Sustainable Tomorrow: Harnessing ICT Potential

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Contents

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Executive summary

Rapid economic growth in the last two decades has lifted many out of poverty, but has been accompanied by depletion of natural resources and deterioration in environmental quality. The two decades have also seen an increased concern with climate change and its potential to magnify existing stresses. Herein the Information & Communication Technology (ICT) Industry have a key role to play.

The ICT industry is playing a transformational role in the way businesses, customers and citizens are serviced, and also leading the way in establishing a new paradigm for Knowledge and Services led economy. ICT solutions have enabled outreach of organizations, improved decision making and pace of the development of new products and services. Greening the Industry through a combination of ICT Solutions and Green Practices, is enabling various Industry verticals to demonstrate leadership towards achieving the goals of sustainable development.

Business Council for Sustainable Development (TERI-BCSD) and National Association of Software & Services Companies (NASSCOM) have been working jointly to develop this White Paper with recommendations put forth by over 70 industry members and government stakeholders. Moreover insights were drawn from TERI's researchers.

The TERI-NASSCOM led initiative seeks to shape a national strategy to promote the role of ICT in enabling India's actions on climate change and sustainable development.

Key messages emanating from the six chapters have been summarized below:

Introduction

- In a country like India, that is moving towards becoming a knowledge-based society, ICTs if applied appropriately can aid development in more ways than one. In the last one and a half decades, India has emerged as the next big thing on the global stage as far as the ICT sector is concerned. It has improved efficiency and contributed to better governance, thereby, changing India's image abroad.
- The potential of the ICT sector is slowly gaining credence. Until now, its contribution has been narrowly viewed by policy makers, business and media. It has not been seen as part of solution to the challenges of climate change and sustainable development. This is however, now changing.
- The SMART 2020 report reveals that by 2020, emissions from the ICT sector will represent an estimated 2.8% of total global emissions. But, ICT will enable others to achieve significant emission reductions, helping industries and consumers avoid an estimated 7.8 gigatonnes of CO_2e (Carbon dioxide equivalent based on the global warming potential of specific greenhouse gases) emissions. That is 15% of predicted total global emissions – or five times ICT's own footprint.

- NASSCOM Perspective 2020 report highlights that ICT industry has a key role to play in enabling a low-carbon society; the sector can enable emission reduction in number of ways – Provide standardised information on energy consumption and emission across sectors; Provide the capabilities and platforms to improve accountability in energy use and carbon emission; Offer innovations that capture energy efficient opportunities across commercial buildings and homes, transport, power, manufacturing and other infrastructure and provide alternatives to current ways of operating, learning, working and travelling.

- Industry focus on the role of ICT in climate change mitigation and sustainable development has largely focused on ICT industry audiences. This does not give any scope for discussion on its larger role as an enabler to sustainable development.

- ICT opportunity remains untapped in the broader debate on climate change and sustainable development. The sector is still in the nascent stages of moving – on to external opportunities.

- ICT has largely focused on cost effective product enhancement and not necessarily driving energy efficiency. This industry is, at present yet to adequately quantify or communicate the association between productivity enhancement and energy efficiency.

- Lack of information on the potential of ICT use, on part of policy makers leave a lot wanting. Decision makers outside the sector are slowly becoming aware of its potential. But at the moment, with limited knowledge, they have the propensity to take decisions that do not tap the sector's full potential.

- Greening the Industry through a combination of ICT Solutions and Green Practices, is enabling various Industry verticals to demonstrate leadership and contribution towards India's actions on climate change and overall sustainability. There is immense scope for ICT Industry and its members to enable customers across verticals to harness Green Technologies and Practices, and create new models for a sustainable and greener tomorrow.

Power

- Over 400 million people in India lack basic access to electricity, requiring additional power generating infrastructure. Peak demand shortage and average energy shortage runs in double digit. Total aggregate technical and commercial (AT&C) loss stands up to 27.15%. Depleting energy resources, enhancing access to energy, and ensuring energy-security are the major challenges facing the Indian power sector.

- ICT can lead to improvements of the efficiency, reliability and flexibility of all sub-sectors viz. generation, transmission, distribution, including the activities of Power Exchanges.

- The generation and transmission sub-sectors have seen significant penetration of ICT and it is progressing further depending on the need. However, in distribution sub-sector, which is presently the weakest link in the power supply chain, ICT interventions are taking place at a very slow pace. At the same time cost-effective ICT interventions in distribution sub-sector can go a long way in improving the operational and financial performance of the entire power sector. An important enabler is Government of India's flagship program Restructured Accelerated Power Development and Reforms Programme (R-APDRP).

- One possible solution to the existing challenges in the power sector is to move from a static grid network to a flexible smart power grid which requires bi-directional information flow which can be realized by implementing ICT. ICT solutions enable one to monitor and control every kWh of power flowing through the system. Such a distribution system seamlessly interfaces with consumer equipments to signal pricing and grid stability conditions.
- Opportunities for ICT interventions in power distribution sub-sector lies in Advanced Metering Infrastructure, Advanced Distribution Operation including Distribution Automation and advanced controls, Asset management, Distributed Energy Resources integration (Smart mini or micro grid), Improved interfaces and decision support, Regulatory Information Management system, Service Delivery Mechanism. Most of the interventions are at nascent stage of execution and thus the reform processes through ICT interventions needs to be expedited.
- North Delhi Power Limited (NDPL) recently renamed as Tata Power Delhi Distribution Limited and BSES have initiated deployment of smart meters which substantially reduced revenue loss incurred through huge AT&C losses.
- An integrated deployment of ICT interventions like Advanced Metering Infrastructure, Distribution Automation, Distributed Energy Resources, yield benefits that more than when deploying them in piecemeal.
- To capitalize on smart power distribution network in India it is recommended that fiscal incentives for mass scale deployment of ICT solutions be provided. Mandate studies and preparation of feasibility reports on need based ICT applications bringing out the likely benefits and costs be done. And the establishment of Regulatory Information Management System at central and state levels should be expedited.

Transport

- The transport sector in most of the developing countries is experiencing an increased share of personal motorized traffic, which has impacts in terms of growing traffic congestion, travel time, road accidents, pollution and most of all high dependence on fossil energy.
- Within the transport sector, the road sector is the largest consumer of commercial fuel energy; it accounts for nearly 35% of the total liquid commercial fuel consumption by all sectors. Within the road sector, cities represent a significant proportion of energy consumption due to concentration of transportation activities within their administrative boundaries.
- Mitigation strategies needed to reduce energy use. ICT sector can enable implementation of such actions in a more safe, efficient and faster manner. ICT sector has a huge potential for addressing concerns.
- The ICT applications that can yield significant energy reduction benefits and which can be implemented with immediate effect include vehicle tracking systems to manage freight and public

transport fleets; intelligent traffic management solutions in urban areas; and ICT applications to make public transit services efficient and convenient to use for commuters.

- There is a need for a multi-pronged strategy to promote the use of ICT applications in road transport sector; the strategy should target addressing all barriers that effect large scale deployment of ICT.
- Enabling policy environment, supporting infrastructure, awareness generation, institutional arrangements, capacity building, funding and research and development are required for large-scale implementation of ICT applications in road transport sector for which key stakeholders like government (at centre/state/city level), ICT industry and private sector need to work together.

Water

- With declining per capita water availability, it is expected that India will fall into the category of "water scarce" countries by 2050. The climate change phenomenon is also predicted to aggravate this situation. Apart from decreasing per capita water availability and inequitable access, urban water supply in India has high unaccounted for water (UFW) due to leakages, thefts, metering inaccuracies and losses. Deteriorating water quality poses another major challenge in water sector, witnessed by the rising levels of BOD and bacteriological contamination often due to mixing with sewage.
- One of the key factors for improving the water use efficiency and conservation would be the establishment of a framework for efficient and dynamic management of database for water through use of latest technologies including ICT tools.
- The application of ICT in water sector would be useful not only in generation of scientific data & information, but also its real time dissemination for effective and timely decision making. This would help in improving the performance benchmarks of the water utilities and would promote accountability and transparency in the water sector. Besides the stated benefits, the use of ICT would definitely help in fulfilling the National Water Mission goals under National Action Plan on Climate Change (NAPCC).
- Some of the potential benefits include:
  - Real-time monitoring of water supply system using ICT tools (sensors, smart meters, GIS, SCADA) would enable quick identification, prediction and prevention of potential problems such as a burst water main, a slow leak, thefts, non-transparent billing, a clogged drain or a hazardous sewage overflow, checks for contamination, etc.
  - ICT (like sensors, automated communication, control system) in industrial process would provide substantial opportunity in reducing the specific water consumption, thus also providing co-benefits on water charges and power consumption.
  - Smart sensors (like Smart Levee, water quality/ water level sensors), GIS, automatic weather station, weather prediction model, etc. can enhance the early warning system during extreme events such as flash flooding

etc. besides also managing infrastructure and reservoir systems.

– ICT can help in scheduling the optimal time of irrigation, remote management of irrigation activities, and optimal water use for agriculture, which helps in preventing damage due to drought stress or over irrigational practices.

- A conservative estimate of implementing ICT interventions in the water supply system may enable avoiding 15% of the losses due to UFW and may lead to potential savings of Rs 27 lakhs and Rs 4 lakhs per day for major metropolitan cities and Class I cities of India respectively.
- Lack of know-how on latest technologies to maximise water use efficiency, intelligent handling and processing of data and initial high costs pose challenges for adopting ICT solutions.
- The suggested roadmap for the ICT industry will be to prioritize urban water supply initially, followed by industrial, integrated water resource management (IWRM) and agricultural sectors.
- It is recommended that national and state water policies emphasise effective information sharing through ICT besides promoting water resource management through tools like ICT, water audits and water conservation. Adoption of ICT tools towards climate resilient management of water resources should be encouraged.
- Strengthened capacity building of government agencies to use ICT and promoting R&D is also recommended.

Industry

- Energy consumption by the Indian industry sector accounts for about 43% of the total commercial energy consumption i.e. 112.91 mtoe (2007-08).
- The total estimated GHG emissions from industry sector were 250 million tonnes (1994 level). 60% of these emissions were accounted by energy use in industry sector and the rest by different processes.
- India's National Mission on Enhanced Energy Efficiency (NMEEE) identifies the need for market-based approaches to unlock energy efficient opportunities with a planned investment of Rs 74,000 crores. The PAT (Perform, Achieve and Trade) scheme of the Bureau of Energy Efficiency under the NMEEE has identified an energy saving potential of about 6.6 mtoe by different Designated Consumers (DCs) including thermal power plants during a 3-year period.
- A number of major producers of the industry use state-of-the-art technologies and automation solutions having energy efficiency levels at par with the global standards. However, the wide range of specific energy consumption (SEC) levels prevailing amongst the DCs indicates significant scope for energy efficiency improvements. In addition, about 50% of the energy consumption is accounted by the non-DC industries which also have significant scope for energy efficiency improvements.
- Achieving industrial energy efficiency involves access to information, financing, human resources and technology, improved decision making processes, and the ability to measure and

verify the achieved energy savings. One of the cross-cutting technological options for improving energy efficiency is "adoption of ICT". Part of the energy savings envisaged through PAT can be met through adoption of ICT solutions.

- Off-the-shelf ICT solutions may not be available for industries and hence there is a need for the ICT solution providers to understand the dynamics of the sector. The ICT solutions are sector-specific and are unique to individual industries. The specific types of ICT solutions would include process automation, use of better control systems and adoption of Energy Management Information System (EMIS) for data analysis and decision making.
- The Government of India schemes focussing on technology upgradation and promote energy efficiency provide significant opportunities for adoption of ICT solutions by the industry sector.
- Industry success stories/ case studies would help in enhancing the awareness levels of the different stakeholders. This will help to bridge the gap between the industry end-users and the ICT solution providers.
- ICT solutions can play a key role in capacity building of plant professionals through virtual platforms. This would create a virtual learning environment for them to efficiently operate the plant.

Driving Implementation of Green ICT Infrastructure in India

Energy efficiency in India's ICT sector

- The Indian ICT industry have undertaken several green practices and adopted green technologies at their facilities. These are separately listed as Annexure.
- A study was undertaken with a cross section of IT industry facilities (both company owned and leased) and it is observed there is scope for improving energy-efficiency by adopting various green practices.
- The lighting design is quite efficient but appropriate lighting controls have not been provided. Lighting system energy performance can be improved further by integrating appropriate lighting controls such as occupancy and daylight-linking controls for artificial lighting.
- The Energy Performance Index of the existing ICT facilities in India varies between 230 kWh/ m^2/year and 310 kWh/m^2/yr. The power usage effectiveness (PUE) is about 1.5. Potential exists to reduce energy consumption of the ICT industry by 25–30% from the current levels.
- Even though high performance materials have been used in the building envelope, there exists a possibility to improve energy performance by using materials specified by ECBC (2007).

- The cooling system efficiency is found to be average and there exists a potential to enhance the system's efficiency by up to 30 per cent.
- Industry-specific energy standards and energy-performance benchmark need to be developed, with energy/environmental rating made mandatory. IT equipment shall also be included in 'standard and labelling' programme introduced by the Bureau of Energy Efficiency (BEE) of the Ministry of Power.
- ICT applications can facilitate gathering information in real-time on energy consumption of every appliance in building in a user friendly way, thereby enabling end-users to take informed decision which will lead to development of effective energy management plan for a facility. ICT sector can also facilitate the design and construction of green buildings by developing a variety of assessment, compliance check, simulation, analysis, monitoring, and visualization tools.
- It is recommended to develop an exclusive environmental rating system for both new and existing ICT facilities, R&D programs for identifying and developing new technologies, which can reduce the direct IT load.

Disposal of end-of-life ICT equipment

- As the usage of ICT equipment increases, the rapid obsolescence and availability of newer and efficient models at affordable rates lead to the concern of managing end-of-life and discarded equipment in an environmentally sound manner.
- Managing end-of-life ICT equipment must be treated as a business responsibility by the ICT industry. The ICT industry in India—as manufacturers and bulk consumers—should take appropriate steps to ensure that the e-waste generated is managed in an environmentally sound manner.
- India's total e-waste generation is expected to increase to 8,00,000 tonnes by 2012. The ICT sector accounts for 34 per cent of the total e-waste generated in India. Reduction of waste from end-of-life ICT equipment is desirable through reuse and recycling.
- Proactive actions are recommended for the ICT industry by considering progressive ICT equipment design and waste-reduction opportunities, establishing an advisory committee for management of e-waste, developing company-level standard operating procedures, developing sustainable partnerships with stakeholders to devise attractive take-back schemes.

Introduction

KEY MESSAGES

- India is moving towards becoming a knowledge-based society, ICT solutions if applied appropriately can aid development in more ways than one. It has improved efficiency and contributed to better governance, thereby, changing India's image abroad.
- The contribution of ICT sector has been narrowly viewed by policy makers, business and media. It has not been seen as part of solution to the challenges of climate change and sustainable development. This is however, now changing.
- The SMART 2020 report reveals that by 2020, emissions from the ICT sector will represent an estimated 2.8% of total global emissions. But, ICT will enable others to achieve significant emission reductions, helping industries and consumers avoid an estimated 7.8 gigatonnes of CO_2e (Carbon dioxide equivalent) emissions. That is 15% of predicted total global emissions – or five times ICT's own footprint.
- NASSCOM Perspective 2020 report highlights that ICT industry has a key role to play in enabling a low-carbon society through innovative solutions across commercial buildings and homes, transport, power, manufacturing and other infrastructure and provide alternatives to current ways of operating, learning, working and travelling.
- ICT opportunity remains untapped in the broader debate on climate change and sustainable development. The sector is still in the nascent stages of moving – on to external opportunities.
- ICT has largely focused on cost effective product enhancement and not necessarily driving energy efficiency. This industry is, at present yet to adequately quantify or communicate the association between productivity enhancement and energy efficiency.
- Lack of information on the potential of ICT use, on part of policy makers leave a lot wanting. But at the moment, with limited knowledge, they decision makers have the propensity to take decisions that do not tap the sector's full potential.

The transformative power of ICT

The impact of Information and Communication Technologies (ICT) is all pervasive. It has penetrated every branch of the economy (see Box 1). In the recent years, the impact of ICT has been tremendous on social dynamics and economy. It has often been termed as "transformative" as it opens up wide possibilities for individuals and society Also, it further strengthens their developmental goals.[1]

Technological innovations of the late 20th century have led to progress in biotechnology, microelectronics, and new materials, along with modern software technology.

BOX 1 DEFINITION OF ICT

"ICT … consists of hardware, software, networks, and media for collection, storage, processing, transmission, and presentation of information (voice, data, text, images)", as defined by the Information & Communication Technology Sector Strategy Paper of the World Bank Group, April 2002.

The OECDdefines the ICT sector as a combination of manufacturing and services industries that capture transmit and display data and information electronically.

[1] Study on the Social Impact of ICT - University of Siegen, April 30, 2010.

The combination of advanced microelectronics and new vistas in software development has led to systemic technologies, which form a cluster of Information and Communication Technologies (ICTs) (Mansell, 1994)[2].

The global revolution in ICT is constantly evolving and changing the way people live and communicate. In an equally important manner,it is also enabling a developmental revolution, whereby people are able to chart their own path towards economic growth, particularly in the developing economies (see Box 2).

Improving business performance: role of ICT

The purpose of ICT is not only reshaping business models, but integrating enterprises in order to deal with the challenges of the network economy with innovative and smart solutions.[3] Uniquely, ICTs are broad-based technologies responsible for increasing the productivity and efficiency of any economy.

ICTs have become the basis of development in every sector because of the following reasons.

- Increased productivity by reducing transaction costs.
- Immediate connectivity of voice, data and visual has improved efficiency, transparency and accuracy.
- It has emerged as a smart and sometimes cheaper alternative for communicating and transaction such as actual physical travel.

BOX 2 ICTS' POWER TO EMPOWER

Overcoming geographic isolations: By substituting physical travel, which can be expensive and time consuming, ICT has overcome geographic isolations. For example, ICT is instrumental in facilitating information exchange, long distance money transfers, and even telemedicine.

Enabling consumer choices: Real-time access to market information and transactions over the Internet and telephone have increased healthy competition, thereby offering consumers more options in the market and finally resulting in price reductions over time.

Encouraging healthy competition: The use of mobile phones and Internet empowers local producers to access market information, thereby reducing monopoly through information on competing market. This enables producers to get best prices over time.

Empowering people: ICT has had a politically liberating effect in countries with repressive governments. These are powerful technologies in the hands of the people to convey their demands internally and internationally. It is also a tool for political empowerment. For e.g. President Obama's election campaign was a huge success on social networking and micro-blogging sites.

Transcending boundaries: One of the flip sides of working away from home is the strain it exerts on family ties. ICTs have allowed people to transcend boundaries by working away from home. In some cases, webcasting weddings and funerals have allowed people to participate without actually being physically present.

[2] Mansell, R. (Ed.).The Management of Information and Communication Technologies: Emerging Patterns of Control. Science Policy Research Unit. Published *by The Associationfor Information Management, London, 1994.*.

[3] Improving Business Performance: Role of ICT in SMEs - Dr. MP Jaiswal, Professor - IT Management, Management Development Institute (MDI) Gurgaon. India.

- By opening up the marketplace, it has encouraged making choices by providing access to goods and services that are otherwise inaccessible.
- Potential markets now enjoy wider geographic scope and reach.
- All kinds of information and knowledge can be channelized.

The unique attributes of ICT have played a key role at the macro-economic level. Various studies have indicated the positive impact of ICTs on GDP through long-term and sustained investment in IT and mobile communications.[4] According to a World Bank survey, "firms using ICT see faster sales growth, higher productivity and faster employment progress". This survey was conducted in approximately 50 developing countries. In India, the NASSCOM–Crisil report (2007) calculated that: "Every rupee spent by the IT–ITeS sector (on domestically sourced goods and services) translates into a total output of Rs 2 in the economy. Also, for every job that is created in this sector, four jobs are created in the rest of the economy." Therefore, there is ample room for understanding the impact of ICT on business and trade in developing countries.

ICT revolution in developing countries

In 2011, the World Bank reported that within ten years mobile phones penetration in developing countries touched 3.7 billion in 2010 from 200 million in 2000. Equally remarkable was the rise in the number of Internet users that had grown tenfold during the same period.[5] The progress in the ICT Millennium Development Goal indicator shows that about 70% of the population in developing countries have access to any form of mobile phone and more than 20% use the Internet. For example, Kenyan farmers in remote villages know the current crop prices as well as methods of money transfer. This is without the help of any intermediaries. The use of mobile banking has drastically changed the life of migrant workers in Sierra Leone and South Africa. Satellite mapping of fish colonies to pick out the best fishing spots has provided a boost to the fisheries business in Sri Lanka. ICT, therefore, is not a mere luxury for the developing nations, but an essential utility. Its pivotal role in economic development and alleviating poverty cannot be overlooked. Economists estimate that the global GDP rises by 0.6% for every 10% of population subscribing to telephones; the same percentage gaining access to broadband Internet in developing countries would raise the global GDP by 1.38%.[6]

Countries at different levels of development have tried to harness the on-going ICT revolution in three fundamental ways that correspond to the various roles of ICT:

- Promoting the ICT industries
- Deploying ICT across sectors, as a general purpose technology

[4] Among others, see Ahmad, Nadim, Paul Schreyer and Anita Wolfl.2004.ICTInvestment in OECD countries and its Economic Impacts. Paris: OECD Also, Waverman, Leonard, MeloriaMeschi and Melvyn Fuss 2005. "The Impact of Telecoms on Economic Growth in Developing Countries."In Vodafone. 2005. Africa: The Impact of Mobile Phones. Vodafone Moving the Debate Forward Policy Paper Series, No.3. London: Vodafone

[5] Embracing the Developmental Power of ICT – The World Bank, February 23, 2011. http://web.worldbank.org/external/default/main?menuPK=6454478&theSitePK=5929282&piPK=64911825&pagePK=7278674&contentMDK=22839789.

[6] *Ibid.*

- Investing in ICT as an enabling and networking infrastructure

In a country like India, that is moving towards becoming a knowledge-based society, ICTs if applied appropriately can aid development in more ways than one. In the last one and a half decades, India has emerged as the next big thing on the global stage as far as the ICT sector is concerned. It has improved efficiency and contributed to better governance, thereby, changing India's image abroad.

ICT in India: mapping the policy landscape

Since the opening up India's economy in the 1990s, economic growth, particularly powered by the progress in the ICT sector, received a tremendous impetus. The reform agenda of the Indian government aimed at taking significant steps to promote ICTs. This also involved the creation of a World Market Policy focussing on software development for export as well as the privatization of the national long-distance and mobile phone markets. The thrust was on developing a comprehensive approach to ICTs. A more conducive environment for addressing enterprise, education, the use of ICTs to meet developmental needs, and domestic infrastructure is fast emerging as the government's strategy imperative.[7]

In mapping the all-pervasive nature of the ICT sector in India, E-governance is a fast emerging area of focus. Even though the concept of E-governance is only a few years old, many states in India already have an IT/ICT policy in place. These states include Andhra Pradesh, Delhi, Goa, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Tamil Nadu, and West Bengal. The recognition of the role of IT as an interface between the public and the government in the Tenth Five-Year Plan has given a boost to the development of IT/ICT. The unique features of ICT are being increasingly and effectively used by the Indian Railways, in transport departments across the country, in courts of justice, in maintaining treasury records, in irrigation departments, and various police departments.

IT/ ITeS (IT-enabled sector) are mainly concentrated in seven Indian cities namely Delhi and National Capital Region, Kolkata, Chennai, Bangalore, Hyderabad and Secunderabad, Mumbai, Navi Mumbai, Thane and Pune. The major IT clusters and potential hubs are depicted in Figure 1. The geographical spread of IT / ITeS activity is gradually expanding to cover cities such as Ahmedabad, Bhubaneswar, Chandigarh, Coimbatore, Jaipur, Kochi, Madurai, Mangalore, Mysore and Trivandrum.[8]

India's ICT industry

India has often been described as the land of paradoxes. Against the background of abject poverty, India was poised to make tremendous success in the global ICT industry. This sector employs over 2.5 million people directly, and over eight million indirectly. It is a rapidly expanding industry across all domains, primarily driven by software services.

[7] Empowering the Poor - Information and Communications Technology for Governance and Poverty Reduction: A Study of Rural Development Projects in India; Roger Harris and Rajesh Rajora; UNDP-APDIP 2006.

[8] The Information And Communication Technology Sector In India: Performance, Growth And Key Challenges - Organisation for Economic Co-operation and Development June 30, 2010

Figure 1 Potential hubs for IT-BPO operations in India
Source A.T. Kearney–NASSCOM Report (2008)

India has become an attractive investment destination for the ICT sector. It also has investor-friendly Foreign Direct Investment (FDI) policies. According to NASSCOM, the total FDI inflow for the ICT sector during April 2010-March 2011 was US$ 665 million. This was mainly governed by Exports that accounted for revenue of US$ 59 billion - growing at 18.7% during 2009-2010. During the same period, the domestic market grew at 16%, aggregating US$ 17 billion.

In 1999, the Prime Minister's National Task Force on Information Technology and Software Development stated that the Indian software and hardware industry were two sides of the same coin (See Box 3). Both were instrumental for India's emergence as a super power in global IT.[9] India's ICTs expertise also has had a tremendous impact on the society. Wider sections of business and society have benefited from investments in Internet and communications infrastructure – an outcome of the demands of the Indian software industry. The spill over effect has been witnessed in other ancillary and supply services. Its effect was also seen in education and in ICT enabled services such as call centres. According to a NASSCOM report, the revenue aggregate of Indian IT-BPO industry is expected to grow by 19.2% and reach US$ 88.1 billion by the end of FY 2010-11 as compared to US$ 73.9 billion in FY 2009-10.

The World Bank has claimed that "India is a leader in the Information Technology (IT) revolution, and states such as Andhra Pradesh and Karnataka are making impressive gains in applying IT solutions to a variety of public sector problems."[10] These two states are ranked as leaders on the Government of India's e-readiness scale along with Tamil Nadu and Maharashtra.[11]

BOX 3 SECTOR FACTS

According to the Telecom Regulatory Authority of India (TRAI), the total number of telephone subscribers increased to 846.32 million at the end of March 2011 from 826.25 million at the end of February 2011. This means a growth of 2.43%. Wireless subscription in urban areas increased from 525.17 million in February 2011 to 538.05 million at the end of March 2011. The rural subscription increased from 266.21 million to 273.54 million.

During the same period, the rural subscription at 2.75% is higher than the urban one i.e., 2.45%.

Table 1 shows the expenditure sheet on ICT by India. India is the leader amongst emerging economies for the period 2000-2007 with a four-fold rise in spending.

ICTs and climate change

"ICTs are a cross-cutting technology that can drive the deep transformation needed in the global effort to combat climate change and advance the implementation of the Convention and the Kyoto Protocol. It is all about opportunity. Forward-thinking leaders already recognize the role of ICTs. The challenge today is to move forward and look to ICTs as a key enabler of a new model of social and economic development."

Hamadoun I Touré, ITU Secretary General

[9] National Task Force on IT and Software Development, http://it-taskforce.nic.in.
[10] World Bank, India: Sustaining Reform, Reducing Poverty, July 2003, ibid.
[11] India: E-Readiness Assessment Report 2003 For States/Union Territories and Central Ministries/ Departments, by the Department of Information Technology, Ministry of Communications and Information Technology, Government of Indiaand the World Bank.

Table 1 ICT expenditure in India by segment 2000-07. Million US Dollars in current prices

Segments of ICT sector	2000	2003	2004	2005	2006	2007
IT Hardware	2257	5013	7204	10264	13630	17910
Software	358	948	1350	1908	2519	3336
IT Services	1120	2859	3876	5243	6607	8356
Communications	12841	16873	23734	29023	32549	35978
Total ICT	16575	25692	36164	46438	55304	65580

Source OECD Committee for Information, Computer and Communications Policy, 2010

Greening efforts in India: needs and challenges

India is at a unique juncture in its development. The Indian economy has been growing at an accelerated rate over the past several years to achieve increasingly high GDP targets. The International Monetary Fund (IMF)[12] projections indicate that the strong economic growth of the past decade is likely to continue to hold true and reach 8 percent per annum until 2015. This rapid economic growth generates substantial potential for public and private investments in development. As outlined in India's 11th Five Year Plan (2007–2012), the Government of India is also aiming to double per capita GDP over 10 years. Such dramatic and rapid income growth for a country as populous as India would require a significant transformation across all sectors of the economy.

India's current energy consumption level on a per capita basis is low, but is expected to grow substantially in the coming decades. Economic growth, increasing prosperity and urbanization, rise in per capita consumption, and spread of energy access are the factors likely to substantially increase the total demand for energy and for electricity in particular[13]. Improving energy access coupled with increased demand for industrial and commercial applications is leading to significant increase in energy demand. Supply expansion has not kept pace with the increasing demand. Thus there is sustained energy supply-demand imbalance. In the electricity sector, energy deficits are of the order of 9% and peak deficits are of the order of 10%[14], which could increase over the long term due to supply side constraints. The problems are aggravated by high transmission and distribution losses on account of inadequacies in network infrastructure and high levels of electricity theft.

According to the UN, India's urban population will increase from 288 million in 2000 to 590 million by 2030, a 2.4% annual increase. The number of cities and towns in India increased from 4,651 in 1991 to 5,161 in 2001, with a significant increase in the number of cities with population above 1 million (12 in 1981 to 35 in 2001) (NIPFP, 2007)[15]. In India what

[12] International Monetary Fund, World Economic Outlook Database, October 2010.
[13] Ministry of Environment & Forests (2011) Clean Technology Fund: Investment Plan for India.
[14] Source: CEA. Data for FY 2011 (April 2010 – March 2011)
[15] NIPFP (National Institute of Public Finance and Policy), 2007, India Urban Report- A summary assessment

is referred to as India's 'RUrban transformation, the country is projected to witness a rapid demographic transition as its urban population rises from 300 million to over 700 million by 2050. By 2025, an estimated 70 Indian cities are expected to have a population size of over one million. This massive urban transformation - the largest national urban transformation of the 21st century – defines India's fundamental opportunities and challenges: to respond to the demands on the urban sector imposed by a growing and sophisticated economy and by the additional 10 million people who will become urban dwellers each year[16]. This will require providing them with adequate public services and infrastructure, and ensuring that urbanization is environmentally sustainable. This rapid urbanization is expected to place substantial stress on existing—often insufficient— transport infrastructure, both for long-distance freight and the movement of people within cities. The transport sector is the second largest contributor to energy related GHG emissions in India, and its share in national GHG emissions has increased from 6.4 percent to 7.5 percent between 1994 and 2007 [INCCA 2010]. Moreover, India imports about 80 percent of its petroleum requirements, a significant part of which is used for transport. The quantity of oil imported, the unit cost of oil and the share of transport fuels (gasoline, diesel, kerosene and aviation turbine fuel or ATF) in the petroleum basket are all steadily increasing. Given the likely oil-constrained future, there is need to lower transport's dependence on petroleum to enhance India's energy security and lower its carbon footprint.

With an economy closely linked to its natural resource base and climate sensitive sectors, India is poised with the challenges of poverty eradication, sustaining the rapid economic growth and dealing with the global threat of climate change. As a response to combat the impacts of climate change, the Prime Minister's Council on Climate Change has released India's National Action Plan on Climate Change (NAPCC) on June 30, 2008. The NAPCC, along with its eight missions, serves as the first country-wide framework on climate change with the approval and support of the Government of India. These eight NAPCC missions map out long term and integrated strategies to achieve key national goals from the climate change perspective. The NAPCC identifies measures that promote development objective of the country while producing co-benefits that address climate change effectively. To make all these eight missions a reality, the participation of all stakeholders is essential, particularly the business community in India. Here business has a key role to play in bringing about a change in direction towards greater sustainability of the country's economic activities in terms of finance, technology and policy influence and decision making.

India's Integrated Energy Policy Report (IEP) 2006 estimates that India needs to increase primary energy supply by 3 to 4 times and electricity generation by 5 to 6 times to meet the lifeline per capita consumption by 2031, and sustain economic growth at 8 % (with an equivalent installed capacity of 320 to 332 GW). To address these needs, India needs an order-of-magnitude increase in renewable energy growth in the next decade, and substantive success in its demand side management and energy efficiency programs.

[16] TERI (2011). Climate Resilient and Sustainable Urban Development.

ICT enabling business action

For India and most of the emerging economies, it is important to have SMART (Standardize, Monitor, Account, Rethink, Transform) ICT solutions. This will help to combat global climate change due to rising GHG levels. These solutions include SMART Buildings, SMART logistics, SMART motor systems, SMART meetings and SMART Grids. There is significant opportunity for lessening the effects of climate change through ICT products and services. However, scope for the sector's innovation potential still remains to be tapped through government and business initiatives.

