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Smart Cities: Environmental Challenges and Green Computing

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***Abstract* - Urbanization is an inevitable progression which comes with development. With an increase in population many of the people are now migrating to the cities in increased numbers, which in turn enhance the burden on the infrastructure and resources available in the cities. Increased urbanization will leave behind a more prominent environmental footprint that has its social, economic and environmental implications as well. To provide long term gains to the citizens and in order to make urbanization a positive and productive transformation, three goals need to be achieved — social equitability, economic viability, and environmental sustainability. Social equitability refers to providing an equal access to all resources and benefits across the whole population, economically viable solutions need the recommendations and changes to be financially self-sustaining and environmental sustainability ensures the preservation of the environment for future generations. These objectives have given rise to a paradigm of a new kind of cities referred to as smart city. A smart city uses advanced technology to provide a better life to its citizens and to minimize the effect of human activities on the environment. For making a city smart use of ICT is inevitable. The high end technologies as are used in smart cities such as sensor networks, cloud computing etc. has constantly increasing high computational demands in order to process data and offer services to users, which in turn present a higher economic and environmental impact due to their very high power consumption. The present paper focuses on many environmental challenges posed by these digital technologies and also to suggest ways to deal with these challenges to make these smart cities environmentally sustainable.**

Keywords:-Smart city, Green Computing, ICT, Environmental challenges, urbanization.

I. INTRODUCTION

As per estimates India is on verge to become the most-populous country in the world by 2030. This makes it one of the most potential and under-penetrated market for global manufacturers and service providers. Due to tremendous increase in population, many people living in villages are now migrating to the cities and this is going to give rise to new megacities.Thisincreaseis estimated to generate 80% of economic growth for the country. The growing urban population will prove to be a potential target to apply modern technologies and infrastructure to promote better use of scarce resources.It has been estimated that 25–30 people will migrate every minute to major Indian cities from rural areas in search of better livelihood and better lifestyles. With this momentum, about 843 million people are expected to live in urban areas by 2050. To accommodate this massive urbanization, India needs to find smarter ways to manage complexities, reduce expenses, increase efficiency and improve the quality of life [1].With these changes it has been reported that in 2007, number of people living in cities surpassed the number living in rural areas. Reports suggest that the proportion of people living in an urban environment will exceed 70% by 2050. People are migrating to urban areas with perceived better job opportunities and good quality of life but along with it leads to complex issues such as congestion, increased demand for a limited pool of natural and other resources such as water, energy, sanitation, education and health care. It is predicted that very soon most of the human civilization will be concentrated in the cities. This increased population will consume more energy and need more space to live. As the cities grow and metropolises, the concern are thatthey will leave behind a more prominent environmental footprint. This has been occurring globally and has led to serious consequences. So, to restrain the burden on traditional cities, a paradigm of a new kind of cities has come up which have been termed as smart city. A smart city is the one which uses advanced technology to minimize the effect of human activities on the environment. These technologies have to come with their own uses and limitations which can impact the life of the people[2].

II. THE SMART CITY

In literal terms, a smart city is the one which has a system to provide such facilities and opportunities for its residents to have an easy access to information, availability and distribution of commonly used amenities. A smart city is an urban development vision to integrate Information and Communication Technology (ICT) and Internet of Things (IoT) technology in a secure fashion to manage a city's assets. A smartcity is promoted to use urban informatics and technology to improve the efficiency of services [4].

A smart city may be defined as a city, well performing in economy, people, governance, mobility, environment, and

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living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens [5]. A smart city uses the ICT infrastructure in an adaptable, reliable, scalable, accessible, secure, safe and resilient manner. Thus a smart city aims at:

- Improvement in the quality of life of its citizens
- High economic growth
- Higher standards of living and employment opportunities for its citizens
- Improvement in the well-being of its citizens including medical care, welfare, physical safety and education
- An sustainable and responsible approach towards environment
- Better and viable physical infrastructure based services such as the transportation (mobility), water, utilities (energy) telecommunications, and manufacturing sectors
- Ability to address the climate change
- Prevention for natural and man-made disasters
- Providing an effective and well balanced regulatory, compliance and governance mechanisms with appropriate and equitable policies and processes in a standardized manner.

The National Conclave on Building Smart Cities organized by Government of India (2014) emphasized on important three key aspects which would make the concept of smart cities more attractive and viable. It suggested that smart cities should be the one which are competitive i.e. able to attract investors and residents; sustainable i.e. socially, financially and environmentally; and capital rich in human and social capital [6].

