpha =0.804 N of items =4	0.782	Demand from Subscribers
		0.601	Pressure from NGO and Public
		0.857	Carbon Trading
		0.845	Energy efficiency measures in response to energy conservation act 2001
F5	Sustainable Benefit Oriented Drivers (Total Variance =6.751 %) Single Variable Chronbach alpha not required .	0.777	Falling price of renewable energy solution for telecom use

Discussions

Factor 1: The variables which have been loaded in factor one showcase cost cutting for competitive advantage, use of energy conservation building code for telecom buildings, Department of Telecommunication directive to use renewable energy technology for telecom towers etc. Hence factor one has been termed as “Regulation and Competition Oriented Drivers”.

Policy intervention by Government in the form of regulation on energy efficiency and cut throat competition among the telecom operators can act as motivating force for energy conservation in telecom sector.

Factor 2: Factor two has been termed as “Organizational policy oriented Drivers” as the variables has been loaded on this factor, such as long term energy strategy, awareness workshop seminars on energy conservation, rising energy prices. Adoption of energy conservation as organizational policy by the telecom operators can drive the energy conservation movement in Indian telecom sector.

Factor 3: The variables which have been loaded in factor three showcase improved working conditions, National energy conservation award for saving energy , energy conservation case studies of foreign telecom operators, Hence factor three has been termed as " Incentive oriented Drivers"

At present there is no recognition and incentives for the energy conservation measures at BTS sites. Energy conservation efforts in telecom sector at present are driven by the case studies of International telecom operators. Availability of the incentives can motivate the telecom companies to energy saving.

Factor 4: Factor four has been termed as "Customer oriented and Financial Benefits Oriented Drivers" as the variables has been loaded on this factor, such as "Demand from Subscribers", "Pressure from NGO and Public" "Carbon Trading" and "Energy efficiency measures in response to energy conservation act 2001".

Presently, telecom companies are focused on gaining the new customers. The customers are not aware about the energy consumption level of the companies. If customers are aware, telecom operator can showcase its energy saving measures to attract new customers. Therefore, energy conservation while saving the cost can attract new customers to the telecom operator.

Factor 5: Factor five has been termed as "Sustainable Benefit Oriented Drivers" as the variables has been loaded on this factor, "Falling Price of Renewable Energy Solution for Telecom Use". The installation of renewable energy solution for telecommunications site ensures sustainable benefits such as elimination of diesel expenditure and reduction in carton emission.

5.6.2 BARRIERS FOR IMPLEMENTATION OF ENERGY CONSERVATION MEASURES IN INDIAN TELECOMMUNICATION SERVICE SECTOR

To identify Before starting the analysis the reliability of the scale was checked using Cronbach's Alpha (Statistical Tool). The results achieved by this statistical test are portrayed below:

Table 5.29: Reliability Statistics: Barriers

Cronbach's Alpha	N of Items
0.621	31

The scale is acceptable as the Cronbach's Alpha value is above 0.5. As the scale was accepted, factor analysis was used to reduce the data by grouping the similar parameters to a few manageable factors.

The Kaiser-Meyer-Olkin (KMO) statistic was used to evaluate whether the sample size used for study was adequate so as to ensure the precision of factor analysis. The value of KMO statistic greater than 0.6 is considered to be adequate. The results achieved by this statistical test are portrayed below:

Table 5.30 KMO and Bartlett's Test: Barriers

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.603
Bartlett's Test of Sphericity	Approx. Chi-Square	7.050E3
	Df	465
	Sig.	.000

The value of KMO statistic is greater than 0.6. As such, the sample size is considered to be adequate and the aptness of factor analysis is ensured

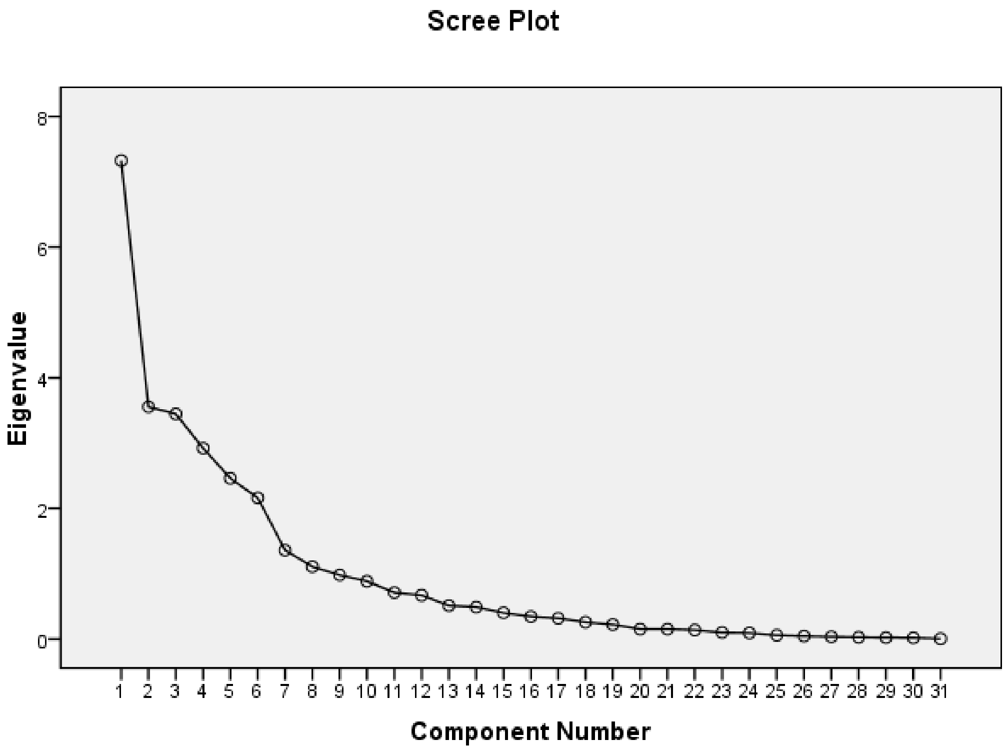
The Principle Component Analysis method was used to analyze these 31 parameters. In this Principle Component Analysis Eigen Value Method and Scree Plot Method were used to determine and justify the factors.

“Eigen Value”: Indicates the amount of variance in the original variables accounted or by each components. The total initial variance in the components will be 31. The extracted 8 factors are contributing 78.505 % of cumulative variance

Barriers affecting the energy conservation measures in Indian telecom sector

Using Principle Component Analysis, 8 factors were determined whose cumulative percentage of variances is explained by 67.30%..

Figure 5.9 Scree Plot: Barriers



After determining the five factors, the factor matrix was prepared which loaded 31 variables on the factors. Thereafter factor rotation matrix was prepared by rotating the factors using Varimax procedure which is an orthogonal method of factor rotation. Cronbach’s Alpha of each of 7 factors was calculated to establish the internal consistency and it was found to be 0.922, 0.879,0.905, 0.858, 0.253, 0.169 and 0.461 respectively for the studied factors and is found to be consistent. For eighth factor, there is only single variable, the computation of chronbach's alfa is not required.

By the application of factor analysis, 31identified variables were reduced to 8 major factors which act as the barriers affecting the energy conservation measures in Indian telecom sector.. The significant factor loadings of each identified variable, the total variance explained for each factor and the Cronbach's Alpha for each factor is shown below:

Table 5.31: Barriers to implementation of energy conservation measures in Indian telecom sector and variables loaded into those Barriers.

Factors	Factor Interpretation	Factor Loading	Variables Included in Factor
F1	Lack of Benchmarks / Targets and Reporting Barriers (Total Variance =23.625 %) Chronbach alpha = 0.922 N of items =8	0.838	Non-availability of energy conservation targets
		0.847	Non-importance of energy as a function of service /production
		0.876	Less awareness about linkage between energy consumption and carbon emission in the organization
		0.473	Lack of information and reporting about energy use by telecom operators
		0.825	Lack of benchmarks for energy consumption in telecom sector
		0.841	Lax attitude of regulator and Government towards energy consumption of telecom sector
		0.877	Problems in maintenance and availability of spares of energy efficient equipment
		0.688	Lack of skilled manpower and training
F2	Bounded Rationality Barriers (Total Variance =11.466 %) Chronbach alpha =0. .879 N of items =4	0.772	Non-importance/less priority of energy management in the organization
		0.813	Confusion that telecommunications being a service industry do not need energy conservation
		0.864	Inadequate financial and technical information about fuel switching

Factors	**Factor Interpretation**	**Factor Loading**	**Variables Included in Factor**
			options
		0.892	High CAPEX of energy efficient and fuel switching technologies
F3	Customer Awareness Barriers (Total Variance = 11.115 %) Chronbach alpha =0.905 N of items = 4	0.858	Non-enforcement of hybrid energy and carbon disclosure directive
		0.818	Lack of customer awareness
		0.879	Lack of pressure from NGOs and public
		0.894	Wrong examples set by public sector telecom service providers
F4	Precedence and Lack of financial incentives Barriers (Total Variance =9.425%) Chronbach alpha =0.858 N of items =4	0.932	Government does not support with financial incentives for energy conservation
		0.866	Lack of information about energy conservation and energy efficiency opportunities
		0.901	Priorities of service providers on expansion of telecom services in new areas
		0.428	Management perception that in telecom services ,energy efficiency is less important
F5	Hiding diesel use information Barriers (Total Variance = 7.940%) . Chronbach alpha =0.253 N of items =5	0.811	No incentive /penalty for meeting/skipping the targets
		(-ve) 0.715	Less awareness in the organization about importance of energy conservation
		0.754	Lack of energy audit methodology of telecom installations
		0.814	Hiding of information by operators regarding use of diesel due to risk of exposing the misuse of subsidized diesel
		-0.656	The workers in the organization is not accountable for energy cost
Factors	Factor Interpretation	Factor Loading	Variables Included in Factor
F6	Lack of Standards of Energy Efficient Products Barriers (Total Variance	0.949	Lack of customer preference for sustainability
		-.535	Energy efficiency benefits cannot be quantified

Factors	Factor Interpretation	Factor Loading	Variables Included in Factor
	=6.971%) Chronbach alpha =0.169 N of items =3	0.967	Poor quality and lack of standards of energy efficient products
F7	Regulatory and Organisational Policy Barriers (Total Variance = 4.391%) Chronbach alpha =0.461 N of items =2	0.409	Lack of regulations by regulator and Government
		.637	Organisation is lacking in policies procedures and systems for energy management
F8	Technical Barriers (Total Variance =3.573 %) Chronbach alpha Not Required for single item N of items =1	-.636	Lack of awareness about telecom sector specific technical measures for energy conservation

Discussions

Factor 1: Factor one has been termed as " Lack of Benchmarks / Targets and Reporting Barriers" as the variables has been loaded on this factor, such as "Non-availability of energy conservation targets", " Lack of benchmarks for energy consumption in telecom sector" etc.

