Energy consumption and CO_2 emissions by the Indian mobile telecom industry

S.S. Krishnan*, N. Balasubramanian and A. Murali Ramakrishnan

Center for Study of Science, Technology and Policy (CSTEP),
Dr. Raja Ramanna Complex, Raj Bhavan Circle,
High Grounds, Bangalore – 560001, India
E-mail: ssk@cstep.in
E-mail: nbalu23@cstep.in
E-mail: murali@cstep.in
*Corresponding author

Abstract: The Indian mobile telecom industry, one of the fastest growing sectors in India, had 584.3 million subscribers in 2010–2011 registering an annual growth rate of 49.15%. The energy consumed by the sector was 163 PJ and the corresponding CO_2 emission was estimated at 32.9 million tons. In this paper, the mobile telecom industry is disaggregated into various segments, based on the lifecycle of the device, and each segment's contribution to the overall energy consumption, and its respective CO_2 emissions are discussed. In addition, the paper evaluates four scenarios that examine the impact of energy efficiency on energy savings and the corresponding CO_2 emissions relative to the 'business as usual' scenario for 2010–2020. The results of the study provide an imperative to researchers working on next generation infrastructure and energy efficiency to develop new technologies that will reduce the energy consumption and the corresponding CO_2 emissions of the growing Indian mobile telecom industry.

Keywords: energy consumption; CO_2 emission; mobile telecom infrastructure; e-waste.

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Biographical notes: S.S. Krishnan is a Principal Research Scientist at CSTEP. He is working on energy efficiency in manufacturing industries, service industries and in appliances.

N. Balasubramanian is a Material Scientist at CSTEP. He is working on energy efficiency in manufacturing industries, service industries and in appliances.

A. Murali Ramakrishnan is a Research Associate at CSTEP. He is working on energy efficiency in manufacturing industries, service industries and in appliances.

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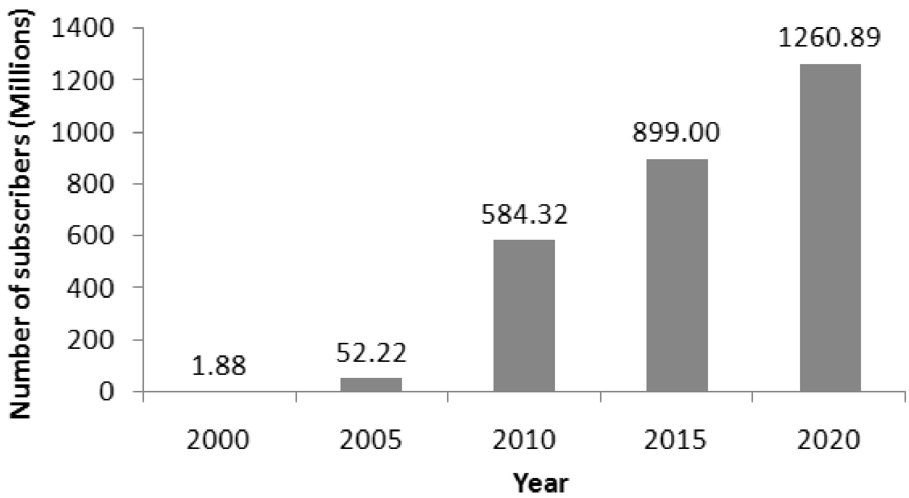
1 Introduction

India has been witnessing enormous economic growth on a sustained basis for the past many years and is expected to continue to do so for the next foreseeable future. Infrastructure development is key to providing an equitable growth and this entails the development of the mobile telecom infrastructure. The mobile telecom infrastructure has played a vital role in the equitable development of India's economic growth story, given the dense penetration across the urban-rural divide and across the various sections of society. The Indian mobile telecom sector has experienced a staggering growth over the last two decades. Through the inception of new technologies and the spread of the network into rural areas, the total number of subscribers has increased substantially. According to the Telecom Regulatory Authority of India (TRAI), wireless subscribers have increased from 391.76 million to 584.32 million from fiscal year (FY) 2008–2009 to FY 2009–2010 – an annual growth rate of about 49.15% (TRAI, 2010). Mobile phone demand in India has increased and the compound annual growth rate (CAGR) is 62.09% between FY 2005–2006 and in 2010–2011 is expected to increase at the rate of 15.7% per year (Singh, 2008). Tele-density, which is the number of wireless connections per 100 people, has increased from 12.86% to 57.29% during the same period (Greenpeace, 2011). Figure 1 indicates the projected growth of the mobile phone subscribers in India. The mobile phone demand is projected to reach 1260.89 million subscribers by FY 2020–2021.