Business Council for Sustainable Development (TERI-BCSD) developed a white paper called the "Corporate Action Plan on Climate Change" in 2008-09. It brought out a vision for the corporate sector under each national mission. It also presented the expectations of the corporate sector from the government in terms of policies and incentives that would help in achieving the roadmap for the industry. The white paper recognized the potential role of the Information and Communications Technologies (ICT) sector to not only address the climate change agenda but also augment implementation of NAPCC. (see Box 4)

NASSCOM Perspective 2020 report highlights that ICT industry has a key role to play in enabling a low-carbon society; the sector can enable emission reduction in number of ways

- Provide standardised information on energy consumption and emission across sectors
- Provide the capabilities and platforms to improve accountability in energy use and carbon emission

BOX 4 BUSINESS OPPORTUNITIES FOR ICT INDUSTRY TO ENABLE BUSINESS ACTION ON CLIMATE CHANGE

National Solar Mission: Extend reach of solar maps/data for beam radiations to potential developers and states under MNRE (Ministry of New and Renewable Energy) initiatives to prepare a Solar Atlas for India.

National Mission for Enhanced Energy Efficiency: Under implementation of energy-efficient technologies and practices, a range of technological options are available for the Indian industry sector ICT is a cross-cutting tool that is essential for reducing energy consumption in process plants and improve overall performance.

National Mission on Sustainable Habitat: City mapping for routing and GPS (global positioning system) tracking systems for vehicles to improve management of municipal solid waste.

National Mission for Sustainable Agriculture: Enable access to information through developing regional databases of soil, weather, agricultural practice, land-use patterns, and water resources to strengthen information dissemination at the farm level;. Using GIS (Geographic Information System) and remote-sensing methodologies for mapping vulnerable regions and pest/disease hot spots and managing risk.

National Mission on Strategic Knowledge on Climate Change: Provide organised-integrated information on agriculture produce, weather and demand forecasting to the farmers through mobiles.

Source TERI BCSD White Paper on Corporate Action Plan on Climate Change (2009)

- Offer innovations that capture energy efficient opportunities across commercial buildings and homes, transport, power, manufacturing and other infrastructure and provide alternatives to current ways of operating, learning, working and travelling.

NASSCOM Perspective 2020 report projected a demand for climate change solutions in 4 key areas –

- Smart Buildings;
- Smart Grids and software to design efficient power plants;
- Smart Transport e.g. efficient vehicles, traffic flow monitoring, etc.;
- Smart motors & Industrial Process automation.

Green IT practices by all accounts are no longer just buzzwords. With environmental concerns ranking high on the agenda of business leaders, 'Going Green' has become a priority for organisations the world over.

The Indian IT-BPO sector is actively participating in the 'Green' movement, increasingly focusing on issues such as energy conservation and on utilising IT to reduce the carbon footprint, enhance efficiency and business capabilities, improve productivity and preserve the environment. This imperative is also reflected in customers demanding more environment friendly products, and solutions to help them to setup Green Data Centres and drive energy efficiency in their facilities and core processes. Besides consciously creating more energy efficient products and services for customers, IT-BPO organisations in India are also working hard to establish Green Practices within their own organizations.

Green practices adopted by IT-BPO organizations for greater sustainability are on three pillars:

- **Facility Management** includes Green Buildings, Energy Efficient Cooling, Water Management, Efficient Lightings, Bio-Diversity, Renewable/Non-conventional sources of energy
- **IT Infrastructure Management** includes Energy Efficient PCs, Green Data Centre, Virtual Meetings, Cloud/Grid Computing, e-Waste Disposal
- **Processes & Practices** includes Energy Audits, Sustainability Reporting, Carbon Disclosure, Employee Awareness & promoting shared or public transport options

About the Report

With climate change posing a global challenge, adopting ICT solutions in various industries would be a win-win situation to reduce India's carbon trail thus, forming the basis of this report. Recognizing that climate change issues are not solely the responsibility of the government but of private companies and institutions too, TERI and its Business Council for Sustainable Development (TERI-BCSD) in association with NASSCOM, a premier trade body and chamber of commerce of IT-BPO industries in India, has developed this report titled "Sustainable Tomorrow: Harnessing ICT Potential".

This Report is aimed at assisting the society in reducing their environmental footprint. This can be done by effectively utilizing the know-how that was accumulated in various TERI-NASSCOM led consultative activities with ICT solution providers and their user industry. They are as follows:

- "Environmental footprint reduction of ICT" such as by making ICT equipment and data centres more energy efficient.

- "Environmental footprint reduction by ICT" that enhances energy efficiency of the society as a whole through the effective utilization of ICT.

The TERI-NASSCOM led initiative seeks to shape a national strategy to promote the role of ICT in reducing India's energy requirements. It encourages practices that promote a healthier environment without impeding the economic growth. This White Paper looks at the potential role that ICTs play at different stages. From mitigating its impact on the most vulnerable parts to developing long-term solutions, both directly in the ICT sector and in other sectors like power, transport, buildings and energy intensive industry sectors, ICT has become highly important in various arenas.

Why Green is important and where ICT can make an impact is clear to all stakeholders; however the problem which remains is what and how. There is a strong need of a clear roadmap for reduction of carbon footprint in India. In this area, India has the opportunity to take a lead and achieve the enhanced competitiveness in various sectors while reducing the carbon footprint. Against this background, the report recognizes the following aspects:

- The potential of the ICT sector is slowly gaining credence. Until now, its contribution has been narrowly viewed by policy makers, business and media. It has only been seen as part of the problem focusing on the sector's own carbon footprint and not the solution. This is however, now changing.
- Industry messaging on the role of ICT in climate change mitigation has largely focused on ICT industry audiences. This does not give any scope for discussion on its larger role as a sustainable development enabler.
- ICT opportunity remains untapped in the broader debate on climate change. The sector is still in the nascent stages of moving – on to external opportunities.
- ICT has largely focused on cost effective product enhancement and not necessarily driving energy efficiency. This industry is, at present yet to adequately quantify or communicate the association between productivity enhancement and energy efficiency.
- Lack of information on the potential of ICT use, on part of policy makers leave a lot wanting. Decision makers outside the sector are slowly becoming aware of its potential. But at the moment, with limited knowledge, they have the propensity to take decisions that do not tap the sector's full potential.

Against this backdrop, the report aims to:

1 Formalize a set of statements on the contribution of ICT in climate change, integrating the best views of leading ICT companies operating in India and independent area experts.

2 Provide the basis for an executive summary for review and approval by CEOs and ICT ministers at TERI's World CEO Sustainability Summit Annual Meeting. This will serve as a tool to gain agreement at the highest level of decision making with the ICT industry nationally.

This will also clarify the role of ICT within the broader context of climate change and sustainability initiatives. It will also strengthen global dialogue and understanding, as well as promote a more focused action plan.


L3

Power Sector

KEY MESSAGES

- Over 400 million people in India lack basic access to electricity, requiring additional power generating infrastructure. Peak demand shortage and average energy shortage runs in double digit. Total aggregate technical and commercial (AT&C) loss stands up to 27.15%. Depleting energy resources, enhancing access to energy, and ensuring energy-security are the major challenges facing the Indian power sector.
- ICT can lead to improvements of the efficiency, reliability and flexibility of all sub-sectors viz. generation, transmission, distribution, including the activities of Power Exchanges.
- The distribution sub-sector, which is presently the weakest link in the power supply chain, ICT interventions are taking place at a very slow pace. Cost-effective ICT interventions can improve the operational and financial performance of the entire power sector. An important enabler is Government of India's flagship program R-APDRP.
- ICT solutions enable one to monitor and control every kWh of power flowing through the system. Such a distribution system seamlessly interfaces with consumer equipments to signal pricing and grid stability conditions.
- Most of the ICT interventions in power distribution sub-sector like Advanced Metering Infrastructure, Advanced Distribution Operation including Distribution Automation and advanced controls, Asset management, Distributed Energy Resources integration, Improved interfaces and decision support, Regulatory Information Management system, Service Delivery Mechanism are at nascent stage of execution and thus the reform processes through ICT interventions needs to be expedited.
- An integrated deployment of ICT interventions yield benefits that more than when deploying them in piecemeal.
- To capitalize on smart power distribution network in India it is recommended that fiscal incentives for mass scale deployment of ICT solutions be provided. Mandate studies and preparation of feasibility reports on need based ICT applications bringing out the likely benefits and costs be done. And establishment of Regulatory Information Management System at central and state levels should be expedited.

Overview

India's power sector has shown impressive growth over the last few years .The total installed power generation capacity has grown from 1.36 MW in 1947 to 181.5 GW in 2010-11; and the gross electricity generated in 2010-11 was 811.1 billion units[1]. Despite such growth, India is currently experiencing a huge deficit between power supply and demand. During periods of peak use, there is a power shortage of 12.7%, and on average, there is an energy shortage of 10.1%[2]. As per the Ministry of Power's plan till 2011-12, India needs about 100,000MW of additional power generating capacity to match the requirement for electricity. Over 400 million people in India lack access to electricity, requiring additional power generating infrastructure. Depleting energy resources, enhancing access to energy, and ensuring energy-security are the major challenges facing the Indian power sector.

Apart from the increasing gap between demand and supply, the main challenge being faced by Indian power sector is the huge Transmission and Distribution (T&D) losses. The national average Aggregate Technical and Commercial losses (AT&C) were reported to around 27.15%[3] in 2009-2010.

1 CEA Energy Generation Report 2010-11.
2 MoP Website as on 4th Oct'11 for year 2009-10.
3 Highlights of the power sector; CEA monthly report for September'11

Some of the major challenges related to the power sector in India (Figure 1):

Access to Energy

- Over 400 million[4] people in India lack basic access to electricity
- Among those who have access to power; shortage to meet demand during peak hours is 12.7%, and average energy shortage is 10.1%

Aggregate Technical and Commercial (AT&C) losses:

- Transmission and Distribution (T&D) losses of 25.47% during 2008-09
- Energy theft due to the absence of energy auditing.
- Revenue management; i.e. Metering, billing, and collection.

Reliability of power supply

- Lack of adaptive protection system leads to frequent network disruptions
- Lack of a predictive emergency management system

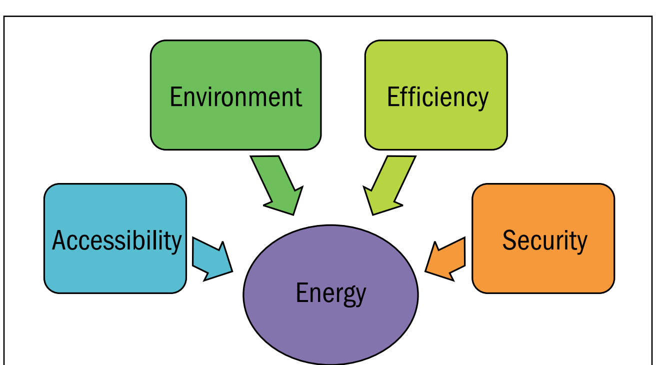

Figure 1 Challenges faced by the power sector in India

- Lack of proactive damage control and self-healing capabilities

Integration of renewable energy sources (RES)

- Necessity to accommodate different generations including intermittent power sources and storage options
- Necessity to accommodate bidirectional energy flow for net metering

Asset management system

- Lack of asset-mapping
- Lack of Enterprise Resource Planning (ERP)
- Lack of a Management Information System (MIS) for streamlining processes

Common protocol for operation

- Standards for compatibility of hardware and software need upgrading
- Lack of interoperability for unified control and communication

The challenges mentioned above underline the scope for improvement in all areas of the power supply sector; viz. generation, transmission, distribution, and utilization. ICT can enable the improvement of the efficiency, reliability, and flexibility of all these sub-sectors, including the activities of Power Exchanges.

ICT can lead to improvements in performance and efficiency in all sub-sectors. The generation and transmission sub-sectors have seen significant penetration of ICT and it is progressing further depending on the need. However, in distribution sub-sector, which is presently the weakest link in the power supply chain, ICT interventions are taking place at a very slow pace. At the same time cost-effective

[4] World Energy Outlook Report-2010

ICT interventions in distribution sub-sector can go a long way in improving the operational and financial performance of the entire power sector.

Recognising this, the Government of India has in recent years initiated a number of programs with special focus on distribution, which recognise the role of ICT. In fact, the thrust of Part A of the flagship program R-APDRP (Restructured Accelerated Power Development and Reforms Programme) is ICT application.

ICT- An enabler to address challenges in distribution sector

One possible solution to the existing challenges in the power sector is to move from a *static grid network* to a *flexible smart power grid*. Such a grid would provide enhanced observability, controllability, and process efficiency. To manage such a vast power network, it is essential to have a *decentralized intelligent control* system which would offer several advantages such as:

- *Increase the reliability, efficiency and safety of the power grid* by preventing outages, and reducing CO_2 emissions.
- *Deploy efficient metering, billing, and collection* by reducing commercial losses and power theft.
- *Allow self-healing* using real time information from embedded sensors and automated controls to anticipate, detect, and respond to system problems
- *Empower consumers:* Advanced communication capabilities will equip customers to exploit the benefits of real-time electricity pricing, incentive-based load reduction signals, or emergency load reduction signals
- *Ensure greater security*: Real-time information will enable grid operators to isolate affected areas and redirect power flows.
- *Accommodate multiple decentralized power generation systems* such as smart mini-grids.
- *Optimize assets* such as ERP, Resource Mapping, inventory management, and process streamlining.

All the above mentioned features require bi-directional information flow which can be realized by implementing ICT. The application of ICT is a pre-requisite for data exchange between different market players in the electricity supply chain to ensure secure, economic, and environmentally benign operations in smart power grids.

Possible ICT interventions in Power Distribution Sector

ICT in the power distribution sector is perceived as an enabler in delivering electricity from suppliers to end-consumers and enables energy saving, cost reduction, and increased reliability and transparency. There are several challenges in the existing power distribution system, but there are IT enabled solutions to tackle these problems. These solutions enable one to monitor and control every kWh of power flowing through the system. Such a distribution system seamlessly interfaces with consumer equipments to signal pricing and grid stability conditions (see Box 1). Some IT enabled power distribution systems which can potentially address existing challenges in the power sector are as follows

BOX I FUTURE GRID

In future, the distribution system may have advanced metering, robust communications capability, extensive automation, distributed generation and distributed storage. Through the integrated use of these technologies smart grid will be able to *self-heal, provide high reliability and high power quality, be resistant to cyber-attacks, operate with multi-directional power flow, increase equipment utilization, operate with lower cost and offer customers a variety of service choices.*

Advanced Metering Infrastructure (AMI)

Advanced metering infrastructure is a key component in a power distribution system. It enables utilities to constantly monitor and price electricity consumption in order to supply electricity more efficiently to customers. The key components of AMI are:

- Smart Meters
- Consumer portals
- Home Area Network (HAN)
- Meter Data Acquisition and Data Management system
- Customer service applications and operational gateway applications

AMI utilizes advanced digital meters (Smart meters) with two way communication, which are able to remotely connect or disconnect services, record wave forms etc and support time of use (ToD) and real-time rate structures. *Real-time rates will incentivize consumers to optimally manage their demand and thereby minimize peak power shortages and also improve performance of the sector*.

HAN can be used to smartly control the loads of a household through a local controller and communication system, which would manage the consumption in a cost-effective manner. See Box 2 and 3 for interventions and benefits accrued by North Delhi Power Limited (NDPL) recently renamed as Tata Power Delhi Distribution Limited and BSES respectively.

Distribution Automation

Distribution Automation (DA) refers to monitoring, control and communication functions related to different power system equipment. DA helps in monitoring the health of different power system equipment through remote/ automatic connect/ disconnect post analysis of the acquired data (electrical parameter). ICT application is key to the functioning of any DA system. IT enabled DA devices today can interrupt fault current, monitor current and automatically reconfigure the system to restore services to customers. The ability to quickly and flexibly reconfigure an interconnected network of feeders is a key component which can be possible through the ICT intervention. Thus, DA not only helps in increasing the reliability and flexibility of the whole power system but it also reduces the operation and maintenance cost thereby substantially increasing the life of power system equipment.

Demand Response

Demand response is the process where end-use customers are empowered to change normal consumption patterns in response to changes in the price of electricity. This also helps in containing the demand during peak hours but also provides economic benefits to the consumers and utilities.

BOX 2 AUTOMATIC METER READING (AMR) – A CASE STUDY OF NDPL, DELHI

North Delhi Power Limited (NDPL) – one of Delhi's power distribution companies, recently renamed as Tata Power Delhi Distribution Limited – distributes electricity in North & North West parts of Delhi and serves a population of 50 lakhs. In 2002, NDPL reported losses of approximately 53%. In an effort to reduce these losses, it focused on deployment of Automatic Meter Reading (AMR) technology. AMR technology works by using intelligent meters that capture and store various power supply parameters. These parameters then can be downloaded by the power company using an optical port node attached with the system, or by a remote server which can virtually talk with consumer's devices. The data collected can be analyzed to understand the consumer's usage pattern and to asses any inconsistencies in the consumption. Deviations from the consumption pattern can help provide crucial leads on possible fault or theft. Intelligent meters are tamper-proof and as there is no manual involvement in the process, it helps to overcome human error. This insures greater accuracy in the bills generated. AMR technology thus helps by:

- Providing accurate meter readings
- Giving improved billing accuracy
- Improving security and tamper detection
- Devising energy management through user profiles
- Saving financial cost of correcting mistakes

Simultaneously, consumers can use their consumption and billing data for budgeting and load planning. The billing of all Large Industrial Power (LIP) and Single Point Distribution (SPD) consumers of NDPL has been connected to a remote server. Thus, the data can be downloaded and monitored by the utility remotely. To increase transparency, the company has provided consumers access to the data collected from their meters over the internet.

In second half of 2009, NDPL started experimenting with Advance Metering Infrastructure (AMI) by installing smart meters in 500 households throughout Delhi. NDPL also collaborated with IBM for technology solutions to Advance Metering Infrastructure (AMI).

Source: Official interaction + NDPL website

BOX 3 IMPACT OF AMR TECHNOLOGY – A CASE STUDY FROM BSES

BSES is a power distribution utility in Delhi, with a consumer base of about 28.31 lakhs (which includes more than 2.5 lakh non-domestic and industrial consumers). When they started in July 2002, BSES recorded a 63% AT&C loss. Thus, the utility started exploring different options for reducing its losses.

The Company decided to install intelligent meters for both three-phase and single-phase consumers. The three-phase meters are capable of capturing eight supply parameters (three of them voltage related, three current related, and two power related) on a half-hourly basis. It is also stored the last 50 events. This data can be downloaded from a meter using a hand-held computer (HHC) with the help of an optical connector. The HHC has a life span of 3 - 4 years in field conditions and costs approximately INR 30,000. The HHC is platform independent, and thus can work on DOS, Mac, Windows, and Linux-based operating systems. The implementation of AMR in the distribution network reduced the annual AT&C losses from 60% to 15% within 8 years, which translates to a year-on-year reduction of 14.9% in AT&C losses.

Source: Official interaction

RE based Smart Mini-Grid System

In recent years, the option of integrating different distributed generation (DG) technologies together more intelligently through IT enabled tools and techniques and providing power in grid-connected as well as isolated modes has gained attention. Such an application with resource optimization and intelligent demand management will foster effective inter-connection and utilization of multiple renewable energy resources, and advance access to energy by improving the efficiency of the overall system (see Box 4 for case on smart mini-grid system of TERI). The role of ICT in the whole process from site selection, design, development, deployment, system operation to grid integration is the key to successfully harnessing the resources to its full capacity.

Such Smart Mini-Grid system has a large potential not only in large commercial and industrial complex but can also be established in hospitals, shopping malls/ complexes, apartments, residential complexes, educational institutions and locations that are either un-electrified or electrified. This ensures maximum flexibility, reliability and safety with enhanced efficiency of the overall system.

India has about 20,000MW[5] of captive power plant for mostly small industrial companies. These captive power plants can be supplemented with Smart Mini-

BOX 4 SMART MINI-GRID SYSTEM – A CASE STUDY FROM TERI

TERI has designed, developed, and demonstrated a unique Smart Mini-Grid system. The objective is to use the smart controls to optimally use the different distributed energy resources along with the intelligent management of loads to improve the efficiency and reliability of the overall mini-grid system.

The Smart Mini-Grid, built with the support of the Ministry of New and Renewable Energy (MNRE), was recently inaugurated at the TERI Retreat in Gual Pahari, Gurgaon. TERI's Smart Mini-Grid facility combines various Distributed Energy Resources (DERs); a 3.3 kWp wind generator, a 1 kWp thin-film solar PV, a 12.5 kWp solar PV, a 100 kWe biomass gasifier, a 600 Ah, 48 V storage battery, and a diesel generator. The diesel generator has been added to the system to meet the intermittency of the renewable resources and hence ensure reliable power supply.

The system is based on the integration of these multiple DERs into the same grid. It is designed with local controllers for each of the DER as well as a central controller called Intelligent Dispatch Controller (IDC). Whereas the local controllers ensure maximum utilization of energy resources with permissible output power, the IDC performs complex system control functions and takes critical decisions such as automating the demand response, dynamically adding or removing DERs in a seamless manner (based on the existing demand) without affecting the grid stability. The system also has the capability to respond automatically to network problems and minimize network disruptions.

With the integration of digital and automation system, it is observed that the number of occurrence of the brownout has been reduced and the reliability of the overall system has improved.

Source Official interaction

[5] Proceedings of the International conference on the Smart Grid Vision For India's Power Sector, USAID, India

Grid system in order to reduce the diesel consumption and thus the reduction in the GHG emission. Whenever feasible, these systems can also be connected to the utility grid.

Similarly, presently there are around 3, 30,000 telecom shelters in India and by 2012, this number would increase to approximately 500,000. Considering the fact that each telecom shelter consumes about 11,000 to 20,000 litres of diesel per annum, 500,000 shelters would consume approximately 5.3 billion litres of diesel. The Smart Mini-Grid system has a huge potential to contribute to reducing diesel consumption in the telecom shelter, and thus to contribute to the overall reduction in the GHG emission.

Improved interfaces and decision support

Improved interfaces and IT based decision support systems provide operators with the tools and techniques required to operate the whole process of power distribution in an efficient and economical way. These systems help in synthesizing the large amounts of acquired data in order to generate relevant information. Based on this information, different alternative course of actions are devised. On a systematic comparison, they provide the most optimum decision in a very quick time. It also helps in translating these decisions in action by helping in smooth and reliable interface with other equipment of power system.

Integrated IT enabled smart distribution system

In order to exploit the full potential of these ICT interventions (AMI, DA, DERs), they need to be integrated together as the benefits of an integrated deployment are more than when deploying them in piecemeal. Much of the integration of functions relates to communication systems, IT systems and business processes.

Integrated ICT enabled interventions can bring many benefits. Table 1 gives the overview of such interventions in power distribution sector. And, Table 2 gives a status of such interventions if they are being employed in Indian power sector.

As shown in the above table, although many of the interventions have started, but it has either been started by few utilities only or done by different project developers as pilot demonstration projects. Most of the interventions are at nascent stage of execution and thus the reform processes through ICT interventions needs to be expedited.

Impact of ICT intervention in the Power distribution sector

Above sections has underlined the role of ICT as an enabler for rapid transformation of power sector to a financially viable, technically smart, and environmentally sustainable proposition. It can improve the performance of power sector by facilitating the deployment of decentralized intelligent control by means of a robust, reliable and cost effective communication system as well by helping in the effective, intelligent integration of renewable energy resources. The quantification of impact of ICT intervention is difficult.

Recommendations

Any recommendation to capitalize on smart power distribution network in India should build on India's

TABLE 1 OVERVIEW OF OPPORTUNITIES FOR ICT INTERVENTION IN POWER DISTRIBUTION SECTOR

Major components of power distribution	Opportunities for ICT sector	Impact /Benefits
AMI and DR	Smart Meters Consumer portals Home Area Network (HAN) Meter Data Acquisition and Data Management System Energy Audit Customer service application and operational gateway applications	Assist revenue management Empower consumers Reliable supply
Advanced Distribution Operation including Distribution Automation and advanced controls	Developing analytical tools and operational applications using different programming techniques for power system automation and controls System Health Monitoring through operational data collected in real-time	Enables self-healing Improve sales Reduced operation and maintenance (O&M) cost Reduced manual interventions
Asset management	Developing central database of information GIS mapping of power line and power system equipment Enterprise Resource Planning (ERP) Management Information System(MIS) Resource optimization	Resource Management Inventory Management Process streamlining Locating leakage and checking conductor theft Quick restoring the services post damage/ outage
Distributed Energy Resources (Smart mini or micro grid)	Site-resource mapping Techno-economic assessment Resource forecasting, resource optimization Intelligent load and resource management Scheduling import/export from grid	Augmenting/supplementing existing grid Loss reduction and improve voltage profile Increase the reliability of the distribution system Reduction in GHG emission
Improved interfaces and decision support	Developing visualization techniques and format for easy understanding of complex data Devising alternatives intelligently	Quick and right decisions
Regulatory Information Management (RIM) system	Centralized document repository containing union and state regulations and supplemental documents Compliance Assistance System Infrastructure	Easy access to required documents Specialized module for specialized application Centralized monitoring system for compliance with regulatory standards
Service Delivery Mechanism	Enabling different modes of billing (e-billing, m-billing) and collection Fault Monitoring System SMS based alerts about services (outages, maintenance, billing etc.)	Empower customers Streamline the service delivery

TABLE 2 STATUS OF DIFFERENT ICT ENABLED INTERVENTIONS IN THE POWER DISTRIBUTION SECTOR

ICT enabled intervention	Status
Distribution Automation	Implemented by many utilities; not universally done by all utilities
Automated Meter Reading (AMR)	Implemented by few utilities ; not universally done by all utilities
Advanced Metering Infrastructure(AMI)	Carried out in pilot scale by few utilities
Broad band over power line(BPL)	Just started by few utilities
Advanced billing and collection system	Just started by few utilities
Network asset management	-
Smart grid pilot rollout	-
Distributed Energy Resources/Smart Micro-grid	Demonstrated at pilot scale
Central database of information at utility level	Not available
Standard communication protocol	Being prepared

continuing efforts to increase accessibility, reduce AT&C losses, improve reliability, enhance efficiency, and ensure the safety and security of the overall system. Based on different source of information gathered through interviews, interactions and consultation, the following are the recommendations for different stakeholders expediting the implementation of ICT enabled smart grid system in India. In order to expedite the ICT penetration in power sector:

Policy makers and Regulators

- Provide fiscal incentives in the form of tax and duty breaks to the industry for mass scale deployment of ICT solutions
- Mandate studies and preparation of feasibility reports by utilities along with ICT companies on need based ICT applications in different parts of the network bringing out the likely benefits and costs
- Expedite the establishment of Regulatory Information Management System at central and state levels

ICT Industry

- Develop cost-effective ICT systems suited to the divergent needs of different utilities
- Spread awareness among the end-users about the benefits of ICT interventions and energy conservation

End Users

- Deploy cost-effective ICT systems available in the market for improved energy efficiency and reduction in operational costs


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Road transport sector

KEY MESSAGES

- The transport sector is experiencing an increased share of personal motorized traffic, which has impacts in terms of growing traffic congestion, travel time, road accidents, pollution and most of all high dependence on fossil energy.
- Within the transport sector, the road sector is the largest consumer of commercial fuel energy; it accounts for nearly 35% of the total liquid commercial fuel consumption by all sectors. Within the road sector, cities represent a significant proportion of energy consumption due to concentration of transportation activities within their administrative boundaries.
- Mitigation strategies needed to reduce energy use. ICT sector can enable implementation of such actions in a more safe, efficient and faster manner.
- The ICT applications that can yield significant energy reduction benefits and which can be implemented with immediate effect include vehicle tracking systems to manage freight and public transport fleets; intelligent traffic management solutions in urban areas; and ICT applications to make public transit services efficient and convenient to use for commuters.
- There is a need for a multi-pronged strategy to promote the use of ICT applications in road transport sector.
- Enabling policy environment, supporting infrastructure, awareness generation, institutional arrangements, capacity building, funding and research and development are required for large-scale implementation of ICT applications in road transport sector for which key stakeholders like government (at centre/state/city level), ICT industry and private sector need to work together.

Greenhouse gas emissions from transport sector: a global challenge

The transport sector in most of the developing countries is experiencing an increased share of personal motorized traffic, which has impacts in terms of growing traffic congestion, travel time, road accidents, pollution and most of all high dependence on fossil energy. According to IPCC (2007), 95% of the total energy used in transport sector globally comes from a single fossil resource, petroleum. The sector was responsible for 23% of the world's energy-related GHG emissions (6.3 Gt) in 2004, about three quarters of which came from on-road vehicles. Sector's GHG emissions have increased at a faster rate than any other energy using sector during the last one decade. According to the World Energy Outlook 2009, global energy-related CO_2 emissions are expected to increase to over 40Gt by 2030, of which emissions from transport sector would be around 9Gt (more than one-fifth) despite significant mitigation policies built into the reference scenario. Transport sector will continue being the second largest energy consuming sector after industry and will be responsible for 60% of the world's liquids consumption by 2035. As per the estimates of the International Energy Agency (IEA), emerging economies like China and India will drive this growth in transport sector's energy consumption.

The Indian scenario

The transport sector in India is facing trends similar to the other developing countries. Witnessing a growth rate of 7.3% and 5.8% per annum between 1980-81 and 2004-05 in the consumption of petrol and diesel, respectively, the sector meets 98% of its energy requirements from petroleum products. Within the transport sector, the road sector is the largest consumer of commercial fuel energy; it accounts for nearly 35% of the total liquid commercial fuel consumption by all sectors. This has primarily happened due to emergence of the road sector as the most dominant means of surface transport, both in terms of passenger and freight traffic (Figures 1 and 2). Within the road sector, cities represent a significant proportion of energy consumption due to concentration of transportation activities within their administrative boundaries (Figure 3). On-road passenger transport activities in just 23 million-plus cities in India had a share of about 25% in country's total on-road passenger transport activities in 2001 (Ghate and Sundar, 2011). The current share of cities in energy consumption of road transport is expected to increase very rapidly, if the current trends of motorization continue. These trends raise serious concerns about energy security and climate change issues that need to be addressed urgently.

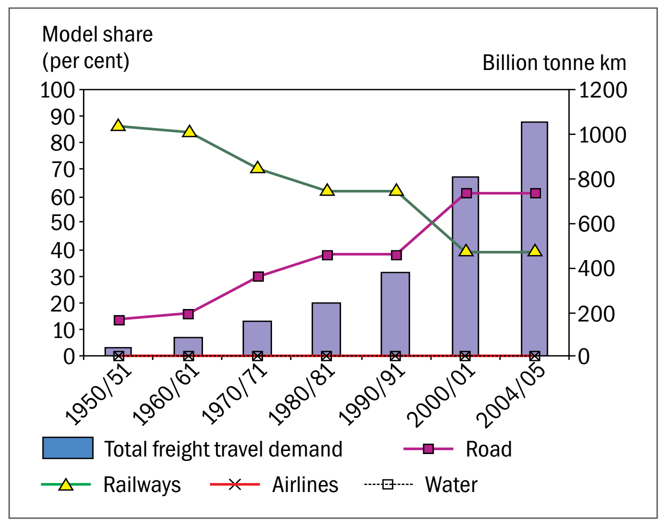

Figure 2 Trends and model shares of different modes in freight traffic
Source Sundar and Ghate, 2011

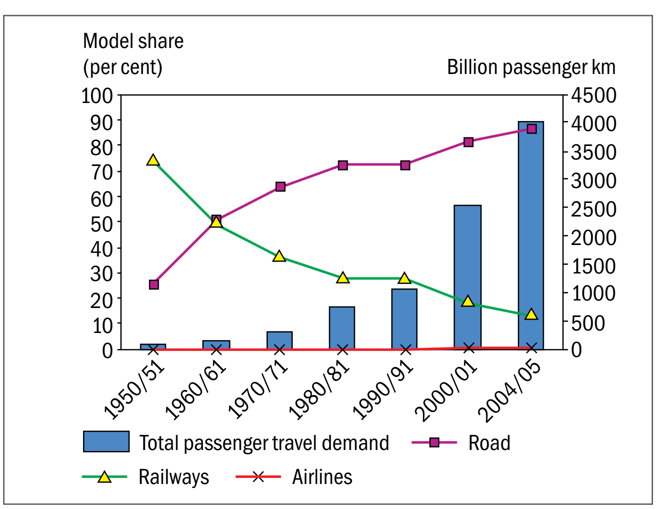

Figure 1 Trends and modal shares of different modes in passenger traffic
Source Sundar and Ghate, 2011

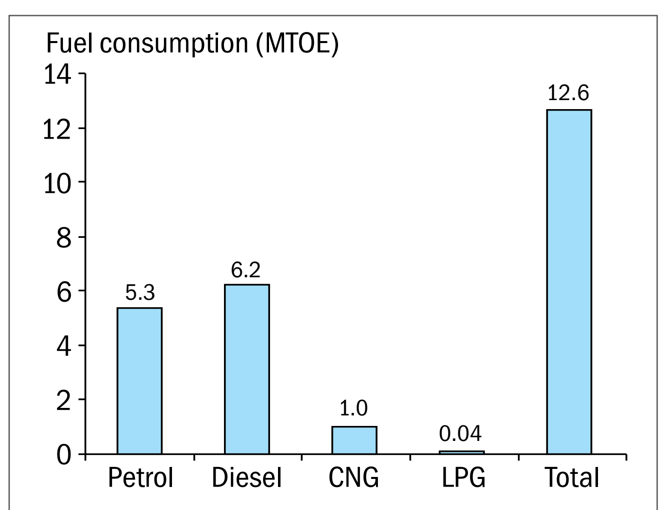

Figure 3 Estimated Fuel Consumption from motorized transport activities in 23 million-plus Cities (2001)
Source Sundar and Ghate, 2011

Strategies to reduce energy consumption in road transport sector in India

The above discussion clearly indicates that any effort/s towards reducing energy consumption/emissions from transport sector would essentially have to prioritize interventions for road sector, for inter-city and intra-city movement. India's National Action Plan on Climate Change also targets the same and promotes actions that would influence energy efficiency and help reduce emissions from road transport sector. Some of the key strategies that need to be adopted include:

At national level:

- Shifting road based movement of passenger and freight to railways
- Establishing fuel economy standards for the vehicles
- Laying out a clear roadmap for emission standards in future
- Promoting clean alternative fuels and technologies
- Establishing a robust mechanism for periodic inspection and maintenance of in use vehicles
- Phasing out old vehicles

At urban level:

- Practicing integrated transport and land use planning
- Improving and augmenting public transport and non motorized transport systems (both in terms of capacity and quality)
- Discouraging the use of personal vehicles by using appropriate policy and planning instruments
- Ensuring efficient movement of traffic and reducing congestion by implementing/using relevant traffic demand management measures and technologies
- Using information technology as substitute to physical mobility

While implementation of several of the above listed interventions is dependent on formulation of appropriate policies and regulations at central/state level, many interventions can be implemented with immediate effect. It can also be observed that use of Information and Communication Technologies (ICT) can enable easy and efficient implementation of many interventions listed above. Use of ICT in improving road transport operations has not been practiced much in India. The sector, however, has a huge potential to address many concerns related to inefficient operations in road transport and consequently reduce its energy consumption.