This is the biggest barrier for energy conservation in telecom industry where there is no benchmark for energy consumption at telecommunication sites. There are no targets for energy conservation of the telecom industry. Being the service industry the telecom companies are not bound to report their energy consumption detail.

Factor 2: Factor two has been termed as "Bounded Rationality" as the variables has been loaded on this factor, such as Confusion that telecommunications being a service industry do not need energy conservation, Inadequate financial and technical information about fuel switching options etc.

This is another significant barrier where energy consumption of telecom sector is neglected considering it as a service industry.

Factor 3: The variables which have been loaded in factor three showcases Lack of customer awareness, Lack of pressure from NGOs and public etc. Hence factor three has been termed as "Customer Awareness Barriers"

The Indian customers are not aware about the energy consumption and use of subsidized diesel by the telecom companies. If customers are aware, they can demand energy efficient practices from telecom operators.

Factor 4: Factor four has been termed as "Precedence and Lack of financial incentives Barriers " as the variables has been loaded on this factor, such as Priorities of service providers on expansion of telecom services in new areas, Government does not support with financial incentives for energy conservation etc.

The priority for the service operators is to expand and gain new customers , on the same time there is no financial incentives from Government for energy saving.

Factor 5: Factor five has been termed as "Hiding diesel use information Barriers " as the variables has been loaded on this factor, Hiding of information by operators regarding use of diesel due to risk of exposing the misuse of subsidized ,Lack of energy audit methodology of telecom installations and etc. , Two variable "Less awareness in the organization about importance of energy conservation" and "The workers in the organization is not accountable for energy cost" has negative figure of factor loading that explains the inverse relationship with in the factor .

In absence of differential pricing system of diesel, subsidized diesel is used by the telecom operators. The operators are not interested to reveal their actual diesel use.

Factor6: Factor six has been termed as "Lack of Standards of Energy Efficient Products Barriers" as the variables has been loaded on this factor "Poor quality and lack of standards of energy efficient products" and "Lack of customer preference for sustainability". One variable "Energy efficiency benefits cannot be quantified" has negative figure of factor loading that explains the inverse relationship with in the factor.

India there is no rating for energy efficiency of telecom equipments. Telecom companies have no choice for energy efficiency at the time of procurement.

Factor 7: The variables which have been loaded in factor seven show "Lack of regulations by regulator and Government" and "Organisation is lacking in policies procedures and systems for energy management". This factor has been termed as "Regulatory and Organisational Policy Barriers".

There is no policy for energy conservation measures, telecom companies are not covered under EC Act .

Factor 8: Factor eight has been termed as "Technical Barriers" as there is a single variable "Lack of awareness about telecom sector specific technical measures for energy conservation." This has negative figure of factor loading that explains the inverse relationship with in the factor.

The technical measures applicable to Indian requirements are not known to the telecom companies .

5.6.3 FINDINGS

Identified Drivers - Based on factor analysis six drivers were identified that affect energy conservation- Regulation and Competition Oriented Drivers, Organizational policy oriented Drivers, Incentive oriented Drivers, Customer oriented & Financial Benefits Oriented Drivers and Sustainable Benefit Oriented Drivers

The Section 5.6.1 have detailed explanation of the identified drivers with reference to Indian telecom sector.

Identified Barriers – Based on factor analysis eight barriers were identified that affect energy conservation - Lack of Benchmarks / Targets and Reporting Barriers, Bounded Rationality Barriers, Customer Awareness Barriers, Precedence and Lack of financial incentives Barriers, Hiding diesel use information Barriers , Lack of Standards of Energy Efficient Products Barriers, Regulatory & Organizational Policy Barriers and Technical Barriers.

The relation of above drivers with Indian telecom sector have been discussed in detail in section 5.6.2

CHAPTER 6

RECOMMENDATIONS AND CONCLUSION

This study has tried to understand the entire spectrum of energy conservation and carbon emission in Indian telecommunication sector. (Figure 6.1)

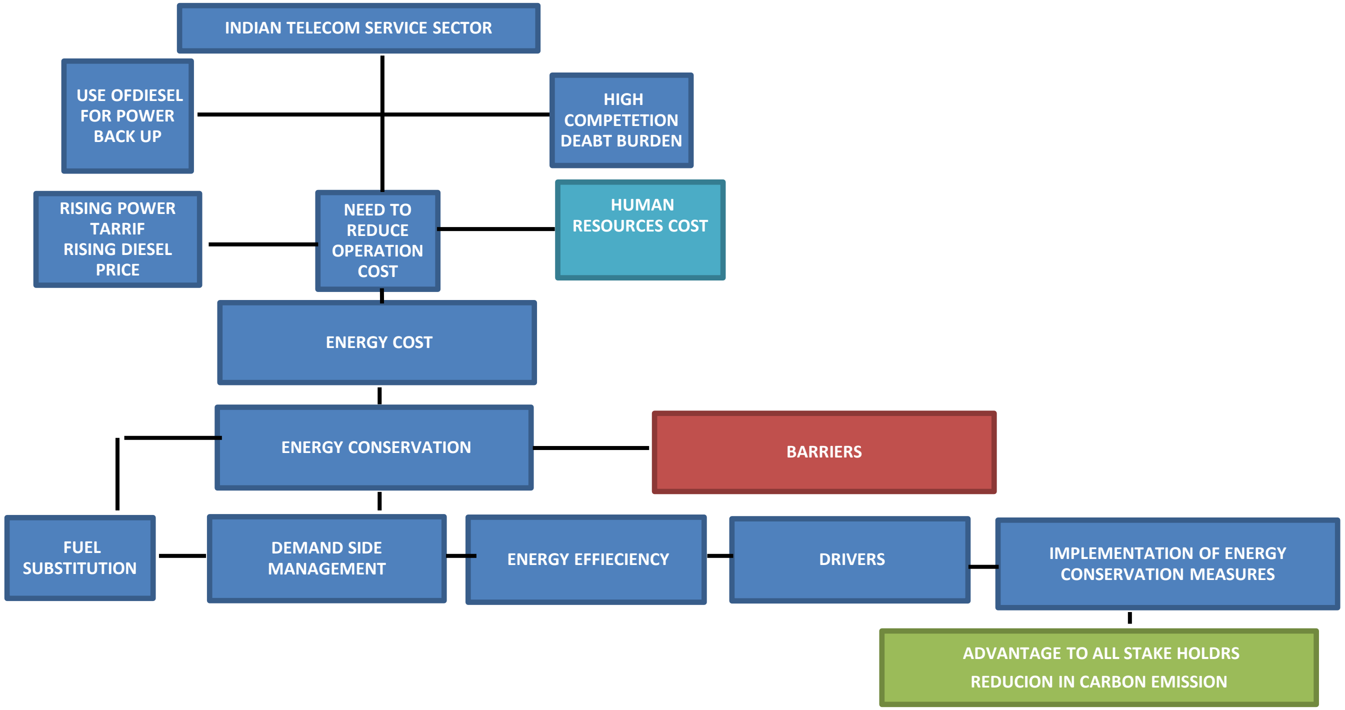
As there is no estimation of energy demand of telecom networks in India, first the electricity requirement of the Indian telecommunication network was established. It has been estimated to be 3.73% of total electricity consumption 938,823Million Units in India. Diesel generators are used to power the telecom network due to power outage and poor grid connectivity and the estimated annual diesel consumption is 3.3 billion liters. The resultant carbon emission due to electricity and diesel consumption of telecom towers is about 32 Million ton per annum.

The energy expenditure of telecom operators have rising trend. A decade back it was just about 2% of revenue but now for some operators it has reached 10%. It was noticed that present energy cost of telecom service providers in India fluctuate from Rs. 150 to Rs. 400 per subscriber per annum.

The variation in expenditure on energy by the telecom operators as well as availability of energy conservation case studies proved the need of energy conservation in Indian telecommunication sector. The study has identified various energy conservation measures suitable for implementation in Indian telecom sector.

The study has identified the fuel substitution methods for telecom towers and calculated payback period.

Figure 6.1 Energy Conservation Frameworks in Indian Telecom Sector



This study has tracked the pathway to reduce carbon emission of telecom network operation by reduction in fossil fuel consumption using fuel substitution and demand side management.

The critical factors (Barriers and drivers) affecting energy conservation in telecommunication sector in India have been identified.