The increase in the number of subscribers has led to greater energy consumption. Our analysis shows that between FY 2005–06 and FY 2010–11, the energy consumed by the mobile telecom sector increased from 39 PJ to 163 PJ – an annual growth rate of 63%. The CO_2 emissions increased from 10.11 to 52.66 million tons during the same period. These numbers indicate there is an imperative to devise new technologies to reduce the energy consumption and the corresponding CO_2 emissions of the growing Indian mobile telecom industry.

Figure 1 Projected growth of mobile subscribers



2 Background and methodology

Life cycle analysis (LCA) comprises all the materials and actions employed to produce and utilise the mobile device. The life cycle starts with the material extraction from quarries or mining, followed by material processing and manufacturing. The devices are then packed and transported to various places and sold to users. At the end of the life cycle, certain parts of the mobile device is either reused or disposed of as a whole.

For the LCA analysis, the mobile telecom industry is categorised into three segments: manufacturing unit, charger usage, and telecom network infrastructure (Yu et al., 2010). Manufacturing unit is further classified into four divisions: raw material extraction and processing; component manufacturing; mobile phone assembly, packaging and transportation. Charger usage is categorised as charging time and standby time. Telecom network infrastructure is sub-divided into base transceiver stations (BTSs), base station controllers (BSCs), and mobile switching centres (MSCs).

The primary objective of this study is to analyse the energy consumed in the three segments and to compute the corresponding CO_2 emissions generated. Energy consumption for the three segments was mainly obtained from Yu et al. (2010). Mobile subscription and growth rates were obtained from TRAI's 2009–2010 (TRAI, 2010) annual report and several secondary reports. The study assumed that all mobile phones used and future subscriptions in India are manufactured in India. The energy consumed from the grid was converted to the amount that needed to be generated at the plant level by accounting for the transmission and distribution (T&D) losses. The average T&D loss for the different years was obtained from Central Electricity Regulatory Commission's monthly report (CEA, 2009). Following this, CO_2 emissions were calculated by multiplying energy generated (at the plant level) by the grid and diesel emission factor. Finally, the study examined four scenarios to understand the impact of energy efficiency on CO_2 emissions in the mobile telecom sector for the period 2010–2020.

3 Results and analysis

In 2010–11, the total energy consumed by the mobile telecom industry was estimated to be 163.3 PJ. Manufacturing, charger usage and network infrastructure consumed 62.6%,11.7%, and 25.6% respectively. The sections below discuss the energy consumed in the different sub-divisions of the three segments.

3.1 Energy consumption during manufacturing

1 *Raw material extraction and processing:* The average energy consumption for material extraction is assumed to be 23 MJ (Yu et al., 2010). Therefore, the annual energy consumption for raw material extraction and processing is calculated by:

$$\begin{aligned}\text{Annual energy consumption (PJ)} &= \text{Energy consumed per unit (MJ)} \\ &\times \text{Total number of mobile phones(million)} \\ &\times 1{,}000\end{aligned} \quad (1)$$

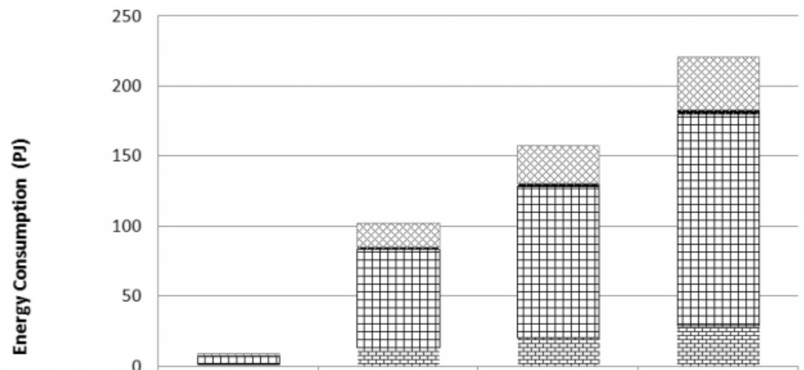
The annual energy consumption of the raw material extraction and processing unit for the year 2010 was estimated to be 13.4 PJ.