ICT applications for road transport sector: a key enabler for reducing energy consumption from the sector

As stated, ICT has a tremendous potential in terms of improving the road transport operations and hence can lead to reduction in the energy consumption. Specifically, in large urban centres where the road transportation activities are concentrated, ICT has a huge potential to improve the existing inefficiencies.

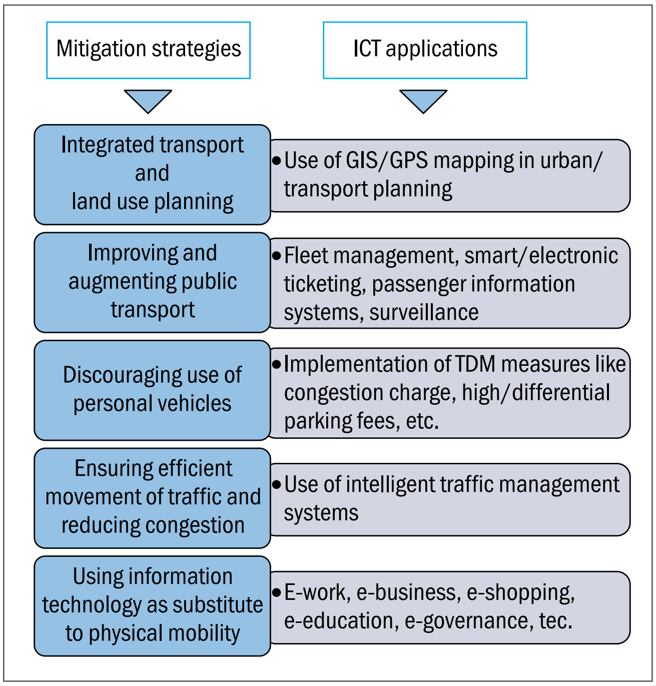

Figure 4 Use of ICT in implementing city level mitigation strategies

If we re-look at the city-level mitigation strategies listed above, we find that ICT can enable efficient, faster and large-scale implementation of most of the listed mitigation strategies (Figure 4). The subsequent sections discuss some of the readily available and used ICT technologies for improving road transport sector efficiency.

Global carbon saving potential of ICT applications

- Global carbon equivalent emissions in 2020 (BAU) – 51.9 $GtCO_{2e}$
- Reduction possible through use of ICT in all sectors – 15% (7.8 $GtCO_{2e}$)
- Reduction possible through use of ICT in transport sector – 4% (2.2 $GtCO_{2e}$)

Source: SMART 2020 report by GeSI

Intelligent/smart traffic management by use of real-time information

"Intelligent Transport Systems (ITS) may be defined as systems utilizing a combination of computers, communications, positioning and automation technologies to use available data to improve the safety, management and efficiency of terrestrial transport, and to reduce the environmental impact" (International Telecommunication Union, 2007). The main focus of ITS is to make transportation services effective and customer friendly by targeting management and operations of the roadway system i.e. handling traffic control, travel demand management, and operation and maintenance of roadway system.

Intelligent traffic management systems deploy several technologies (figures 5 and 6) which help in capturing real-time traffic information. Data collection involves continuous monitoring (surveillance) of network locations to determine the traffic movement and monitoring obstacles in the road network. The monitoring is done with strategically located sensors or television cameras i.e. through video cameras and/or aerial surveillance (helicopter), fixed sensors and vehicle probes. The surveillance system includes Automatic Vehicle Location System (AVLS), automatic number plate recognition, wireless tele-communications etc. (CII-DESC, 2010; Black, Geenhuizen, 2006). The public and private agencies aggregate and analyse the data received from these surveillance systems into information to be disseminated to the operators and public through different mediums, which can be used for journey planning, managing traffic, etc. (Ezell, 2010).

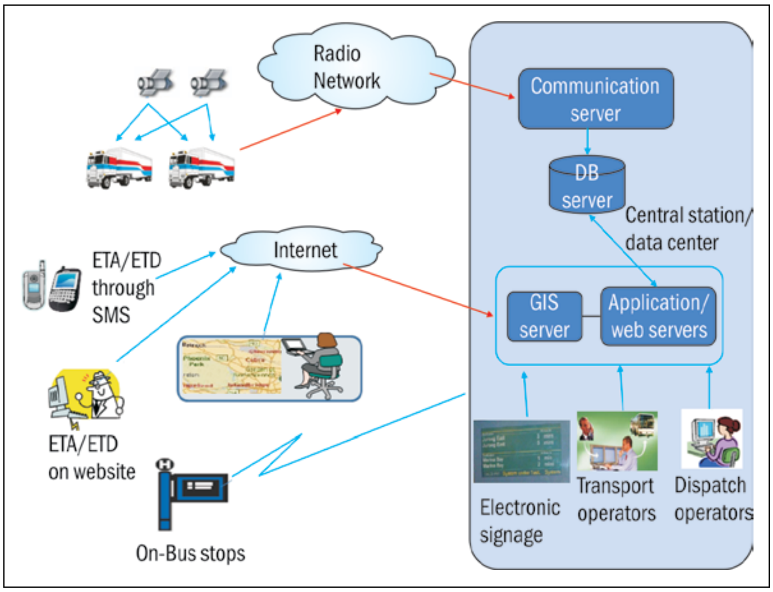

Figure 5 ITS System overview
Source CMC Limited

Smart traffic management technologies using real-time traffic information help in:

- **Traffic management/congestion reduction:** Real-Time Information Systems (RTIS) can be used for effective operations of traffic signals based on given traffic conditions. Traffic signals' synchronization allows a series of signals on a street to turn green according to recorded levels of congestion. It is a cost effective way to reduce overall stops and travel delays[1] by decreasing the amount of vehicle idling time (Black, Geenhuizen, 2006). Use of this technology holds a

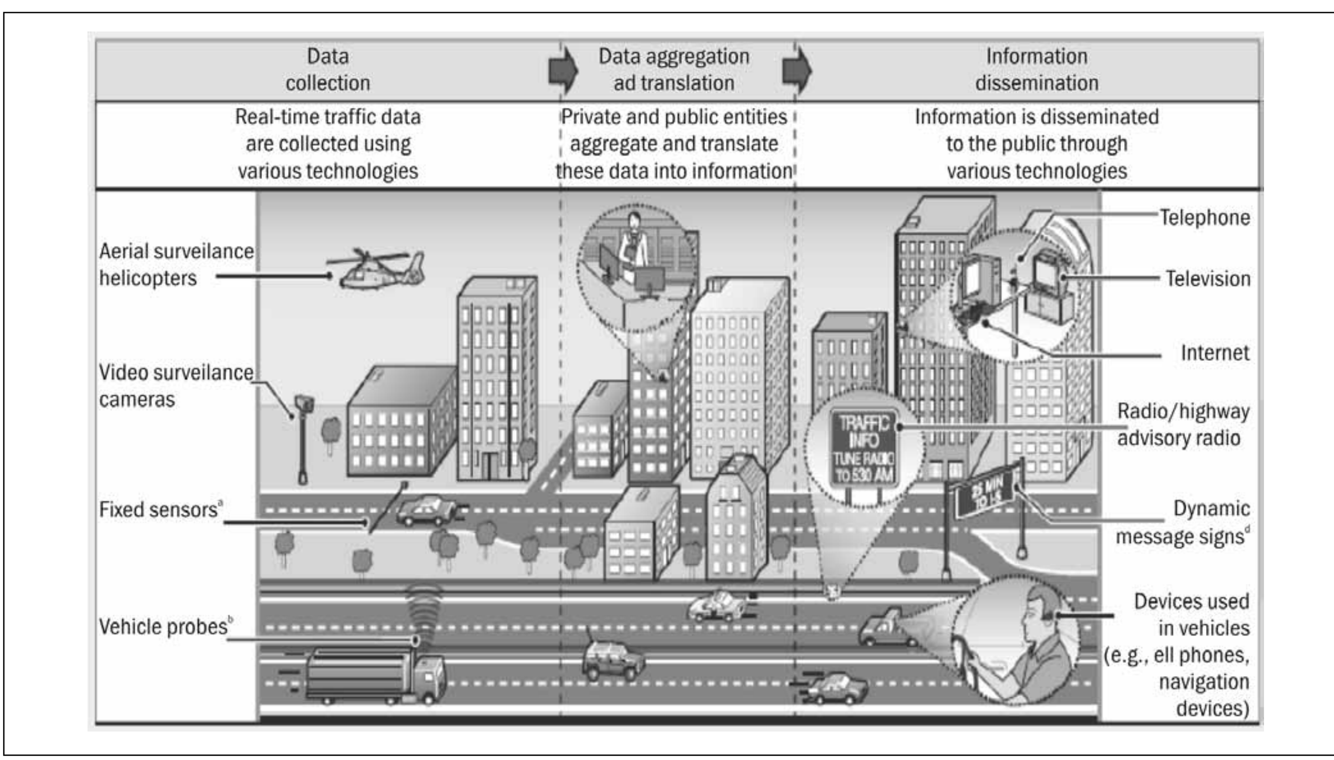

Figure 6 Example of technologies associated with collecting real-time traffic information
Source Ezell, 2010

[1]http://www.octa.net/uploadedfiles/Files/pdf/ocsignals.pdf <Last Accessed on September 3, 2011>

Congestion increases fuel consumption and emissions

Road congestion doubles fuel consumption and magnifies the environmental impact of exhaust emissions by a multiple of two to four.

- Fuel consumption
  - Gasoline vehicles, operating Speed:
  - (Normal) 40 km/h - 69 cc/km
  - (Congested road conditions) 10 km/h - 170 cc/km
- Comparison of emissions volumes for heavy diesel vehicles running at different speeds (5 km/h vs. 40 km/h)
  - NO_x: approx. 3:1
  - CO_2: approx. 2:1
  - CO: approx. 4:1

Sources: http://www.toyota-global.com/sustainability/sustainability_report/pdf_file_download/99/pdf/p66_67.pdf
SMART 2020 report by GeSI

huge potential in large Indian cities, where traffic congestion levels and idling time of vehicles is very high leading to significant energy losses.

A study carried out by the Central Road Research Institute (CRRI) in 2005 helps understand the scale of energy losses due to idling at intersections in Delhi.

The study concluded that about 0.13 million litres of diesel, 0.41 million litres of petrol and 0.37 million kg of CNG are being burnt every day due to the idling of vehicles on the intersections of Delhi (Parida and Gangopadhyay, 2008). This translates into monetary losses of about Rs. 9944.6[1] million per annum (Table 1). These losses are increasing daily as more than 1000 new vehicles get added to Delhi's roads daily. Similar energy losses can be expected in other large urban centres of the country facing rapid motorization and increasing congestion levels.

As discussed above, ICT applications like synchronization of traffic signals using Area Traffic Control Systems, installation of vehicle actuated traffic

Table 1: Annual fuel losses due to idling at intersections in Delhi

Intersection volume	*No. of intersections*	*In million litres*			*Million Rs.*
		CNG	*Diesel Petrol*	*Petrol*	
Low	69	8.4	1.4	7.6	504.1
Medium	118	17.7	5.0	18.1	1215.5
High	413	109.7	41.0	122.1	8224.9
Total	600	135.9	47.4	147.8	9944.6

Note: CNG is in million kg
Source: Parida and gangopadhyay, 2008

[2]*Based on fuel prices in October 2005.*

signals, and optimization of signal cycle timings can facilitate efficient/smooth traffic flows and reduce idling, hence contributing towards reduction in quantum of fuel losses. Mumbai has recently introduced a Modern Traffic Management System using these technologies (box).

Modern traffic management system, Mumbai

A modern Traffic Management System has been introduced in Mumbai as part of World Bank supported Mumbai Urban Transport Project (MUTP) to ease congestion on roads. The technology chosen helps in adjustment of traffic signals as per the given traffic conditions, thereby providing efficient traffic flow and reducing congestion. More than 600 high-tech cameras have been installed to remotely monitor 220 junctions and sensors have been installed beneath the surface to intelligently monitor traffic flow.

Source: World Bank in India Newsletter, May 2011

Transport operations and management plan by Lavasa

Lavasa, a hill city planned in the state of Maharashtra has planned to use 3D-enabled Geographic Information System (GIS) combined with Global Positioning System to assist in traffic management.

- **Trip/journey planning:** Satellite based navigation systems have been used successfully in several countries and have a huge potential in Indian cities, especially due to the high number of mobile phone users in cities and the introduction of 3G technologies.[3] These systems use in-vehicle GPS devices (with a display screen) to receive detailed instructions en route to plan journey efficiently while avoiding congested stretches/taking shortest routes (Black, Geenhuizen, 2006). In the Indian context, mobile telephones can substitute the GPS devices/in-vehicle display screens and help in faster penetration of technology at lower costs. The navigation systems help in choosing shortest paths to avoid congested stretches in order to reduce energy losses.

- **Demand management:** ICT technologies have the potential to be used for efficient implementation of several demand management measures like congestion pricing/electronic road pricing, parking management (including parking fee payment), collecting tolls, etc. Latest technologies like Smart Dust are being used for the same. The Smart Dust technology comprises of small wireless sensors or motes in which each mote carries a tiny computer (composed of processing unit and memory) with one or more sensors and a communication system to wirelessly connect with other devices in the range (Steel, 2005, Arief, n.d.). The Smart Dust devices use Radio-Frequency Identification (RFID) technology which enables automatic identification and tracking with the help of radio waves.

Like London, many Indian cities like Delhi, Mumbai and Kolkata have been planning to initiate congestion charging in the central business districts. ICT

[3] *4G technology has also been started to get used to the efficient fleet management. City of Charlotte, North Carolina will be among the first city to* deploy 4G Long Term Evolution (LTE) technology that can profoundly improve the effectiveness of the first responders. This implies that local emergency workers like police officers, fire fighters and emergency medical teams will respond to critical situations quicker and better. Alcatel Lucent has been chosen to deliver an advanced wireless broadband public safety network for the same.

Congestion charge in London's central business district

Congestion charging in London's central business district is a good example of ICT application for efficient implementation of the traffic demand management measures (congestion charging, in this case). There is a network of 197 camera sites which monitor traffic at exit and entry points to the congestion charging zone. All cameras have an integrated Automatic Number Plate Recognition (ANPR) computer system that encrypts the images and transmits these to the central data centre where the images are checked against a database to work out whether the user needs to pay the congestion charge. Congestion charge is then implemented through the automated payment system, which bills the congestion charge to the vehicle owners. Alternatively, road users can also pay their congestion charge through online payment portals.

Congestion charging in London's central business district has resulted in fuel savings of about 44 million litres in one charging year.

Source: Transport for London

applications like the ones used in London can help implement the same in an effective and efficient manner.

ICT application for intelligent/ smart public transport

Intelligent Public Transport Management (IPTM) uses ICT applications to make public transport operations more efficient and customer-friendly. The ICT systems enhance the efficiency by optimizing the delivery of transit services; applications include computerized timetabling, dispatch and rostering, fleet monitoring, and intelligent control systems. It also targets disseminating real-time/comprehensive information of public transport operations to the users, which help them to make modal choices and trip decisions[4] (Button & Hensher, 2001). Some of the key ICT interventions used in IPTM to improve public transport service levels are discussed below[5] (CII-DESC, 2010):

- **Public transport fleet management:** It involves managing the public transit fleet with the help of AVLS and Surveillance by CCTV cameras. AVLS employs one or more technologies to track vehicle location (Casey, 1998) (Figure 7). Surveillance helps in anticipating/detecting violence and ensuring security of commuters.[6] It can also help in collecting real time data on traffic situation (NTDPC, 2011). The information collected with the help of mentioned technologies is received by control centres, which disseminate the estimated arrival/departure time of the public transit fleet at various locations. The various mediums used for information dissemination include internet, display screens, SMS or WAP services.
- **Electronic ticketing:** It involves developing advanced and easy ways of collecting public transit fares by payment services like common mobility card and smart cards. Smart cards are contactless cards used for automatic

[4] http://www.calgary.ca/portal/server.pt/gateway/PTARGS_6_0_771_217_0_43/http%3B/content.calgary.ca/CCA/City+Hall/Business+Units/Transportation+Planning/Transportation+optimization/What+makes+up+Intelligent+Transportation+Systems.htm(Last Accessed on August 5, 2011)

[5] http://www.acet-uct.org/research/research-projects/intelligent-transport-systems/(Last Accessed on August 19, 2011)

[6] Delhi Government is planning to install CCTV cameras in DTC buses to check harassment of women and petty crimes and also to collect real-time data on traffic situation.

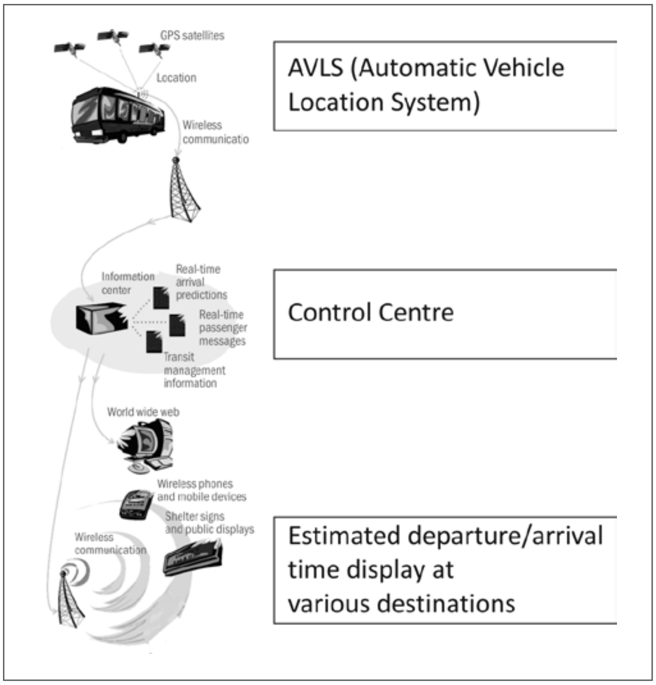

Figure 7 AVLS used for Intelligent Public Transport Management
Source CMC Limited

fare collection. It is cash-less transaction with complete security, which also reduces the waiting time for ticket collection. These cards offer passenger convenience as they need not buy tickets everyday for mass transit services. Smart cards that can be used across different public/para transit modes make inter-modal transfers even more convenient for commuters and help in making these modes attractive to commuters.

Use of ICT applications in public transport systems as discussed above, leads to improvement in overall efficiency while also making the systems more commuter-friendly and attractive for users. It may be difficult to attribute the benefits of a well-designed

Automatic Fleet Management System (AFMS) for Delhi Transport Corporation using GPS and GIS

Delhi Transport Corporation (DTC) is one of the largest city Road Transport Undertaking in India with a fleet of around 15,000 vehicles. It operates city and inter-city services on 800 routes from 33 depots spread all over Delhi. CMC Ltd. has designed, developed and implemented the Automatic Fleet Management System for public transport (AFMS) which is currently operational from two depots for 200 buses, since last two years. The AFMS includes vehicle tracking system, software for billing, operational transportation model for scheduling of buses, integration of smart card reader with the vehicle tracking system, and real time passenger information system within the buses at major terminus.

Vehicle tracking system for Andhra Pradesh State Road Transport Corporation (APSRTC)

CMC Limited has developed and deployed a vehicle tracking and Real-time Passenger Information System (RPIS) for APSRTC which assimilates state-of-the-art technology: GSM/GPRS and GIS. The system allows APSRTC to track the buses by displaying the information on a digital map at the control centre. The drivers can both send and receive digital messages to the RPIS control centre which is displayed in Telugu and English on the vehicle-mounted unit. The pilot implementation of RPIS included 26 buses within Hyderabad and 49 buses operating between Hyderabad-Vijayawada and beyond. Vehicle-mounted units have been installed in these buses. The display boards located at Hyderabad, Suryapet, Kodad, and Vijayawada provide information about arrival of buses, type of services and number of seats available in the approaching bus..

[8]ICT as an Enabler for Smart Water Management, ITU-T Technology Watch Report, 2010.International Telecommunication Union, <www.itu.int/dms_pub/itu-t/oth/23/01/T23010000100003PDFE.pdf> assessed August 2011.

public transport system to its components (better buses, use of smart technologies, fare policies, rationalized routes etc.), it is to be understood that all such elements including ICT use are critical for success of the public transport systems.

Use of ICT in Janmarg-Ahmedabad BRT system

There has been a recent positive trend of using ICT in the new public transport systems being implemented in Indian cities; Ahmedabad BRT is a good example of the same. Ahmedabad's Bus Rapid Transit Service (BRTS) 'Janmarg' was launched in October, 2009. IT components used in the system include (Figure 8).

- Operations Control
- Automatic Vehicle Tracking System
- Electronic Fare Collection
- Real-Time Passenger Information System
- Traffic Management (ATCS)

The AVLS displays real time information for tracking the fleet. It helps in tracking the buses, the current time schedule of the buses, their speeds etc. The bus stations use RFID technology which is specially designed to synchronize the opening and closing of bus and station doors. The bus gates open for boarding and de-boarding for passengers when the

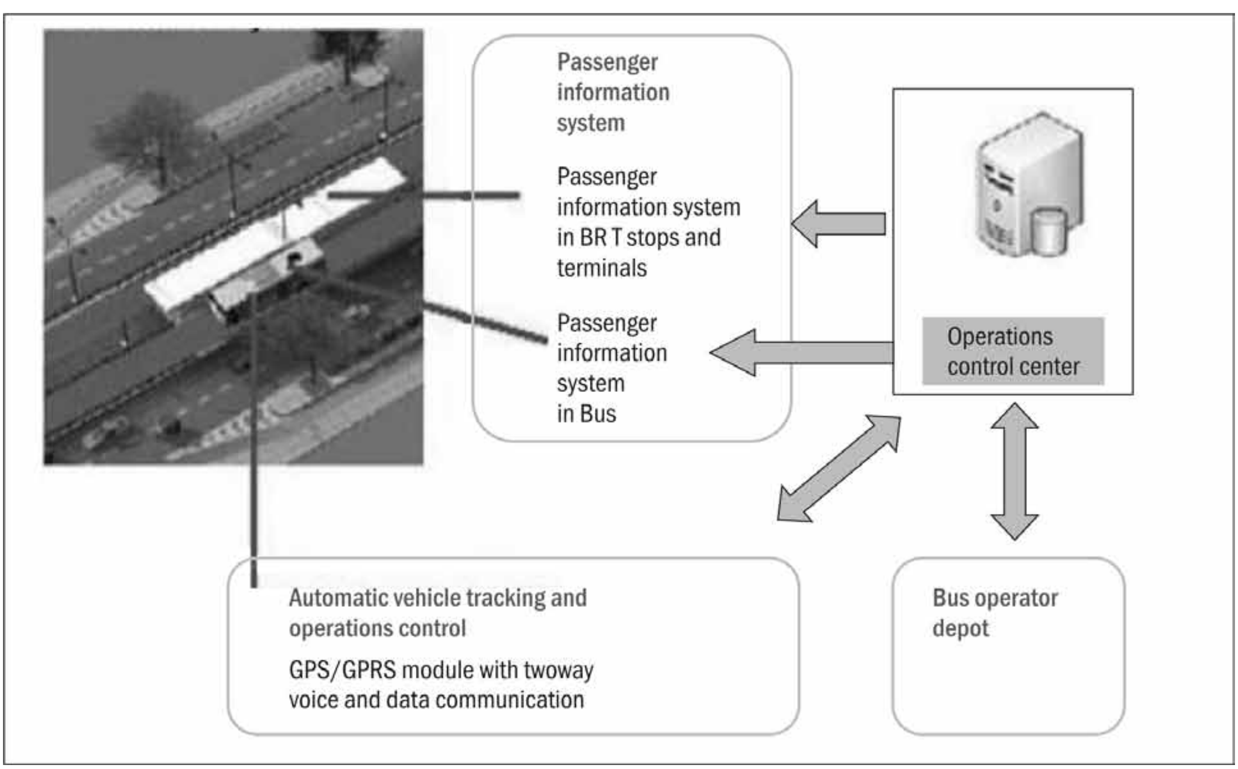

Figure 8 Use of ICT applications in Ahmedabad BRT
Source NIUA

RFID tags of the bus come in contact with the tags located on the station glass doors. The use of smart cards for ticketing is in the pilot phase.

The use of ICT applications has undoubtedly contributed to the success of the system. Overall, the system has been running successfully and able to generate significant benefits as compared to the pre-BRT situation in the city (Table 2).

Replicating Janmarg experience in other cities

Janmarg, one of its kind successful examples in India, is a source of learning for other cities for BRTS planning. Currently, 9 cities in India are planning/ implementing the BRTS system. It is expected that these cities would also be using ICT interventions in the BRTS systems as has been done in Ahmedabad; this will be critical for the success of these projects.

The ICT solutions used in Ahmedabad need to be promoted and other cities need to be made aware of their success in order to ensure replication.

ICT application for intelligent/ smart freight management

Freight Management: Freight management systems use ICT applications to improve the reliability, service quality, and efficiency of the commercial vehicles. This is done by controlling the operations of the fleet through vehicle tracking systems, computerized scheduling, and two-way communications (Button and Hensher, 2001). It comprises of a range of software and hardware tools that monitor, optimize and manage operations of vehicles travelling empty or partially loaded (CII-DESC, 2010). Freight Management System helps in the following.[9]

Table 2: Impact of Ahmedabad BRT

	1st month	11th month
Average daily ridership	17,315[7]	69,759[8] (300% increase)
Frequency of service	5 minutes (peak hours, weekdays)	2.5 and 4 minutes (peak hour)
Speed	16-18 kmph	24 kmph (1.5 times increase)
Revenue	Rs. 4,500 per bus per day	Rs. 8,000 per bus per day*
Modal shift to BRT**	From AMTS*** – 40%	
	From three wheelers – 25%	
	From two-wheelers – 20%	
	From cars – 10%	

*During the first four months
** In 11th month
*** Buses run by Ahmedabad Municipal Transport Service
Source: NIUA

[7]18 buses in operation
[8]45 buses in operation
[9]Communication with Mahindra Satyam

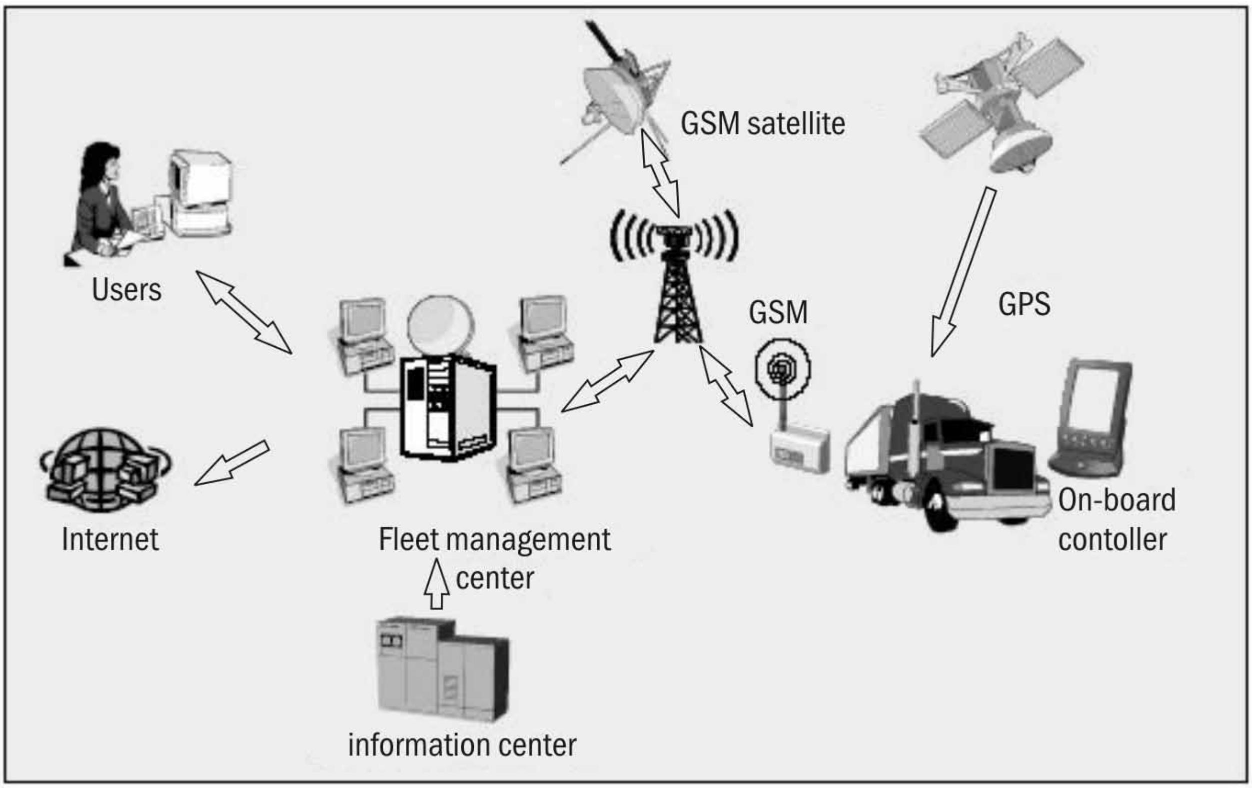

Figure 9 Control and communication systems for Freight Management Systems
Source lhttp://www.osmose-os.org/documents/200/hungary_ITS.pd (Last Accessed on September 5, 2011)

- Route planning which provides the capability to set an optimal route when there are multiple destinations to be covered in a single trip.
- Consolidating multiple orders.
- Selecting the correct size of vehicles.
- Tracking the status of shipments.

ICT applications for end-users/ commuters

As discussed above, some of the ICT technologies have an interface with passengers/commuters; these technologies focus on convenience of the end-users of transport services. Commonly referred to as Passenger Information Systems (PIS), these systems disseminate information to commuters through several media to:

- Help in pre-trip journey planning
- Give 'during trip' route guidance (en route) and warnings (NTDPC, 2011).

The different means for information dissemination to the commuters include:

Mobile travel information devices: The routes can be planned through Internet based information systems such as public transport timetables, route guidance systems, real time alerts on transport or road network conditions (Giannopoulos, 2004; NTDPC, 2011).

Fixed travel information devices: The users can access real-time information through fixed information devices like self service touch screen kiosks, LED displays and screens inside stations/vehicles, etc. Information is delivered at fixed locations through internet, Electronic Data Interchange (EDI), etc. (Giannopoulos, 2004; NTDPC, 2011).