The study has identified various barriers which prevent the implementation of energy conservation measures in Indian telecommunication sector and they are as follows:-

- Lack of Benchmarks / Targets and Reporting Barriers
- Bounded Rationality Barriers
- Customer Awareness Barriers
- Precedence and Lack of financial incentives Barriers
- Hiding diesel use information Barriers
- Hiding diesel use information Barriers
- Lack of Standards of Energy Efficient Products Barriers
- Regulatory and Organisational Policy Barriers
- Technical Barriers

These Key barriers are further classified as barriers pertaining to policy, knowledge information and management & financing barriers. For better understanding of the barriers and to recommend a suggestive frame work to remove/minimize these barriers. The following measures are recommended with the help of literature review and also by interviewing the policy makers, industry experts, and academicians. (Table 6.1)

Table 6.1 Recommendations to Minimize the Barriers to Energy Conservation in Telecommunication Sector in India

S. No.	Key Barriers	Solutions
1.	Policy • Regulatory and Organisational Policy Barriers • Lack of Benchmarks / Targets and Reporting Barriers • Lack of Standards of Energy Efficient Products Barriers	• Inclusion of telecommunication industry under the purview of Energy Conservation Act • Transparent and effective implementation of "Green Telecom" directive of DoT • Setting of benchmarks for energy consumption and targets for reduction • Reporting framework for energy consumption and carbon emission of the industry • Setting of standards for energy efficient telecom network components on the line of star rating of Bureau of Energy Efficiency
2.	Knowledge information • Bounded Rationality Barriers • Customer Awareness Barriers • Hiding diesel use information Barriers	• Establishment of exclusive knowledge management centre • Documentation and sharing of experiences • Training and information sharing • Comparative studies • Sponsoring research and development activities • Inter and intra regional research • Mapping of gaps and strengths • Involvement of NGOs and media for in awareness to customers • Highlighting the companies for reduction in diesel consumption

3.	Management and financing barriers • Precedence and Lack of financial incentives Barriers • Technical Barriers	• Development of energy audit methodology for telecom installations especially the telecom towers • Ensuring finance for energy efficiency from financial institutions • Subsidy and technical assistance from Ministry Of New And Renewable Energy Sources (MNRE) for fuel switching • Inclusion of telecommunication industry as a separate category for National Energy Conservation Award

The following drivers for the energy conservation measures in telecommunication sector have been identified in this study:-

1. Regulation and Competition Oriented Drivers
2. Organizational policy oriented Drivers
3. Incentive oriented Drivers
4. Customer oriented and Financial Benefits Oriented Drivers
5. Sustainable Benefit Oriented Drivers

These identified driving forces help the energy managers, policy makers, academician and various stake holders of Indian telecom sector to take better decisions on the implementation of energy conservation measures. If these factors are taken in to consideration by the top management of telecom companies before arriving any decision, better execution of energy saving measures can be achieved.

The government and regulator can also design and adopt the new policies or ensure effective implementation of the existing policies keeping these factors in to consideration.

The study has showcased that if all the drivers for energy conservation works simultaneously the energy conservation movement in telecom sector will gain momentum. At present some of the drivers in India like customer demand for sustainable telecom services are not much effective.

Based on the findings of the study and further discussion with stake holders , policy makers and academicians following points emerged that can be summarized as key recommendations of the study:-

- **Inclusion of Telecommunication Industry under EC Act** - The review

of energy conservation measures in India has shown that there is a need for the effective implementation of legislative /regulatory tool in India. There are no national or local laws or regulations for telecommunication companies to invest in energy conservation activities. The energy conservation in telecom sector is not mandated by any enforced law, statue or regulatory framework. There are no set guidelines /mandates laid out for telecommunication companies with regards to energy consumption for their operations. Even the telecommunication industry is not recognized as designated consumers under the EC Act.The provision of EC Act are applicable to big telephone exchange buildings housing wired line network while the diesel guzzlers 'telecom towers' are out of its ambit. The first phase of PAT scheme was limited to energy intensive industries like aluminum, steel cement etc. no incentive under NAPCC missions (PAT scheme) exist for energy efficiency in telecom space. Even the "Carbon Trading" scheme for telecom sector envisaged in TRAI consultation paper could not materialize for the telecom sector. It is recommended a scheme for telecommunication sector on line of PAT is to be designed and implemented to boost the energy conservation.

- **Financial Incentives and Subsidy for Energy Efficiency in Telecom Sector**-

Due to high prices of spectrum, debt burden and pressure to expanding in new areas the telecom companies need financial support and subsidy from Government to implement energy conservation measures. National and

International financial institutions can be involved to finance energy conservation projects in telecom sector. Subsidy form MNRE for fuel switching options at telecom sites is to be ensured.

Bureau of Energy Efficiency undertakes annual energy conservation awards where energy intensive sectors are awarded on basis of energy efficient practices in the year. A total of 40 different sectors including industries like Fertilizers, Steel rolling, automobile, consumer goods, refinery, sugar mills, glass, soap etc are awarded on energy efficiency. This provides an incentive for players to under efficiency measures. Telecom sector does not have a category for these awards. Considering its size and efforts of industry, inclusion of telecom as a category “energy efficiency in telecom space” for telecom operators and infra providers should be considered.

The subject of energy conservation in telecommunication sector is a multidisciplinary subject. It involves all the stream like electronics and telecommunication engineering, electrical engineering, energy engineering, economics and management. This centre should be responsible for comparative studies, research and development work on the subject. Establishment of a specialized knowledge centre for further research and development is need of the hour for low carbon growth of the sector.

- **Bench Marking and Reporting** -As telecom service providers are categorized as service industries under Indian Companies Act, the declaration of consumption of electricity and diesel is not mandatory for them. Therefore, some telecom companies do not provide any information regarding energy consumption and conservation. As subsidized diesel is used by telecom service providers, telecom companies are not willing to disclose the detail of their energy consumption. In India so far only one Indian telecom company Vodafone India has disclosed its diesel and electricity consumption in its sustainability report. It was also noticed that no Indian telecom company participated in Carbon Disclosure Project (CDP). The CDP is a voluntary movement where global companies declare their carbon emission as a corporate social responsibility measure. The mandate for submission of half yearly carbon emission report could not achieve the any result so far. There is no third party verification and even after four years the carbon emission of the telecommunication industry for the base year 2012 could not declared. At present there is no benchmark for comparing the energy performance of the Indian telecom operators. The bench marks identified in this study "energy expenditure per subscriber per annum "and "energy cost as a percentage of revenue "can be used in for comparison of energy performance of telecom service providers . The researcher has developed the reporting layout of energy consumption and carbon emission (Table6.2) that can be used as sustainability index for telecom companies. The second reporting format (Table 6.3) developed by the researcher can be used by the industry associations COAI and AUSPI etc. and government to compare the energy performance of the telecom operators. A report layout has been developed for Diesel Consumption and Carbon Emission Saving in Table 6.4. This report can be used as a controlling tool to promote fuel switching at off grid sites.

Table 6.2: Suggested Layout for Sustainability

(Quarterly Energy consumption and resultant CO_2 emissions) Report

<table>
<tr><td colspan="9">Sustainability (Quarterly Energy consumption and CO_2 emissions) Report

Name of Telecom Operator -------------------- Quarter -------------</td></tr>
<tr><td colspan="3">Quarterly Energy consumption and resultant CO2 emissions at sites and facilities operationally controlled by the telecom service Provider</td><td colspan="3">Quarterly Energy consumption and resultant CO2 emissions for BTS sites and third party tower company sites</td><td rowspan="2">Quarterly Total CO_2 emissions</td><td rowspan="2">No. of Subscribers</td><td rowspan="2">CO2 emissions per subscriber</td></tr>
<tr><td>Quarterly Electricity Consumption
(kWh)</td><td>Quarterly Diesel Consumption
(Liters)</td><td>CO2 emissions</td><td>Quarterly Electricity Consumption
(kWh)</td><td>Quarterly Diesel Consumption
(Liters)</td><td>CO2 emissions</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 6.3: Suggested Layout for Quarterly Energy Performance

Report of Telecom Operators

<table>
<tr><td colspan="7">Energy Performance Report
Name of Telecom Operator -------------------- Quarter -------------</td></tr>
<tr><td>Quarterly
Energy Expenditure made at sites and facilities operationally controlled by the telecom service Provider
(Rs.)</td><td>Quarterly
Annual payment made to third party tower company regarding energy use
(Rs.)</td><td>Quarterly
Total
Energy expenditure
(Rs.)</td><td>Revenue
(Rs.)</td><td>No. of
Subscribers</td><td>Energy expenditure per subscriber
(Rs. Per Subscriber)</td><td>Energy cost as a percentage of revenue
(Percentage)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 6.4: Suggested Layout for Quarterly Diesel Consumption and Carbon Emission Saving Report for off grid Telecom Tower Sites

Diesel Consumption and Carbon Emission Saving Report for off grid Telecom Tower Sites Name of Telecom Operator -------------------- Quarter -------------				
Diesel Consumption of off grid telecom tower sites in preceding quarter	Diesel Consumption of off grid telecom tower sites in this quarter	Number of off grid telecom tower sites working with Hybrid (Renewable energy and battery backup)	Quarterly Saving in diesel consumption achieved by use of battery and renewable energy	Quarterly Saving in CO_2 Emissions by use of battery and renewable energy at off grid telecom tower sites

The Indian telecom service industry is working on an unsustainable business model; the industry is dependent on fossil fuel for the operation of telecom network. In a country where 70% of oil requirement is met by the import, the estimated 3.3 billion liters annual diesel consumption of telecom towers is a cause of concern. The carbon emission caused by round the clock operation of telecom networks is another area of concern. The reporting frameworks developed by the researcher can be utilized for energy performance and sustainability index of the telecom service providers. This study will pave the way for sustainable development of the telecommunication sector in India.

LIMITATIONS OF THE STUDY

- Study is limited to energy consumption and carbon emission of Indian telecom networks, energy used in manufacturing and end use of telecom devices were not part of this study.
- Telecom is not energy intensive industry as per prevailing law, so it is not mandatory for them to declare energy consumption data. Data availability was a real constraint as telecom operators were not willing to share number of telecom towers, diesel consumption etc.
- Due to unavailability of data of electricity and diesel consumption of telecom operators impact of energy conservation measures could not be studied.
- Lack of awareness of stakeholders (challenge to collection of responses) in India.
- Study has focused on technical measures only, behavioural aspects' and significance of employee awareness was not part of this study.
- There is no data available regarding carbon emission of Indian telecom service providers in public domain. Research was to be made limited to assessment of carbon emission of telecom towers only.