2 *Component manufacturing:* The integrated circuits and other components like capacitors and resistors are mounted on a printed circuit board. About 120 MJ energy is consumed during component manufacturing (Yu et al., 2010). When aggregated to the total number of mobile phones, the annual energy consumption for manufacturing mobile components was about 70 PJ.

3 *Mobile phone assembly:* All the components manufactured are assembled along with the liquid crystal display to create a mobile phone. The typical energy consumption during this stage is 2 MJ (Yu et al., 2010). In 2010, 1.2 PJ was consumed to assemble all the mobile phones.

4 *Packaging and transportation:* According to Yu et al. (2010), 30 MJ of energy is utilised for packaging and transportation. This amount varies greatly for different mobile devices. A total of 17.5 PJ, was consumed by the packaging and transportation unit in 2010. Figure 2 projects the manufacturing unit's energy consumption for the year 2005–2020. We observe that the component manufacturing division consumes the highest energy whereas the assembly division consumes the least.

Figure 2 Projected energy consumption of different sub-divisions in the manufacturing segment



	2005	2010	2015	2020
Packaging and Transportation	1.57	17.53	26.97	37.83
Mobile Phone Assembly	0.10	1.17	1.80	2.52
Component Manufacturing	6.27	70.12	107.88	151.31
Raw Material Extraction and processing	1.20	13.44	20.68	29.00

3.2 Energy consumption during charger usage

Energy consumption during charging is calculated by considering the charging time and the standby or idle time, when the charger is plugged in the power socket and left alone. Annual unity energy consumption (UEC) is determined by multiplying the weighted average power use by the number of hours in a year as follows:

$$UEC = \left(\sum_{i=0}^{m} \overline{P}_i T_i \right) \frac{8760h}{yr} \tag{2}$$

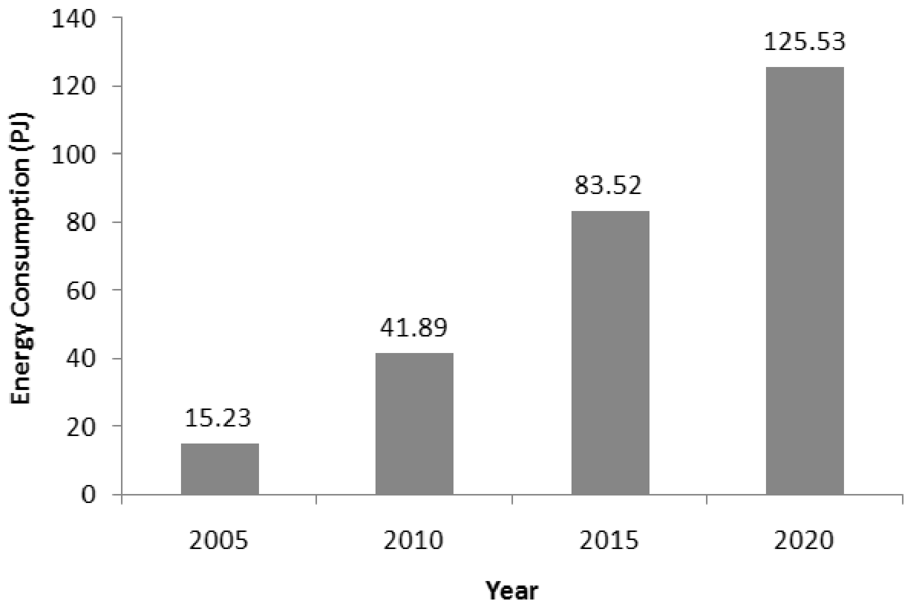
where M is the number of modes, P is the power drawn in each mode, T is the percentage time that the mobile unit is in each mode and when added, the sum of T in all mode should be equivalent to 100% (Yu et al., 2010). Charging, standby and unplugged are the three type of modes considered in this study. Further, an assumption of four hours in charging mode, five hours in standby mode and 15 hours of unplugged mode per day is made to determine the total energy consumed during charger usage.

In 2010, the total energy consumed by all mobile devices during the charging mode was15.35 PJ, with 3.8 PJ consumed in the standby mode. Thus, a total of 19.2 PJ was consumed during charger usage.

3.3 Energy consumption of mobile phone network infrastructure

The mobile phone network infrastructure comprises BTSs, BSCs, and MSCs. The BTSs act as an interface through which the mobile phones and the mobile network providers communicate. A BSC provides the control functions and physical links between the MSC and BTS (Telecom Towers-India, 2010). Typically, one BSC is required for approximately 100 BTSs. An MSC coordinates all communication channels and processes. Typically, one MSC is required for two BSCs (Yu et al., 2010). The performance of the mobile network provider is determined by the number of BTSs, as the increase in the BTSs improves the coverage at a geographical location. According to TRAI (2011), in 2010–2011, India had 400,000 towers across the country.