III. ICT AND SMART CITY

Information and Communication Technologies (ICTs) is the key ingredient to fulfill the objectives of a smart city and in providing solutions to the issues that these cities are facing. ICT provides services such as security, transport and healthcare for citizens, improved and cost effective power supply for industries, remote working and e-commerce for businesses, as well as entertainment and communications for individuals [7]. Potential areas of improvement with ICTs include the management of water, energy, solid waste, public transport, traffic and congestion. It has to be taken care that the people living in the smart cities have to be smart themselves so as to be more environmentally friendly and economically viable. It can be made possible by making cities 'smarter' by efficient management of resources, efficient infrastructure, greener environment, smart governance resulting in high quality of life of the people [8].

IV. GLOBAL SCENARIO

In the last 50 years, world population has grown exponentially at an average rate of 1.2% per year. As the global population continues to grow at a steady pace, more and more people are moving to cities every single day. In 2007, for the first time in the history of mankind, the number of people living in cities surpassed the number living in rural areas and it is estimated that the proportion will exceed 70% by 2050. The World Health Organization (WHO) estimates report that the global urban population will grow approximately 1.84% per year between 2015 and 2020. Currently, developed nations have a larger percentage of population inhabiting its cities. The WHO however expects that by 2017, even in less developed countries, majority of the population will be living in urban areas[3].The urban concentration has a role to play in the socioeconomic development as it provides better job opportunities for millions of people around the world. As per UN World Economic and Social Survey 2013, 80% of the world's urban population will live in developing regions, especially in cities of Africa and Asia. In India, the urban population currently makes a share of 31% of the total population and it contributes over 60% of India's GDP which will increase to nearly 75% of the national GDP in the next 15 years. Thus cities are rightly referred to as the engines of economic growth.To provide long term gains to the citizens and in order to make urbanization a positive and productive transformation, three goals need to be achieved — social equitability, economic viability, and environmental sustainability. Social equitability refers to providing an equal access to all resources and benefits across the whole population, economically viable solutions need the recommendations and changes to be financially self-sustaining and environmental sustainability ensures the preservation of the environment for future generations. These objectives have given rise to a paradigm of a new kind of cities referred to as smart city.

V. INDIAN SCENARIO

A. Challenges in urban India

Although the concept of smart cities has been introduced in the country with the objective of providing its citizens with a good quality of life, it's still in a state of situation where it has to confront many challenges. The concept of a planned urban administration is yet to be addressed in India's cities and severe supply and demand gaps require having a planned approach to tackle urbanization. Piecemeal efforts have been made but there seems to be a gap between demand and supply leading to certain mega issues which need to be addressed. The fundamental challenges range from supply and demand gaps across sectors such as water, waste and sanitation, and mobility, to quality and affordability issues across sectors such as health and education. A report by World Economic Forum (2016) our country faces certain challenges which create certain hurdles in the making of smart cities [9]. These issues have been discussed as under:

Challenges in the water sector

a) *Insufficient access to drinking water:* India faces acute water shortages and a lack of safe drinking water.

b) *Inadequacy of water:* Rapid urbanization has led to a drastic reduction in the amount of water available per person over the past few years India's water reserve hasreduced to1000 cubic meters per person per year in 2011 from 4000 cubic meters per person per year in 1951 which has made the country water stressed.

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c) *Leakages in distribution:* Water pilferage and leakage at various sources has led tonon-revenue water in urban India accounting for 50% of total water production. It primarily arises due to leaking pipes, the pilferage of water, a lack of meters and tampered meters.

d) *Dependency on rain:*There is a lack of robust and replicable mechanism for rainwater harvesting which make much of the rain water unused.

B. *Challenges in the power & energy sector*

e) *Incomplete access to electricity:* Urban India is still short of 100% access to electricity. Very few urban areas have access to electricity 24/7. This has led to increased reliance on non-commercial sources of energy and hydrocarbon-based generators.

f) *Leakages in distribution:* The aggregated technical and commercial (AT&C) losses for electricity distribution in India are over 25% for most cities (with AT&C losses in states raging between 15% and 75%) which impacts the capacity of the network and the cost of electricity paid by consumers.

g) *Excessive reliance on hydrocarbons:*India is the fourth largest consumer of electricity but lacks abundant hydrocarbon resources to meet its energy demands. An estimated 61% of power is generated from coal and 9% from petroleum products (gas and diesel), leading to excessive imports and detrimental environmental impact.