FURTHER SCOPE OF THE STUDY

- With availability of energy consumption and carbon emission data of telecom service providers, further research in the subject can be carried out.
- Impact of new generation telecom network in India on energy consumption can be studied.
- Comparative studies of energy conservation practices of national and international telecom operators can be undertaken.
- Research may be undertaken in impact of green telecom directive on Indian telecom industry.

CONTRIBUTIONS TO LITERATURE/ THEORY

- Development of estimation model for electricity requirement of telecom networks. This model can be used for estimation of electricity requirement of telecom networks in a country.
- Development of estimation model for, electricity, diesel consumption of telecom towers. This model can be used for estimation of electricity, diesel consumption of telecom towers in a country.
- Development of estimation model for carbon emission of telecom towers considering T&D losses and sharing of towers by telecom operators. This model can be used for estimation of carbon emission of telecom towers in a country.
- Formulation of fuel substitution strategy for telecom sector.
- Contribution to policy matters-This study will provide baseline to the policy makers for promoting energy conservation and especially the fuel switching in telecom sector in India.
- Contribution towards regulation and governance of energy conservation behavior of telecom operators.

REFERENCES

1. Airtel Bharti (2001).Annual Report. New Delhi. Bharti Airtel Limited.
2. Airtel Bharti (2002).Annual Report. New Delhi. Bharti Airtel Limited.
3. Airtel Bharti (2003).Annual Report. New Delhi. Bharti Airtel Limited.
4. Airtel Bharti (2004).Annual Report. New Delhi. Bharti Airtel Limited
5. Airtel Bharti (2005).Annual Report. New Delhi. Bharti Airtel Limited
6. Airtel Bharti (2006).Annual Report. New Delhi. Bharti Airtel Limited
7. Airtel Bharti (2007).Annual Report. New Delhi. Bharti Airtel Limited
8. Airtel Bharti (2008).Annual Report. New Delhi. Bharti Airtel Limited
9. Airtel Bharti (2009).Annual Report. New Delhi. Bharti Airtel Limited
10. Airtel Bharti (2010).Annual Report. New Delhi. Bharti Airtel Limited
11. Airtel Bharti (2011).Annual Report. New Delhi. Bharti Airtel Limited
12. Airtel Bharti (2012).Annual Report. New Delhi. Bharti Airtel Limited
13. Airtel Bharti (2013). Annual Report. New Delhi. Bharti Airtel Limited
14. Airtel Bharti (2014) . Annual Report. New Delhi. Bharti Airtel Limited
15. Airtel Bharti (2015) .Annual Report. New Delhi. Bharti Airtel Limited
16. Airtel, Bharti (2013).Bharti Airtel Ltd. India Sustainability Report 2011- ‘12. doi:www.airtel.in/sustainabilitypdf/sustainabilityreport.pdf
17. Akbostanci C E. Turut E . Asik S . Tune G I (2009). The Relationship Between Income and Environment Turkey. Energy Policy 37, 861 – 867.
18. Anayochuku Anivicent(2013).Environmental Impact Assessment of Power Generation Systems at GSM Base station Site. Electronic Journal of Energy and Environment .1(2) 2013

19. Apergis N . Payne J E (2010) . Energy Conservation Growth in South America. Energy Economics , 32,1421 – 1426

20. Ashok Desai. (2006). India's Telecommunications Industry History, Analysis, Diagnosis. New Delhi . Sage India.

21. Azad C S (2006). Energy Management System. Telecommunications Journal 56 (2), 56-58. Retrieved from www.tnd.bsnl.co.in

22. Azad C S. Swapnil P (2014). Renewable Energy Options for Mobile Telecom sites. Energy and Fuel Users Journal .1(2014). 14-22

23. Azad C.S & Bajpai Sc (2010) Use of solar and wind energy for Powering Telecom Towers-IETE-ATC Proceeding.

24. Baliga, J., Hinton, K., Ayre, R., & Tucker, R. S. (2009). Carbon footprint of the internet. Telecommunications Journal of Australia, 59(1), 1–14. doi:10.2104/tja09005

25. Baliga, J; Ayre, R; Sorin, W V; Hinton, K; Tucker, R S. 2008a. 'Energy consumption in access networks'.Proceedings of the Optical Fibre Communications (OFC) Conference. February; San Diego, California:1–3

26. BEE (2012). Energy Efficiency Guidelines and Best practices in Indian Datacenter. Bureau of Energy Efficiency

27. BEE (2015). PAT. Bureau of Energy Efficiency. Retrieved from www.beeindia.gov.in

28. Bertoldi, P., Ricci, A., & Almeida, A. (2001). Energy Efficiency in Household Appliances and Lighting. Springer , 468-474.

29. Bhardwaj Shruti. (2013). Infrastructure Sharing in Telecom Industry: Growth of New Business Models & their Prospective Trends. International Journal of Research and Development - A Management Review (IJRDMR), Volume-2(1, 2013), 20–24. Retrieved from www.irdindia.in/journal_ijrdmr/pdf/vol2_iss1/4.pd

30. BSNL (2001) .Annual Report. New Delhi.Bharat Sanchar Nigam Limited

31. BSNL (2002). Annual Report. New Delhi.Bharat Sanchar Nigam Limited

32. BSNL (2003). Annual Report. New Delhi.Bharat Sanchar Nigam Limited

33. BSNL (2004). Annual Report. New Delhi.Bharat Sanchar Nigam Limited

34. BSNL (2005). Annual Report. New Delhi.Bharat Sanchar Nigam Limited

35. BSNL (2006) .Annual Report. New Delhi.Bharat Sanchar Nigam Limited

36. BSNL (2007) . Annual Report. New Delhi.Bharat Sanchar Nigam Limited

37. BSNL (2008). Annual Report. New Delhi.Bharat Sanchar Nigam Limited

38. BSNL (2009 . Annual Report. New Delhi.Bharat Sanchar Nigam Limited

39. BSNL (2010). Annual Report. New Delhi.Bharat Sanchar Nigam Limited

40. BSNL (2012).Annual Report, New Delhi. Bharat Sanchar Nigam Limited.

41. BSNL(2011).Annual Report. New Delhi. Bharat Sanchar Nigam Limited.

42. BSNL(2013).Annual Report, New Delhi. Bharat Sanchar Nigam Limited.

43. BSNL(2014).Annual Report, New Delhi. Bharat Sanchar Nigam Limited.

44. BSNL(2015).Annual Report, New Delhi. Bharat Sanchar Nigam Limited.

45. Bunse, K., M. Vodicka, et al. (2010). Integrating energy efficiency performance in production management - gap analysis between industrial needs and scientific literature. Journal of Cleaner Production 19(6-7): 667-679.

46. Bureau of Energy Efficiency. (2010). Energy Efficiency Guidelines and Best practices in Indian Data centre: Bureau of Energy Efficiency.

47. Bureau of Energy Efficiency.(2002). General Aspects of Energy Management & Energy Audit. New Delhi: Bureau of Energy Efficiency.

48. Central Statistics Office. Energy Statistics. (2013). National statistical organization, Ministry Of Statistics and Programme Implementation Government of India. www.mospi.gov.in

49. Ch. Mahmood Anwar. (2010). Green Telecom Technology (GTT): Think Green – A step to achieve improved techno-environmental and socio-economic effects in Pakistan. Science, Technology & Development, 29(4), 1–6.

50. Chattopadhyay B. Chattopadhyay, B.Das, P & Das, P. (2004). Information and Communication Technology for Sustainable Development. Retrieved from http://agropedia.iitk.ac.in/openaccess/sites/default/files/WS 5.pdf

51. Chhaya L K (2012). Legislative and Regulatory Issues and Prospects in the Indian Telecom Sector. Retrieved from papers.ssrn.com

52. Chowdhury, P., Member, S., & Tornatore, M. (2010). Building a Green Wireless-Optical Broadband Access Network (WOBAN), 28(16), 2219–2229.

53. Cohen, M. S. (2012). Increasing power consumption awareness in critical communications sites with fuel cells. In INTELEC, International Telecommunications Energy Conference (Proceedings). doi:10.1109/INTLEC.2012.6374514

54. Costanzo Mark, Archer Dane, Aronson Elliot, & Thomas Pettigrew. (1986). Energy Conservation Behavior. University of California, Santa Cruz.

55. Dahle, M., & Neumayer, E. (2001). Overcoming barriers to campus greening A survey among higher educational institutions in London, UK. International Journal of Sustainability in Higher Education , 139-160.

56. Dara, R. (2013). Policy Instruments for Green Telecommunications. doi:http://dx.doi.org/10.2139/ssrn.2254541

57. Department of Telecommunications. (2008). First Report of Committee on Renewable Energy " Hybrid Wind/Solar Power for Rural Telephony Green Solution to Power Problems." Retrieved from usof.gov.in/usof.../Renewable Energy Committee Report.pdf

58. Department of Telecommunications. (2012). National Telecom Policy - 2012, Retrieved from http://www.dot.gov.in/WriteReadData/userfiles/file/NTP 2012.pdf

59. Dhingra Sunil, Dr. Mathur Ritu, K. Ramanathan, Dr. Leena Srivastava.(2013). "The Energy Report– India 100% Renewable Energy by 2050 ". WWF-India and The Energy and Resources Institute 2013.