In-vehicle driver information and navigation systems: These include combination of audio and visual devices which contain automated annunciators and in vehicle displays, respectively (Casey et al., 1998). The on-board computers help in various in-vehicle information system applications e.g. traffic and parking information via RDS-TMC,[10] Digital Audio Broadcasting (DAB),[11] dynamic route guidance systems, etc. (Giannopoulos, 2004).

Roadside driver information systems: Variable Message Signs (VMS), a road side dynamic on-trip information system can be used to inform drivers to avoid upcoming congestion points. (Giannopoulos, 2004).

ICT application in Indian road transport sector

The discussion above highlights the role that ICT can play in improving the delivery of transport services and addressing several concerns like congestion, inefficient fleet operation, etc. There are several ICT technologies that are readily available and have been successfully employed. The instances of their application in Indian road transport sector are however limited and there is lack of scaling-up.

There is a huge potential of applying these technologies in the Indian road transport sector, specifically in urban centres to improve efficiency and reduce energy consumption on account of inefficient operations. Wide-spread cellular phone network and the recent introduction of 3G technology further increase the potential of these applications in the Indian context.

The ICT applications that can yield significant energy reduction benefits and which can be implemented with immediate effect include:

- Vehicle tracking systems to manage freight and public transport fleets.
- Intelligent traffic management solutions in urban areas.
- ICT applications to make public transit services efficient and convenient to use for commuters.

Key ICT applications to be promoted in the Indian road transport sector

- Vehicle tracking systems to manage freight and public transport fleets
- Intelligent traffic management solutions in urban areas
- ICT applications to make public transit services efficient and convenient to use for commuters

[10] Radio Data System – Traffic Message Channel (RDS-TMC): It is medium by which real-time traffic information is displayed via FM radio.
[11] Digital Audio Broadcasting (DAB): It is a technology to receive better in-vehicle reception than FM

These ICT applications in inter-city and intra-city road movement can go a long way in addressing energy and emission concerns. However, implementation faces several challenges that are discussed in the next section.

Challenges in large-scale implementation of ICT technologies in road transport sector

The ICT solutions and examples of their application in transport sector, discussed in the previous sections, indicate its potential in improving efficiency of the sector. However, large scale implementation of these technologies is not an easy task; there are several challenges, ranging from technical to capacity that may hinder with the implementation.

Inadequate policy thrust to promote ICT: issue of lack of awareness on ICT potential for road transport sector and lack of institutional arrangements/ professional capacity to design and operate ICT solutions

There is inadequate policy thrust on promoting ICT use in road transport sector. A key reason for this is the lack of awareness about the benefits of ICT technologies in the transport sector; policy makers, fleet operators, city traffic managers, etc. are yet to recognize the utility of ICT in rectifying several inefficiencies of road transport sector. Though recently there have been a few initiatives to understand and strategize ICT use in road transport sector, these initiatives are at a very nascent stage and lack scaling-up. Lack of adequate awareness about ICT potential has resulted in.

Inadequate policy and regulatory environment to promote use of ICT; there aren't strong/enough policies that recommend and endorse the use of ICT in transport.

Inadequate use of these technologies by fleet operators like state road transport corporations, city bus service operators, city traffic police, etc.

Another key challenge in use of ICT is that of inadequate capacities to conceptualize, design and implement ICT solutions for road transport. The public sector agencies responsible for transport service provision lack adequate capacity, both in terms of institutional arrangements and skilled manpower for implementation. Though private companies working in ICT can provide the much-needed capacity, the government agencies still need to get an understanding for ensuring sustainable functioning of ICT initiatives. Even in private sector, though it would make business sense to use ICT solutions, the examples of ICT applications are limited; there is much larger potential for the same.

Cost of ICT technologies

Road transportation being a low margin business does not invest much in technology use. There is a perceived notion that application of ICT will be a costly affair; there is lack of full cost benefit analysis and long-term thinking regarding benefits of technology applications. Also in terms of prioritization of investments in road transport sector, ICT interventions like ITS generally have to compete for funding with conventional projects like building new roads, repairing roads, etc., which are typically prioritized.

Technology related challenges

Discussions with ICT companies highlight some specific technology challenges in promoting use of ICT in transport sector. These are listed below.

- Inconsistent GPRS coverage in cities/along highways makes it difficult to collect real-time traffic data, which is required in applications like Passenger Information Systems, Freight Management Systems, etc. Low GPRS signal strength affects computation of arrival or departure time, a critical component in application of these technologies.
- Unavailability of detailed GIS maps for Indian cities impedes the use of GPRS-based technologies.
- Lack of availability of high-quality and affordable internet services hampers services like e-work, e-business, etc.

Implementation related challenges

- Challenges in inter-state deployment of ICT applications- Deployment of a particular technology by a state may have limitations if the other states don't follow/allow deployment of the same.
- Lack of adequate institutional arrangements to implement/manage ICT solutions affects large-scale implementation.
- Challenge to change behaviour of service providers and users; e.g. drivers and cleaners may perceive vehicle tracking system as 'people tracking system', hence hampering its effective deployment.
- Cultural shifts in an organization's function are difficult to attain as adoption of new ways of working is a necessity. Company employees may resent change of shifting to ICT solutions. E.g. e-working makes collaboration with employees difficult; the organizational structures are not evolved to implement such e-work solutions.

The challenges discussed in this section highlight the need to identify/adopt a clear strategy to address the barriers in large scale-deployment of ICT solutions in the transport sector. The next section focuses on recommending a broad framework to promote the use of ICT.

Recommendations

There is a need for a multi-pronged strategy to promote the use of ICT applications in road transport sector; the strategy should target addressing all barriers that effect large scale deployment of ICT. Figure 10 depicts the keys elements of such a strategy.

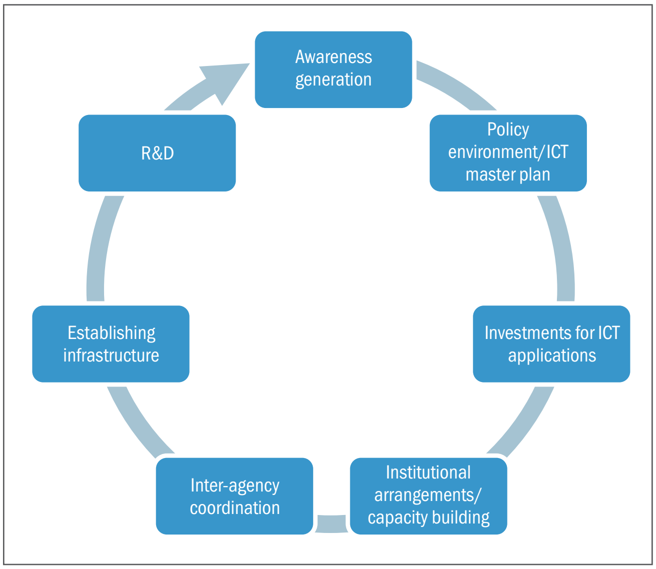

Figure 10 Strategy to promote the use of ICT applications in road transport sector

Key elements of the strategy for large-scale implementation of ICT applications in road transport sector

There are three key-stakeholders who need to participate in order to realise the proposed strategy for promoting ICT in transport sector; these include:

- Government (at centre/state/city level)
- ICT industry
- Private sector

Government interventions required (at centre/state/city level)

- **Formulation of new policies/amendments in existing policies and allocating investments for promoting the use of ICT in road transport sector.** Formulation of/changes in policies should be a multi-stakeholder process as it ensures successful implementation of the proposed policies. National Transport Policy, which is currently under preparation, should give adequate recommendations for promotion of ICT. In addition, Ministries of Road Transport, Urban Development and agencies like NHAI; State Transport departments should change their existing strategies/policies or formulate new strategies to include/promote ICT. E.g. Ministry of Urban Development can promote mandatory provision of few technologies like electronic ticketing, passenger information systems, vehicle tracking of bus fleets, etc. and also ask cities to include the same in their Comprehensive Mobility Plans (CMPs). The investment needs for implementing these technologies can also be met by the cities through the CMP route.

The policies to promote ICT in road transport should essentially target (NTDPC, 2011):

- Incentivizing technology adoption through innovative funding mechanisms (e.g. provisions for innovative funding mechanisms can be made in the National Urban Transport Policy)
- Seamless multi-modal transport
- Enabling common payment gateway mechanism in transport
- Protection of passengers' personal information
- Discontinuing paper based tickets
- Implementation of the following by transport operators:
  - Central Command centers to monitor and manage the system with 24x7 Help Desk facilities
  - Training of drivers on use of new technology
  - Use of GPS (or similar) devices, speed governors along with Driver Feedback systems
  - Internet hotspots and kiosks at bus and train stations
  - Surveillance and security systems
  - Contact less smart card system for payment
  - Service related updates to end-users through electronic means

Government interventions required with support from ICT industry

- **Capacity building to ensure adequate institutional arrangements and staff**

capacity to identify, conceptualize, design and implement several ICT applications.

Agencies like state transport corporations, city bus service providers, traffic police, freight fleet operators, logistic companies, etc. should strengthen their capacities to deploy ICT solutions. In addition, agencies responsible for transport planning should formulate overarching ICT strategies/guiding **ICT master plans** for road transport/cities. The **ICT industry's support** is critical in this context. It needs to manage and build the capacities of the governmental agencies to conceive and plan for ICT interventions. The detailed technological solutions can always be provided by the ICT industry; however, the governmental agencies need to have the capacity to conceive such projects and also be able to plan for them effectively.

For e.g. as stated earlier, cities can formulate ICT implementation strategy/plan for transport sector in their CMPs. Cities/transport agencies can additionally set-up dedicated cells responsible for planning and implementing ICT solutions. **Stakeholders, as identified earlier, in partnership with ICT companies should identify the range of ICT solutions that can be deployed in road/urban transport.** The solutions targeted should complement the capacity/technical maturity of agencies/cities to handle their implementation.

A recent report by a Working Group on urban transport for NTDPC has recommended the following ICT implementation plan for urban transport sector that could be adopted/ implemented.

- **T + 5 years:** Implement the following systems:
  - Vehicle Tracking System
  - Real Time Traffic Control and Adaptive Signals
  - Real-Time Passenger Information System

  To operate the above systems, data centres will be required along with pilot helpdesk facilities. The above systems will help in increasing the transport system management efficiency, achieve optimum utilisation of assets and increase the utilisation of the public transport systems.

- **T + 10 years:** Implement the following systems:
  - Fare Integration through Common Mobility Card
  - Integrated Information across Modes
  - Cashless Toll Collection

  The above systems will require enhanced data centers to manage and record the increased flow information and 24 X 7 helpdesks to improve consumer services. It will lead to better passenger satisfaction, better management of the transport system and help move towards a totally integrated multi modal transport system.

- **T + 15 years:** Implement the following systems:
  - Fare Integration through UID
  - Intelligent Traffic Management Systems
  - Predictive Traffic Management

  This will require an integrated metropolitan transport monitoring and control system. It will enhance passenger satisfaction and help manage and reduce congestion.

- **T + 20 years:** Implement the following systems:
  - Advanced vehicle safety systems
  - Seamless Intelligent Transportation System
  - High Level Analytics

Government and private sector partnership

3. **Government and private sector partnership is required to create the requisite infrastructure for promoting the use of ICT in transport sector.**

   Deployment of the roadmap as given above would require establishment of a robust infrastructure for successful implementation. Private sector partnership can help creation of the same.

Interventions required from ICT industry with support from government

4. **ICT industry needs to conduct continuous research and development of new technologies** that can be used to improve efficiency of transport sector. Government also needs to encourage and provide enabling policy environment to promote such R&D.

5. **Awareness creation on potential ICT interventions in transport sector and their benefits.** In addition to creating an enabling policy environment and complimentary capacities/institutional structures/infrastructure, etc., there is a need for awareness creation. ICT industry and knowledge institutions should partner for the same and should undertake awareness creation exercise to sensitize the key stakeholders on benefits of ICT applications. The sensitization programmes should also focus on addressing behavioural barriers and the notions related to the cost of technologies. Some of the key stakeholders that could be targeted for awareness creation programme are listed below:

a. Ministry of Road Transport and Highways

b. Ministry of Urban Development

c. National Highways Authority of India (NHAI)

d. Large freight fleet agencies (public and private)

e. Representatives of HCV/LCV owners

f. State transport departments

g. State road transport corporations/city public transport operators

h. Companies dealing with logistics solutions

i. Companies requiring large scale logistics solutions (e.g. auto-manufacturing companies, oil companies, etc.)


3 हफ्ते से
खाँसी
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हो सकती है
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Water sector

KEY MESSAGES

- With declining per capita water availability, it is expected that India will fall into the category of "water scarce" countries by 2050. The climate change phenomenon is also predicted to aggravate this situation. Apart from decreasing per capita water availability and inequitable access, urban water supply in India has high unaccounted for water (UFW) due to leakages, thefts, metering inaccuracies and losses. Deteriorating water quality poses another major challenge in water sector, witnessed by the rising levels of BOD and bacteriological contamination often due to mixing with sewage.
- One of the key factors for improving the water use efficiency and conservation would be the establishment of a framework for efficient and dynamic management of database for water through use of latest technologies including ICT tools.
- The application of ICT in water sector would be useful not only in generation of scientific data & information, but also its real time dissemination for effective and timely decision making. This would help in improving the performance benchmarks of the water utilities and would promote accountability and transparency in the water sector. Besides the stated benefits, the use of ICT would definitely help in fulfilling the National Water Mission goals under NAPCC (National Action Plan on Climate Change).
- Some of the potential benefits include:
  - Real-time monitoring of water supply system using ICT tools (sensors, smart meters, GIS, SCADA) would enable quick identification, prediction and prevention of potential problems such as a burst water main, a slow leak, thefts, non-transparent billing, a clogged drain or a hazardous sewage overflow, checks for contamination, etc.
  - ICT (like sensors, automated communication, control system) in industrial process would provide substantial opportunity in reducing the specific water consumption, thus also providing co-benefits on water charges and power consumption.
  - Smart sensors (like Smart Levee, water quality/ water level sensors), GIS, automatic weather station, weather prediction model, etc. can enhance the early warning system during extreme events such as flash flooding etc. besides also managing infrastructure and reservoir systems.
  - ICT can help in scheduling the optimal time of irrigation, remote management of irrigation activities, and optimal water use for agriculture, which helps in preventing damage due to drought stress or over irrigational practices.
- A conservative estimate of implementing ICT interventions in the water supply system may enable avoiding 15% of the losses due to UFW and may lead to potential savings of 27 lakhs INR and 4 lakhs INR per day for major metropolitan cities and Class I cities of India respectively.
- Lack of know-how on latest technologies to maximise water use efficiency, intelligent handling and processing of data and initial high costs pose challenges for adopting ICT solutions.
- The suggested roadmap for the ICT industry will be to prioritise urban water supply initially, followed by industrial, integrated water resource management (IWRM) and agricultural sectors.
- It is recommended that national and state water policies emphasise effective information sharing through ICT besides promoting water resource management through tools like ICT, water audits and water conservation. Adoption of ICT tools towards climate resilient management of water resources should be encouraged.

– Strengthened capacity building of government agencies to use ICT and promoting R&D is also recommended.

Introduction

Background

Water sector in India faces multiple challenges of availability, access and quality posed by demographic growth, urbanization, industrialisation and other developmental activities. With changing water consumption patterns and increasing demand from various sectors, the pursuit for efficient water management has become increasingly challenging. This section highlights the state of the water resources in the country and the need of using smart solutions and ICT for enhancing water use efficiency and management.

State of the resource

Existing state of water use & availability

Increasing water demand and developmental activities has led to a tremendous decline in the per capita water availability from 5177 m^3 in 1951 to 1654 m^3 in 2007. With continuous decline in water availability India is already in the category of "water stressed"[1] countries and is expected to fall into the category of "water scarce" countries by 2050. Increasing groundwater

[1]"Water stressed" is the condition when per capita water availability falls below 1700 m^3, while "Water Scarce" is the condition when per capita water availability falls below 1000 m^3.

draft to cater to the irrigational, industrial and domestic needs has rendered the groundwater critically overexploited in several parts of the country. The stage of ground water development in several states & cities has increased significantly for e.g. Delhi (170%), Punjab (145%) & Rajasthan (125%). Of the 7928 blocks/ talukas/ watersheds, 673 are overexploited units and 425 are in the dark and critical categories (Planning Commission, 2008).

Sectoral water use & inefficiencies

There is an increasing & competing water demand amongst various sectors primarily the irrigation, industries and domestic (drinking water). Water requirement for various sectors of Indian industries had almost doubled during the last decade and are expected to increase to 102 BCM (about seven folds) by 2050 as compared to the requirements of 1997 level.[2]

There is a high disparity in the per capita water availability amongst various cities as well as within the cities leading to inequitable access. For e.g. while the city of Triuvannamalai gets 584 lpcd (litres per capita per day), Tuticorin gets only 9 lpcd. Average access to drinking water in class I towns is 73%, followed by class II towns (63%), class III towns (61%), and other towns (58%) . Besides the inadequate quantity, availability of water supply is inconsistent in the urban areas. None of the major Indian cities have a 24 hour water supply. The average availability of water supply in most of the cities is between 4 to 5 hours a day. A study by MoUD & ADB in 20 major cities of India shows an average water availability of 4.3 hours/day.[3]

The Unaccounted for water (UFW) is quite high in the urban water supply in India and generally varies between 20-50%. The UFW in the NCR of Delhi is as high as 30-50%. A study by TERI in four cities of Madhya Pradesh (viz. Indore, Bhopal, Gwalior and Jabalpur) shows that the non-revenue water in these cities ranges from 28 to 44%. High UFWs are indicative of inefficient water use mainly due to leakages and losses (including pilferage) in the water supply system. Besides this a significant amount of water is supplied without metered connections resulting in loss of revenue and proper accounting of water distributed. The average metered connection in 20 major cities studied by MoUD and ADB was only 24.5% (2007). Further the data on the installed meters actually functional is scarce and evidences suggest many meters are often non-functional. These coupled with irregular water supply, losses & leakages, thefts, inadequate data/information on water supply along with institutional and financial issues are major reasons for under-performance of urban water sector in India.

Water quality issues

Many of the surface and groundwater source face threat due to the industrial and domestic wastewater discharges. Contamination of groundwater mainly due to presence of high concentration of fluoride, arsenic, iron, nitrate, salinity, high TDS, heavy metals, and bacteriological contamination are the prime areas of concern in several states of India. The discharge of untreated or partially treated sewage and industrial wastewater stands a major challenge for many surface water sources (rivers & lakes) in many urban cities.

[2]As per the CWC (Central Water Commission) data source
[3]Source: Indian Water Utilities Data Book; Benchmarking Water Utilities Data Book for India, MoUD, ADB, 2007.

According to the WWDR 2003, in developing countries, 70 per cent of industrial wastes are dumped without treatment, thereby polluting the usable water supply. Deteriorating surface water quality poses another major challenge witnessed by the rising trend of BOD and bacteriological quality of rivers in past years & observed pollution of lakes and wetlands.

Potential challenges due to climate change

Intergovernmental Panel on Climate Change (IPCC, 2007) has predicted some of the observations over the 20th century which includes increase in temperatures, decrease in snow and ice cover, rise in global average sea level rise (SLR), rise in Sea Surface Temperatures (SSTs) and increase in frequency and intensity of extreme events (such as floods and droughts). Climate change is known to lead to intensification of the global hydrological cycle with changes in the frequency and intensity of precipitation, thus directly or indirectly affecting the ground and surface water supply for irrigation, domestic, industrial supply, hydropower generation and navigation. The climatic changes are likely to have a direct effect on the runoff rates and shall influence the occurrence and intensity of floods and droughts. With the changes in intensity and frequency of rainfall the water quality too is expected to be affected.

Existing relevant policies

Government of India released National Action Plan on Climate Change (NAPCC, 2008) to address the challenges due to climate change. One of its eight missions viz. National Water Mission (NWM) focuses on the water resources of the country envisaging integrated water resource management that will help in conserving water, minimizing wastage and ensuring more equitable distribution both across and within states. Amongst its identified goals, the mission puts emphasis on

- Comprehensive water data base in public domain and assessment of the impact of climate change on water resource
- Promotion of citizen and state actions for water conservation, augmentation and preservation
- Focused attention on vulnerable areas including over-exploited areas
- Increasing water use efficiency by 20%, and
- Promotion of basin level integrated water resources management

While various actions will be required to achieve the above goals, one of the key factors for improving the water use efficiency and conservation would be the establishment of a framework for efficient and dynamic management of database for water through use of latest technologies including ICT tools.

Potential role of ICT in water sector

Need for ICT intervention in water sector

Water resources management, in present times, calls for an increased focus on efficient water use and management. This not only requires the water resource planners and managers to produce comprehensive & reliable information, but more importantly their timely dissemination and real-time access for effective decision making in the short term and appropriate interventions and strategies in the long run. The application of ICT (Information and Communication Technology) framework in this context shall be useful wherein not only the scientific data & information generation, but also its real time dissemination for effective and timely decision making, is emphasised.

Since long the lack of timely information on water quantity and quality has rendered the basic management components like operation, maintenance and monitoring into jeopardy leading to non-accountability, leakages, and disorganized decision making. Use of ICT based technologies (e.g. softwares and sensors) can automate monitoring and database sharing for improving water services with nationwide coverage. It can generate real-time knowledge about a number of physical and environmental variables (such as rainfall, water level, quality parameters, flows etc.) and can help to assess real time demand and supply across water distribution networks and sources through web enabled sensors and communication networks. This would help in improving the performance benchmarks of the water utilities and would promote accountability and transparency in the water sector.

Besides the potential benefits in various sectors, the use of ICT tools in water sector shall also help in achieving the goals of National Water Mission which, amongst others, emphasises the need for comprehensive water data base in public domain including the establishment of network for collection of additional necessary data and development of a 'web enabled' Ground Water Information System.[4]

Potential areas of ICT involvement for improving water use efficiency

Application of ICT tools and techniques can play significant role in improving the water use efficiency in many areas including agriculture, industrial and domestic sector. This section discusses the significant immediate opportunities (low hanging fruits) in urban water sector besides the possibilities in industrial sector, basin level management and agriculture sector.

Urban Water Supply Management

As mentioned earlier, city water supply systems in most of the urban local bodies (ULBs) in India have an inefficient water distribution with significant losses and UFWs. One of the challenges in managing the leakages, theft, inefficient customer billing, operation & maintenance, asset management etc. is the lack of real-time data/information at the decision making level. Use of ICT can change the face of the entire information management system in urban water supply and distribution network which involves

- Water source and reservoir management
- Raw water treatment plant and storage system
- Pipeline and distribution network
- Sewerage and drainage network
- Wastewater treatment

A coordinated and integrated use of ICT tools such as sensors, wired and wireless communication networks, remote sensing, geographical information systems

[4] National Water Mission under National Action Plan on Climate Change, Comprehensive Mission Document, Vol-I, April 2011. (http://mowr.gov.in/index2.asp?slid=794&sublinkid=579&langid=1)

(GIS) etc. in the above mentioned areas of urban water supply system can help in generation, access and dissemination of various set of data and information on a real-time basis at all the appropriate levels of management and user ends. Such information can be programmed with alerts and action prompts to initiate an action without any need of physical presence. Some of the important areas where such ICT tools can be effectively used for generation and provision of real-time data/information include the following.

- **Water flows and quantum:** ICT devices integrated with Supervisory Control and Data Acquisition (SCADA) system can provide real time data on flows and volume of water at all the important locations of the water distribution network as mentioned above. The generated data can be relayed in real-time to various level of management network such as zonal, regional and national command centres for accounting and real time decision making.

- **Water quality:** Various relevant parameters of water quality such as pH, temperature, TDS/conductivity, salinity etc. can be monitored with appropriate sensors at raw water treatment plant and distribution network to ensure right quality water supply, besides also checking any pollution and contamination in the network through a real-time alarm programmed for the system. Such water quality data management can also help in wastewater discharge monitoring to avoid pollution and identify areas for recycling and reuse. Sensor based real time water quality monitoring can provide data with high spatial and temporal resolution, at high frequency and low cost.

- **Metering:** In a water supply and distribution network, use of sensors and smart meters at strategic locations from start to end point can assist the water utilities to remotely monitor and detect the problem in a real-time manner and take proactive actions. Smart and integrated metering technology can help ULBs in accurately measuring the water consumption at consumer end and hence implement a transparent pricing and billing system that encourages water conservation. For e.g. there are two types of smart meters available i.e. Automated Meter Reading (AMR) with one way communication of usage data to the utility; and Advanced Metering Infrastructure (AMI) which is a 'two-way' communication between the meters/devices and the utilities' information systems. The system can monitor real-time water consumption, can send alarms for excessive consumption, identify leakages, thefts etc. so that timely action could be initiated to save water and manage assets using quantifiable decision support and prediction. Various combinations of such smart meters can be used to monitor the efficacy of water and wastewater treatment system. Even submersible sensors can be used for accumulating real-time information on quality and level of groundwater.[5] In the state of California, by implementation of smart water meters it is expected that water consumption would be reduced by about 5–15%.[6]

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[5]Observator Instruments, <http://www.observatormeteohydro.com/products.php?id=191&main=2>, assessed September 2011.
[6]ICT as an Enabler for Smart Water Management, ITU-T Technology Watch Report, 2010.International Telecommunication Union, <www.itu.int/dms_pub/itu-t/oth/23/01/T23010000100003PDFE.pdf> assessed August 2011.

- **Pressure monitoring (leakages & thefts):** ICT based sensors, smart meters and web based communication tools can also help in real-time monitoring and access to water pressure in the pipelines and valves. Any major change in pressure can be detected in real-time basis and can help trigger timely action (either programmed or manual). This will not only help save significant losses & leakages in the system due to lack of timely information but also help curb water thefts.
- **Asset management:** One of the major challenges in urban water supply is asset management where information on the type, material, size, capacity, age/life, functionality etc. of the supply infrastructure is often poor. Combination of ICT tools such as GIS and sensors can create layers of such information at one platform where data regarding infrastructure such as pipelines, valves, meters, pumps, treatment plant units etc. can be generated and accessed remotely to understand and take decisions for repairing/replacement of aging assets. Besides this such tools can be used to create a network of interactive maps and platform that can improve the surveying capability and information sharing at various levels of management planning and user ends. Such technologies coupled with SCADA system, internet and mobile devices can also enable field workers to access the information required for repairs and operations more effectively. For e.g, innovative wireless sensors installed in sewage treatment plants (STP) can provide automatic alerts through SMS/ phone call, when configuration threshold is reached so that remedial actions can be taken to avoid any damages.[7]
- **Energy consumption & pump efficiency:** Water supply involves massive use of pumps and associated energy consumption. Use of ICT tools to provide real-time data on the pump efficiency and power consumption can significantly reduce excessive power consumption and can help improve pump efficiency by timely interventions for pumps with low efficiency. This would ultimately improve water supply and reduce bills incurred on power consumption, thus ultimately reducing the cost of water supply.
- **Tariff collection and payment system:** Use of smart and integrated metering system are capable to not only help in remote meter reading but also to remotely activate meters/devices that can help in effective billing with appropriate volumetric pricing. For e.g. any additional/excessive use of water by a consumer beyond an allocation can help the utilities to charge additional tariff in appropriate tariff slab while also sending a real-time alarm for such increased water consumption to consumer who can check the excessive consumption. This shall also improve the transparency and compatibility amongst the users and suppliers.
- **Grievance redressal:** Use of web based ICT tools with systematic alerts, and information on water consumption and billing can help in improving consumer satisfaction and rapport with the utilities. For e.g. creation of an e-billing and payment system can help the consumers avoid infuriating queues at the bill payment centres. Also a web based or mobile network based system with facilities like mobile SMS and emails for complaint registration and grievance redressal can save significant time and manpower for both

[7]EnvEVE, <http://www.enveve.com/?page_id=796>, assessed September 2011.

the users and service providers thus ultimately improving the system efficiency and performance

Opportunities in industrial sector

The use of ICT tools in industrial water management is yet to take a larger role though the potential benefits are many in improving their operations and management. Like water utilities, use of ICT tools like sensors and smart metering equipments in water supply networks of an industry can not only help in centralized real-time monitoring of actual water consumption in its operating/ process units but also can help in minimizing wastes and energy consumption for pumping water. Some of the major processes/units in the industrial water use where ICT can bring about significant improvement includes the following

- Raw water reservoir and storage system
- Raw water treatment plant
- Cooling Towers, Boilers
- De-mineralized water (DM water) units
- Process/product water use
- Ash handling (in case of power plants)
- Wastewater generation and discharge system
- Recycling, reuse and zero discharge
- Residential township water consumption

Use of ICT tools (sensors, smart metering, automated communication and control system etc.) in such industrial processes/units can be done to monitor the water consumption pattern, identify leaks, and conduct repairs, on real time basis. This would provide substantial opportunity to save water and undertake water conservation, recycle and reuse activity thus also reaping co-benefits on water charges and power consumption.

For e.g. water use efficiency can be significantly improved in power plants, the largest consumers of industrial water. Use of sensors and advanced communication interface for automation and control can provide real-time monitoring and integrated information on water flows, losses and leakages in the cooling towers, ash handling units, DM water units & boilers etc. and can save significant volume of water. Such integrated system can provide real-time information (report/alerts) on the water quality parameters such as dissolved solids, temperature, conductivity etc. and can help in real-time (even programmed) action for appropriate chemical treatment that can improve the cycle of concentration (COC) of water used in closed loop in the cooling towers. Such interventions can save significant volume of water in the power plants besides providing co benefits through savings in power and water bills.

Use of water level sensors and web based softwares for information on the water level of the water sources (lakes, rivers, groundwater) or reservoirs (underground sump, overhead tanks etc.) can help in advanced planning of water withdrawal and allocation in industrial processes. Similarly ICT tools can also be used in monitoring the water quality and usage pattern in various stages of industrial processes thus identifying opportunities for recycling and reuse of water. An automated sensor for flow & quality monitoring at wastewater treatment system of industrial units can help identify avenues for water recycling and zero discharge. Many industries use significant amount of water for their residential townships and real-time monitoring and control of water supply in these can save wastage and reduce their per capita water consumption. Industrial water use needs to be regularly audited and managed in order to ensure improved water use efficiency and reduced specific water consumption besides safeguarding the environment.

Integrated Water Resources Management

With the changing climate, the availability of real-time information in a particular scenario on timely basis could be crucial in decision making for integrated water resource management especially in the context of river basins and watersheds. Technologies such as satellite remote sensing in combination with semantic sensor web/ automatic weather station, online water level sensor, water-quality sensors, weather prediction models, rainfall runoff model and GIS etc. can be used innovatively by water authorities to obtain real time information on water use, to track and forecast the level of rivers, lakes etc.

Use of such technologies in an integrated manner can help in

- Early warning systems for failure of embankments/ levees/dams used for flood protection thus enhancing the efficacy of measures for preventing damage to economic infrastructure and people. Satellite, radio communication and telecommunication devices can be utilized to track the extreme weather events like hurricane, tornadoes, thunderstorms, etc which can help in detection and mitigation of the impacts of natural disasters.[8]
- Integrated monitoring and sensing system at strategic locations of river & canals that can help profiling of the water flow and quality on a real-time basis and help undertake immediate interventions to maintain flows, identify conservation interventions and curb water pollution. This can also help address the upstream and downstream challenges, along with linking and prioritizing the social and environmental needs with quantity/ quality of water resource required for different users thus providing opportunity for optimizing water allocation on a dynamic basis and improving Integrated Water Resource Management (IWRM).

Cloud computing technology, that use the internet and central server system to maintain information (even the real-time data) helps in information/data dissemination at different level viz. community, policy makers, field level water managers, centre and state. The process of data monitoring, compilation, storage, maintenance and dissemination through cloud computing can also be programmed for controlled action by appropriate authority at different levels. ICT Web tools (e.g. blogs, wikis or social media sites), can be used to create awareness about the existing water stress condition and climate change impacts.

Agricultural water use management

Agriculture sector stands to be the biggest water user worldwide, accounting nearly 70 % of total water withdrawals. Although the expansion of the irrigated land is considered to be vital for ensuring food security of the growing world population, but increasing water scarcity stands a potential threat to it. Efficient water

[8]ICT as an Enabler for Smart Water Management, ITU-T Technology Watch Report, 2010.International Telecommunication Union, <www.itu.int/dms_pub/itu-t/oth/23/01/T23010000100003PDFE.pdf> assessed August 2011.

use thus has to play a major role in agriculture sector as well to make a major impact in addressing water vulnerabilities.