C. *Challenges in the waste & sanitation sector*

h) *Low waste collection efficiency:* Waste collection efficiency ranges from 70-90% and less than 50% in smaller cities.

i) *Poor recovery of costs:* Even at current levels of waste collection, 25-50% of ULBs' budgets are spent on waste collection. The recovery of operations and maintenance expenses are less than 50%.

j) *Open defecation and manual scavenging:* The situation in the sanitation sector is also alarming with over 50 million people defecating in the open.

k) *Low treatment of sewerage:* Even in large cities, 50% of households are not connected to sewerage, and only 20% of waste water generated is treated.

l) *Inadequate citizen participation:* Communities do not participate in waste management. Citizens are indifferent to waste management in general and to the segregation of waste in particular.

D. *Challenges in the mobility sector*

m) *Inadequacy of public transport:*The absence of public transport infrastructure leads to overcrowding and poor quality of service. Public transport accounts for only 22% of transport in India, and only 20 cities (out of 85 with a population of 0.5 million or more) have a city bus service.

n) *Increased reliance on private transport:* Inadequacy of public transport leads to an increased reliance on private transport. Between 1951 and 2004, India witnessed a 100-fold increase in private vehicles, with the share of buses decreasing from 11% in 1951 to 1.1% in 2001.

o) *Congestion*

The increase in the number of private vehicles, however, has not been accompanied with commensurate increases in road infrastructureresulting in congestion at critical nodes within the city.

E. *Challenges in the built environment sector*

p) *Urban sprawl:* Inadequacy of well perceived plans sometimes results in urban sprawl. Few cities in India have a development plan that is updated on a timely basis. In some cases these plans are not implemented. Cities land use plans are not integrated with mobility plans or socio-economic development plans.

q) *Lack of affordable housing:* Real estate prices in India have increased manifold in the last two decades, leading to a lack of housing for the economically weaker segments of society.

r) *Informal dwellings:* The scarcity of affordable housing for the urban poor and migrants to depend upon informal dwellings. Many Indian cities are known for their informal settlements. These dwellings are not equipped with such basic urban infrastructure as water, sanitation, waste management or electricity, leading to poor quality of life and health concerns.

s) *Deprecated inner cities and central business districts:*some cities have not developed and grown in infrastructure as per the population growth. This leaves these areas vulnerable to natural and man-made disasters.

F. *Challenges in the education sector*

t) *Lagging literacy rate:* Although India has increased its literacy rates, still it lags far behind many of other Asian countries. According to the 2011 census, literacy rates in India increased by 8% over the previous statistics with 74% overall literacy.

u) *Insufficient quality of education:* Enrolment in schools has improved in urban India over the last two decades, but student learning across scholastic and non-scholastic dimensions remains poor.

v) *Skills gap:* A gap exists between the skill level required in industry and knowledge level of students. This reduces employability and increases the cost of training, which the private sector must provide and pay for to bridge the skills gap.

w) *Lack of infrastructure and funding for research:*One of the reasons for the talent exodus from India is the lack of infrastructure and funding for research and development (R&D), although R&D is crucial for the competitiveness of cities. India attracts insufficient high-quality R&D and most institutes lack research infrastructure. R&D is a critical aspect of smart cities as innovation will continue to be a key driver.

G. *Challenges in the healthcare sector*

x) *Low availability of healthcare:* The overall capacity, which includes both public and private healthcare professionals, is low. Against an expected level of 85 doctors per 100,000 people, India has only 45 doctors per 100,000 people,22 and the situation is the same with nurses and midwives. The problems are likely to worsen due to an increasing population and life expectancy in urban India.

y) Unaffordable healthcare: The percentage of the population with insurance cover is fairly small, putting added pressure on incomes.

*z) Lack of preventive health and wellness programmes:*The government focus in India has been on curative medicine rather than on preventive health. Outbreaks of malaria and dengue are common in India and preventive programmes are often ineffective. The rise in diabetes and cardiovascular diseases in urban India calls for increased focus on preventive health and wellness.

Some challenges emerge out of ineffective governance structures or the lack of autonomy of urban local bodies. In view of these issues, the Government of India initiated urban rejuvenation programmes in 2015 to address the challenges that the country's cities are facing. All these issues and challenges need concerted efforts to bridge the gaps between availability and implementation of the governmental and private policies. The role of ICT cannot be underestimated, but ICT comes with its impact, positive as well as negative on our immediate environment, which has to be assessed and dealt with.ICT is an industry in a state of constant change and development, with the continuous production of new, different, and more advanced devices. The manufacturing of these products utilizes a very high level of technology and the use of specific elements and chemical compounds. Some of these elements can be very toxic like heavy metals
such as cadmium (Cd), lead (Pb) and arsenic (As). These elements are all present in desktop computers or in standard computer monitors. Other compounds are also hazardous. An example can be the use of brominated flame retardants (BFRs). BFRs are chemicals which are applied to the electronic parts of the devices for safety reasons.