Figure 3 Projected energy consumption of mobile phone network infrastructure



Further, the power supply from the grid is available from 7–21 hours across the telecom circles in India (Greenpeace, 2011). This results in an inadequate supply of electricity. The annual energy consumption of the mobile network infrastructure in 2010 is determined by multiplying the average power consumption of a component per hour by the total number of hours in a year. The average number of hours during which the device was utilised is taken from Karmayog (2010). Figure 3 shows the projection of energy consumption in the mobile phone network infrastructure. By 2020, energy consumption by the network infrastructure is expected to raise to125.53 PJ, an increase of 200% from 2010. The section below describes the energy consumption by BTS, BSC, and MSC.

1 *Energy consumption of BTSs:* The non-availability of a reliable power supply compels a BTS to have a secondary power source which is primarily a diesel generator (DG) set. In 2010, the total annual grid energy consumption of all the BTSs across India was 33.63 PJ. Typically, a 15–25 kVA DG is used as a backup source (Indiamart, 2011). About 51.5 PJ energy is consumed by the BTSs through DG sets. This is for both urban and rural installations. The analysis assumes that the total number of installations is expected to grow at the rate of 17% between 2011–2015 and 8.5% during 2016–2020 (Telecom Towers-India, 2010). Table 1 highlights the different assumptions employed in the analysis. We observe that the urban area consumes 13.41 PJ and 2.68 PJ of energy from grid and DG set respectively, whereas the corresponding figures for the rural areas are 20.21 PJ and 5.32 PJ.

Table 1 Assumptions used to calculate energy consumed by BTS

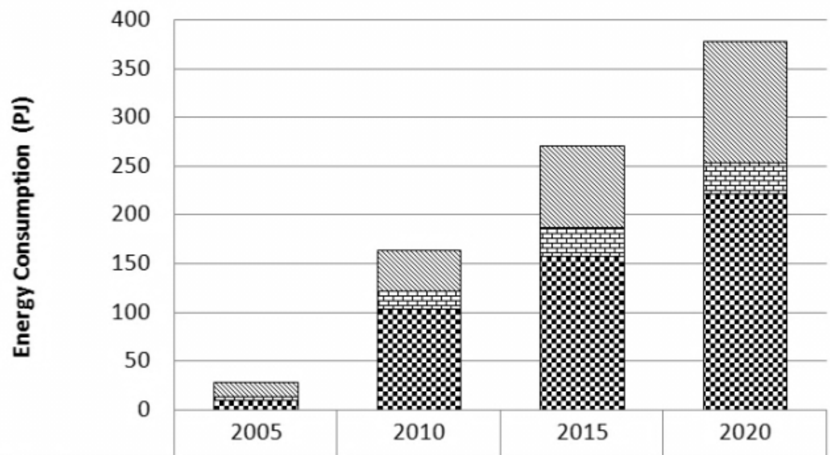
Type	*Variable*	*Rural*	*Urban*
Grid	Power consumption	20 kW	20 kW
	Number of hours per day	15	20
Diesel	Power rating	20 kW	20 kW
	Fuel consumption	20.4l	9l
	Number of hours per day	9	4

2 *Energy Consumption of BSCs and MSCs:* In 2010, the energy consumed by the BSCs was 0.013 TWh (0.049 PJ). The power consumed by a BSC was 4 kW (Nokia Siemens Network, 2011). The total number of BSCs erected in the country was 3300 (Yu et al., 2010). Total energy is computed by multiplying the power consumed by each BSC with the number of operating hours in a year. In 2010, the total number of MSCs installed in the country was 1,650. Each MSC was operating at a capacity of 4 kW which consumes 0.208 PJ.

3.4 Final energy consumption of mobile telecom industry

Final energy consumption is computed by adding the energy consumed by the three primary divisions of the mobile telecom industry. In 2020, the final energy consumed is expected to reach 377.78 PJ, with manufacturing unit consuming 220.65 PJ, 31.6 PJ being consumed by charger usage, and with telecom network infrastructure consuming the remaining 125.53 PJ. Figure 4 portrays the present and projected final energy consumption of all the divisions in the mobile telecom industry. The analysis projects the energy consumption to grow by 131.2% from 377.78 PJ in 2010.