In agriculture sector, the key to efficient water use is irrigation with optimal volume of water at the right moment. ICT tools like automatic weather stations, wireless sensors, etc. can be used in agriculture fields for monitoring the humidity levels, soil moisture, crop water retention, weather information, plant characteristics etc. These can automatically activate the valves of the irrigation system to provide the required volume of water needed for the normal growth of the plant. Monitored data can be transferred using communication networks like mobile, internet, GPS devices etc, enabling farmers to monitor plant growth, fertilizer usage, budget water for irrigation, analyze the daily water consumption of crops, and schedule the optimum time for irrigation. Such technologies can not only help in preventing the damage caused by drought stress and excessive irrigation, but can also help in minimizing water use inefficiencies which is otherwise high in irrigation system. ICT tools in agriculture and landscaping systems have been adopted in different parts of the world (for example The Netherlands, Australia, Canada and the US amongst others).[9] Use of ICT tools in irrigation management system can thus help water authorities in regulating allocation of irrigation water from reservoirs and minimizing the distribution losses in command areas.

Interfacing government & non-government organisations

Opportunities for improving the water use efficiency/ water resource management will involve action on the part of several water authorities for ensuring proper monitoring and dissemination of information on water resources. A smart grid/network based information management system can provide an interface between various governmental and non-governmental agencies involved in basic information and database generation for research and development (R&D) on water resources. Such an interface can foster effective R&D activities to improve knowledge base for wider use and timely decision making by the concerned authorities such as CGWB, DDWS, CPCB, MoWR, PHED, Municipal Corporations/ Jal boards etc. At the same time, ICTs can foster a more effective coordination between the institutions that are responsible for the planning and management of water resources in different sectors.

Potential benefits & challenges

Potential Benefits

- Smart Meters and ICT tools are much likely to benefit both, the water utilities and final consumers, thus promoting efficient use of water both at the supply and demand side. Besides, such interventions shall improve the credibility of the utilities amongst the consumer and shall improve revenue collection thus reducing non revenue water (NRW).
- Smart metering enables customer to analyse their household consumption pattern (hourly, weekly, display of historical data) increasing their awareness and behavioural changes towards water conservation.
- The ability to monitor water supply & distribution system on a real-time basis shall enable quick

[9]ICT as an Enabler for Smart Water Management, ITU-T Technology Watch Report, 2010.International Telecommunication Union, <www.itu.int/dms_pub/itu-t/oth/23/01/T23010000100003PDFE.pdf>

identification, prediction and prevention of potential problems such as a burst water main, a slow leak, a clogged drain or a hazardous sewage overflow thus ultimately conserving water and bridging the demand.

- The use of ICT system can monitor real-time water consumption, for timely action to ensure water conservation and reduction in losses and UFWs. Such systems can also improve the efficacy of water and wastewater treatment system.
- Use of smart sensors can enhance the early warning system during extreme events such as flash flooding etc. besides also managing infrastructure and reservoir systems.
- Use of integrated monitoring and sensing system (along with GIS) at river & canals can help in profiling the flow and quality on a real-time basis and help undertake immediate interventions to curb water pollution maintain flows and help address the upstream and downstream issues thus providing opportunity for optimizing water allocation on a dynamic basis and improving IWRM at basin and watershed level.
- ICT in industrial sector would provide substantial opportunity to enhance water conservation, recycle and reuse activity and reduction in specific water consumption thus also providing co-benefits on water charges and power consumption.
- ICT tools can help in information/data dissemination at different level viz. community, policy makers, field level water managers, centre and state. ICT assisted interface between various government agencies can foster effective decision support system for wider use of database and timely decision making thus improving the coordination between the institutions.
- ICT can help in scheduling the optimal time of irrigation, remote management of irrigation activities, optimal water use for agriculture, which helps in preventing damage due to drought stress or over irrigational practices. ICT tools can also help water authorities in regulating allocation of irrigation water from reservoirs and minimizing the distribution losses in command areas.
- Use of ICT shall help in achieving the policy goals of the National Water Mission by efficient database management in public domain and improving the water use efficiency in various sectors.

Potential water savings

Currently robust data on the use and benefits of ICT tools in water sector remains unavailable primarily because of the fact that the use of such tools in water sector has been limited. However, based on the limited available information from various cities and a rough estimation shows that a significant potential exists to conserve and save water.

Assuming two scenario where

1) a minimum of at least 15% volume of UFW/NRW water can be saved by use of ICT tools (such as sensors and smart meters etc.);[10] and
2) Full scale implementation of ICT tools where about 50% volume of UFW/NRW of water can be saved.

[10]Based on discussions with IT companies on possible water savings by use of ICT tools such as metering, sensors

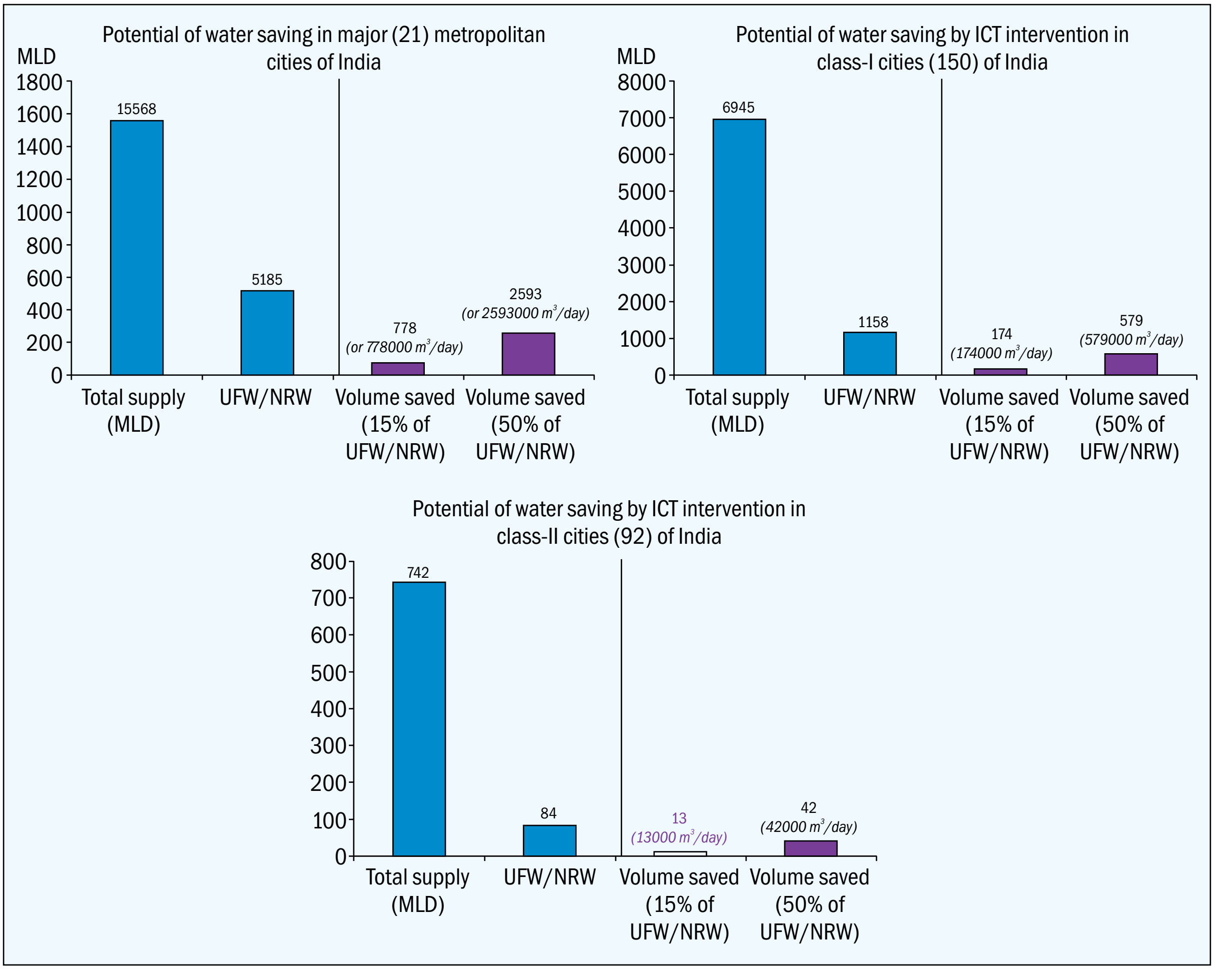

Figure 1 Potential water saving (MLD) that can be achieved in some of the metros, class-I and class-II cities of India

For a sample of metro cities (21 no.s), Class-I cities (150 no.s) and Class-II cities (92 cities), a rough estimate shows that use of ICT tools can reduce the UWF or the NRW and save water (Figure 2):

- By at least about 964 MLD (or 9,64,000 m³/day) in total considering 15% savings on UFW,
- By about 3213 MLD (or 32,13,000 m³/day) in total considering 50% savings on UFW

Figure 1 shows the possible water saving that can be achieved in some of the metros, class-I and class-II cities of India.

A saved volume of this magnitude can cater the water demand of good number of cities as shown in Table 1 below.

Table 1 Number of cities that can be catered by these potential water savings

Sample cities	*Average supply (MLD)*	*No. of cities that can be catered by saved water*	
		by 15% savings	*by 50% savings*
Metro	728	1.3	4
Class-I	46	21	70
Class-II	8	120	402

Note: The values are indicative in nature and actual figure would vary from city to city depending on size. Average supply is taken based on data referred for respective cities.

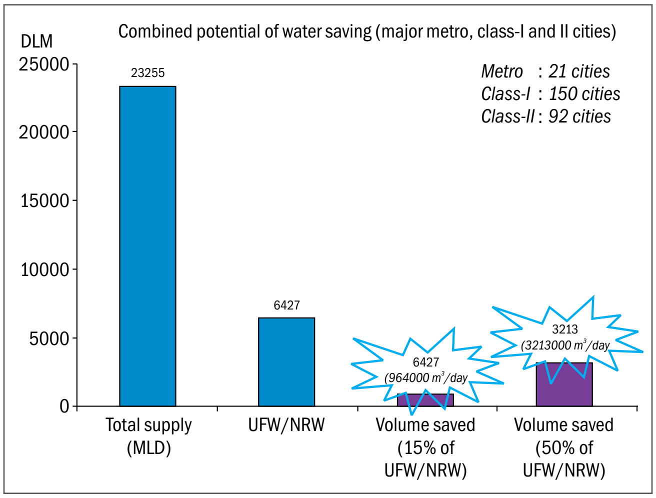

Figure 2 Potential water saving (MLD) that can be achieved in total in selected metros, class-I and class-II cities of India

Note: The values estimated are based on available data source of CPHEEO (1999) and MoUD (2009) combined together for estimation.

The range of potential financial benefits[11] for some selected cities is presented in Table 2, Figure 3 which is significant.

Thus in the given scenarios, it is recommended for the ICT industries to focus on the interventions in the metro cities first where maximum immediate benefits (both in terms of volume of water saved as well as financial savings) can be achieved in context of the urban water supply system.[12]

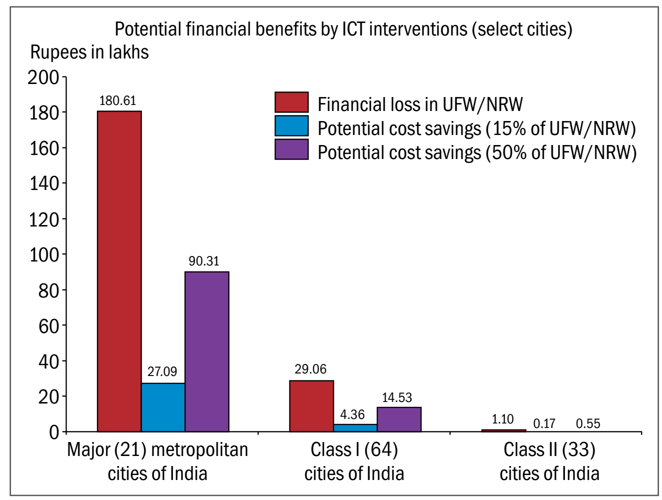

Figure 3 Potential financial benefit by ICT interventions in selected metros, class-I and class-II cities of India

Potential Challenges

- A significant proportion of the stakeholder-base especially in the rural India, is uninformed about the latest techniques (or need) to maximize water-

Table 2 Potential financial benefits for some selected cities in India

Sample Cities	*Financial loss due to UFW/NRW (INR Lakhs/day)*	*Potential Cost savings*		*Potential Cost savings (@ 50% savings of UFW/NRW)*	
		INR Lakhs/ day	*INR Lakhs/ Month*	*INR Lakhs/ day*	*INR Lakhs/ Month*
Major (21) Metropolitan Cities of India	180.61	27.09	824	90.31	2747
Class I (64) Cities of India	29.06	4.36	133	14.53	442
Class II (33) Cities of India	1.10	0.17	5	0.55	17

Note: The estimated values are based on available limited data on production cost of water for some of the cities
Data Source: CPHEEO (1999) and MoUD (2009); combined together for estimation.

[11] Calculated based on the data on cost of production incurred by respective ULBs (CPHEEO, 1999); (MoUD, 2009)

[12] It may be noted that volumetric and financial benefits are based on data that are rather dated (1999) in many cases. Hence current benefits can be expected to be more than the estimates.

use efficiency because of the limited access to media channels like television, newspapers, or the Internet. Besides for wider coverage and usage, ICT solutions shall require to be aligned to each stakeholder's preferred language.

- The handling of volumes of data, its extraction from various sources and real time response to huge system shall need specialized water management intelligence and models that are scalable and responsive to a huge network and system.
- With growing population, the scale of operation of water utilities is going to increase simultaneously. Hence large scale employment and training would become necessary at the institutional level if ICT solutions are adopted to address water management. This shall also be necessary at the consumer level such as the domestic consumers, farmers, industries etc.
- The initial cost for deploying such ICT technologies might be costly for water authorities, as the irrigation canal system, urban water supplies etc. are spread over a larger area in the entire country. Also when adopted and installed, there might be threat of damage and theft.

Success models and case studies

Smart Water Management

IBM partnered with Dubuque, for building a web-based portal solution to produce advanced water consumption analysis and leak alerting. The solution is based on IBM Smarter City Sustainability Model. It delivers innovation and insights from data and information using the cloud computing environment. The goal is to allow the city and residents to visualize and understand their consumption patterns and sustainability footprint and to receive leak alerts in near-real time. Solution providers like Mahindra Satyam and Itron, can provide an end to end solution for water resource management in India, who can support hardware, firmware and embedded software which means designing, selection, integration of flow control and metering solutions can be handled.

Smart Electrical Grid and Water Utility System

Malta's national electricity and water utilities setup a consortium with Enemalta Corporation (EMC) and Water Services Corporation (WSC), for the design and delivery of a nationwide AMI and smart grid implementation in Malta. The ICT solution is provided by IBM, which is designed to improve operational efficiency and customer service levels by introducing smart meters that allows clients to better manage consumption. The project will involve replacing a quarter-million conventional electric meters with smart meters and upgrading the water system where it can be monitored and managed remotely. Further SAP's ERP-based system and its billing application will also be implemented under this study, which will help customers to track their utility usage in real-time using internet.[13]

[13]ICT as an Enabler for Smart Water Management, ITU-T Technology Watch Report, 2010.International Telecommunication Union, <www.itu.int/dms_pub/itu-t/oth/23/01/T23010000100003PDFE.pdf> assessed August 2011.

Water Quality Monitoring in Lake Wivenhoe, Australia

Commonwealth Scientific and Industrial Research Organization (CSIRO) in partnership with Seqwater (water authority of south-eat Queensland region, Australia), developed an integrated intelligent wireless sensor network for monitoring drinking water of Lake Wivenhoe.[14] This system has the capacity to monitor the micro-climate of the surrounding region (temperature, rainfall, humidity, wind speed and direction), drought condition, water quality, and pasture condition. For measuring water quality and climate condition, an autonomous solar-powered device (catamaran) was developed that travels in the lake between the floating sensor nodes to gather the data. All these sensor nodes function in a web/mesh network to wirelessly transfer data to central data base for analysis. Further the device can be programmed and integrated with web-interface or web enabled mobile phone for collecting the data without the need to travel to the location. Such technology will provide Seqwater a cost-effective way of integrating different measures of weather condition, discharges, water quality, and pasture conditions as well as the movement of cattle in the catchment.

"NICTOR" for efficient irrigation

National ICT centre for excellence, Australia in association with University of Melbourne and Victorian water authorities, designed and developed "NICTOR" device, which is used to control the canal gates and pumps based on the real time monitoring of crop water requirement. Experiments carried out on dairy farms employing flood irrigation showed that the irrigation water reduced by 26% than actual and resulted in 38% improvement in gross margin earned per hectare. Similarly, the trials carried out on apple orchard employing drip irrigation showed 73% increase in gross return per hectare and 74% increase in economic water productivity measured in dollars earned per mega litre of irrigation water. The results of such experiments indicated potentials for expanding the water efficiency gains from individual farms to the basin-scale infrastructure used to deliver water, including reservoirs, dams, rivers, canal and pipe networks.[15]

Recommendations

Use of ICT in water sector has a significant role in improving the water use efficiency in agriculture sector, urban water supply and industrial sector and can help in addressing the challenges of water scarcity and vulnerabilities in water sector. The potential areas of ICT interventions and details of their benefits are mentioned in section 2.0 earlier. In order to realise and maximise water conservation and efficient use through use of ICT tools, following major areas of recommendations are suggested for intervention by ICT industries.

- **Urban Water Supply Management:** Given its potential, ICT industry must prioritize and venture first in a big way in the urban water supply sector for use and implementation of various ICT tools. Tools such as semantic sensors, smart meters,

[14] CSIRO ICT Centre < http://research.ict.csiro.au/research/labs/autonomous-systems/sensor-networks/water-quality-monitoring> assessed September 2011

[15] National ICT Centre of Excellence: improving water use efficiency, Department of Broadband, Communications and Digital Economy, Australian Government, www.dbcde.gov.au

SCADA and advanced communication devices shall help in real-time data base and information management and thus improving the performance of Urban Local Bodies (ULBs) in urban water sector. Following areas should be targeted by the ICT industry in short term and long terms basis to help conserve water and improve efficiency

- Smart metering in supply and distribution network
- Sensor based real-time monitoring of flows and quantum of water
- Sensor based real-time water quality monitoring
- Sensor based real-time leak detection &water pressure monitoring
- Asset management with use of GIS, sensor and web tools
- Real time monitoring of energy consumption & pump efficiency
- Smart billing system and tariff collection with online support
- Online grievance redressal system

ICT industry should have an initial focus on the metropolitan cities since the size of benefits would be maximum in these cities (Followed by class-I & II cities). Smart Grids/DMA (District Metered Areas): the work on urban water supply may be taken up like smart grids where a particular part of the distribution system can be isolated and used as grid or DMA to fully implement the ICT tools. With the benefits accrued, such DMA can be then up-scaled. Such ventures/interventions in the ULBs can be done by entering into a public private partnership (PPP) with the municipal corporations or the local administration of city water supply.

- **Industrial water management:** ICT industry should target water intensive industries (such as power plant, textile, pulp and paper industries etc.) to provide automation, advanced monitoring & control system in their processes/units on a real time basis. This would provide substantial opportunities for reducing leakages/losses and specific water consumption while also identifying avenues for water conservation, recycle and reuse in these industries (besides reaping co-benefits on water charges and power consumption).Some of the processes/units that can be focused for ICT tools application include:
  - Raw water reservoir, storage & treatment system: automation and real-time water flows and quality monitoring
  - Cooling Towers, Boilers, DM water units, ash handling units: Sensor and SCADA or cloud computing based automation and real-time water flows and quality monitoring
  - Process/product water use: Automation and real-time water flows and quality monitoring with GIS based asset management system
  - Wastewater generation and discharge system: Automation and real-time water flows and quality monitoring, asset management
  - Residential township water consumption: Real-time water consumption and quality monitoring
- **IWRM and agricultural water management:** ICT industry has potentially largest opportunity in the agriculture sector. As discussed earlier ICT industry should make use of various tools of ICT such as sensors etc. for real-time monitoring and decision making to bring about significant

changes in agricultural water use by focusing on some of the following areas

- Agriculture field monitoring for humidity, soil moisture, crop water retention, weather information, plant characteristics etc.
- Irrigation water reservoirs, canal & command area

Besides this such tools can also be used at basin level to provide early warning system, weather prediction as well as decision making for water allocation & basin management.

- The ICT industries should invest in the R&D with lab scale design and development of specialized tools for water sector and later develop full scale products for implementation in the above mentioned areas. Apart from being robust, the technology developed must be flexibly designed for to be easily handled or operated by water authorities or by farmer and local communities.
- In order to improve the water use efficiency in urban water supply system ICT industries should enter into a PPP to initiate pilot level and then full scale projects on aforementioned areas. This is a low hanging fruit in water sector and can be prioritized by ICT industries.
- Besides above training and capacity building of relevant end users in all the sectors shall help dissemination of knowledge and benefits on the use of ICT and can help improve user base for wide scale impact in water sector.
- Pilot level implementation of ICT technologies should be undertaken for assessing the economic feasibility and cost benefit analysis of adopting such devices. Such pilot scale experiments can also be used as model for capacity building and increasing awareness among the water authorities and farmers.

Figure 4 depicts a brief on the role and prospects of ICT industry in water sector and a possible roadmap for future interventions.

Policy recommendations

- In light of the above discussions and opportunities it is important that need of improved and effective information sharing through various effective mechanisms including the use of ICT be emphasized in the national and state water policies.
- ICT tools should be used to build the capacity of the government agencies for improving the data and information management between states and the centre as well as other institutions. Data sharing through use of ICT should be encouraged at all levels in a coordinated manner to promote research and development in water sector.
- Indian water utilities should be given specific mandate to undertake mandatory water audits and integrate the database management through use of ICT for improving the water use efficiency and reduce the burden on UFWs.
- In light of climate change, policy approaches including use of ICT tools for encouraging climate-resilient water management of water resources should be adopted at various level of water governance and management.
- State and central governance on water resources should undertake the role of water regulator and

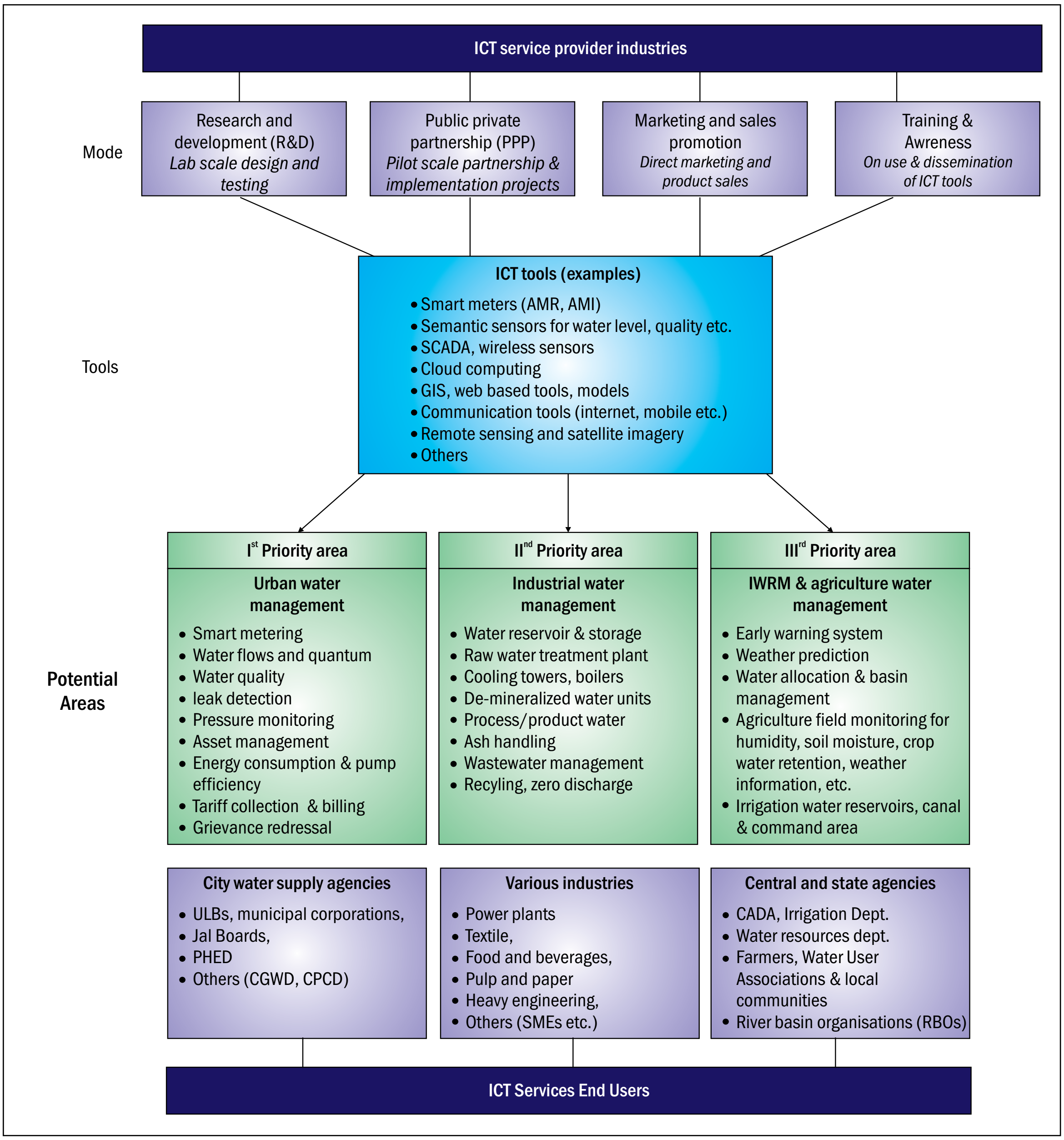

Figure 4 Role and prospects of ICT in water sector
Source: TERI 2011

should promote water demand management through tools like regular water audits, use of ICT, and water conservation.

Conclusion

The water resource in India is under stress due to increasing water demand by growing population and decreasing fresh water availability. The need of ICT solution for improving water use efficiency and water resources management has been increasingly felt in water sector. The use of ICT tools such as smart sensors, integrated metering systems, cloud computing etc. along with use of GIS and internet based tools have a promising future in the water sector specially the water utilities and the industries. Dovetailing the ICT tools with interventions on water conservation shall significantly reduce the water losses and improve the water use efficiency besides improving the customer satisfaction. In the basin systems such tools have the potential for forecasting and early warning system for floods and provide a platform for database management for understanding and addressing the upstream and downstream issues besides enabling dynamic water allocations. Various government and non-government agencies should promote use of ICT for improving data base integration and sharing thus also strengthening the institutional mechanisms. Such approaches on use of ICT should be emphasized in the relevant policies and regulation frameworks.

Energy Intensive Industry Sector

KEY MESSAGE

- Energy consumption by the Indian industry sector accounts for about 43% of the total commercial energy consumption i.e. 112.91 mtoe (2007-08).
- The total estimated GHG emissions from industry sector were 250 million tonnes (1994 level). 60% of these emissions were accounted by energy use in industry sector and the rest by different processes.
- India's National Mission on Enhanced Energy Efficiency (NMEEE) identifies the need for market-based approaches to unlock energy efficient opportunities with a planned investment of Rs 74,000 crores. The PAT (Perform, Achieve and Trade) scheme of the Bureau of Energy Efficiency under the NMEEE has identified an energy saving potential of about 6.6 mtoe by different Designated Consumers (DCs) including thermal power plants during a 3-year period.
- A number of major producers of the industry use state-of-the-art technologies and automation solutions having energy efficiency levels at par with the global standards. However, the wide range of specific energy consumption (SEC) levels prevailing amongst the DCs indicates significant scope for energy efficiency improvements. In addition, about 50% of the energy consumption is accounted by the non-DC industries which also have significant scope for energy efficiency improvements.
- Achieving industrial energy efficiency involves access to information, financing, human resources and technology, improved decision making processes, and the ability to measure and verify the achieved energy savings. One of the cross-cutting technological options for improving energy efficiency is "adoption of ICT". Part of the energy savings envisaged through PAT can be met through adoption of ICT solutions.
- Off-the-shelf ICT solutions may not be available for industries and hence there is a need for the ICT solution providers to understand the dynamics of the sector. The ICT solutions are sector-specific and are unique to individual industries. The specific types of ICT solutions would include process automation, use of better control systems and adoption of EMIS (Energy Management Information System) for data analysis and decision making.
- The Government of India schemes focussing on technology upgradation and promote energy efficiency provide significant opportunities for adoption of ICT solutions by the industry sector.
- Industry success stories/ case studies would help in enhancing the awareness levels of the different stakeholders. This will help to bridge the gap between the industry end-users and the ICT solution providers.
- ICT solutions can play a key role in capacity building of plant professionals through virtual platforms. This would create a virtual learning environment for them to efficiently operate the plant.

Background

The total commercial energy consumption of India was estimated to be 263.24 million tonnes of oil equivalent (mtoe) during 2007-08 in India. The industry sector forms a sizeable component of energy consumption– with a share of about 43% (112.91 mtoe) apart from non-energy and other energy uses. Concerted efforts are required by the industry sector to adopt energy efficient technologies and practices to reduce their overall energy intensity. The co-benefits through adoption of energy efficiency include

- reduced fuel and material use
- reduced local emissions
- improved product quality.

In 2001, the Government of India enacted the Energy Conservation Act (ECA),providing the legal mandate for the implementation of energy efficient measures. The Bureau of Energy Efficiency (BEE) has been identified as the "Apex Agency" and entrusted with the responsibilities for implementation of ECA.

As per the national greenhouse inventory (1994), the direct CO_2 emissions from the industry sector[1] accounted for about 31% of total emissions from India. The total estimated emissions from industry sector were 250 million tonnes. 60% of these emissions are accounted by energy use in industry sector and the rest by different processes. To address the challenges of climate change, the Prime Minister of India released the National Action Plan on Climate Change (NAPCC) in June 2008 with 8 broad national missions. One of them is National Mission on Enhanced Energy Efficiency (NMEEE). he major initiatives of NMEEE include,

- Perform, Achieve and Trade (PAT),
- Market transformation for energy efficiency,
- Energy Efficiency Financing Platform for promoting Demand Side Management programs and
- Framework for energy efficiency economic development.

NMEEE identifies the need for market-based approaches to unlock energy efficient opportunities. How much would such activities cost for the industry sector? The answer is about Rs 74,000 crores. This would also help in realizing

- annual fuel savings in excess of 23 mtoe,
- cumulative avoided electricity capacity addition of 19,000 MW and
- CO_2 emission mitigation of 98 million tonnes per year by the year 2014-15.

The Bureau of Energy Efficiency (BEE) has identified 477 energy end-users[2] as Designated Consumers (DCs) for employing energy efficiency schemes. These sectors include aluminium, cement, chlor-alkali, fertilizer, iron & steel, pulp & paper, textile, thermal power plants and railways.

In 2009, the BEE introduced an online system called 'e-filing'. This required the DCs to provide inputs to BEE on their annual energy consumption. Since 2010, this has been made mandatory.

[1] National Action on Climate Change, Government of India, Prime Minister's Council on climate change.
[2] PAT Consultation Document 2010-11, BEE

Studies by the government and private organizations suggest that there is a significant potential for energy savings in the industry sector. Adoption of conservation measures would help in improving the efficiencies of various production processes. The studies also indicate that there is a wider bandwidth in the Specific Energy Consumption (SEC) i.e. energy consumed to produce one unit of the product, usage within each sector. While few industry sub-sectors like cement and fertilizers have SECs in par with the global level, there are a large number of units having significant potential to reduce their energy consumption. Table 1 depicts the sizeable range of SEC of the Indian industries.

The PAT initiative aims to introduce energy efficiency targets for individual DCs. It launched the concept of "ESCerts", i.e., energy efficiency certificates which will be issued to those individual industries who achieve more than the set targets. These certificates can also be purchased by other DCs for the purpose of compliance. Under this scheme, the energy saving potential identified for the Designated Consumers is about 6.6 mtoe. Thus, the PAT system is expected to establish a competitive market of Indian industries.

Table 1 SEC range of Indian industries

Industry	Unit	Indian plants
Aluminium		
- Smelter	kwh/t	15875-17083
- Refinery	Mhcal/t alumina	3.28-4.12
Cement	Kcal/kg clinker	665-900
	kwh/t cement	66-127
Chlor alkali	kwh/ t caustic soda	2300–2600
Fertilizer	Gcal/ t urea	5.86-9.11
Iron & steel	GJ/t crude steel	6.15-8.18
Pulp & paper	GJ/t	25.3-121
Textile	Kcal/kg	3000-16100
	kwh/kg	0.25-10

Source PAT consultation document (2010–11), Bureau of Energy Efficiency

Some of the major producers of the industry use state-of-the-art technologies and automation solutions. Their energy efficiency levels are quite high which are at par with the global level. However, the wide range of SEC levels prevailing amongst the DCs as shown in table 1 indicates significant scope for energy efficiency improvements. In addition, about 50% of the energy consumption is accounted by the non-DC industries which also have significant scope for energy efficiency improvements. ICT solutions have been identified as one of the options for improving energy efficiency among Indian industries.