60. Diwan, P., & Dwivedi, P. (2009). Energy conservation. New Delhi. Pentagon Press.

61. DOT (2000) Annual Report New Delhi Department of Telecommunications

62. DOT (2001) Annual Report New Delhi Department of Telecommunications

63. DOT (2002) Annual Report New Delhi Department of Telecommunications

64. DOT (2003) Annual Report New Delhi Department of Telecommunications

65. DOT (2004) Annual Report New Delhi Department of Telecommunications

66. DOT (2005) Annual Report New Delhi Department of Telecommunications

67. DOT (2006) Annual Report New Delhi Department of Telecommunications

68. DOT (2007) Annual Report New Delhi Department of Telecommunications

69. DOT (2008) Annual Report New Delhi Department of Telecommunications

70. DOT (2009) Annual Report New Delhi Department of Telecommunications

71. DOT (2010) Annual Report New Delhi Department of Telecommunications

72. DOT (2011) Annual Report New Delhi Department of Telecommunications

73. DOT (2012) Annual Report New Delhi Department of Telecommunications

74. DOT (2013) Annual Report New Delhi Department of Telecommunications

75. DOT (2014) Annual Report New Delhi Department of Telecommunication

76. DOT (2015) Annual Report New Delhi Department of Telecommunications

77. Dua, T. R. (2011). Green Telecom – An Indian Perspective. Journal of Green Engineering, 3(11), 113–126. Retrieved from http://riverpublishers.com/journal/journal_articles/RP_Journal_1904-4720 _321.pdf

78. Dua, V. (2012). IT & Mobile Tower Infrastructure Industry Collaboration - Leap towards Green, Smart & Sustainable Future. Modern Applied Science, 6(12), 37–50. doi:10.5539/mas.v6n12p37

79. Faruk N .Ayeni A A. Muhammad M Y. and Abdulkareen A(2012). Hybrid Power System for Cell Sites in Mobile Cellular Networks . IRJSE Jan 2012. Retrieved from www. unilorin.edu.ng/publications/farukn

80. Gandhi .AD, Newbury M E, (2011)“Evaluation of the energy efficiency metrics for wireless networks”, Bell Labs Technical Journal, vol. 16, issue 1, pages 207-215, June 2011.

81. Gangwar Sneh. (2013). Energy Exploitation, Conservation and Management: A View from India. Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 3, Number 8 (2013), pp. 1045-1050 © Research India Publications. http://www.ripublication.com/aeee.htm

82. Generation Systems at GSM (Global Systems for Mobile Communication) Base Station Site. (www.ejee.cl). DOI 10.7770/ejee-V1N2-art502.

83. Gerhard Fettweis Ernesto Zimmermann. (2008). ICT Energy Consumption – Trends And Challenges. In The 11th International Symposium on Wireless Personal Multimedia Communications (WPMC 2008). Retrieved from https://mns.ifn.et.tu dresden.de/Lists/nPublications/Attachments/559/Fettweis_G_WPMC_08.pdf

84. Hasan, Z., Boostanimehr, H., & Bhargava, V. K. (2011). Green Cellular Networks: A Survey, Some Research Issues and Challenges. IEEE Communications Surveys & Tutorials, 13(4), 524–540. doi:10.1109/SURV.2011.092311.00031

85. Hasanbeigi, A. C., Menke, C., & Du Pont, UP. (2010). Barriers to energy efficiency improvement and decision-making behavior in Thai indstry. Energy Efficiency , 33-52.

86. He, A., Amanna, A., Tsou, T., Chen, X., Datla, D., Gaeddert, J. Bose, T. (2011). Green Communications: A Call for Power Efficient Wireless Systems. Journal of Communications, 6(4), 340–351. doi:10.4304/jcm.6.4.340-351

87. Huawei Technologies Co. Ltd. (2009). Huawei Whitepaper on Energy Ef ficiency and Carbon Reduction Huawei Whitepaper on Energy Efficiency and Carbon Reduction.

88. Idea Cellular (2006), Annual Report, Mumbai. Aditya Birla Group

89. Idea Cellular (2007), Annual Report, Mumbai, Aditya Birla Group

90. Idea Cellular (2008), Annual Report, Mumbai, Aditya Birla Group

91. Idea Cellular (2009), Annual Report, Mumbai, Aditya Birla Group

92. Idea Cellular (2010), Annual Report, Mumbai, Aditya Birla Group

93. Idea Cellular (2011), Annual Report, Mumbai, Aditya Birla Group

94. Idea Cellular (2012), Annual Report, Mumbai, Aditya Birla Group

95. Idea Cellular (2013), Annual Report, Mumbai. Aditya Birla Group

96. Idea Cellular (2014), Annual Report, Mumbai, Aditya Birla Group

97. Idea Cellular (2015), Annual Report, Mumbai, Aditya Birla Group

98. Ikebe, H., Yamashita, N., & Nishii, R. (2007). Green energy for telecommunications. INTELEC, International Telecommunications Energy Conference (Proceedings), 750–755. doi:10.1109/INTLEC. 2007.4448882

99. Infratel Bharti (2012). Annual Report. Gurgaon . Bharti Ifratel Ltd.

100. Infratel Bharti (2013). Annual Report. Gurgaon . Bharti Ifratel Ltd.

101. Infratel Bharti (2014). Annual Report. Gurgaon . Bharti Ifratel Ltd.

102. Infratel Bharti (2015). Annual Report. Gurgaon . Bharti Ifratel Ltd.

103. Initiative, Global e Sustainability. (2008). Smart 2020: Enabling the low carbon economy in the information age. doi:www.smart2020.org/publications/

104. Intelligent Energy. (2012). The True Cost of Providing Energy to Telecom Towers in India Whitepaper. Retrieved from http://www.intelligent-energy.com/media/uploads/the_true_cost_of_providing_energy_to_telecom_towers_in_india.pdf

105. Intelligent Energy. (2013). Green Solutions for Telecom Towers : Part I, (July). Retrieved from http://www.intelligent-energy.com/media/uploads/green_solutions_for_telecom_towers_part_1.pdf

106. Inter-Ministerial Working Group on Energy Conservation (IMWGEC). (1983). Report on Utilization, and Conservation of Energy. Govt. of India.

107. IPCC (1990) ; Climate Change : The IPCC scientific assessment . J. T, Houghton, G. J. Jankins and J. J. Ephraums (eds), Cambridge University Press; Cambridge, UK , 365pp.

108. ITU (2008).ITU and Climate Change . International Telecom Union . Retrieved from www.itu.int

109. ITU(2015). ICT Sustainability and Climate Change. International Telecom Union. Retrieved from www.itu.int

110. Joshi Asheesh,Dr. Bansal Kamal, Tyagi A.K., Biswas Saurabh. (2013). “Handbook on Energy Conservation” ,“Energy Conservation – Policies & Initiatives”. www.ureda.uk.gov.in , www.upes.ac.in

111. Kablan, M. M. (2004). Decision support for energy conservation promotion: Energy Policy, 32(10), 1151–1158. doi:10.1016/S0301-4215(03)00078-8

112. Koomey, J. G. (2008). Worldwide electricity used in data centers. Environmental Research Letters, 3(3), 034008. doi:10.1088/1748-9326/3/3/034008

113. KPMG. (2013). The green challenge for telecoms Stories from the front line in China. doi:https://www.kpmg.com/BR/PT/Estudos_Analises/artigosepublicacoes/Documents/Industrias_ICE/Green-challenge-for-telecoms-201103.pdf

114. Krishnan, S. (2012). Energy consumption and CO 2 emissions by the Indian mobile telecom industry. The 4th Annual International Conference on Next Generation Infrastructures, Virginia Beach, Virginia. Retrieved from http://inderscience.metapress.com/index/R8J320340207N26K.pdf

115. Kulkarni, S., & Singh, A. K. (2012). Green Telecom Towers – an attractive option for sustainable tomorrow. Retrieved from http://www.tsmg.com/download/article/Green Telecom Towers.pdf

116. Laneman, J. N., Tse, D. N. C., & Wornell, G. W. (2004). Cooperative diversity in wireless networks: Efficient protocols and outage behavior. IEEE Transactions on Information Theory, 50, 3062–3080. doi:10.1109/TIT.2004.838089

117. Louhi J. T, “Energy efficiency of modern cellular base stations,” '(2007) 29th International Telecommunications Energy Conference (INTELEC), 2007,pp.475-476, Sept. 30 2007-Oct. 4 2007.

118. Lubrito C. (2010). Telecommunication Power System: Energy Saving, Renewable Sources and Environmental Monitoring. Trends in Telecommunications Technologies, Christos J Bouras (Ed.), ISBN: 978-953-307-072-8, InTech

119. Lubritto, C., Petraglia, A., Vetromile, C., Curcuruto, S., Logorelli, M., Marsico, G., & D'Onofrio, A. (2011). Energy and environmental aspects of mobile communication systems. Energy, 36(2), 1109–1114. doi:10.1016/j.energy.2010.11.039

120. Malhotra, R. (2010). Energy management & backup unit for telecom base stations. In Telecommunications Energy Conference (INTELEC), 32nd International (pp. 1-5). IEEE

121. Malmodin, J., Bergmark, P., & Lundén, D. (2013). The future carbon footprint of the ICT and E & M sectors. In B. Lorenz M. Hilty & G. A. and W. L. Aebischer (Eds.), ICT4S 2013:Proceedings of the First International Conference on vehicles etc.).Information and Communication Technologies for Sustainability (pp. 12–20). Zurich. doi:http://dx.doi.org/10.3929/ethz-a-007337628

122. Malmodin, J., Moberg, Å., Lundén, D., Finnveden, G., & Lövehagen, N. (2010). Greenhouse Gas Emissions and Operational Electricity Use in the ICT and Entertainment & Media Sectors. Journal of Industrial Ecology, 14(5), 770–790. doi:10.1111/j.1530-9290.2010.00278.x

123. Matthews, E. P., Nici, J., Polonsky, B., & Wisniewski, J. F. (2010). Operating in the green: Modeling eco-friendly telecom network management. Bell Labs Technical Journal, 15(2). 175–192. doi:10.1002/bltj.20448

124. McKenna, R. C. (2009). Industrial energy efficiency; Interdisciplinary perspectives on the thermodynamic, technical and economic constraints. UK: Thesis submitted for the degree of Doctor of Philosophy; University of Bath.