Figure 4 Projected energy consumption of different segments in Indian mobile telecom industry



	2005	2010	2015	2020
Network Infrastructure	15.23	41.89	83.52	125.53
Charger Usage	2.96	19.19	29.53	31.60
Manufacturing	9.14	102.26	157.33	220.66

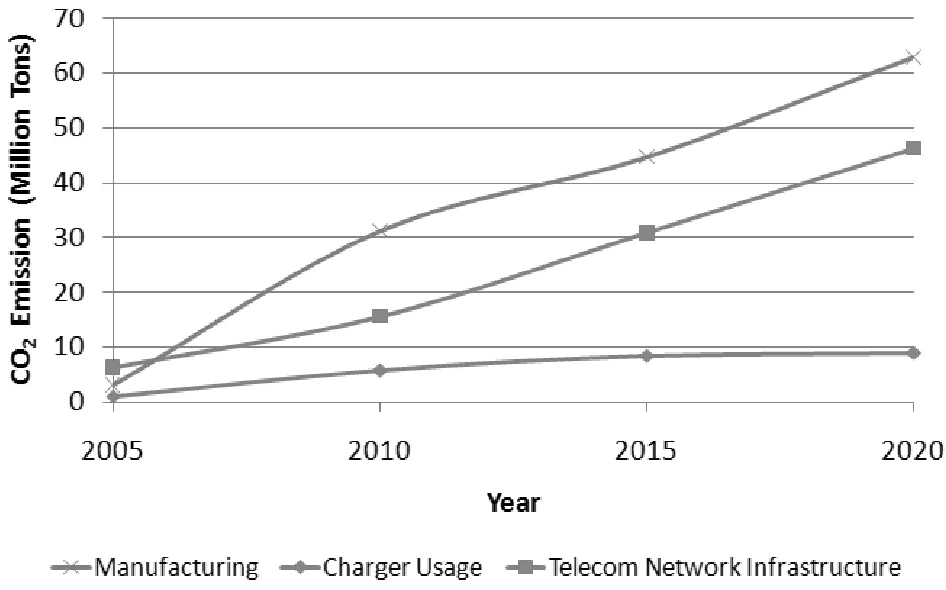
3.5 CO_2 emission from mobile telecom industry

To calculate the CO_2 emission, Intergovernmental Panel on Climate Change's (IPCC, 2006) Tier 1 approach was employed. In the Tier 1 approach, emissions from each greenhouse gas from stationary sources are calculated by multiplying fuel consumption by the corresponding default emission factor. The CO_2 emissions were calculated for the three divisions in the aforementioned manner. The grid and DG set are the primary sources of energy. The DG is primarily used as back-up power in the telecom network infrastructure division. The emissions were calculated as follows:

$$\text{CO}_2 \text{ emission}\left(\text{from grid}\right)\left(tCO_2\right) = \text{Total energy consumptionfrom grid}\left(MWh\right) \times 0.82 \frac{tCO_2}{MWh} \tag{3}$$

The emission factors 0.82 tCO_2/MWh and 0.0027 tCO_2/l were obtained from Central Electricity Authority (CEA, Ministry of Power, 2009) and United States Environmental Protection Agency (EPA, 2005). Further in equation (3) the total energy consumption from the grid includes T&D losses at the source and the emission factor represents the average emission of all stations in the grid, weighted by net generation. Figure 5 highlights the total CO_2 emissions of the three divisions from 2005–2020. The study finds that the mobile telecom sector would emit 118.18 million tons of CO_2 in 2020. Thus, the CO_2 emissions are expected to increase by 124% from that of 2010 emissions. The plot shows that the higher number of mobile phones and corresponding transceiver stations directly attributes to the increase in the emissions. Further, in 2020, manufacturing, charger usage and telecom infrastructure division contributes 53.2%, 7.6% and 39.2% respectively of the total emissions.

Figure 5 Projected CO_2 emissions from different segments of the mobile telecom industry



3.6 Scenario analysis

Energy consumption in mobile telecom industry can be reduced by using smart towers, green base stations, mobile devices operating on solar technology, and energy efficient handsets. Alcatel-Lucent is currently manufacturing BTSs with low wattage radio sets comprised of a small antenna mounted on top of a miniature-amplifier. This product reduces energy consumption compared to the existing installations. Further, the clustered processors used in these BTSs provide quicker and more flexible carrier routing and switching than the normal ones, and at a lower wattage compared to the traditional ones (Alcatel-Lucent, 2011).