Importance and role of ICT in Indian industries

A number of options are available for achieving energy efficiency in industry sector. These include technology modernization, fuel switch, adopting recycling and cross-cutting technologies (Figure 1). The NAPCC suggests 'cross-cutting technological options' as one of the means for improving energy efficiency in industries which has an energy saving potential of 5-15%. Achieving industrial energy efficiency is a multifarious task. It involves access to information, financing, human resources and technology, improved decision making processes, and the ability to measure and verify the achieved energy savings. One of the cross-cutting technological options is "adoption of ICT (Information and Communication Technologies)". This solution assumes immense importance for the industrial sector. Application of ICT tools in critical processes and equipment of industries would help in its optimization and also maintain the operating parameters close to the design level. Close control of various operating parameters in production processes may be achieved through advanced control, metering and feedback information. Further, the data and information being readily available for comparison with future projects are useful for reducing perceived risks associated with energy efficiency investment opportunities.

There are a number of areas where ICT tools can contribute significantly to enhance the energy efficiency levels. These include:

- Design and simulation of energy use profiles covering the complete life cycle of energy intensive products, processes and services both for green-field projects (new plants) and brown-field projects (expansion of existing plants).

- Intelligent and interactive monitoring of energy use and close control of operating parameters.

- Innovative tools and platforms to help in planning and designing efficient manufacturing processes.

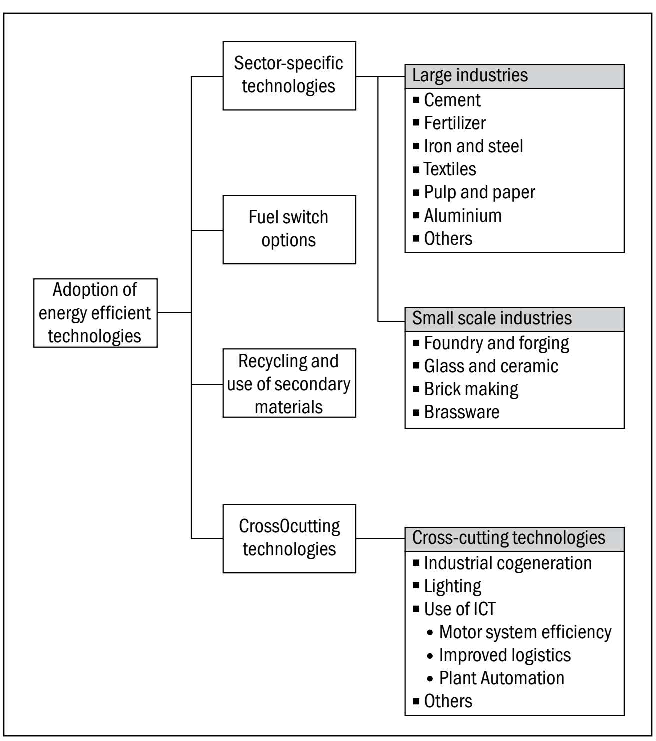

Figure 1 Options for improving energy efficiency in industry sector

Potential ICT applications in industry sector

Application of ICT tools can be either process related or cross-cutting across different industry sub-sectors. Few examples of process related ICT solutions include operating conditions of reformers in fertilizer industry or application in state-of-the-art smelter technology in an aluminium industry. Apart from sector-specific options, there are many applications of ICT tools that are cross-cutting across industries, irrespective of the type of manufacturing processes. An example is the Enterprise Resource Planning (ERP) systems. Several Indian industries have acquired the benefits of standardised procedures through adoption of ERP systems. However, the use of Energy Management Information System (EMIS) to have real-time analysis of the operating parameters is yet to be exploited. These tools can be effectively utilized for close control of process parameters in various energy intensive industries. Various benefits of use of ICT tools in industry sector include the following:

- ICT tools help in plant automation. Optimization of process parameters close to design level helps in improving system efficiency and maximizing the productivity (see Box1).

- ICT tools are useful in cutting down developmental costs for a green-field plant. A virtual system is developed to find out the possible issues that need to be addressed while putting up a new plant (See Box 2).

- Use of ICT tools would optimize designs of various equipment and systems thereby and reducing implementation cost.

- The ICT based data management system would help in fast and easy access to relevant information. It would enhance safety, quality and accessibility to data (See Box 3). The ICT training tools would help in providing a virtual environment for training of plant personnel on operation and maintenance of the plant.

- The ICT tools support development of energy management information system. This assists the top management in decision making. . Standardization of business processes, deploying new innovations and business technologies, delivering high value information and developing a

BOX 1 CASE STUDY OF CONTROL OF OPERATING PARAMETERS IN THE CEMENT INDUSTRY

Sector *Cement*

Challenge
Reduce high variability in plant operation

Solution provider
Accenture

Industry end-user
Cement industry

Type of ICT solution
In a cement plant, higher variations were observed in the oil temperature in two furnaces. Although, a temperature of 120°C needed to be maintained, a wide fluctuation of 90 to 165°C in the oil temperature was observed. These large variations in oil temperature had resulted in higher energy consumptions of inductive heater. A temperature control loop with a set point of 120°C was providing oscillations with 60°C amplitude due to aggressive tuning. The tuning of the loop was corrected to decrease its variability and reduce signal to the inductive heater. Elimination of oscillations had resulted in close control of oil temperature to the required level.

Benefits reported
Elimination of oscillations had helped in reduction in variability and brought more stability in system operation. An energy saving of about 45% has been reported by the plant.

Source
Industrial process optimisation, Case study, Accenture, 2009

BOX 2 CASE STUDY OF FEASIBILITY OF USING ICT SOLUTION FOR REFURBISHING OF A FACILITY

Sector Power

Challenge
To perform a refurbishing feasibility study on a power plant and evaluate the cost and time it would take to perform the project

Solution provider
IBM and Dassault Systemes

Industry end-user
Hydro-Quebec

Type of ICT solution
The softwares offered by the solution providers include CATIA and DELMIA. These were used to virtually represent the plant and equipment. It also helped in dismantling and moving the equipment inside the plant. Many of the Hydro-Quebec plants have been in operation for 30 to 40 years. Hence, Hydro Quebec decided to refurbish these plants to reduce operation costs, extend plant life and optimize energy efficiency. Replacing the inefficient equipment and undertaking repairs would be time intensive. The shutdown of the plant for prolonged period was also needed. To optimize the process, Hydro Quebec decided to perform a refurbishing feasibility study in a 3–Dimensional virtual environment. One of the challenges faced by the unit included non-availability of up-to-date documented view of the existing, plant. Simulation of various equipment in a 3-D environment helped to clearly identify the interferences while dissembling, moving and reassembling equipment.

Benefits reported
The refurbishing study took 6 weeks from scanning to simulation. This helped Hydro-Quebec to save 200 weeks of work. The study hence proved the advantage of the software tools. Nearly CAN$50 million were saved. As a result, Hydro-Quebec planned to develop similar virtual simulations in other refurbishing projects.

Source Customer case study – IBM and Dassault Systemes

disciplined approach to the process architecture are few examples.

The ICT solutions can also help to enhance energy efficiency through process optimization. The next sensible question which comes in our mind is, process optimization of what and how? Close control of critical operating parameters through ICT solutions is one such method. To understand this well, let's have a look at few of the examples below:

- Cement kiln and grinding are key process centres in a cement plant. Energy efficiencies can be increased with optimum operation of these processes. For example, as shown in Box 1, the use of temperature loop control helped in reducing the temperature variations and brought stability in the system. This helped in saving 45% of energy in the induction heater.

BOX 3 CASE STUDY OF ICT BASED DATA MANAGEMENT SYSTEM

Sector Refinery

Challenge
To manage large quantities of product data generated throughout the life of a refinery plant

Solution provider
Dassault Systemes

Industry end-user
Preem Petroleum

Type of ICT solution
The use of ENOVIA Smar Team helps in managing large quantities of design data. It also helps in taking care of technical documentation for the equipment in the Lysekil refinery. This software keeps a track of the revisions to equipment designs making sure that the correct procedures are followed. At the same time, it also ensures better workflow management. Mapping of internal workflows and standardized automatic approval system are its added advantages. In addition, it avoids human errors and helps in smart use of the processes as per the standard procedures. This also ensures continuous improvements in the system.
Benefits reported
By providing fast and easy access to relevant information, ENOVIA Smar Team has considerably improved the accessibility of data and documents.

Source
Customer story – Dassault Systemes

- In the aluminium industry, optimum operation of smelter is critical in achieving higher energy efficiencies since smelter. Ideally, smelter consumes about 85% of total energy in aluminium production unit.
- In the iron & steel industry, blast furnace and coke oven plants are the essential processes. Their optimum operation would help in improving their functional efficiencies..
- Reformer, ammonia synthesis and CO2 removal systems are important areas in a urea plant and their operation is critical in minimizing energy consumption.

Some specific applications of ICT solutions in the industry sector are shown in Table 2.

Challenges for adopting ICT solutions in industry sector

There are two types of challenges for the adoption of ICT solutions in the industry sector. These include

Table 2 ICT applications in industry sector

Industry sector	ICT solutions	Potential benefits
Aluminium	Advanced process control for smelter	About 2–4% energy savings
Cement	Kiln control system, optimization of grinding process, energy management system	About 1–5% energy savings
Chlor alkali	Advanced cell controls, energy management system	About 3–4% energy savings
Fertilizer	Advanced process controllers for primary reformer, ammonia synthesis & CO_2 removal systems, energy management system	About 1% energy savings
Iron & steel	Process optimization of coke oven plant and blast furnace system, energy management system	Up to 10% energy savings
Pulp & paper	Process automation	About 5–10% energy savings
Textile	Spinning area - Variable frequency drives, energy management system	Up to 15% energy savings

Source: ICT's contribution to India's National Action Plan on Climate Change (2010), CII

the end-user i.e. the industry and the ICT solution providers.

End-user industry perspective

Possible challenges from the perspective of end-user industry are:

- There is a low level of awareness on ICT solutions available in the country. This may be attributed to the limited or non-availability of repository of available solutions that cater to the Indian industries.
- The ICT solutions are industry specific as well as process specific. Hence these solutions need to be implemented on case to case basis. Also there is limited availability of commercial solutions which can be successfully used in the industries..
- There is also uncertainty of savings for the investments made on ICT solutions. Although ICT solutions can help in optimizing the plant performance, the range of energy saving can vary widely from industry to industry. This can directly influence the return on investments.
- Budget allocations by the industry do not prioritize energy efficiency projects. Energy efficiency projects are not generally considered to be mainstream activity of the industry. Rather, emphasis is more towards enhancing the productivity to increase profits. Investments on energy efficiency projects take back seat during budgetary allocations.

ICT solution providers perspective

The case studies depicted as Box items show typical ICT applications and associated benefits such as energy savings in the industry sector at global level. Large scale adoption by the end-use industries in India poses certain challenges to the ICT solution providers as well which are discussed below.

- The ICT solution providers should understand the dynamics of the industry sector. This would help in addressing the decision making at individual industry/ corporate level.
- The industry base in India shows diverse conditions – type of industry, production capacity, product, process used, technology adopted, raw material usage, vintage, etc. Off-the-shelf ICT solutions may not be available for individual industries. This would require customized solutions to be developed, which may be resource intensive.

Conclusions and way forward

Adoption of ICT solutions by the Indian industry sector would help in improving their energy efficiency levels. To take this forward, following initiatives would be required for adoption of ICT solutions.

Effective use of existing policies/ schemes: The PAT (Perform, Achieve and Trade) scheme of the Bureau of Energy Efficiency has identified an energy saving potential of about 6.6 mtoe by the Designated Consumers (DCs) including thermal power plants during a 3-year period. Part of this energy saving can be met through adoption of ICT solutions. Also, a study by the CII indicates an energy saving potential of 1-10% in industry sector by adopting ICT solutions, equivalent to about 6 mtoe of CO_2 reduction potential. Apart from PAT, a number of other schemes of the Government of India focus on technology upgradation and promote energy efficiency (e.g. Technology Up gradation Fund Scheme under the Ministry of Textiles). These schemes provide significant opportunities for the ICT solution providers to enhance close interactions with the end-use industries. This would in turn influence the industry for procuring energy efficient solutions rather than least cost options.

Development of customized ICT solutions: The ICT solutions are sector-specific and are unique to individual industries. Therefore, the solution providers must focus on individual industries and develop customized solutions for the industry. The specific types of ICT solutions would include process automation, use of better control systems and adoption of EMIS (Energy Management Information System) for data analysis and decision making.

Awareness generation through case studies and success stories: There exists a gap between the ICT solution providers and industry end-users. How can we reduce the gap? Will sharing of information help? Yes, information generation holds the key. The industries can make success case studies and share them amongst the end users and the solution providers. These stories can be both from the Indian and the international perspective. These inputs would also help in enhancing the awareness levels of the different stakeholders. It is said that such an effort would also help in enhancing the demand for ICT solutions.

Capacity building through virtual platforms: The plant professionals should understand the processes in industries. This would help them in better handling of real-time situations. Here, the ICT solutions can play a key role. Sector/industry specific training modules can be developed for the plant professionals. This would create a virtual learning environment for them to efficiently operate the plant. These training modules may be created keeping in mind the equipment and industry specific system.

Driving Implementation of Green IT Infrastructure in India

KEY MESSAGES

Energy efficiency in India's ICT sector

- The Indian ICT industry have undertaken several green practices and adopted green technologies at their facilities. These are separately listed as Annexure.
- A study was undertaken with a cross section of IT industry facilities (both company owned and leased) and it is observed there is scope for improving energy-efficiency by adopting various green practices.
- The lighting design is quite efficient but appropriate lighting controls have not been provided. Lighting system energy performance can be improved further by integrating appropriate lighting controls such as occupancy and daylight-linking controls for artificial lighting.
- The Energy Performance Index (EPI) of the existing ICT facilities in India varies between 230–310 kWh/m^2/yr. The power usage effectiveness (PUE) is about 1.5. Potential exists to reduce energy consumption of the ICT industry by 25–30% from the current levels.
- Even though high performance materials have been used in the building envelope, there exists a possibility to improve energy performance by using materials specified by ECBC (2007).
- The cooling system efficiency is found to be average and there exists a potential to enhance the system's efficiency by up to 30%.
- Industry-specific energy standards and energy-performance benchmark need to be developed, with energy/environmental rating made mandatory. IT equipment shall also be included in 'standard and labelling' programme introduced by the Bureau of Energy Efficiency (BEE) of the Ministry of Power.
- ICT applications can facilitate gathering information in real-time on energy consumption of every appliance in building in a user friendly way, thereby enabling end-users to take informed decision which will lead to development of effective energy management plan for a facility. ICT sector can also facilitate the design and construction of green buildings by developing a variety of assessment, compliance check, simulation, analysis, monitoring, and visualization tools.
- It is recommended to develop an exclusive environmental rating system for both new and existing ICT facilities, R&D programs for identifying and developing new technologies, which can reduce the direct IT load.

Disposal of end-of-life ICT equipment

- As the usage of ICT equipment increases, the rapid obsolescence and availability of newer and efficient models at affordable rates lead to the concern of managing end-of-life and discarded equipment in an environmentally sound manner.
- India's total e-waste generation is expected to increase to 8,00,000 tonnes by 2012. The ICT sector accounts for 34% of the total e-waste generated in India. Reduction of waste from end-of-life ICT equipment is desirable through reuse and recycling.
- Proactive actions are recommended for the ICT industry by considering progressive ICT equipment design and waste-reduction opportunities, establishing an advisory committee for management of e-waste, developing company-level standard operating procedures, developing sustainable partnerships with stakeholders to devise attractive take-back schemes.

Although information and communications technology (ICT) is usually perceived as a facilitator and enabler of business and social objectives, its use does not come without cost. This cost is not only financial, but progressively also one of impact upon the environment. In the December 2007 report, Gartner estimated that global ICT usage accounts for approximately 2% of all global carbon dioxide (CO_2) emissions. These originate mostly from the use of built environment, computers, servers, cooling mechanisms, fixed and mobile telephony, telecommunications and printers in offices, and so on. However, ICT's impact on the environment also extends to chemicals and waste (resulting from the disposal of e-waste).

This chapter deals with the procurement, operation, and disposal of green IT infrastructure. Section A describes the energy efficiency aspects, while Section B describes the safe disposal methods of IT equipment.

A: Energy efficiency in India's ICT sector

Indian ICT sector

Over the last two decades, the Indian ICT sector has recorded phenomenal growth. It has contributed significantly towards India's GDP, and its role in employment generation has also been significant. However, in order to maintain its high growth rate, the sector has also witnessed a tremendous surge in development of the requisite infrastructure. Numerous facilities of ICT firms have emerged in almost all the important cities of India—a trend that will only climb upward in the near future. These ICT facilities consume important resources, and generate a lot of waste. Their consistently high growth rate will not only put more pressure on demand for existing resources—which is already quite high vis-à-vis their supply in many cities—but also adversely impact the environment. Therefore, it is important to plan, design, construct, operate, and maintain these facilities in a manner that will ensure they are resource efficient and sustainable.

Data collection

During the initial stage of this study, a detailed questionnaire was circulated among various ICT companies. The collected data was thoroughly analysed to gauge the respective energy-efficiency level, and identify the prevalent infrastructure-related practices in ICT facilities (such as building envelope; lighting; heating, ventilation, and air-conditioning; IT equipment; and so on).

The results have also been used to find out the existing energy efficiency level in the Indian ICT industry, and to assess the potential of improving it further. The existing energy-efficiency level is defined through two parameters: energy performance index (EPI[1]) and power usage effectiveness (PUE[2]). Subsequently, various energy-conservation measures have been identified to enhance the energy efficiency of both existing and new ICT facilities.

Energy performance

The energy consumption in an ICT facility depends on the proportion of its area that is air-conditioned. A study of the facilities already built in India reveals that the air-conditioned area varies from 35–90% of the total built-up area of a facility. A facility's energy performance—defined by a parameter called the energy performance index (EPI), which is defined as the ratio of total energy consumed in a facility to its total built-up area—has been found to vary from 230 kWh/m^2/yr to 310 kWh/m^2/yr.

Within ICT facilities, energy is consumed by the power distribution system, lighting, air-conditioning and the IT equipment. In a typical IT facility, IT equipment accounts for 46% of the total energy consumed.

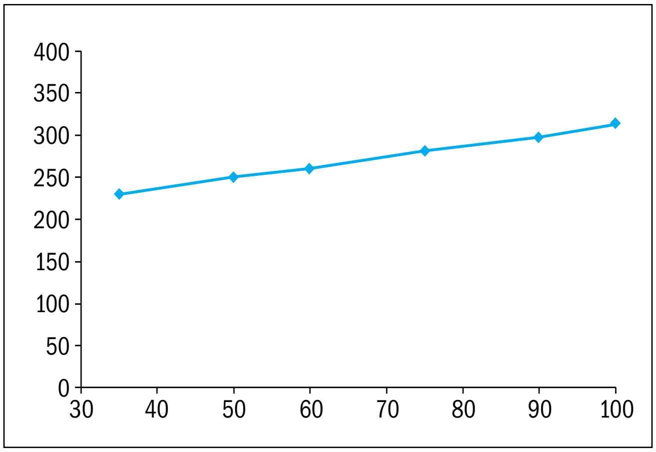

Figure 1 EPI and % conditioned area of various in the existing facilities

[1] Energy performance index of a facility is defined as the ratio of the total annual energy consumption to the total built-up area of a facility.
[2] The power usage effectiveness is the ratio of the total energy consumed in an ICT facility to its total IT-energy use.

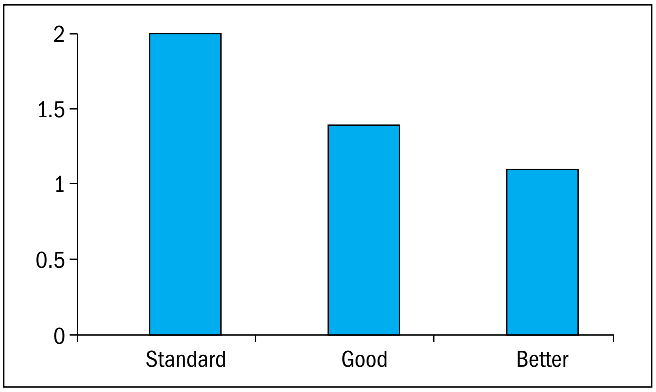

Figure 2 PUE benchmark for data centre

The remaining 56% is consumed by the heating, ventilation, and air-conditioning (HVAC) system, lighting, power distribution, and other loads (such as vertical transportation, pumping, canteen, and so on).

Load densities (defined as total connected load of a system divided by the area) are also indicative of design efficiency. In existing ICT facilities, the lighting power density (LPD) has been found to be 6.5 W/m^2, cooling system density was 70 W/m^2, IT load density in office area was 8 W/m^2, and IT load density in server room was 14 W/m^2.

Infrastructural efficiency

Infrastructural energy efficiency norms or benchmarks are useful in tracking energy performance and in identifying potential measures to reduce energy use of an ICT facility. The power usage effectiveness (PUE), which is the ratio of total energy consumed in an ICT facility to total IT- energy use, is recommended and accepted in many parts of the world to evaluate data centre efficiency. The PUE benchmark for data centres has also been developed. For instance a data centre with PUE less than 1.4 is considered good. If the PUE is equal to or less than 1.1, then it is even better. PUE can also be developed based on power rather than on energy.

However, there are no such benchmarks for ICT facilities. The good news is that an attempt has been made to evaluate the infrastructural efficiency of existing ICT facilities in India. Those with existing systems efficiencies have been converted into data centres with varying areas and PUE is calculated for each stage. The PUE of 90% converted area as data centre is then compared with the recommended benchmark. The PUE of existing facilities was calculated to be 1.5, which is higher than the recommended 1.4. This means the existing infrastructural efficiency is not up to the mark and there is potential to reduce the existing facilities' energy consumption, and at the same time, design new facilities with higher efficiency by improving the design of their HVAC system, lighting system, and power distribution system.

Existing practices

Existing practices currently being followed under various heads, such as building envelope, lighting, air-

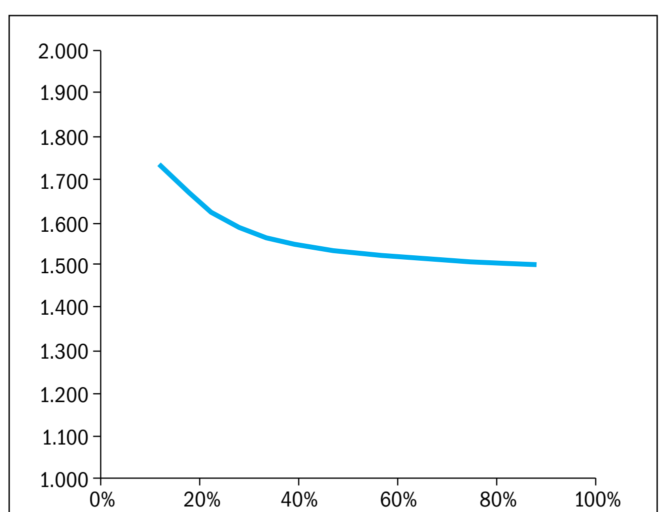

Figure 3 PUE variation with % server area

conditioning, power distribution, IT equipment, and so on have been explained in detail below (see annexure on Green practices adopted at the ICT facilities in India).

Building envelope

Many recently built facilities have a window wall ratio (calculated as total glass area on outer facades divided by the total area of outer facades) of more than 60%. The heat gain through windows is several times higher than that through opaque surfaces. Moreover, the heat gain is instant which means that the heat immediately enters through windows, thereby adding to the room total heat. On the other hand, in case of opaque surfaces, because of their thermal mass and heat-absorption capacity, there is a time lag between heat absorbed and heat remitted.

High-performance glass (for example, double glazed) with low-e is predominately used in windows and roofs and walls are insulated. When compared with the 2007 Energy Conservation Building Code's (ECBC) recommended building envelope characteristics, it is observed that many facilities do not comply with the recommendations for all three components, namely, roof, walls, and glazing.

Lighting system

Indoor lighting in existing ICT facilities is predominately provided by energy-efficient lamps, for example, compact fluorescent lamps (CFL) and T-5 lamps (energy-efficient fluorescent lights) .

Fluorescent lamps of 36 watt with electronic chokes are also used in many facilities. Few facilities are still using inefficient 12-volt miniature halogens for decorative lighting.

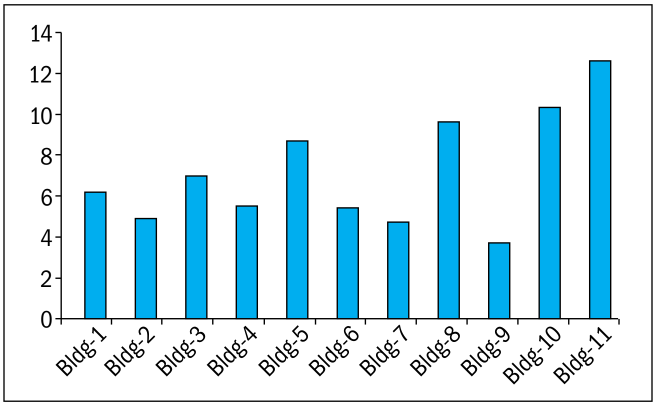

Figure 4 LPD of various facilities

Lighting power density (LPD) has been found to vary from 4 W/m^2 to 13 W/m^2. However, the sector average has been found to be 7 W/m^2, which is less than the ECBC's (2007) recommended 10.8 W/m^2. Thus, the potential for efficiency improvement in lighting systems is quite low in the ICT sector.

Shut-off and space lighting controls are mainly provided by occupancy sensors and pull card switches, while timers are used for controlling staircase lights and outdoor lighting. There are several facilities, where no automatic controls are being used. Automatic daylight-linking controls for on-off or continuous dimming are also rarely being used in the existing ICT facilities.

Cooling systems

Cooling in existing ICT facilities is required both for human comfort and for effective functioning of IT equipment. Cooling is provided by centralized as well as distributed cooling systems. The centralized cooling systems are mainly used for providing comfort air-conditioning; while distributed cooling systems that include precision air-conditioners are installed in server rooms.

The centralized cooling systems that have been installed are of both water-cooled and air-cooled types. In some of the facilities, based on the availability and quality of water, the centralized cooling systems have both water-cooled and air-cooled chillers. Air-cooled chillers are only used when either water is not available or its quality is not as desired.

Comfort conditioning of a building is done mostly with the help of centralized air-conditioning. In certain cases, distributed air-conditioning system like variable refrigerant volume system is used for comfort conditioning.

Air-conditioning of the server systems installed at a facility is achieved by using the chilled water generated from a central plant. In some cases, a separate direct-expansion (DX) coil system called precision air conditioners (PACs) is used.

Centralized air-conditioning systems

Centralized air-conditioning systems include water- or air-cooled chillers, chilled water pumps, and air handling units (AHUs) of fan coil units (FCUs) for air circulation. If water-cooled chillers are used, the system also includes condenser water pumps and cooling towers.

In a water-cooled system, the compressor consumes the maximum energy, accounting for 59% of the total power used in the centralized system. Pumps consume 17%, cooling towers 2%, and the AHUs share is approximately 22%.

In a water-cooled centralized system, three different types of configurations were found to be deployed in existing facilities.

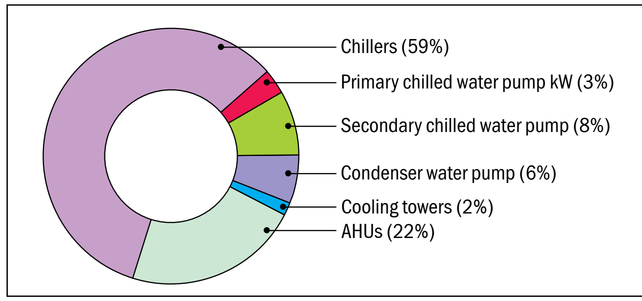

Figure 5 Percentage Load break-up for a typical HVAC System

- **Type 1:** This type of system comprises of constant speed water chillers, two loop chilled water line (where primary pumps are of constant speed but secondary water pumps are of variable speed), condenser water pumps, and cooling tower fans (also of constant speed). The design efficiency of this type of plant is found to be 0.9 kW/TR (where TR=tonnes of refrigeration, and is equivalent to a refrigeration capacity of 3,516.85 W).
- **Type 2:** In this type, everything remains same as type 1, except that the constant speed chillers are replaced with variable-speed ones. The design efficiency remains more or less the same as that of type 1, but depending on variation in cooling-load demand, the overall part load efficiency of this type of system gets improved as compared to that of type 1.
- **Type 3:** This type of system consists of variable-speed water chillers, only variable primary pumps, while condenser water pumps and cooling tower fans are of constant speed. The design efficiency of this type of plant is found to be 0.71 kW/TR.

Distributed system

Distributed systems usually comprise small air-conditioners, and hence, can be directly installed inside rooms. One such system, which is being used for comfort cooling in place of centralized systems in mid-range ICT facilities, is the variable refrigerant volume (VRV) system.

In a VRV system, multiple indoor units are driven by a single outdoor unit having multiple compressors. The refrigerant flows through smart valves to different units. These valves are automatically controlled, so as to allow only the required volume of the refrigerant to flow in through each indoor unit. Rooms with less heat load at one point in time will require less refrigerant flow; while those with a high heat load receives more refrigerant. This controlled flow ensures optimum cooling, and makes the system quite efficient. The system operates efficiently at part load, which is generally the case during the actual operation of any building. The cooling capacity starts from 4 TR. The average part-load efficiency of a VRV system is in the range of 0.8–0.9 kW/TR.

Cooling-system efficiency

In common practice, cooling-system efficiency is defined by either the chiller efficiency or, at the most, plant efficiency, which includes both chiller

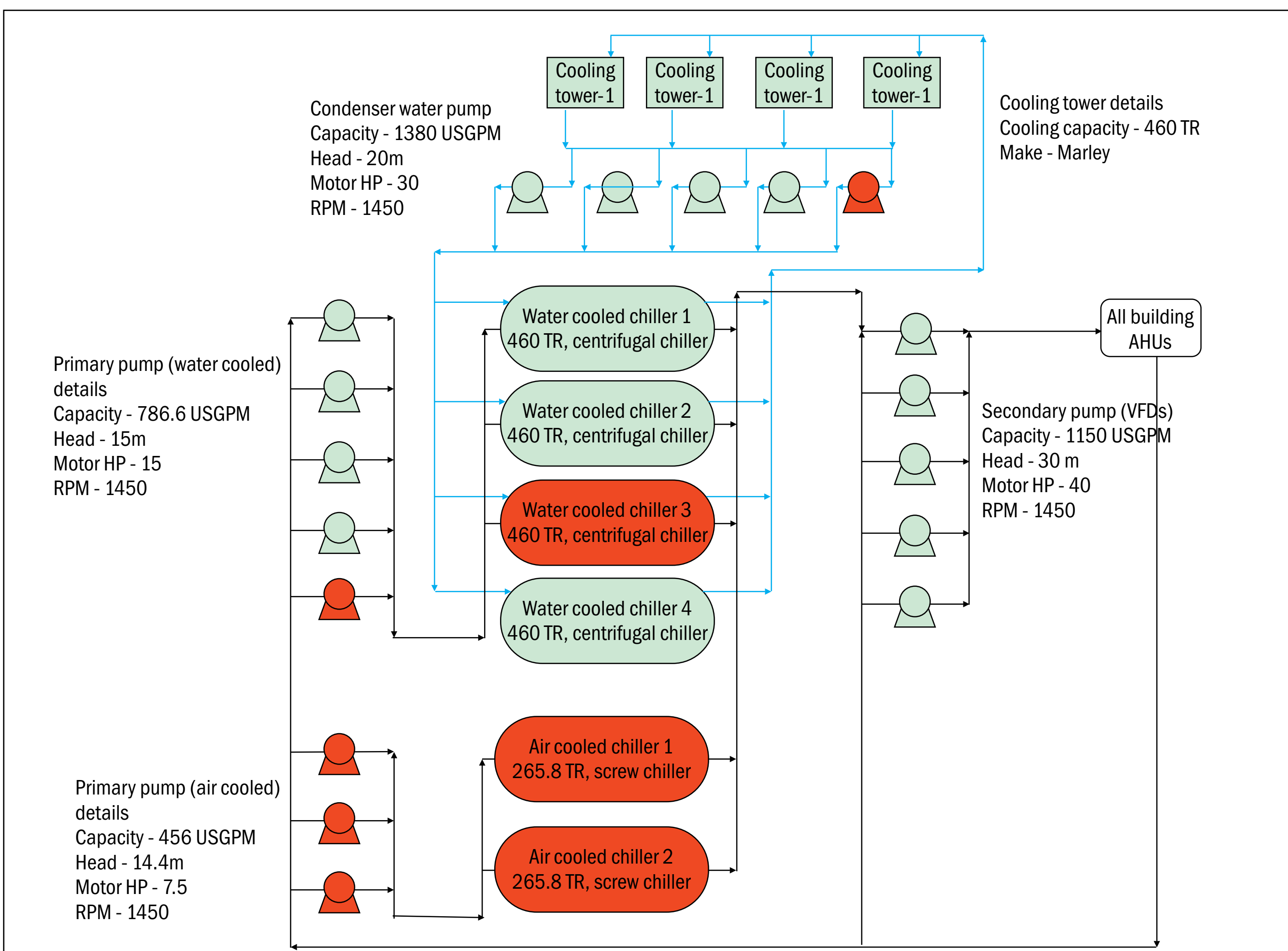

Figure 6 HVAC Plant Layout

and auxiliary. But, cooling system also includes air distribution system, which should also be included in efficiency calculation and then that cooling-system efficiency should be compared to the benchmarks of cooling systems developed to define the current efficiency level of cooling systems in the ICT industry.