125. Mendelsohn R. Efficient Adaptation to Climate Change. Climate Change , 45 (2000). 583 - 600

126. Morosi S .Pinuti P (2012).Energy Efficient Sleep Mode Mangement for Cellular Networks. ETSI Workshop on Energy Efficiency Genoa ,Italy

127. MTNL (2002). Annual Report. New Delhi. Mahanagar Telecom Nigam Limited.

128. MTNL (2003). Annual Report. New Delhi. Mahanagar Telecom Nigam Limited.

129. MTNL (2004). Annual Report. New Delhi. Mahanagar Telecom Nigam Limited

130. MTNL (2005). Annual Report. New Delhi. Mahanagar Telecom Nigam Limited.

131. MTNL (2006). Annual Report .New Delhi. Mahanagar Telecom Nigam Limited.

132. MTNL (2007) .Annual Report. New Delhi. Mahanagar Telecom Nigam Limited.

133. MTNL (2008). Annual Report. New Delhi. Mahanagar Telecom Nigam Limited.

134. MTNL (2009). Annual Report, New Delhi. Mahanagar Telecom Nigam Limited.

135. MTNL (2010) .Annual Report, New Delhi. Mahanagar Telecom Nigam Limited.

136. MTNL (2011). Annual Report, New Delhi. Mahanagar Telecom Nigam Limited.

137. MTNL (2012) .Annual Report, New Delhi. Mahanagar Telecom Nigam Limited.

138. MTNL (2013) .Annual Report, New Delhi. Mahanagar Telecom Nigam Limited.

139. MTNL (2014) .Annual Report, New Delhi. Mahanagar Telecom Nigam Limited.

140. MTNL (2015) .Annual Report, New Delhi. Mahanagar Telecom Nigam Limited

141. NAPCC (2008). National Action Plan on Climate Change. Ministry of Environment and Forest. Retrieved from www.moef.nic.in

142. Niti Ayog (2015). India Energy Security Scenario 2047. Retrieved from niti.gov.in

143. Odazdic B. Panajotovic B.Jankovic M (2011).Energy Efficiency and Renewable Energy Solution in Telecommunication. Retrieved from reserchgate.com

144. Pachauri R K . Chauhan YK (2014).Hybrid PV/FC standalone Green Power Generation : A perspective for Indian rural telecommunication systems. Conf . Paper. Int. Conf. on issues and challenges in intelligent computing techniques(ICICT).Retrieved from www.researchget.net

145. Paiano A .Giovanni L .Andreia C(2011) . Energy consumption in Italian mobile phone sector. Retrived from www.enea.it

146. Pande G (2009). A Case Study of solar Powered Cellular Base Stations .Master thesis submitted to University of Galve. Retrieved from www.diva.portal.org

147. Panigrahi, P. K. (2012). Green Energy : A Perspective for Indian Rural Telecom. Journal of Green Engineering, 2, 103–114..

148. Pao H and Tsai (2010).CO_2 Emissions energy consumption and economic growth in BRIC countries. Energy Policy 38. 850 – 860

149. Pragya Nema,R.K. Nema. Saroj Rangnekar. (2010). PV-solar / wind hybrid energy system for GSM/CDMA type mobile telephony base station. International Journal Of Energy And Environment, Volume 1,(2), pp.359–366.Retrieved from http://www.ieefoundation.org/ijee/vol1/issue2/IJEE_14_v1n2.pdf

150. Prasad, . R. (2010). Back to Green. Journal of Green Engineering, 89–110. Retrieved from http://researchwebshelf.com/uploads/108_article1-5.pdf

151. Prasad, S. (2011). Green Networks: Transforming Telecommunications on Sustainable Energy Alternatives. Gurgaon, Bharti Infratel Limited

152. Rahman, S., & Quaiyum, S. (2012). Employing Biogas Powered Base Transceiver Station In Bangladesh : Current And Future Prospect. American Academic & Scholarly Research Journal, 4(2), 2010–2013.

153. Rais Miftakhutdinov (2010). Energy Saving Drives New Approaches to Telecommunications Power System .Trends in Telecommunications Technologies, Christos J Bouras (Ed.), ISBN: 978-953-307-072-8, InTech

154. Rajput Dr. Namita and Chopra Parul (2014)." Carbon Credit Market in India: Economic and Ecological Viability". Global Journal of Finance and Management. ISSN 0975-6477 Volume 6, Number 9 (2014), pp. 945-950 © Research India Publications http://www.ripublication.com

155. RCL (2007) Annual Report, Mumbai, Reliance Communications Limited.

156. RCL (2008) Annual Report, Mumbai, Reliance Communications Limited.

157. RCL (2009). Annual Report, Mumbai, Reliance Communications Limited.

158. RCL (2010) Annual Report, Mumbai, Reliance Communications Limited.

159. RCL (2011) Annual Report, Mumbai, Reliance Communications Limited.

160. RCL (2012) Annual Report, Mumbai, Reliance Communications Limited.

161. RCL (2013) Annual Report, Mumbai, Reliance Communications Limited.

162. RCL (2014) Annual Report, Mumbai, Reliance Communications Limited.

163. RCL (2015) Annual Report, Mumbai, Reliance Communications Limited.

164. Reddy B. Sudhakara and Gaudenz Assenza. (2007). Barriers and Drivers to Energy Efficiency – A new Taxonomical Approach. Indira Gandhi Institute of Development Research, Mumbai

Retrieved from www.docbox.etsi.org.

165. Riberio E F F. Cardoso A J M and Boccaletti C (2009). Uninterruptible Energy Production in Standalone Power Systems for Telecommunication. Proceedings Int. Conf. on Renewable Energy and Power Quality, Valencia

166. Rohdin, P., & Thollander, P. (2006a). Barriers to and Driving Forces for Energy Efficiency in the Non-Energy Intensive Manufacturing Industry in Sweden. Energy , 1836-1844.

167. Rohdin, P., Thollander, P., & Solding, P. (2006b). Barriers to and drivers for energy efficiency in the Swedish foundry industry, . Energy Policy , 672-677.

168. Roth, K. W., Goldstein, F., & Kleinman, J. (2002). Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings,Volume I. Retrieved from http://www.biblioite.ethz.ch/downloads/roth_adl_1.pdf

169. Roth, K. W., Larocque, G. R., Kleinman, J., & Doe, B. C. (2004). Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings Volume II : Energy Savings Potential. Arthur D. Little Reference No. 72895-00 For Office of Building Equipment Office of Building Technology State and Community Programs (Vol. II).

170. Roy, S. (2008). Energy Logic for Telecommunications. Emerson Network Power .Retrieved from www.emersonNetworkPower.com/EnergySystems

171. Sahu, S. K., Schultz, M. G., & Beig, G. (2015). Critical Pollutant Emissions from the Indian Telecom Network. Atmospheric Environment, 103(x), 34–42. doi:10.1016/j.atmosenv.2014.12.025

172. Sarkar A N (2010). Emissions trading and Carbon Management .New Delhi. Pentagon Press.

173. Sarkar, A. N., & Dash, S. (2011). Emissions Trading and Carbon Credit Accounting For Sustainable Energy Development with Focus on India. Asia-Pacific Journal of Management Research and Innovation, 7, 50–80. doi:10.1177/097324701100700104

174. Saxena S D (2009). Connecting India: Indian Telecom Story. New Delhi: Konark Publishers.

175. Schaefer, C., Weber, C., & Voss, A. (2003). Energy usage of mobile telephone services in Germany. Energy. Retrieved from http://www.sciencedirect.com/science/article/pii/S0360544202001548

176. Sekar K . Duraisam V (2015). Efficient energy management System for Integrated Renewable Power Generation Systems Journal of Scientific & Industrial Research Vol 74, June 2015, pp 325 – 329.

177. Shivaji Bhandarkar, M. K. M. (2014). Green energy for Indian telecom towers. doi:http:/dx.doi.org/10.14303/jpger.2013.015

178. Shukla, P. R. (1993). Strategic management of energy conservation : with case studies in Indian industries. New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd.

179. Sirohi, K. (2011). Carbon Emission Estimation & Reduction in Indian Telecom Operations: A Standardization & Policy Perspective. doi:10.13052/jicts2245-800X.12a7

180. Sirohi, K., & Lathia, K. P. (2011). Green telecom initiative in India. 2011 Technical Symposium at ITU Telecom World (ITU WT).

181. Soytas U and Sari R (2009). Global warming and economic growth compatible? Evidence from 5 OPEC countries. Applied Energy 86, 1887 – 1893

182. Soytas U. Sari R and Ewing, BT (2007). Energy consumption income Carbon emissions in the United State. Ecology &Economics 62 , 482 – 489.

183. Suarez, L., Nuaymi, L., & Bonnin, J.-M. (2012). An overview and classification of research approaches in green wireless networks. EURASIP Journal on Wireless Communications and Networking, 2012(1), 142. doi:10.1186/1687-1499-2012-142

184. Sutherland, E. (2009). Climate Change: the Contribution of Telecommunications. Communications and Strategies, 4th Q.(76), 61–76.

185. Sutherland, E. (2011). Telecommunications and climate change : African and European experiences and requirements. SSRN, (July), 1–17. Retrieved from www.ssrn.com/abstract=1894605

186. Sutherland, R. 1990. “An Analysis of Conservation Features in Commercial Buildings.” Energy Systems and Policy 13:153-166.