VI. THE EFFECTS OF ICT ON THE ENVIRONMENT

ICT has both positive and negative impacts on the environment.

It has to be understood that ICT can play both positive and negative roles as the relationship between ICT and the environment is complex and multifaceted[10].

Positive impacts can come from:

- Dematerialization and online delivery
- A reduction in the need for travel i.e. transport and travel substitution
- A host of modeling, monitoring and management applications
- Greater energy efficiency in production and use and recycling.

Negative impacts can come from:

- The production and distribution of ICT equipment
- Energy consumption in use (directly and for cooling)
- Short product life-cycles and e-waste
- Potentially exploitative applications e.g. remote sensing

These impacts, whether positive or negative can be direct or indirect.Increase in energy consumption, more collection of e-waste can directly impact the environment by an increased emission of GHG while indirect impacts can come from ICT applications as intelligent transport systems, buildings and smart grids, or third-order and rebound *i.e.* the impacts enabled by the direct or indirect use of ICT such as greater use of more energy efficient transport. The total impacts i.e. direct, indirect and the potential rebound effect has to be taken into account for analyzing ICTs role in development [11].This is not only so because of its operational usage but more so because of the electronic waste generated at the end of the useful lifecycle of an ICT gadget. As one observes, the use of ICTs is growing in multiples - engrossing all aspects of our lives: at work, at home, in the air, on the water and in many shopping centers, to name but a few.

There is a common perception that ICT has had a negative effect on the environment due to four main factors[12].

- The use of energy in producing and running ICT equipment which results in increased carbon footprint with its associated production of carbon dioxide.
- The use of toxic chemicals in the manufacture of ICT equipment, and the subsequent problem of disposal of old equipment. Recycling may mitigate much of this problem.
- The use of rare earth elements in the production of ICT equipment and the problems arising from mining, processing and usage of these elements which are usually found in low concentrations and associated with radioactive minerals.
- The rapid development cycle of most ICT equipment, which means that large amounts of it become obsolete and must be disposed of even though it is still able to fulfill the original purpose. Obsolescence can be a particular problem for organizations. They may find that a large amount of equipment, such as a complete set of PCs may need replacing at the same time due to external circumstances that make the PCs obsolete. An example of this is the decision by Microsoft to end support of Windows XP.

As per a report by The Climate Group (2008) it has been estimatedthat the production and use of ICT equipment is estimated to be equivalent to 1% to 3% of global CO_2 emissions (including embedded energy) and a higher and growing share of electricity use. The operational aspect of ICTs generate regular carbon dioxide (CO_2) from the myriad electronic devices we use in homes and offices, and so do the industrial-strength data centers feeding organizations and individuals alike with information[13]. In 2006, it was estimated that ICT equipment (excluding broadcasting) contributed around 2% to 2.5% of worldwide Greenhouse Gas (GHG) emissions – 40% of this was reported to be due to the energy requirements of PCs and monitors, 23% to data centers, 24% to fixed and mobile telecommunications, and 6% to printers. Data centers are a particular focus, and it has been estimated that worldwide electricity use for servers doubled between 2000 and 2005 and this consumption would increase by a further 40% by 2010[14].

VII.ENVIRONMENTAL

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ProblemsComputers, electronic devices and ICT infrastructureconsumesignificant amounts of electricity, placing a heavy burden on our electricgrids and contributing to greenhouse gas emissions. In 2007, the total footprint ofthe ICT sector – including personal computers (PCs) and peripherals, telecomsnetworks and devices and data centers was 830 Mt CO_2emission, about 2% of theestimated total emissions from human activity released that year. ICT hardware poses severe environmental problems both during its productionand its disposal. Each stage of a computer's life from its production, throughout its use and finally into its disposal presents environmental problems. Manufacturingcomputers and their various electronic and non-electronic components consumeselectricity, raw materials, chemicals, and water, and generates hazardous waste. Allthese directly or indirectly increase carbon dioxide emissions and impact theenvironment [15].