A very efficient cooling system has been selected from the existing facilities, whose efficiency has been found to be 1.05 kW/TR.

As per the internationally accepted standard, the efficiency benchmark of an efficient cooling system should be 0.8kW/TR or lower. Therefore, there exists the potential to enhance the existing cooling-system efficiency through innovation in design, using more efficient equipment and control systems or by using new technologies.

Power distribution system

In ICT facilities, electricity is supplied though 11kV/415V and 33kV/415V step-down transformers. Electricity from the transformers is catered to various electrical loads like lighting, air-conditioning, and water pumps installed inside the facilities.

UPS, which supplies power to critical IT load, also forms a part of the power distribution system. It acts as backup power source during power cuts for all computers and servers located inside a building. UPS use a battery bank. There occurs continuous charging and discharging of these batteries.

IT equipment and peripherals

A server is any electronic device serving out applications or services. It is a combination of hardware configured with specific programmes that delivers services to its clients. Traditionally, low-power density servers were used in data centres. As the demand increased, the requirement of number of servers also increased. With this continuously rising demand, the low-density servers became difficult to use, which led to a new server technology called blade servers, in which many small single core servers are consolidated together. A blade server is a high-density server.

Power consumption in servers

Servers are operated on direct current (DC), while utilities deliver alternating current (AC) and that, too, at higher voltages than what is required by computers. The conversion of AC to DC requires one or more power distribution units (PDUs). To ensure uninterrupted service, even entry-level servers are supplied with redundant power supply sources. Typical breakup of power consumption in a server is given in Table 1.

Summary of energy efficiency in existing ICT facilities

- The EPI of the existing ICT facilities varies between 230 kWh/m^2/year and 310 kWh/m^2/yr. The PUE is about 1.5. Neither of these parameters lies in the poor performance range, but none of them is in a desirable range, either. This leads to the possibility of further enhancing the energy performance of the facilities by 25–30%.
- Even though high performance materials have been used in the building envelope, these do not conform to ECBC (2007)-recommended specifications. There exists a possibility to improve energy performance by using materials specified by ECBC.

Table 1 Typical power breakup in a server	
Component	Peak Power (W)
CPU	80
Memory	36
Disks	12
Peripheral Slots	50
Motherboard	25
Fan	10
PSU losses	38
Total	251

- The lighting design is quite efficient but appropriate lighting controls have not been provided. Lighting system energy performance can be improved further by integrating appropriate lighting controls such as occupancy and daylight-linking controls for artificial lighting.
- The cooling system efficiency is found to be average and there exists a potential to enhance the system's efficiency by up to 30%.

Recommended energy conservation measures

Low-energy design

While designing buildings, bio-climatic architectural principles should be kept in mind. In bio-climatic designs, equal importance is given to elements like the sun, air, wind, vegetation, water, soil, sky, and so on for heating, cooling and lighting. Some of the strategies are:

- *Landscaping*: Trees provide buffer to sun, heat, noise, and air pollution. Landscaping using vegetation can be used to direct or divert air flow. Trees offer shade to buildings from intense direct solar radiation. Species of trees can be selected depending upon the respective climate zone and building design. For example, deciduous trees provide shade in the summer and sunlight in the winter when their leaves fall. Planting them to the west and south-west of a building will ensure natural shade. Similarly, evergreen trees provide shade and wind control round the year.
- *Waterbodies*: Water has a moderating effect on air temperature. It possesses a very high capacity to store heat—much higher than building materials like brick, concrete or stone. A large body of water—in the form of a lake, river or stream has the ability to moderate air temperature in a micro climate. Water evaporation has a cooling effect on the surroundings by taking up heat from the air.
- *Orientation*: In passive solar buildings (buildings designed to collect solar energy in the form of heat, in winter and reject solar energy in summer) orientation is a major design consideration, mainly with regard to solar radiation, daylight, and wind. In places with tropical climate, like India, long facades of buildings oriented towards north-south are preferred.
- *Window-wall ratio*: A window-wall ratio of less than 40% is preferable to enhance energy performance. But in any case, this ratio should not be more than 60%.

Building envelope

Choosing the correct building material for the envelope is important in order to reduce the energy consumption of a building. This is achieved through reduced solar heat gain or loss, thus reducing air-conditioning loads. However, the building envelope should comply with ECBC recommendations.

External wall specifications: Thermal performance of external walls should conform to ECBC 2007 recommendations, as tabulated below for different climatic zones of the country.

Table 2 Wall assembly U-factor requirements (as per ECBC 2007)

Climate zone	3-Shift Facilities	1-Shift Facilities
	Maximum U-factor of the overall assembly (W/m^2K)	Maximum U-factor of the overall assembly(W/m^2K)
Composite/Hot and Dry/Warm and Humid, Moderate	0.44	0.44
[Note: Rate of heat loss of a window assembly is denoted in terms of U-factor. Lower the U-factor better is a window's insulating properties.]		

Roof specifications: Roof should conform to the ECBC 2007 requirements as tabulated below for different climatic zones of the country.

Table 3 Roof assembly U-factor requirements (as per ECBC 2007)

Climate zone	3-Shift Facilities	1-Shift Facilities
	Maximum U-factor of the overall assembly (W/m^2K)	Maximum U-factor of the overall assembly(W/m^2K)
Composite/Hot and Dry/Warm and Humid	0.261	0.409
Moderate	0.409	0.409

Windows: The U-factor and solar heat gain coefficient (SHGC) for windows should conform to the ECBC 2007 recommended values, as given in the table below for vertical windows in different climatic zones of the country

Lighting system

- Lighting power density (LPD) of indoor lighting system of an ICT facility should not be more than 10.8 W/m^2.
- General and task lighting should be preferred in indoor spaces. General lighting should be provided with CFL or T-5 and task lighting with LED or CFL.
- CFLs should always be used with electronic chokes.
- T-5 lamps should be given preference over 36 W mono-phosphor fluorescent lamps.

Table 4 Vertical fenestration U-factor and SHGC requirements (as per ECBC)

Climate Zone	Maximum U-factor (W/m2-K)	Maximum SHGC for WWR ≤ 40%	Maximum SHGC for 40%<WWR≤60%
Composite/Hot & Dry/Warm & Humid	3.30	0.25	0.20
Moderate	6.9	0.4	0.3
[*Note*: (U-factor in W/m2K)]			

- Facilities with areas that need to be illuminated due to some unavoidable reasons during unoccupied hours, should use LED strip lights
- Outdoor lighting, where rendition colour is not an issue, should utilize sodium vapour lamps.
- Lighting of cabins (with area less than 30 m^2), meeting and conference rooms, storage spaces, server rooms, and corridors should be controlled with occupancy sensors.
- Programmable timers should be installed to turn lights on or off of various areas with different operating schedules.
- Automatic daylight controls to switch lights on or off or dim lights should be provided in day-lit zones.
- Outdoor lights, which are kept switched on from dusk to dawn should be controlled with a photo sensor or an astronomical time switch.

Cooling system

- Variable refrigerant volume (VRV) systems should be given priority over split ACs or window ACs.
- Chillers with high coefficient of performance (COP) shall be selected, based on recommendations by ECBC. Also, water-cooled chillers should be preferred over air cooled chillers if availability of water for the cooling tower is not an issue.
- All variable centralized cooling system consisting variable-speed chillers, variable-speed-only primary pumps, variable-speed condenser water pumps, variable-speed cooling tower fans, and using demand-based controls based on the Hartman loop principle instead of PID controls should be preferred. The operating efficiency of such type of plants can be as low as 0.6 kW/TR.
- If possible, the chilled water should be supplied at higher temperatures. Typically, a saving of approximately two per cent of input energy per degree Fahrenheit can be realized (or about four per cent per degree Celsius) by raising the temperature of chilled water. This principle applies to all types of chillers, with minor variations.
- There should be provision for automatic reset of the condenser water temperature. Energy consumption of chillers can be reduced by keeping the condensing temperature as low as possible. Typically, compressor power drops by about 1.5% per degree Fahrenheit (about 3% per degree Celsius) of condensing temperature. COP improves with lower condensing temperature.
- Air-side economizer should be integrated in the air handling unit (AHU) to directly feed the outside air in the building when it is cooler outside.
- Energy recovery ventilators should be installed to pre-cool fresh air by the exhaust cool air.
- Installing energy-efficient motors: motors in AHUs, cooling tower, pumps shall be having minimum efficiencies as recommended by ECBC.
- Variable-speed drives should be installed on AHU fan motors for better control during part-load conditions.
- Chilled water distribution system should be provided with two-way water valves instead of three-way valves in order to reduce the pump's energy consumption.
- Instead of installing two-loop chilled water distribution system with the primary on constant

speed and variable on secondary loop, single-variable chilled water loop system should be installed.

- Pumps with higher efficiencies should be installed.
- Cooling towers with low-approach temperature should be installed.
- Alternate hot and cold aisle design should be followed in a server's air distribution system for efficient air management.
- Return air suction points in a data centre should be provided above the hot aisle areas.
- Wherever possible, particularly in moderate and hot and dry climatic zones, radiative cooling (process by which a body loses heat through radiation) should be preferred over convective cooling (process by which a body loses heat through natural, upward flow of hot air).

Power distribution system

- Transformer losses at 50% load and 100% load should be in compliance with the losses recommended by the ECBC.
- The power factor of the facility should be more than 0.95 lag—a level that should be maintained with the help of auto power factor correction relay.
- An automatic transfer switch enables redundant UPS, backup generators, DC to AC inverters, or other AC power sources to be used for a single load. Automatic Transfer Switches (ATS) should be used when no downtime from a power outage is tolerated.
- As per the Institute of Electrical and Electronics Engineers (IEEE) standards, it is a recommended practice that both the input circuit to the UPS and the associated bypass circuits (including the manual bypass circuit) be equipped with effective Transient Voltage Surge Suppression (TVSS).
- Appropriate techniques should be used to enhance the efficiency of UPS through loading optimization. Modularity is one of the methods to improve the efficiency. Modularity allows any user to size UPS as close to the size required during its operation.
- Modular power distribution units (PDUs) should be used as their major benefits are easy retrofit of the existing system, and easy modification of power distribution which helps in reconfiguration of rack power.
- Static transfer switch should be used to secure critical applications using two independent power sources.
- Advance power strips should be used to distribute power within network cabinets and server racks. This will also enable remote monitoring and/or control of power distribution at the load/equipment level.
- The efficiency of the UPS system varies with loading. Typically, a UPS system has maximum efficiency at 75–80% loading. When loading is less than 40–45%, efficiency reduces drastically. It is recommended that the UPS loading be maintained at more than 40%.
- An energy optimizer should be installed to continuously monitor the load demand, control the operation of the number of UPSs at any point of time, and also to maintain optimum loading on all UPSs.

- Continuous monitoring of the key electrical parameters is recommended, since they play a key role in maintaining the efficient performance of the electrical distribution system. Parameters such as voltage, current, power factor, and total harmonic distortion should be monitored on a regular basis. Whenever there is a deviation in the values of one or more of these parameters, necessary action has to be taken to bring it/them back to the desired level(s).
- Energy-efficient power supplies should be used. Stepping down of voltage at the transformer and conversion of power at the UPS switching circuit involve losses. The latest PDUs and UPS use low-loss switching devices, which minimize losses in the system, and hence maintain efficiency.
- Regular maintenance and testing of electrical systems are recommended. As in any other equipment, maintenance ensures efficiency. Maintenance implies not only repair and upkeep of the equipment, but also to ensure that it operates in a safe, reliable, and efficient manner. Maintenance personnel have to keep track of all the above aspects to ensure operational excellence in electrical systems.
- Regular maintenance of the capacitors in the UPS is recommended. The DC capacitors used in UPS wear out after some time. If these worn-out capacitors are not replaced, it would result in the inverter failing to operate under load and would cause increase in the ripple current in the batteries.
- Energy-efficient motors should be used. Selection of motors should be made according to the IS12615 code, and only energy-efficient ones should be chosen. Such motors lead to 3–4% more efficiency in the system.
- Energy-efficient cabling/busbars should be used. Selecting cables/busbars (strips of copper or aluminium that conducts electricity within a switchboard, distribution board, and so on) with proven lesser voltage drops per metre of its length helps in reducing transmission losses and contributes appreciably towards an energy-efficient system. Further, on occasions it might be a good idea to select cables 'one-size-up', which means just by opting for a bigger-sized cable, one can ensure lesser drops, and consequently, higher distribution efficiency.

IT equipment and peripherals

- *Use low-power processor:* Normally, 80–103 W is consumed by any typical thermal design power, which is 30 W more than what a low-power processor available in the market today consumes.
- *Use high-efficiency power supply:* In any conventional server room or data centre, the estimated average efficiency of installed server power supplies is 79% across a mix of servers. The available efficiency in the market today is 90%, which means 11% of energy drawn can be saved by using high-efficiency power supplies.
- *Use a server with built-in power management:* The load variation in a data centre is such that it increases progressively from 5 am to 11 am, and tends to decrease after 5 pm. It has been observed that even when the load on a server decreases, the server consumes relatively high power. Reportedly, even when it is in the idle mode, a server consumes 70–80% of full operating power. Hence, server processors should have a power-management feature built in, which can reduce

power consumption when the load on the server is low or when the server is idle.

- *Use blade servers*: Blade servers are servers with modular design in which a complete server (comprising processor, system memory, network connection, associated electronics, and so on) is on a single motherboard. The motherboard slides into a blade enclosure. Blade servers decrease the number of conventional servers required and consequently, the physical space to house them. Another advantage of a blade server is that we can remove or add any blade when the server is in power mode. Moreover, blade server consumes 10% less power than any conventionally mounted rack server, simply because the multiple servers share common power supplies, cooling fans, and other components.
- *Use server virtualization:* Virtualization is being used to increase server utilization and reduce the number of servers required. It has been estimated that 8:1 virtualization can reduce the initial power consumption by anywhere between 12 and 20%.
- *Optimize power distribution architecture:* In many server rooms or data centres, double-conversion type UPS are being used, which convert the incoming power first to DC and then back to AC within the UPS. The conversion enables the UPS to generate a clean, consistent waveform for IT equipment. At the same time, it enables the IT equipment to work in isolation from the power source. Many UPSs do not convert the incoming power, and operate at higher efficiency, as the losses that occur during the conversion process are eliminated. Generally, UPS supplies power at 208 V. Any server can handle AC input of up to 240 V without any negative consequence. So, if we can increase the voltage up to 240 V, the power supplies in the server will operate at an increased efficiency.
- *Implement best cooling practices:* Cooling efficiency can be improved by sealing gaps in floors and avoiding mixing of hot and cold air. Optimizing air flow also increases cooling efficiency. In addition to air-side management, opportunities exist on the chilled-water side of the cooling system. When the temperature required is above 68 ^{0}F, the temperature of the chilled water supply can be increased up to 50 ^{0}F which, results in energy savings.
- *Provide variable-capacity cooling:* Data centre IT systems are geared to handle peak computational load, which is a rare occurrence. Thus, the heat-generation rate also varies. Consequently, the cooling system, which, too, is sized for peak conditions, operates at part load, at which its efficiency drops. To improve the cooling system's efficiency at part load, several latest technologies—such as digital scroll compressors and variable frequency drives in computer-room air conditioners (CRACs)—can be used, which maintain higher operating efficiency at part load. A digital scroll compressor dynamically regulates the capacity of air-conditioners to match the room conditions without turning the compressor on and off. Typically, CRAC fans run at a fixed speed, and deliver a constant volume of air flow. Converting these fans to variable frequency drive fans allows both fan speed and power to be reduced as the load falls.
- *Provide high-density supplemental cooling:* A safe, controlled environment for IT equipment can be ensured by traditional room air-conditioners.

However, these ACs are well suited to server room/data centre densities (2–3 kW per rack). Higher densities (in excess of 30 kW) increase the server room/data centre efficiency. In order to maintain a safe, controlled environment for such higher densities, supplemental cooling units will be required. These units are mounted above or alongside the equipment racks. They pull hot air directly from the hot aisle and deliver cold air to the cold aisle. Supplemental cooling units can reduce cooling costs by 30%. The savings are achieved through reduction in fan-power consumption by bringing the cooling action closer to the source of heat. It also uses more efficient heat exchangers to remove sensible heat from the dry hot air generated by electronic equipment. The refrigerant is delivered to the supplemental cooling modules through an overhead piping system. This piping system provides more flexibility and allows cooling modules to be easily added or relocated as the environment changes.

- *Monitoring and optimization*: One of the consequences of rising equipment density is more diversity within the server room/data centre. Rack densities are rarely uniform across

Table 5 Potential saving in IT equipment & peripherals

Sl No.	Strategy	Initial data centre	Optimized data centre	Saving (KW)	%
1	Low-power processor	91W/processor (Average)	70W/processor	111	10–30
2	High-efficiency power supplies	AC-DC(79%)	AC-DC (90%)	124	11
		DC-AC(85%)	DC-AC(88%)		
3	Server power management	Power consumption 80% of full load (when idle)	45% of full load (when idle)	86	8
4	Blade servers	All rack-mount	20% blades	7	1
5	Server virtualization	No virtualization	20% servers virtualized	86	8–11
6	Power distribution architecture	208 V AC	41 5V AC provides 240V single phase	20	2
7	Implement best cooling practices	Hot aisle/cold aisle	Optimized cold aisle and chilled water temperature, no mixing of hot and cold air	15	1
8	Variable-capacity cooling	Fixed-capacity cooling	Variable-capacity refrigeration and airflow	49	4–11
9	High-density supplemental cooling	Floor-mount cooling only	Floor-mount plus supplemental cooling	72	6
10	Monitoring and optimization	No coordination between cooling units	Cooling units work as a team	15	1
Initial data centre load: 1,127 kW 50%+			Total savings 585 kW		
Source: Emerson Network Power					

a facility, and create hot zones in a server room/ data centre. Therefore, overall, a cooling system would operate in high cooling mode to maintain adequate cooling in hot zones, which creates inefficiency in cooling system. The implementation of adequate monitoring and proper optimization would suffice to minimize the inefficiencies of the cooling system.

Summary of recommended energy efficiency measures

A list of recommended measures to enhance the energy efficiency of both existing and new ICT facilities is given below.

For existing facilities:

- Enhance the building-envelope efficiency by replacing existing glazing with ECBC-recommended high-performance glazing, and providing cool roof.
- Enhance the lighting-system efficiency through replacement of slightly less-efficient lamps with more efficient lamps (for example, 36 W tubular fluorescent lamps and 36 W CFL with T-5, low-volt halogens with LEDs, and so on). Integrate automatic shut-off and space controls and daylight controls in the lighting system to avoid wastage.
- Enhance the cooling-system efficiency through retrofit measures, such as installation of variable-speed drives on motors, controls, replacement of inefficient chillers, pumps and so on, and by providing energy-management controls such as chilled water reset, demand-based controls, and so on.
- Deploy energy-monitoring systems to identify any deficiency in the existing systems, and have a check on operational inefficiencies.
- Appropriately utilize the existing IT capacity through consolidation, virtualization, and other strategies.
- Thorough analysis should be undertaken while replacing existing IT equipment with new ones to avoid any mismatch with the available supporting infrastructure (such as cooling system).

For new facilities:

- Design a building in an optimal way to harness natural resources available, and use high-performance building materials.
- Design the lighting scheme so that the lighting-power density of the facility is lower than the ECBC-recommended value. Provide lighting controls both,—occupancy-based as well as day-lighting-linkage based—as recommended by ECBC.
- Design an efficient cooling system with design efficiency not more than 0.8 kW/TR, and provide suitable controls to optimize performance at part loads.
- Design an efficient power distribution system in the facility.
- Design the IT equipment and peripherals in a balanced manner: vetting the immediate and future required capacities.

Existing government initiatives

There is no direct support to the ICT sector in the form of government policies. The Government of India has embarked on a number of programmes and initiatives to support stakeholders of the building sector to comply with and follow several strategies for achieving resource- and energy-efficiency in buildings.

Key findings and recommendations

- Potential exists to reduce energy consumption of the ICT industry by 25–30% from the current levels.

Ministry of Power/Bureau of Energy Efficiency

- Energy conservation act 2001 enacted
- Energy conservation building code (ECBC) 2007 launched (voluntary)
- Appliance labelling (party mandatory)
- Star rating programme for existing buildings (rates commercial buildings on energy performance)

Ministry of Environment and Forests

- Mandatory environmental clearance from the Ministry of Environment and Forests/state Environment impact assessment authority mandatory for all large constructions (built up rea>20000 sqm and area development projects>5 ha), 2006
- Resource (energy, water) efficiency integral part of clearance
- ECBC mandatory

Ministry of New and Renewable Energy

- Promotes energy efficient buildings through its solar buildings program
- National green building rating system "GRIHA" launched (partly mandatory), 2007
    - Mandatory for central government and PSUs to go for minimum 3 star rating (2010), 100 million sq ft registered
    - Incentives given by MNRE
- Solar cities programme
- Coordinating the Jawaharlal Nehru National Solar Mission

Prime Minister's Office

- National Action plan on Climate Change -Change Relates to sustainable development, co-benefit to society at large, focus on adaptation, mitigation, and scientific research

Ministry of Urban Development

- Coordinating the National Mission on Sustainable Habitats

Ministry of New and Renewable Energy

- Coordinating the Jawaharlal Nehru National Solar Mission

- The energy-intensity reduction potential existing in the ICT industry can be realized by improving envelope efficiency, integrating automatic daylight controls, developing efficient cooling systems with optimized part-load performance, ensuring an efficient power distribution system, and by using efficient IT equipment.

- Real-time remote monitoring system shall be deployed for continuous monitoring of energy performances of the facilities to have a check on operational efficiencies.

- Industry-specific energy standards and energy-performance benchmark need to be developed, with energy/environmental rating made mandatory.

- IT equipment shall also be included in 'standard and labelling' programme introduced by the Bureau of Energy Efficiency (BEE) of the Ministry of Power.

Way forward and plan of action

Undoubtedly, various actions have been taken by the ICT sector to make it more efficient. But there is still a lot of scope to make this sector more energy efficient. New technologies and innovation in design will help enhance energy efficiency of both existing ICT facilities and the ones that are coming up. The same technologies can also be employed in 'greening' the other sectors, too. In a nutshell, there is a need to develop a comprehensive action plan and take proactive actions, which are mentioned below.

- *ICT assistance expected in building sector:* ICT applications can prove to be pivotal in improving the current energy-efficiency level of the building sector. ICT's role in the following areas is deemed to be necessary:

    - *Real-time remote monitoring of energy performance of buildings:* ICT will allow information in real-time on energy consumption of every appliance in a building in a user-friendly way, thereby enabling end-users to take informed decisions, which will lead to:

    - *Effective energy management:* The ICT sector can provide tools that are vitally needed to collect, process, and manage data for calculation of the energy performance of buildings according to the directive on their energy performance. Energy performance of multiple facilities can be examined, and corrective measures can be taken by employing fewer experts even from a remote location.

    - *Collect quality data:* In order to develop discrete energy-efficiency maturity level within the building sector—such as for hospitality, hospitals, institutions, and so on—the sub-sector-specific quality data, can be collected through smart metering. This data can then be utilized in developing policy/regulatory framework to trim down energy intensity of various sub-sectors within the building sector.

- *ICT facilitating design and construction of green buildings:* The ICT sector can take centre stage in design and construction of green buildings by developing a variety of assessment, compliance check, simulation, analysis, monitoring, and visualization tools.

- *Establish energy-efficiency maturity level of the ICT sector:* There is an urgent need to carry out a detailed study to establish the current energy-efficiency level of the ICT sector. The study will also identify the gaps and ways to bridge them within a stipulated time frame.

- *Develop energy-efficiency design standards/ norms and performance benchmarks:* In the absence of standards and performance benchmarks developed exclusively for the Indian climatic conditions and operations, it has been very difficult to ensure energy efficiency in ICT facilities at the design level. Hence, these standards need to be developed at the earliest.

- *Develop environmental guidelines for the ICT sector:* These guidelines should be developed to help professionals involved in various ICT projects and for greening their respective facilities.

- *Develop exclusive environmental rating systems for the ICT sector:* Green building certifications have commenced in India. But there is a need to develop an exclusive environmental rating system for ICT facilities both new and existing. Once these rating systems are developed, these should be made mandatory for the ICT sector.

- *R&D for reducing direct IT load:* IT load contributes significantly to overall energy performance of ICT facilities. With effective design support and innovations, the efficiency of an ICT facility with respect to the ICT load may increase, but such facilities will continue to consume more energy. Therefore, identifying and developing new technologies, which can reduce the direct IT load is required. R&D programmes should be developed and supported at the national level to reduce direct IT power. Energy star labelling of IT equipment is also recommended.

B: Disposal of end-of-life IT equipment

Background

As the usage of ICT equipment increases, the rapid obsolescence and availability of newer and efficient models at affordable rates lead to the concern of managing end-of-life and discarded equipment in an environmentally sound manner. These end-of-life ICT equipment—also known as e-waste—include all hardware and accessories, including networking equipment, monitors, central processing units (CPUs), printed circuit boards (PCBs), wires, printers and their cartridges, keyboards, mouse, facsimile and copying instruments, and so on. In addition, e-waste encompasses a wide range of electrical and electronic devices, such as cellular phones, personal stereos; as well as large household appliances, such as refrigerators and air-conditioners. Owing to their hazardous constituents, this new waste stream needs special care and attention.

In fact, India is emerging as a significant generator of e-waste in its own right. According to an estimate made by the Central Pollution Control Board (CPCB) in 2008, the country's total e-waste generation is expected to increase from approximately 1,00,000 tonnes in 2005 to 8,00,000 tonnes by

2012 (see Box 1). The ICT sector accounts for 34% of this total (see Figure 7).

Impact of e-waste on environment and GHG reduction

The International Telecommunications Union recognizes the fact that the production and use of ICT

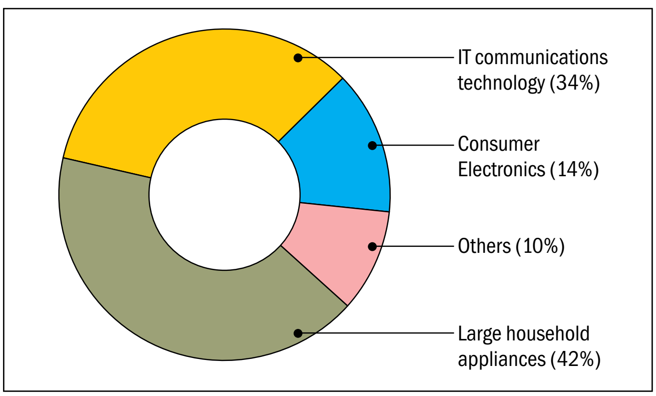

Figure 7 Sources of e-waste in India (MAIT 2008)

BOX 1 E-WASTE GENERATION SCENARIO IN INDIA

- There has occurred a steep growth in computers. Desktops, notebooks, and netbooks combined are expected to cross 12.6 million units during 2011–12 —a growth of 35% in FY 2012.
- Total number of mobile phone users in India has reached 791.38 million, making it the world's second largest user base.
- Huge quantum of old and obsolete PCs (about 2 million) need immediate and safe disposal.
- India's total e-waste generation is expected to increase to 8,00,000 tonnes by 2012

[Source: MAIT (2011), TRAI (2011), CPCB (2010)]

equipment are increasing worldwide, thereby leaving behind rapidly growing amounts of e-waste. If not handled properly, e-waste poses a serious threat to human health and the environment, and contributes substantially to GHG emissions. ICT equipment has to be managed using a life-cycle approach, including design for easy reuse and recycling, systematic take-back systems, and energy-efficient reuse and/or recycling procedures. E-waste avoidance and minimization can play a significant role in GHG-emission reduction.

Three levels of toxic emissions are associated with e-waste[3]:

Primary emissions: Hazardous substances that are constituents of e-waste (for example, lead, mercury, arsenic, polychlorinated biphenyls (PCBs), fluorinated cooling fluids, and so on).

Secondary emissions: Hazardous reaction products of e-waste substances resulting from improper treatment (for example, dioxins or furans generated by incineration/inappropriate smelting of plastics with halogenated flame retardants),

Tertiary emissions: Hazardous substances or reagents that are used during recycling (for example, cyanide or other leaching agents, mercury for gold amalgamation) and those released due to inappropriate handling and treatment.

Reduction of waste is achieved through reuse and recycling. From a climate perspective, the benefits of both reuse and recycling are realized in avoided GHG emissions from waste treatment and disposal.

[3] UNEP (2009). Recycling – from E-waste to resources

Moreover, GHG benefit is achieved through avoiding resource extraction and reducing manufacture of new products. Table 6 depicts the total CO_2 emissions at a global level during production of key primary metals used in manufacturing ICT equipment. Recovering metals from state-of-the art recycling processes generates only a fraction of these emissions, and also has significant benefits when compared to mining, in terms of land use and hazardous emissions.

Considering the emissions from primary mining of metals used in one personal computer (see Table 2), it may be estimated that reuse and recycling of 40 personal computers may lead to avoidance of

Table 6 CO_2 emissions during primary metal production

Important EEE metals	Main applications	Demand for EEE t/a (2006)	Data for primary production [t CO_2/t metal]	CO_2 emissions (Mt)
Copper	Cable, wire, connector	45,00,000	3.4	15.30
Cobalt	Rechargeable batteries	11,000	7.6	0.08
Tin	Solders	90,000	16.1	1.45
Indium	LCD glass, solder,			
semiconductor	380	142	0.05	
Silver	Contacts, switches, solders	6,000	144	0.86
Gold	Bonding wire, contacts, integrated circuits	300	16,991	5.10
Palladium	Multilayer capacitors, connectors	32	9,380	0.30
Platinum	Hard disc, thermocouple, fuel cell	13	13,954	0.18
Ruthenium	Hard disc, plasma displays	6	13,954	0.08
CO_2 total (t)				23.4
[*Source*: EcoInvent 2.0 database, UNEP (2010)]				

Table 7 Emissions from primary production of metals used in a personal computer

Metal	Emissions from primary mining per tonne of metal (in tonnes of CO_2)	Amount of metal in one PC (in kg)	Emissions from primary mined metals in one PC (in tonnes of CO_2)
Steel	2.04	6.193	0.01263372
Aluminium	10.02	0.549	0.00550098
Lead	3.2	0.00658	0.000021056
Nickel	19.53	0.0127	0.000248031
Copper	3.4	0.413	0.0014042
Gold	16991	0.00026	0.00441766
Silver	144	0.0017	0.0002448
Palladium	9380	0.00012	0.0011256
Total			0.025596047
[Source: Adelphi Consult (2011)]			

BOX 2 SAFETY MEASURES NECESSARY FOR E-RECYCLING

Six core performance elements of environmentally sound management related to evaluation, dismantling, refurbishment, pre-treatment, treatment, and disposal applicable to all e-waste management facilities require that a facility should have:

- An applicable environmental management system (EMS) in place
- Sufficient measures to safeguard occupational and environmental health and safety
- An adequate monitoring, recording, and reporting programme
- An appropriate and adequate training programme for the personnel
- An adequate emergency plan
- An adequate plan for closure and after-care

[Source: Adapted from the Basel Convention]

1 MTCOE or CO_2 emissions from 2.1 barrels of oil consumed.

While legislative approaches to restrict the use of hazardous substances—such as the European Union's Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment i.e. RoHS—exist, these can only address primary emissions, and partly secondary emissions. However, even the 'cleanest/greenest' products cannot prevent tertiary emissions, if inappropriate recycling technologies are used. Box 2 enumerates the safety measures for e-recycling.

Hazards of handling e-waste

Parts of the end-of-life ICT equipment such as the CRTs, printer circuit boards, printer wire boards, semi-conductors, transistors, and so on contain precious metals, such as gold, silver, copper, platinum, lead, cadmium, and mercury.