187. Sutherland, R. 1991. “Market Barriers to Energy-Efficiency Investments.” The Energy Journal 12(3):15-34.

188. Telecom Regulatory Authority of India. (2011a). Consultation Paper No.: 3/2011 Consultation Paper on Green Telecommunications. Retrieved from http://www.trai.gov.in/Content/ConDis/392_68.aspx

189. Telecom Regulatory Authority of India. (2011b). Recommendations on Approach towards Green Telecommunications. Retrieved from http://www.trai.gov.in/Content/ReDis/232_23.aspx

190. Thollander P. Ottossom M (2008). An energy efficient Swedish pulp and paper industry-exploring barriers to and driving forces for cost-effective energy efficiency investments. Energy Efficiency, 21-34

191. TRAI (2000) Annual Report New Delhi Telecom Regulatory Authority of India

192. TRAI (2001) Annual Report New Delhi Telecom Regulatory Authority of India

193. TRAI (2002) Annual Report New Delhi Telecom Regulatory Authority of India

194. TRAI (2003) Annual Report New Delhi Telecom Regulatory Authority of India

195. TRAI (2004) Annual Report New Delhi Telecom Regulatory Authority of India

196. TRAI (2005) Annual Report New Delhi Telecom Regulatory Authority of India

197. TRAI (2006) Annual Report New Delhi Telecom Regulatory Authority of India

198. TRAI (2007) Annual Report New Delhi Telecom Regulatory Authority of India

199. TRAI (2008) Annual Report New Delhi Telecom Regulatory Authority of India

200. TRAI (2009) Annual Report New Delhi Telecom Regulatory Authority of India

201. TRAI (2010) Annual Report New Delhi Telecom Regulatory Authority of India

202. TRAI (2011) Annual Report New Delhi Telecom Regulatory Authority of India

203. TRAI (2012) Annual Report New Delhi Telecom Regulatory Authority of India

204. TRAI (2013) Annual Report New Delhi Telecom Regulatory Authority of India

205. TRAI (2014) Annual Report New Delhi Telecom Regulatory Authority of India

206. TRAI (2015) Annual Report New Delhi Telecom Regulatory Authority of India

207. Tyagi A K (2003) . Hand Book on energy Audits and Management. New Delhi. The Energy Research Institute

208. UNEP. (2006). Barriers to Energy Efficiency in Industry in Asia: A review of barriers to energy efficiency in industry in Asia and guidance to policy makers to address these. United Nations Environment Programme, 109 pp.

209. Varadharajan, S. (2011). The Telecom Revolution in India: Technology, Regulation, and Policy. New Delhi. Oxford University Press.

210. Vasudevan Reshmi ,Dr. Cherail Koshy ,Cdr. Bhatia Ramesh ,Jayaram Nisha. (2011). Energy Efficiency in India History and Overview. Alliance for an Energy Efficient Economy. www.aeee.in.

211. Von Weizsäcker, E., Lovins, A. B., & Lovins, L. H. (1997). Factor Four: Doubling Wealth, Halving Resource Use, The New Report to the Club of Rome. London, UK: Earthscan Publications Limited.

212. Weber (1997). Some Reflections on Barriers to the Efficient Use of Energy. Energy Policy 833 - 835

213. WEC. (2004). Energy efficiency: a worldwide review - indicators, policies, evaluation. London, UK: World Energy Council.

214. Wedge, R. (2003). Energy Efficiency: Key to Managing Costs in NZ Forest Industries. .

215. Worrell, E., Laitner, J. A., Ruth, M., & Finman, H. (2003). Productivity benefits of industrial energy efficiency measures. Energy , 1081-1098.

216. Yang, T., Zhang, Y., Huang, J., & Peng, R. (2013). Estimating the energy saving potential of telecom operators in China. Energy Policy. Retrieved from http://www.sciencedirect.com/science/article/pii/S0301421513005107

217. Yi Chen, Y. Z. and Q. M. (2010). Building Energy Efficiency Design for Telecommunication Base Stations in Guangzhou. In C. J. Bouras (Ed.), Trends in Telecommunications Technologies (pp. 561–582). Retrieved from http://www.intechopen.com/books/trends-in-telecommunicationstechnologies/building-energy-efficiency-design-for-telecommunication-base-stations-in-guangzhou

218. Yu, J., Williams, E., & Ju, M. (2010). Analysis of material and energy consumption of mobile phones in China. Energy Policy. Retrieved from http://www.sciencedirect.com/science/article/pii/S0301421510002041

219. Zhang XP and Cheng XM (2009) Energy consumption , Carbon emissions and economic growth in China . Ecological Economics 68 . 2706 – 2712

220. ZTE (2011).Green Technology Innovations White Paper. ZTE Tech Corporation

APPENDIX-1

TableA.1: Questionnaire to identify the driving forces for the energy conservation in Indian Telecom Sector

Name:

E Mail Address:

Category: Energy Manager / Operation Manager / Energy Auditor / Renewable Energy Industry Expert /Representative from TRAI/DoT / Academicians

	Question	Response				
I.	In your view what is degree of importance of following drivers for energy conservation and fuel switching in Indian telecom sector	Not at all Important (1)	Not very Important (2)	Some What Important (3)	Very Important (4)	Extremely Important (5)
1.	Demand from subscribers					
2.	Improved working conditions					
3.	Pressure from NGOs and public					
4.	Long term energy strategy					
5.	Carbon trading					
6.	Commitment from top management					
7.	Awareness workshops/seminars on energy conservation					
8.	Cost cutting for competitive advantage					
9.	Rising energy prices					

	Question	Response				
10.	Energy efficiency measures in response to energy conservation act 2001					
11.	National energy conservation award for saving energy					
12.	Cost reduction due to energy conservation					
13.	Share of energy cost in operation cost					
14.	Focus on sustainability					
15.	Declining average revenue per unit(ARPU) of service providers					
16.	Rise of telecom infrastructure companies					
17.	Energy conservation case studies of foreign telecom operators					
18.	Government announcement to cut carbon					
19.	Restriction on use of subsidized diesel for telecom industry					
20.	Department of Telecommunication's directive to use renewable energy technologies for telecom towers					
21.	Availability of energy efficient telecom network equipments					
22.	Availability of BEE certified energy auditors/Managers in telecom organizations					
23.	Reduction in carbon emission by fuel switching and reducing energy consumption					
24.	Use of energy conservation building code for telecom buildings					
25.	Falling price of renewable energy solution for telecom use.					

APPENDIX-2

TableA.2: Questionnaire to identify the Barriers to the Energy Conservation in Indian Telecom Sector

Name:

E Mail Address:

Category: Energy Manager / Operation Manager / Energy Auditor / Industry Expert /Representative from TRAI / DoT / Academicians

According to the aggregated experience, how do you value the following factors impact on the energy conservation in Indian telecom sector?

Table: Questionnaire to identify the barriers to the energy conservation in Indian Telecom Sector

II. Barriers in Energy Conservation in Telecom Sector						
	Question	Response				
	In your view what is degree of importance of following barriers in energy conservation and fuel switching in telecom sector in India	Not at all Important (1)	Not very Important (2)	Some What Important (3)	Very Important (4)	Extremely Important (5)
1.	Lack of regulations and by regulator and Government					
2.	Non enforcement of hybrid energy and carbon disclosure directive					
3.	Lack of customer awareness					
4.	Lack of pressure from NGOs and public					
5.	Wrong examples set by public sector telecom service providers					

6.	Government does not support with financial incentives for energy conservation					
7.	Organisation is lacking in policies procedures and systems for energy management					
8.	Lack of information about energy conservation and energy efficiency opportunities					
9.	Energy efficiency benefits cannot be quantified					
10.	Priorities of service providers on expansion of telecom services in new areas					
11.	Non-availability of energy conservation targets					
12.	No incentive /penalty for meeting/skipping the targets					
13.	Non-importance/less priority of energy management in the organization					
14.	Non-importance of energy as a function of service /production					
15.	Management perception that in telecom services ,energy efficiency is less important					
16.	Less awareness in the organization about importance of energy conservation					
17.	Less awareness about linkage between energy consumption and carbon emission in the organization					
18.	Lack of awareness about telecom sector specific technical measures for energy conservation					

19.	Lack of information and reporting about energy use by telecom operators					
20.	Hiding of information by operators regarding use of diesel due to risk of exposing the misuse of subsidized diesel					
21.	Lack of customer preference for sustainability					
22.	Confusion that telecommunications being a service industry do not need energy conservation					
23.	Lack of energy audit methodology of telecom installations					
24.	Lack of benchmarks for energy consumption in telecom sector					
25.	Inadequate financial and technical information about fuel switching options					
26.	High CAPEX of energy efficient and fuel switching technologies					
27.	Lax attitude of regulator and Government towards energy consumption of telecom sector.					
28.	Lack of skilled manpower and training					
29.	Poor quality and lack of standards of energy efficient products					
30.	Problems in maintenance and availability of spares of energy efficient equipment					
31.	The workers in the organization are not accountable for energy cost					

APPENDIX-3

Table A.3. Total Variance Explained using Principal Component Analysis

(Driving Forces for Energy Conservation in Indian Telecom Sector)

Component	Initial Eigen Value			Extracted Sum of Loadings			Rotation Sums of Squared Loadings		
	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %
1.	10.406	41.622	41.622	10.406	41.622	41.622	9.255	37.019	37.019
2.	3.912	15.647	57.269	3.912	15.647	57.269	3.355	13.422	50.441
3.	2.997	11.987	69.257	2.997	11.987	69.257	3.331	13.325	63.766
4.	1.990	7.959	77.216	1.990	7.959	77.216	2.728	10.914	74.680
5.	1.054	4.215	81.431	1.054	4.215	81.431	1.688	6.751	81.431
6.	0.780	3.121	84.552						
7.	0.710	2.840	87.392						
8.	0.661	2.645	90.037						
9.	0.536	2.145	92.182						
10.	0.461	1.843	94.025						
11.	0.320	1.279	95.304						
12.	0.240	0.960	96.264						