Compact BTSs are another source of innovation. These can be installed as alternatives to distributed BTSs with remote radio heads (SenzaFili Consulting, 2010). Unlike traditional BTSs, the compact BTSs do not require ground shelters and cooling equipment. They consume less power, due to the absence of ground devices and cooling units. Power consumed by the compact BTS is 65–150 W, in comparison with ground-based BTSs which consume 335–800W, and distributed BTSs with 300–600 W of power consumption (SenzaFili Consulting, 2010). Solar or battery power can be used as a back-up power source in place of DG set.

In April 2010, Indian Government initiated a programme to promote use of solar power in the telecom sector (*Renewable Energy World*, 2011). It is envisaged in this programme that between 30% to 50% of the cost of solar retrofits are subsidised. Over

250,000 towers are expected to be outfitted with solar panels, reducing diesel use by as much as two billion litres per year (Greenpeace, 2011). Benefits experienced by renewable energy generation include minimal maintenance requirements, reduced environmental and safety liability, minimal green house gas (GHG) emissions and added income source (GHG offset credits) (Willson, 2009).

Considering the above energy efficient measures, the study included four scenarios to understand the impact of energy efficiency on CO_2 emissions in the mobile telecom sector. Only energy efficient technology in the mobile phone network infrastructure has been considered in the scenarios.

The four scenarios are as follows. Scenario A represents the business as usual (BAU) case without upgrading technologies over the next ten years. Scenario B assumes that only quarter of all the new BTSs (used in network infrastructure) installed post-2010 are energy efficient; the underlying assumption is that new technology uses 25% less power compared to the traditional technology. Scenario C considers that 25% of the existing installations are upgraded to new technology and 25% of the newer BTSs are employing new technology. Scenario D assumes that all the current and newer installations adopt energy efficient BTS.

Barring the engagement of energy efficient technology in network infrastructure, all the scenarios have employed the same assumptions used in the BAU. Energy consumption, energy saving, CO_2 emission and savings are analysed for all the scenarios. Figures 6, 7 and 8 exhibit the projections of energy consumed, energy saved and corresponding reduction in CO_2 from 2010–2020 for the different scenarios. The differences in energy consumption between BAU scenario and others are seen clearly in these graphs. The study finds that Scenario D results in the highest savings of 31.19 PJ in 2020 compared to the BAU. Furthermore, this scenario yields 76.7% higher CO_2 savings in 2020 compared to the BAU scenario.