Recovery of these valuables from the electronic scrap involves use of acids and other hazardous chemicals often accompanied with methods, without protection to the environment or health like open sky incineration, cyanide leaching, "cooking" of circuit boards etc. lead to dramatic effects on health and environment. The absence of an effective method for collection and reporting of e-waste will lead to exposure to hazardous elements like lead, cadmium, mercury, arsenic, barium, beryllium and brominated flame-retardants (BFR).

Current practices & challenges of the Indian IT industry

According to the 2007 MAIT-GTZ study titled 'E-waste Assessment in India—a quantitative assessment on the generation, disposal and recycling of electronic waste in India', in the informal sector, only about 5% of e-waste reaches authorized recyclers. The remaining 95% is either processed by unauthorized recyclers (informal sector) or is resold, or refurbished and resold, or recycled in an unhygienic and unsafe manner in many remote parts of our country. Managing end-of-life IT equipment presents a business opportunity for the recycling industry, but must be treated as a business responsibility by the ICT industry. Several proactive steps have been taken in this regard by the ICT sector both at the global level as well as at the national levels (see Box 3). The ICT industry in India—as manufacturers and bulk consumers—should take appropriate steps to ensure that the e-waste generated is managed in an environmentally sound manner.

BOX 3 PROACTIVE BUSINESS ACTIONS FOR MANAGING END-OF-LIFE IT EQUIPMENT

Global context - Swiss e-waste management system: Switzerland has been a pioneer in legislating e-waste management. Even before the Swiss Federal Office for the Environment introduced the Ordinance on The Return, the Taking Back and the Disposal of Electrical and Electronic Equipment in 1998, management of waste electrical and electronic equipment (WEEE) was driven by voluntary initiatives of the ICT industry through creating producer responsibility organizations (PROs). Currently, there are four PROs in Switzerland, of which SWICO Recycling Guarantee and SENS (Swiss Foundation for Waste Management) are the largest. According to the SENS (2010) Report of the Technical Inspectorate for the year 2009, nearly 113,000 tonnes of WEEE were collected, sorted, and dismantled within the Swiss recovery systems; out of which 41% was office equipment, IT and telecommunication equipment, consumer equipment and graphical devices.

In the Swiss e-waste management system, the producers pay the advanced recycling fee (ARF) to the PROs on the sale or import of any appliance. This ARF is passed down to the distributors and retailers, who, in turn, invoice the consumers on the purchase of a new appliance. The ARF is used to pay for the entire system for collection, transport, dismantling, decontamination, and recycling of the disposed appliances. Despite the fact that ARF does not take into consideration new-generation products, which incorporate special materials or features that make them more environmentally friendly to recycle at the end-of-life, it remains customer-friendly as a customer is far more willing to pay a small fee charged at the time of purchase than paying for the disposal of a product that is worthless.

Indian Context - HCL Infosystems Ltd: Even in the absence of a regulatory framework in the country and the lack of extended producer responsibility (EPR) laws, HCL has been providing its customers a free e-waste take-back and recycling service since 2008. It has subsequently extended the campaign to the retail customers, and has reported to have collected and recycled 73,092 kg of e-waste in 2009-10 which is 17% more than that of the previous year.

In line with its demonstrated position and continued commitment to greener products, HCL has adopted a proactive stance on Restriction of Hazardous Substances (RoHS) compliance, keeping in mind the emerging requirements of the stakeholders to eliminate /restrict the use of hazardous substances in all its manufactured products. Initiated in 2006, HCL has achieved RoHS compliance status for desktops, laptops, workstations, and servers in 2008. As of September 2010, HCL is also phasing out PVC and BFR, antimony, beryllium, and phthalates in product manufacturing.

[Source Annual Report of SENS, Switzerland (2010) and official interaction with HCL Infosystems Ltd]

The new generation of environmental laws aimed at products rather than end-of-pipe pollution focuses on new product design mandates, substance restrictions, energy efficiency, and take-back mandates. The industry needs to take into account these emerging trends of legislation to identify and manage risks. Some the challenges for the industry are enumerated below:

Functioning of EPR systems: Identifying the producers of non-branded and counterfeit products poses a challenge for effective functioning of an EPR system for the industry. Moreover, during product repair, original components often get replaced with those of other brands. Also, unlike the formal e-waste recyclers who meet global standards, the informal e-waste recycling sector has low operating costs and can offer better prices for end-of-life products. The effective functioning of an EPR system is further hampered by the lack of know-how when it comes to putting in place collection systems for recyclables, and establishing good practices for environmentally sound recycling of e-waste.

Transparency in downstream the recycling industry: IT managers are concerned about where their electronic equipment land up after disposal because they are worried about sensitive data loss. Often IT companies seek out sale of their IT scrap—mixed with other scrap—through auction. Alternatively, an asset recovery agency is engaged to handle the IT scrap (see Box 4). In both cases, the IT industry has limited control on the entire downstream flow of hazardous e-waste through their facilities, until it reaches the area of final disposition. The lack of transparency also poses a threat to data security and chance of data-leakage that many organizations fear while discarding hard drives and other data-storage devices.

Limited success of take-back policies: While several companies have initiated take-back schemes, green boxes, and collection centres, these initiatives have met with little or no success. To incentivize the adoption of these schemes, there is a need for the industry to develop partnerships with waste-recycling companies, other generators and the corporate sector (see Box 4).

Existing government initiatives

To tackle the concerns pertaining to management of e-waste in India, the Government of India has enacted several regulations, as mentioned below:

The Hazardous Wastes (Management and Handling) Rules, 1989 (amended in 2000, 2003, 2009) which stipulate the control of generation, collection, treatment, transport, import, storage, and disposal of hazardous wastes, including e-waste.

Guidelines for Environmentally Sound Management of Electronic Waste, which was issued by the CPCB in 2007.

E-Waste (Management and Handling) Rules, 2010, which will be operational from May 2012.

Draft National Policy on Electronics, 2011 of the Department of Information Technology, Ministry of Communications and Information Technology

The state governments of Delhi, Maharashtra, Tamil Nadu, and Andhra Pradesh have initiated a number

BOX 4 ECORECO: E-WASTE SUCCESS STORY

The Mumbai-based Eco Recycling Limited (Ecoreco), established in 2007, offers a full range of e-waste services: from doorstep collection of unwanted electronics to dismantling end-of-life equipment and sorting components. It is Mumbai's only authorized recycler. For an assured supply of e-waste, the company has secured agreements of up to five years with several companies, which are typically multinational corporations that have outsourced some services to India.

Ecoreco is working in partnership with a leading nationwide logistics enterprise to offer e-waste collection from over 600 locations in India. The company has also introduced a 'shredding van'—the first of its kind in India—which collects e-waste from offices and brings it to the Ecoreco recycling plant where it can be processed. This reassures customers that all the data contained in the electronic devices is destroyed.

Source Official interaction with Eco-Recycling Pvt Ltd of schemes on registration of facilities for recycling of e-waste. Altogether, 22 recyclers have been granted authorization by the Government of India to manage e-waste. Additionally, to promote greener electronics and phasing out of hazardous metals used for manufacturing hardware the Maharashtra IT policy has laid down certain specifications (see Box 5).

Way forward and plan of action

It is evident that emerging technologies like cloud computing will lead to significant reduction in the volume of electronic equipment used, and thereby the quantum of e-waste generated. However, keeping in mind that the e-Waste Rules will be operational by 2012, the following proactive actions are recommended for the IT industry for creating enabling conditions for implementation of the regulation:

Consider progressive ICT equipment design and waste-reduction opportunities

Research and development for greener products: To remain competitive, the industry needs to stimulate design changes in products through elimination of harmful substances and RoHS-compliant equipment.

Design of recyclability: While some Indian companies have progressed to manufacturing PVC- and BFR-free equipment, recyclability also needs to be incorporated into the product design. It includes methods for making products that are more easily disassembled, repaired, remanufactured, and reused.

Procurement of greener products: The industry needs to adopt policies at the company level to ensure that green products are preferred at the procurement stage.

BOX 5 MAHARASHTRA IT/ITES POLICY, 2009: PROMOTION OF 'GREEN IT'

The policy proposes path-breaking initiatives to promote 'green' IT and electronic hardware, as well as e-waste recycling.

- Awards will be instituted for demonstrated, efficient natural-resource management by IT units.
- The development of comprehensive e-waste collection and recycling systems and their use by the state as well as private agencies for the disposal of IT products will be promoted.
- While procuring IT products, the government will give preference to firms that have an expressed end-of-life product, take-back policy, and e-waste recycling processes.
- Government departments and agencies will give preference to 'green' and energy- efficient IT products in their procurement.
- In consultation with the Environment Department, and with the approval from the empowered committee, norms will be determined to facilitate 'green' IT parks.

Source Industries Department, Government of Maharashtra

Establish an Advisory Committee for management of e-waste

An interface with the government: The proposed advisory committee will act as an interface with the government. It will coordinate and monitor the industry when it comes to managing end-of-life equipment or e-waste in an environmentally sound manner. The committee can engage experts from the Central Pollution Control Board and state pollution boards, and think-tanks such as TERI and NASSCOM. All generators will have to maintain a register of e-waste generated and the disposal route. An inventory system will help the recycling industry to cope with the capacities generated.

Recycling fund: The committee will create a recycling fund to cover the e-waste management costs. This will ensure that the authorized facilities get access to the e-waste generated by the IT industry and manage the recycling of computers and telecom equipment, which are lying unused, occupying space, and are ready for disposal.

Accountability in downstream recycling industry: The IT industry needs to be responsible for the entire downstream flow of hazardous e-waste through their facilities, until it has reached the final point of disposition (the last point in the recycling chain for each type of toxic material, at which time the hazardous e-waste either ceases to be a waste by no longer needing further separation or recycling, is fully tested, labelled, packaged, and sent for reuse; or is finally disposed of). Documentation and reporting on management of e-waste need to be included in the company's existing management system and sustainability-assessment framework.

Developing company-level standard operating procedures: Rather than simply loading up containers of untested or non-working equipment and selling them to the highest bidder, there is a need for creation of the operational governance system and in-house processing of the IT scrap to ensure that technicians are capable of executing procedures for sanitizing, removing, and destroying data on hard drives and other data-storage devices. This will include maintaining a reporting system to capture and report all critical data on each device.

Labelling scheme for e-products

Product disclosure: A labelling scheme can be initiated to disclose product details when they are made available in the market. Labelling will list the harmful constituents, including RoHS compliance. To begin with, the scheme can be initiated and made mandatory for public-sector procurements with the Department of Information Technology, Government of India.

Develop sustainable partnerships with stakeholders

Cooperation with authorized treatment facilities: Develop models for cooperation with authorized e-waste treatment facilities to dispose of obsolete electronic equipment. Targets for recovery, reuse, and recycling should be set with these facilities, and the information on quantity and fate of end-of-life equipment should be recorded and disclosed.

Attractive take-back schemes: Developing partnerships with stakeholders for devising attractive take-back schemes, green boxes, and collection centres. These stakeholders would include waste-recycling companies, other generators, and the corporate sector. An asset-recovery company can also be engaged, which will go to customer's facilities and take control of the equipment there, sort those with reuse potential from those without, and ship the scrap directly to a vetted downstream recycler. Widespread communication and high levels of transparency will be critical to the success of such a scheme.

Conduct information, education, and communication campaign

Awareness for all stakeholders: There is an urgent need to generate awareness among citizens and stakeholders about e-waste through guidelines for consumers with lucid 'Dos and Don'ts' and eco-labels for electronic products.

Identical treatment of e-waste in home and offices: E-waste is not limited to obsolete computers, but also includes other equipment and appliances, such as refrigerators, televisions, air-conditioners, and so on. Strategies designed to manage e-waste should take this aspect into account.

Document and showcase benefits: Documentation and reporting on management of e-waste need to be included in a company's existing management system and sustainability-assessment framework.

Annexure – Green practices adopted at the ICT facilities in India

Case study of facility no-1

Lighting & Miscellaneous

- Reduce excessive illumination levels to standard levels in all common areas such as parking, lobbies, toilets etc. using switching or decamping.
- Aggressively control lighting with clock timers, delay timers, sequential timers, and photo cell & occupancy / motion sensors.
- Replacement done of copper / aluminium winded choke by energy saver electronic ballast for tube fittings.
- Replaced CFL lamps by LED lamp fittings which are working 24 X 7 in common areas.
- Regulated workings of Lifts, Vending machines, Ventilation systems, Water coolers etc. – Lifts are shut off except one during night hours. Same case with tea vending machines, coolers etc.

Air-Conditioning

- Ensure no cool air leakages from each air conditioned area
- Reduction in server rooms by rationalizing its usage.
- Done server room wall insulation where ever required. (mainly where other side of the wall is not in the air-conditioned areas)
- Reduced working hours of air conditioned systems time to time. (e.g. In Winter , night hrs., weekends etc.)
- Installed watt miser system in all AHU system for saving consumption in chiller system.

Computers

- Replaced CRT monitors by TFT monitors & Turned off PC when not in Use.
- Usage of thin client in place of CPU
- Installation done of Computer power management software for all desktops without affecting productivity. This is our Computer Power Management Green IT Initiative through a product called En-power. En-power will automatically switch computers to low power mode (Monitor Off / Standby / Hibernate / Shutdown) when they are idle / not in use.

The benefits of this application are:-

- Automatic Power Management: No longer need to worry about switching off your computer when you leave your desk. En-power will take care of the same.
- Savings Reports: view comprehensive reports that illustrate how much power has been saved by powering down your computer.
- Light footprint: The En-power client consumes minimal CPU and RAM and runs quietly in the background.
- Timely Notifications: receive a notification message before your computer switches to low power mode. You can prevent your computer from switching merely by moving your mouse.

- Work hour, post work hour policies: During work hours, a less aggressive power policy was set as opposed to post work hours.

D.G. Sets

- Optimize loading by synchronization
- Cleaning of air filter /diesel filters / Diesel tanks regularly.
- Using additive in DG Fuel (HSD) to saving in fuel & lube oil.

Electrical Distribution System

- Daily monitored feeder wise electrical consumption
- Power factor maintained unity under rated load condition
- Set main Transformer taps positions to optimum settings.

Water Conservation

- Usage of auto level controllers eliminates over flows at water tanks
- Reduce water flow at water taps by using plugs which reduce flow of water but does not appear.
- Promptly repair leaking in washrooms, pipes lines etc.
- Monitoring water meter readings daily
- Water recycling process –STP in process

Usage of renewable energy

- Procured 2.1 MW windmill at Chakla, Dhule through Suzlon & expected net generation will be 31.5 lakh units/annum, commissioned on 30th June 2011
- Usage of Thermal Solar water heaters for warm water for cafeteria ,energy saving .

Green initiatives taken by organization

- Distribution of CFL bulbs (Energy saving bulbs) as Diwali Gift to the employees. More than 12,000 CFL bulbs were distributed
- Development of Car & Bike Pooling System to motivate employees follows Car & Bike Pooling practice while commuting to office.
- Free PUC check-up camp for employees' vehicles – More than 700 vehicles were PUC certified.
- Distribution of medicinal saplings to employees – More than 1600 saplings were distributed
- Virtualization – Current infrastructure holds 500+ virtual machines
- Ventilation System at Basement Parking Zones: to reduce carbon levels

Case study of facility no-2

Lighting & Miscellaneous

- Internal lighting integrated with occupancy sensors reducing energy consumption
- Streetlights converted from Metal Halides 150W to 65W CFLs
- Converted T8 - 36W lights to T5 - 28W lights
- Changed Elevator lights from 11W CFLs to 2W LEDs
- Optimized of LUX level in working areas by removing extra lights

Air-Conditioning

- AC grouping done as per building orientation and heating pattern from east to west direction and sub divided into areas like cabins, common work area and lobbies. The operations are altered to these groups according to the demand.

Operational hours are decided as per the above designed group.

- Temperature settings decided on the seasonal ambient temperature variation.
- Common areas and meeting room ACs switched ON on call basis.
- Procedures set to review of AC operation calls and rearranging the AC grouping
- Facility round in place to switch off AC & Lights not required
- AC system installed with VRF technology facilitating in the control of local cooling and thus resulting in considerable saving vis a vis a conventional central AC system
- Installation of Ozonized air purification system considerably reduced load on AC system.
- Variable Refrigerant Volume (VRV) air conditioning system has been installed which results in considerable reduction in energy consumption. This was instrumental in helping us win the Emerson Cup GOLD award for the Lowest Energy Consumption in India and South East Asian countries.

Computers & Servers

- UPS shutdown at night and on weekends
- Switching off PCs in non-working hours drive
- CRT monitors replaced with LCD monitors
- Auto PC shutdown software installed
- 130 servers moved into virtualization
- Replacing PCs with energy efficient thin clients
- Implemented private cloud and virtual desktops using thin client solutions resulting in significant reduction in energy consumption (deployed the Vblock Platform for a Virtual Desktop Interface [VDI] implementation to serve 1,200 users across India. Previously a desktop used to consume about 150W. Now, with VDI using thin client it is down to around 60W.)

D.G. Sets

- Periodic monitoring of stack to check proportion of SO_2 & other suspended particulate matter in emissions from D G Sets.

Electrical Distribution System

- Correction done to capacitor bank to achieve 1.0 power factor to minimize the power losses

Water Conservation

- Hydro pneumatic system of water supply installed, thereby ensuring minimum wastage of water
- Urinals equipped with motion sensors
- 125,000 ltrs of recycled water generated through sewage treatment plant used for gardening purposes
- Average Water consumption was 157cum (1.57 lakh litres) daily for FY10 i.e. 52.33 litres / per day /per employee at the beginning of the year. Achieved 10% reduction in fresh water consumption i.e. 47.1 litres per day per employee by FY10 end.

Usage of renewable energy

- Facility is built in such a way wherein we make maximum use of natural light thus saving energy.
- Internal gardens make the facility cooler which helps in reducing dependency on AC.
- Solar power used in cafeteria kitchen & gym.

Green initiatives taken by organization

- Deployed a unified communications solution based on Microsoft Office Communications

Server (OCS) 2007 and Microsoft Exchange Server 2007 resulting in reduction of carbon footprint by lower travel / logistics

- Reduced paper usage by double-side printing, promoting soft copies of minutes of meting & mails instead of printed copies, using of reusable and environment friendly stationery items, Using electronic signatures / digitized accounting in accounts instead of printed invoices and challans, distribution of soft copies of study-material for training etc.
- Various steps taken in employee transport to reduce fuel consumption such as route optimization, control on unscheduled cab requirements thereby ensuring optimum seat utilization, use of buses in lieu of cabs etc. Additionally, a number of employee car pools are in operation, thus further reducing the carbon footprint of the organization. Another employee initiative is "Cycle-a-thon", wherein a number of cycling enthusiasts come to work on their bicycles daily.
- A vermi compost plant has been set up to generate organic manure by treating organic waste

Green Design considerations

- The facility has been built to conserve energy, control water consumption and ensure low life cycle cost of building maintenance.
- The north building has been built by making extensive use of glass to allow natural light to percolate without any direct sun rays incident on it, thus reducing the heat load on the building
- Use of skylights throughout the building ensures a good distribution of natural light, thus reducing artificial lighting.
- The use of double glazing with reflective glass for the windows along with clay tiles ensures minimum heat load on the building.
- Indoor and outdoor plantations ensure minimum glare and radiation. It also helps to maintain micro climatic control, as well.

Waste Management

- Waste segregation at source such as e-waste, bio-degradable waste, non-biodegradable waste
- Printer cartridges returned to OEM for recycling
- Bio-degradable waste (food waste, garden waste, etc) is recycled through the vermi culture plant.
- E-waste sent for recycling through authorized certified agency.
- Reduction of Business Travel –
- Deployment of a unified communications solution leading to 15 % reduction in travel

Case study of facility no-3

Lighting & Miscellaneous

- De lamping / Switching off
- High efficiency lamps
- Voltage transformer
- Photo sensors & automatic ON/OFF
- Timer linked ON/OFF
- Smart energy meters incorporation and pulling data to platform
- LED based lights in place of conventional

Air-Conditioning

- VFD for AHUs
- High efficiency chilled water pumps
- Automatic ON/OFF
- Sequential operation of chillers

- User temperature recording & optimizing AHU/ DX/packaged units operation
- Timer linked ON/OFF
- Smart energy meters incorporation and pulling data to platform
- Critical temp/humidity recording profile & importing to platform
- High efficiency chillers

Computers

- Sleep mode operation / switch off when not in operation
- Electrical Distribution System
- PF correction & capacitor addition
- Sub metering & pulling data to platform

Usage of renewable energy –

- Solar based hot water systems; LED solar PV based street lights. – Implemented in few of the buildings.

Case study of facility no-4

Lighting & Miscellaneous

- Use of LED & CFL lights, Timer control and motion sensors - LED lights are used with 1watts, CFL and Electronic chocks for less power consumption, Motion sensor lights work only on movement and use of timers based control for outside, staircase lights and Toilet exhaust fans
- Maximum utilization of natural lights
- Windows are used in side walls, also on passages, toilets to get maximum natural lights to save energy

Air-Conditioning

- HVAC uses VRV feature (Variable Refrigerant Volume) - VRV system provides considerable savings on energy, costs, and space requirements.
- Use of Double glazed window and wall constructions to reduce load on HVAC.
- Use environment friendly gas for FM200 system & HVAC system. Use environment friendly gas in HVAC R-410A gas & FM200 (Inergen) INERGEN is a mixture of nitrogen, argon and carbon dioxide)

Computers and servers

- Used LCD monitors, replaces, CRT based monitors. Provided laptops to employees (based on requirement), than desktops.

Servers

- Used VMWare for server consolidation. Only 19 physical servers used VMWare to host 155 virtual servers. This initiative replaced 155 physical servers use and saved energy more than 13KW.

Electrical Distribution System

- Weight sensitive elevators with Auto synchronization - With weight sensitive option, Elevators doesn't stops at each floor when elevator reached to its capacity, and synchronization ensure only nearest elevators takes the floor call)

Water Conservation

- STP Plant – STP plan used to filter waste water and same is used for Gardening & toilet flushing this minimize overall water requirement
- Toilet Sensors – Toilet sensors used for urinals for low water consumption
- Drip Irrigation system – Drip Irrigation system used to minimize water usage & avoid wastage, time

is set for irrigation during morning and evening to avoid vaporization of water

- Ground water recharge, rainstorm pipeline, Wells
- Connected to roof top rain water pipes and Rainstorm to 20ft bore for ground water recharge and wells water used
- Use of paving blocks - Use of paving blocks for internal roads & parking space which helps in storm water seepage into ground and helps in ground water recharge

Green initiatives taken by organization

- Biogas Plant – Disposal of kitchen waste is used to create biogas and collected biogas for use in cooking and heating
- Carbon Calculator – For awareness within the associates use of carbon calculator to help monitoring carbon foot print
- Use of recycle material – Use recycled material such as partition boards are made from recycle material, in day to day operation wherever possible old furniture and furniture parts etc. used to create small seating places etc.
- Erosion control – Erosion control due to least ground coverage and maximum utilization of open area's
- Use of Canteen waste & Garden waste for gardening – Use canteen waste as vermin compost and fertilizer
- Carpool & Bus facility, Use of cycle
- Encouraged Carpool within the associates for coming & going, using cycles to reach nearby co-locations.
- Use of plastic cups banned & provided ceramic cups
- Tree Plantation Campaign at Campus

Case study of facility no-5

- All the new building built by the company are resource efficient and company has a target to reduce ten folds the resources utilized.
- Peer reviews of structural design of all new buildings are carried out to ensure optimum use of concrete, steel and glass.
- During the past two year company has been able to achieve 17.6% reduction in per capita electricity consumption.
- 3.6 million kWh of energy was generated by the renewable energy sources installed at various facilities across the country during year 2009-10
- Lighting – Installation of occupancy sensors and LED lighting fixtures
- Introduction of power management in employ care centres to manage air conditioners effectively during non-operational hours
- Installation of VFDs in AHUs
- In the new upcoming buildings the radiant cooling technology has been adopted.
- Electricity monitoring – Installation of meters not only at the building level but also at the equipment level which has started giving us intelligent data to help us take informed decisions
- Optimize UPS electricity utilization after office hours and during weekends
- Reduce the number of elevators operating during weekends and holidays
- Solar hot water system of 645700 lpd installed at different facilities

- Encouraged the employees to meet and collaborate on virtual platforms like video, audio and web conferencing, thus reducing the travel related emissions.
- Minimized the usage of ozone depleting substance at all the facilities during past three years.
- STP plants in place in facilities to recycle and reuse the waste water generated. The recycled water is utilized to meet the landscape water demand. Also rain water harvesting structures have been built.
- On an overall around 1.4 lakh trees exists in different campuses.
- Paper usage in facilities was reduced significantly by opting for digital documents wherever possible
- All the old desktop computers were replaced by newer power efficient systems which helped in bringing down the power demand by 0.7kWh per desktop per day.
- Data centres and Server rooms – Consolidation of servers, remodelling of racks as per cold and hot aisle design, replacement of older systems with newer ones, room resizing, and usage of overhead cable trays to ensure better airflow beneath the floor.
- Internal enterprise cloud - Leveraging the cloud concepts, an internal enterprise cloud has been built for software application development/ or concept development, powering project delivery environment.

Case study of facility no-6

- During off season the chillers set point changed by 2 degrees from 7°C to 9°C and saved the energy consumption up to 10170 units per month.
- Switched OFF the extra running CSU at QA labs by doing the duct modification and saved the energy up to 20819 units per month.
- Switched OFF the extra running PAHU at data centre by closing the diffuser lowers at unnecessary location and saved the energy up to 2450 units per month.
- Switched OFF the extra running AHU at UPS room by controlling the VCD at unnecessary areas and saved the energy up to 576 units per month.
- Modified the existing emergency lighting circuit and saved energy consumption up to 8709 units per month.
- Installed motion sensors at data centre, IDF Rooms, QA Labs and conference room and saved energy consumption up to 3119 units per month.
- Alternated the parking lights and saved energy consumption up to 2488 units per month.
- Screw chillers run more efficient on part load, by which the energy consumption reduced up to 16888 units per month.
- Incoming supply voltage optimization done and saved the energy consumption by 5532 units per month
- Installed LED Street Lights and corridor lights and saved the energy consumption by 17152 units per month.
- Introduced blanking panels and grommets inside the data centre to avoid shot circuit of cool air with hot air, arrested the air leakages from the cable entries cut-outs and achieved the energy savings by 2708 units per month.

Case study of facility no-7

- Orientation of the building is such that it receives less amount of radiation from Sun.

- Architecturally size of the glazing/windows was optimized to further reduce the radiation.
- Reflective paint used on terraces to reduce heat absorption.
- Air conditioning design to suit for different heat load conditions as per business needs.
- 55% reduction in potable water consumption in the building by using water efficient fixtures & treated wastewater.
- Energy consumption for major areas are monitored and recorded
- On real time basis energy consumption monitoring is done through BMS.
- Water cooled screw chillers of 5.38 COP were installed
- VFD for AHUs, HRW Units, CT Fans & Secondary chilled water pumps.
- High Performance Double Glazed Glass with SHGC of 0.2
- Pre-cooling of fresh air to reduce energy consumption in HVAC.
- Motion sensors are installed in all meeting rooms.
- Demand Control ventilation with CO_2 Sensors.
- High efficiency fresh air filters (MERV 8 & MERV 13)
- Eco friendly house keeping chemicals for the building maintenance.

Case study of facility no-8

- "Switching off" the non-critical systems after working Hours
- VFD's are installed in the AHU's to optimize the utilization of Electrical power
- Planned Preventive maintenance (PPM) is following for all the equipment
- Calibration of sensors & measuring instruments
- Motion detection sensors are planned to deploy in cabins and other areas
- Ambient light sensors & timers for street lights
- Utilization of natural Lighting where ever possible
- VAV installation for required ODC's
- Load optimization during DG power.
- Continuous monitoring on connected UPS load and requirement of UPS power.

Case study of facility no-9

- Restriction of AC operating hours during holidays and after office hours.
- Maintenance of PF between 0.99 to unity.
- Switch off redundancy transformers during weekends.
- Improving the efficiency of the AC equipment.
- Arresting leakages in all Air conditioning systems
- Replacing the fluorescent lights with CFL lamps in toilets.
- Cafeteria AC Operations hours standardization i.e. 09.00-10.30hrs, 12.30-14.30Hrs & 16.30-18.00Hrs
- Switching off the PCs in non-working hours
- Operational control of data projector in conference rooms.
- AC temp settings changed from 23 to 24°C on working hours
- AC units will be switched on from 08:30Hrs to 19:30Hrs
- Optimization of Servers in the Data centre
- Making elevators into duplex mode

Glossary

Automatic Vehicle Location System (AVLS): It is an advanced method of remote vehicle tracking and monitoring. Each vehicle is equipped with an AVL unit that receives signals from the GPS satellites. The GPS receiver determines its current location, speed and heading. This data can be stored or can be directly transmitted to an operating centre. Current position can be displayed on a PC in digital maps. Most popular Automatic Vehicle Location is based on Global Positioning System (GPS) and Global standard of mobile communication (GSM) (Source: http://www.gsm-modem.de/avl-system.html)

Central Ground Water Board (CGWB): A subordinate office of the Ministry of Water Resources, Government of India, is the National Apex Agency entrusted with the responsibilities of providing scientific inputs for management, exploration, monitoring, assessment, augmentation and regulation of ground water resources of the country.

Class-I cities: cities with a population of between 100,000 and 1,000,000.

Class-II cities: towns with a population of between 50,000 and 100,000.

Cooling towers: Heat removal devices used to transfer process waste heat to the atmosphere.

Central Pollution Control Board (CPCB): Statutory organization under Ministry of Environment and Forests, Government of India. Principal functions of CPCB is (i) to promote cleanliness of streams and wells in different areas of the States by prevention, control and abatement of water pollution, and (ii) to improve the quality of air and to prevent, control or abate air pollution in the country.

Cycle of concentration in cooling towers: Maximum allowed multiplier for the amount of miscellaneous substances (dissolved minerals) in circulating water by the amount of those substances in make-up water.

Department of Drinking Water and Sanitation (DDWS): The Ministry of Drinking Water and Sanitation is the nodal department for the overall policy, planning, funding and coordination of programmes of drinking water and sanitation in the country.

De-mineralized water: Water from which the (mineral) ions have been removed

Flash flooding: Rapid flooding of geomorphic low-lying areas. It may be caused by heavy rain associated with a storm, hurricane, or tropical storm or snow flowing over ice sheets or snowfields or the collapse of man-made dam.

Geographical Information System (GIS): A system designed to capture, store, manipulate, analyse, manage, and present all types of geographically referenced data

Global Positioning System (GPS): It is a space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites.

Groundwater development: Percentage of net groundwater availability to the total groundwater extracted for all uses.

Intelligent Traffic Systems (ITS): It is defined as systems utilizing a combination of computers, communications, positioning and automation technologies to use available data to improve the safety, management and efficiency of terrestrial transport, and to reduce environmental impact.

Public Health Engineering Department (PHED): Department controls the Water Supply & Sanitation Budget of the State Government and undertakes programmes of implementation of water supply and sanitation services.

Public-Private Partnership (PPP): Agreement between government and the private sector regarding the provision of public services or infrastructure.

Raw water treatment: Process for enhancing the quality of water so that it meets the water quality criteria for its fitness for the intended use.

Real-time data/information: Denotes information that is delivered immediately after collection.

Real-Time Traffic Information Systems (RTIS): It involves data collection, data aggregate and translation and information dissemination. Data is collected using strategically located sensors or television cameras i.e. through video cameras and/or aerial surveillance (helicopter), fixed sensors and vehicle probes. The public and private agencies aggregate and analyse the data received from these surveillance systems into information to be disseminated to the operators and public through different mediums, which can be used for journey planning, managing traffic, etc.

Remote sensing: Process of acquisition of information about an object or phenomenon, without making physical contact with the object. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth by means of propagated signals (e.g. electromagnetic radiation emitted from aircraft or satellites.

Sensor: Device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.

Smart Dust: The Smart Dust technology comprises of small wireless sensors or motes in which each mote carries a tiny computer (composed of processing unit and memory) with one or more sensors and a communication system to wirelessly connect with other devices in the range.

Smart meter: Usually an electrical meter that records consumption in particular time intervals and communicates that information to the utility for monitoring and billing purposes

Sewage Treatment Plant (STP) or Wastewater Treatment: It is the process of removing contaminants from wastewater generated from residential, institutional, and commercial and industrial establishment. It includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants.

Soil moisture: Quantity of water contained in soil material, on a volumetric or gravimetric basis.

Unaccounted for Water (UFW) or Non-Revenue Water (NRW): Water that has been produced and is "lost" before it reaches the customer. Losses can be real losses (through leaks, sometimes also referred to as physical losses) or apparent losses (for example through theft or metering inaccuracies).

Urban Local Bodies (ULB): These are the constitutionally provided administrative units that provide basic infrastructure and services in cities and towns.

Zero discharge: Recycling and reuse of all industrial wastewater, in order to prevent release of wastewater to the environment.