Component	Initial Eigen Value			Extracted Sum of Loadings			Rotation Sums of Squared Loadings		
	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %
13.	0..207	0.826	97.090						
14.	0.177	0.707	97.797						
15.	0.140	0.559	98.356						
16.	0.111	0.446	98.802						
17.	0.075	0.302	99.104						
18.	0.058	0.233	99.336						
19.	0.048	0.194	99.530						
20.	0.037 .	0.147	99.677						
21.	0.028	0.112	99.789						
22.	0.020	0.079	99.868						
23.	0.017	0.067	99.935						
24.	0.013	.0.051	99.987						
25.	.003	0.013	100.000						

APPENDIX-4

Table A.4: Total Variance Explained using Principal Component Analysis

(Barriers to Energy Conservation in Indian Telecom Sector)

Component	Initial Eigen Value			Extracted Sum of Loadings			Rotation Sums of Squared Loadings		
	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %
1.	7.324	23.625	23.625	7.324	23.625	23.625	5.334	17.205	17.205
2.	3.554	11.466	35.091	3.554	11.466	35.091	3.317	10.700	27.905
3.	3.446	11.115	46.206	3.446	11.115	46.206	3.315	10.693	38.599
4.	2.922	9.425	55.631	2.922	9.425	55.631	3.261	10.518	49.117
5.	2.461	7.940	63.571	2.461	7.940	63.571	3.252	10.490	59.607
6.	2.161	6.971	70.542	2.161	6.971	70.542	2.657	8.569	68.176
7.	1.361	4.391	74.933	1.361	4.391	74.933	1.732	5.588	73.764
8.	1.108	3.753	78.505	1.108	3.753	78.505	1.470	4.742	78.505
9.	0.981	3.164	81.670						
10.	0.886	2.857	84.527						
11.	0.713	2.299	86.826						
12.	0.671	2.165	88.991						
13.	0.514	1.657	90.648						
14.	0.491	1.583	92.230						

15.	0.403	1.298	93.529						
16.	0.345	1.113	94.642						
17.	0.319	1.030	95.671						
18.	0.260	0.837	96.508						
19.	0.223	0.718	97.226						
20.	0.154	0.495	97.722						
21.	0.153	0.493	98.215						
22.	0.139	0.448	98.663						
23.	0.101	0.327	98.990						
24.	0.093	0.301	99.291						
25.	0.059	0.190	99.481						
26.	0.047	0.153	99.634						
27.	0.036	0.117	99.751						
28.	0.028	0.091	99.842						
29.	0.023	0.075	99.917						
30.	0.020	0.064	99.981						
31.	0.006	0.019	100.000						

APPENDIX-5

Table A.5: Factors rotation matrix using Principle Component Analysis

(Drivers for Energy conservation in Telecom Sector)

Factor Matrix	Component				
	1	2	3	4	5
Carbon trading	-.009	.298	.059	.857	.179
Commitment from top management	.824	.148	-.050	-.071	.329
Awareness workshops/seminars on energy conservation	.101	.883	-.009	.131	.174
Cost cutting for competitive advantage	.879	-.054	-.041	.025	.313
Rising energy prices	.289	.884	-.091	.123	-.154
Energy efficiency measures in response to energy conservation act 2001	-.012	.334	-.082	.845	-.013
National energy conservation award for saving energy	.094	-.138	.860	-.012	-.171
Cost reduction due to energy conservation	.947	.007	-.066	.057	.018
Share of energy cost in operation cost	.906	.174	-.030	-.104	-.105
Focus on sustainability	.080	-.081	.912	-.107	-.003
Declining average revenue per unit(ARPU) of service providers	.876	.268	.043	-.057	.223
Rise of telecom infrastructure companies	.717	.202	.059	-.077	.256

Factor Matrix	Component				
	1	2	3	4	5
Energy conservation case studies of foreign telecom operators	-.200	-.177	.764	.166	-.114
Government announcement to cut carbon	.729	.192	.135	-.247	.045
Restriction on use of subsidized diesel for telecom industry	.943	.090	.078	.074	-.067
Department of Telecommunication's directive to use renewable energy technologies for telecom towers	.962	-.037	.084	-.002	-.094
Availability of energy efficient telecom network equipments	.806	.105	.048	-.111	-.153
Availability of BEE certified energy auditors/Managers in telecom organizations	.778	.235	-.073	.141	.453
Reduction in carbon emission by fuel switching and reducing energy consumption	.592	.481	-.185	.136	.349
Use of energy conservation building code for telecom buildings	.749	.350	-.110	.017	.430
Falling price of renewable energy solution for telecom use.	.261	.096	-.231	.245	.777

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

APPENDIX-6

TableA.6: Factors rotation matrix using Principle Component Analysis

(Barriers to Energy conservation in Telecom Sector)

Factor Matrix	Component							
	1	2	3	4	5	6	7	8
Lack of regulations and by regulator and Government	0.090	0.157	0.261	0.187	-0.003	-0.096	0.409	-0.125
Non enforcement of hybrid energy and carbon disclosure directive	-0.132	-.062	.858	.166	.171	- .080	.005	-.043
Lack of customer awareness	.029	.108	.818	.020	.021	.213	.103	-.028
Lack of pressure from NGOs and public	-.127	.054 .	.879	.082	.139	042	.083	.036
Wrong examples set by public sector telecom service providers	.036	.035	.894	.027	. .046	.045	.057	.112
Government does not support with financial incentives for energy conservation	-.422	.449	.300	-.505	.315	.242	.162	.073
Lack of information about energy conservation and energy efficiency opportunities	-.443	.308	.380	-.625	.136	.187	.096	-.097
Energy efficiency benefits cannot be quantified	.319	-.410	.069	-.110	.114	-.524	-.228	-.130
Priorities of service providers on expansion of telecom services in new areas	-.421	.484	.224	-.420	.352	.250	.192	.090
Non availability of energy conservation targets	.746	.401	.112	.014	-.245	-.113	.298	.044
No incentive /penalty for meeting/skipping the targets	-.509	-.110	-.024	.083	-.702	-.133	.273	.073

Factor Matrix	Component							
	1	2	3	4	5	6	7	8
Non importance/less priority of energy management in the organization	.481	-.533	.276	.124	.064	.250	.363	.062
Non importance of energy as a function of service/production	.615	.531	.288	.039	-.011	.040	-.258	.002
Management perception that in telecom services, energy efficiency is less important	-.327	.373	-.275	-.197	.040	.148	.075	.353
Less awareness in the organization about importance of energy conservation	.385	.253	-.435	.189	.513	-.136	.274	.142
Less awareness about linkage between energy consumption and carbon emission in the organization	.762	.436	.161	.016	-.193	-.078	.226	.040
Lack of awareness about telecom sector specific technical measures for energy conservation	.364	-.258	.276	-.456	.003	-.176	.179	-.384
Lack of information and reporting about energy use by telecom operators	.473	.345	-.118	-.346	-.225	-.180	.135	.429
Hiding of information by operators regarding use of diesel due to risk of exposing the misuse of subsidized diesel	-.181	-.120	.151	.022	.814	.139	-.047	.118
Lack of customer preference for sustainability	-.036	-.036	.135	-.001	.010	.949	.051	.094
Confusion that telecommunications being a service industry do not need energy conservation	.031	.813	-.060	.047	.120	-.284	-.217	-.242
Lack of energy audit methodology of telecom installations	-.169	-.140	.227	.044	.754	.119	.154	.292
Lack of benchmarks for energy consumption in telecom sector	.825	.117	-.133	-.008	.000	-.022	-.173	.076

Factor Matrix	Component							
	1	2	3	4	5	6	7	8
Inadequate financial and technical information about fuel switching options	-.029	.864	.092	-.094	-.143	.046	.196	-.092
High CAPEX of energy efficient and fuel switching technologies	.116	.892	.057	-.106	-.054	078	.087	.136
Lax attitude of regulator and Government towards energy consumption of telecom sector	.841	.181	-.069	.070	.078	-.214	.165	-.036
Poor quality and lack of standards of energy efficient products	-.063	-.033	.068	-.022	.027	.967	-.021	-.004
Problems in maintenance and availability of spares of energy efficient equipments	.877	-.038	-.023	-.087	-.247	.017	-.009	-.110
Lack of skilled manpower and training	.688	-.010	-.094	-.310	-.135	.157	-.014	-.209
Organisation is lacking in policies procedures and systems for energy management	-.143	-.011	.096	.206	.106	.064	.637	.165
The workers in the organization is not accountable for energy cost	-.063	-.172	.044	-.223	-.656	-.011	-.359	.388

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 8 iterations

phd

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

BRIEF PROFILE

C S Azad, Senior Manager (ERP-MM and SRM), Bharat Sanchar Nigam Limited (BSNL) belongs to P&T BWS – Electrical Service, Government of India. He obtained his bachelor degree with honors in Electrical Engineering from Z H College of Engineering, Aligarh Muslim University (AMU). He has master degree in Operation Management. He qualified as a Certified Energy Auditor in the first batch of National Certification Examination for Energy Auditors and Managers. He is honorary secretary of UP state chapter of Society of Energy Engineers and Managers (SEEM):- The National body of energy professional in India. He is a life member of Energy and Fuel Users Association of India. He is also member of All India Management Association and Global ICT Standardization Forum of India. He has more than 23 years industry experience in various capacities and associated with a no. of prestigious electromechanical projects of Department of Telecommunications.

He has also worked as Asst. Director (Building Science – Electrical) at Advanced Level Telecom Training Centre (ALTTC), Ghaziabad where he was responsible for training of Indian Engg Service probationers and serving officers of Department of Telecommunications. Presently he is looking after the implementation of SAP-ERP (Material Management Module) in BSNL on pan India basis.

He has presented numerous papers in various national, international conferences, conducted workshops and guest lecturers in various institutions. He has contributed research articles to the journals in the field of management, energy and telecom.

He won state level prizes in debates and science completions in school days. Apart from research, his interests include poem writing, visiting new places, listening ghazals and reading classic literature.