Figure 6 Energy consumed in the four scenarios

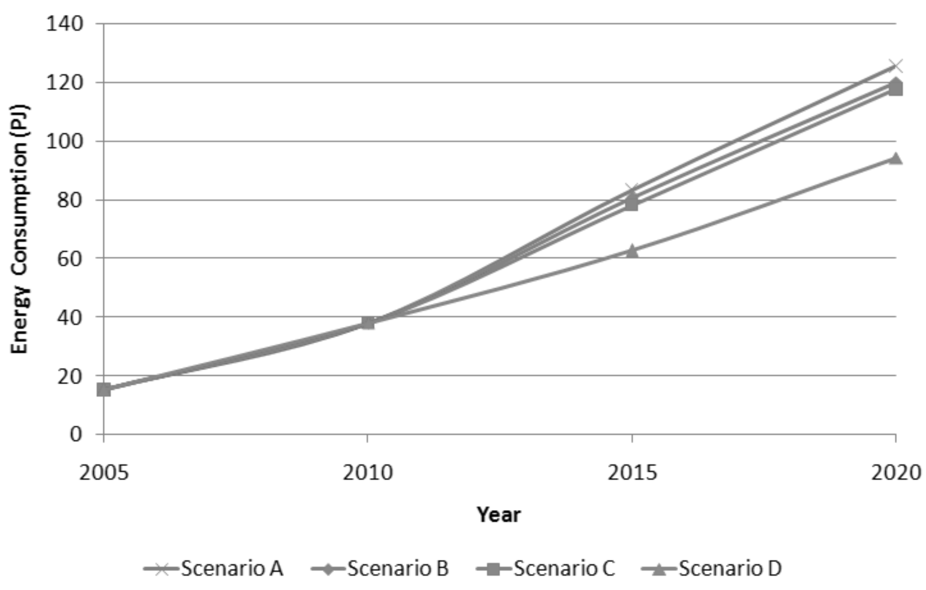


Figure 7 Energy savings in three scenarios relative to BAU

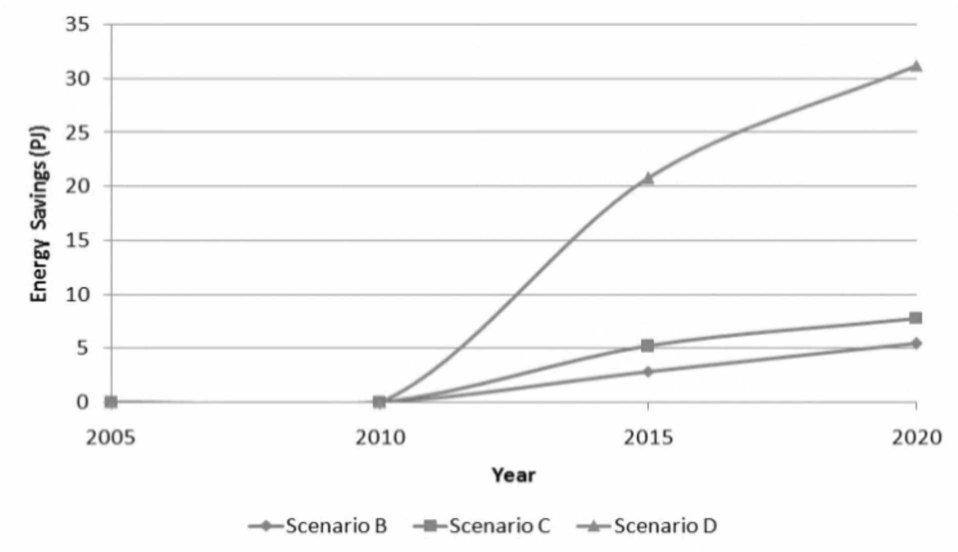
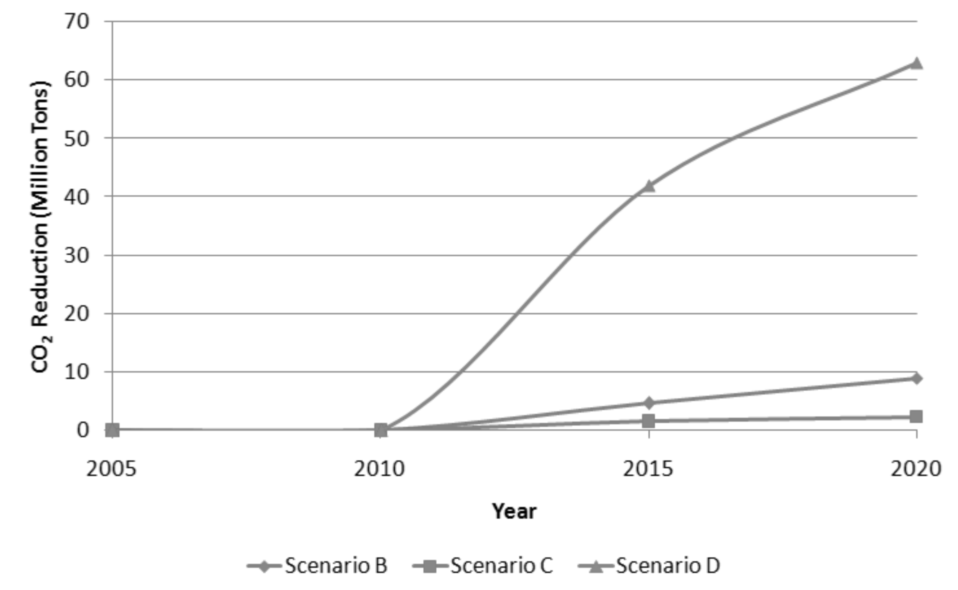