Although a lot is being talked about the negative impacts of ICT on the environment with increased carbon dioxide emissions and residual wastes, still ICT has been identified to have potential enabling effects. The Climate Group (2008) identified key areas of enabling impacts potentially leading to global emissions reductions by 2020 that were five times the ICTs direct footprint[16]. The balance of outcomes depends on incentives and policies.ICTshave helped us solve many challenges too such as connecting us globally, entertaining us in every possible way, and helping us to be more productive, efficient and effective. Despite having a challenging aspect to it, ICTs has proven to be an enabler to alleviate climate change and global warming. The perceived negative effects should however be looked at in conjunction with the positive effects of ICT on the environment[17]. Some of these are:

- The use of ICT has led to the designing and production of more efficient and energy efficient machines. This has saved much more energy than has been used by ICT equipment.
- ICT has enabled thereplacement of wasteful and polluting technologies to some extent e.g. the use of electronic documents instead of paper, the use of digital cameras instead of silver based photographic film.

VIII.GREEN COMPUTING AND GREEN ICT

As there is a growing concern for the environment the technologies being used have to be greener and smarter. This concern has given rise to Green Computing as it has been found to reduce the negative effects of ICT on sustainability. This solution protects the environment by dealing with the power management techniques, saving electricity and reducing e-waste. Green computing deals with manufacturing, using and destroying the computers in environment friendly way. It also helps in exploiting existing computing resources in more efficient way by implementing new concepts like green clouds [18]. Cloud providers must emphasize on the need to reduce the electricity demand of clouds and take major steps in using renewable energy sources rather than just looking for economic incentives like cost minimization. Green ICT sustainability addresses issues such as: using renewable energy sources to power data centres, reducing e-waste, designing energy efficient hardware, middleware and software, running multiple operating systems via virtualization, providing information to customers in order to encourage them to make green choices, reducing transportation cost and emissions by telecommuting.

Since it has been found that ICT has a role to play in enhancing the environmental emissions through its various tools and equipment used for a smart city, some policies have to be framed and measures to be adopted to counterbalance these negative impacts. Also ICT has a key role to play in the process of development through smart cities. So ICT has to be used in its better form to nullify the issues and challenges associated with it, which comes in the form of Green ICT. Green ICT is the study and practice of designing, manufacturing, using, anddisposing of computers, servers, and associated sub-systemssuch as monitors,printers, storage devices, and networking and communications systemsefficientlyand effectively with minimal or no impact on the environment.Green ICT includes the dimensions of environmental sustainability, the economics of energy efficiency and the total cost of ownership, which includes the cost ofdisposal and recycling. Green ICT benefits the environment by improving energyefficiency, lowering greenhouse gas emissions, using less harmful materials, andencouraging reuse and recycling.

Green design, Green manufacturing, Green use, Green disposal are complementary paths of Green ICT. Only focusing on these four fronts, total environmental sustainability from the ICT can be achieved and make IT greenerthroughout its entire lifecycle.Both private and public sector must test and adopt modern technologies like virtualization, cloud computing, data center consolidation and reusability of data/information in order to be greener.

Theusageofrecycledcomponents, theadoption of rulesand guideinesthat contribute to lower power consumption to ensure the energy efficiency, These practices shouldbe standard choices at the IT industry, which have to also be indicated byrecognizable marks/signsin order for the consumerstobefamiliarwithspecsandcertificationsthatensurethe recyclingandtheenergyefficiencyof thoseICTproducts.

IX.OBJECTIVES OF GREEN ICT

The main objectives of Green ICT are:

I. To raisethe Green ICT issues to make it more sustainable and optimal and environment friendly.

II. To promote the ideas of Green ICT among the users and service providers.

III. To ensure that the ICT professionals have the required knowledge to handle the Green ICT issues and are capable to design solutions and operate systems inaccordance to the Green ICT requirements.

IV. To mobilize the ICT products to end usersin order to change habits and to ensure that they purchaseand use ICT devices which arecompatiblewith Green criteria and in a way more friendly to the environment.

V. To promote the good practices on Green ICT by adopting a Green ICT certification ora Green ICT mark.

X.CONCLUSION

With Prime Minister Sh. NarendraModi's mission of flooding India with smart cities, it has been recognized that Green Computing and Green ICT have a potential positive roles to play in development. Although smart technologies come with their negative impacts as well, still the positive outcomes outweigh the negative ones. It has to be kept in mind that combined efforts on the part of government, civic bodies and people can bring a positive change to make these high end technologies sustainable and eco-friendly. A few suggestions can be put forward to help in the process:

a) Raise awareness of the benefits associated with the use of green ICTs
b) Engage the private sector, civil society and academic community
c) Promote national, regional and international cooperation
d) Integrate ICT, climate change, environment, green computing and green energy policies

Figure 3: ICT Impact: The global footprint and the enabling effect.

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