Figure 8 CO_2 reduction in three scenarios relative to BAU



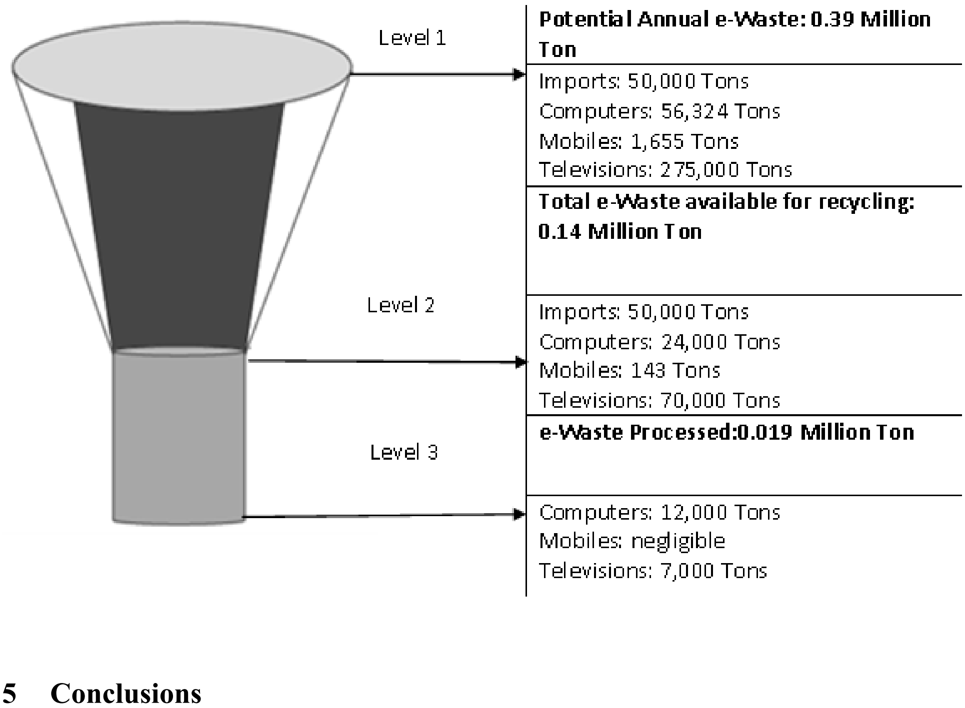
4 E-waste

This section discusses the e-waste system in India. The study does not project the e-waste generated in India but merely presents information on the current situation. E-waste is one of the fastest growing waste streams worldwide, indicating the rapid growth shown by the electronic sector. The e-waste system is comprised of three levels. These levels represent the cradle-to-grave approach starting from generation to the disposal of waste. The first level represents electrical and electronic equipment (EEE) generation, the second is waste electrical and electronic equipment (WEEE) generation, and the final layer represents WEEE re-processing (Wath et al., 2010).

4.1 Estimation of e-waste in India

A funnel based approach is employed to ascertain the estimates of e-waste in India. According to GTZ (Killgus, 2009), the level 1 (potential annual e-waste) is comprised of products, with inactive life, that are stacked in store rooms and products that are unsold by consumers. The total amount of potential annual e-waste generated in 2007 was 380,000 tons. The second level, namely e-waste available for recycling is estimated to be 140,000 tons. These are products that are exchanged, and are being reused or refurbished for their second life. The third and the final level indicate the processed e-waste which corresponds to 19,000 tons. This accounts for products and components that are disposed, recycled and dismantled. Figure 9 represents the funnel-based approach.

Figure 9 Funnel-based approach representing the classification of e-waste



5 Conclusions

In this paper, we have evaluated the energy consumed and the corresponding CO_2 emissions generated by the different segments in the Indian mobile telecom industry. In addition, we have evaluated seven scenarios to examine the impact of energy efficiency on energy savings and the corresponding CO_2 emissions relative to BAU scenario for the period 2010–2020. The study also provides a basis for initiating suitable policy mechanisms for the increased use of energy efficient and low carbon based equipment in the mobile telecom infrastructure. These measures will contribute significantly to a low carbon roadmap for India's long term equitable economic growth. The study also finds that 31.2 PJ of energy can be saved by replacing all the new and existing BTS by efficient ones by the year 2020 resulting in 63 million tons of CO_2 reduction. Even though the energy and emission savings in telecom industry are not as high as in other sectors like cement and steel, there is an imperative to develop energy efficient technologies to reduce these numbers even further.

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Acronyms

BAU	business as usual
BSC	base station controller
BTS	base transceiver station
CAGR	compounded annual growth rate
DG	diesel generator
EEE	electrical and electronic equipment
E-waste	electronic waste
FY	fiscal year
GHG	green house gas
kVA	kilo volt ampere
kW	kilo watt
l	litre
LCA	life cycle analysis
MJ	mega Joules
MSC	mobile switching centre
PJ	peta Joules
T&D	transmission and distribution
TRAI	Telecom Regulatory Authority of India
TWh	terawatt tour
UEC	unity energy consumption
WEEE	waste electrical and electronic equipment.