ENERGY CONSERVATION IN BUILT ENVIRONMENT IN SMART CITIES

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ABSTRACT

Installed capacity of power generation in India is 344 GW and there is not likely to be any significant capex investment in coal fired plants. The Government is providing thrust on the generation side through renewables and on the demand side through energy efficiency of built environment. As more and more people move to the cities for livelihood, the Ministry of Housing and Urban Affairs is implementing 100 Smart City projects in the country with smart solutions to enhance liveability index in urban areas. Energy efficient infrastructure is a key component of these smart solutions. This paper describes various concepts adopted for energy conservation in built environment especially in smart cities along with integration of renewables.

1. INTRODUCTION

Total installed capacity of Power Generation in India, as of March 31, 2018, is 344 GW[1]. Coal-fired plants account for 57% of this and Renewable Energy 20%. Projected installed capacity by 2021-22 is 479 GW and by 2026-27, 619 GW. The projections indicate that there would not be addition of any new coal based plants in the near future and the only addition would be from plants which are in various stages of construction. The Government of India has taken policy decisions for adding more Renewable Energy which is targeted to reach 44% by the year 2027 and Solar alone is targeted to reach 100GW of installed capacity by the year 2022 [1]. The Government also has plans on the Demand Side Management, through which measures are taken at each consumer end for Energy Conservation, for e.g., Energy Efficiency measures in Building Codes and building designs, time of use tariff, reduction in AT&C losses, energy efficient lighting solutions, distributed generation and micro-grids.

The Smart City initiative of Government of India is primarily intended to improve quality of life in an environment friendly manner and also adopt some of the above measures which would minimize carbon foot print in city space and provide sustainable living conditions to the population at large. An attempt is made in this paper to review Energy Conservation techniques and Renewable Energy technologies that could be adopted in Built Environment, Urban spaces and Manufacturing sectors in Smart Cities.

2. SMART CITIES PROGRAM OF THE GOVERNMENT OF INDIA

As per 2011 Census data of the Government of India, about 31% of India's Population lives in Urban Areas contributing 63% to the GDP of the country. As per projections, urban population in India would be 40% of total population by 2030 and would contribute 75% of the overall GDP. This necessitates a comprehensive development of Physical, Institutional, Social and Economic Infrastructure of Urban Local Bodies (ULBs) of the country. The Ministry of Housing and Urban Affairs (MOHUA) has come up with the Smart City Mission Program as a structured strategy to face this challenge. The mission is to cover 100 cities over a period of 5 years starting from Financial Year 2015-16 and ending by 2019-20.

The objective of the Smart City Mission in these 100 cities, which are already providing basic infrastructure to their citizens, is to adopt Smart solutions which would have an impact on Liveability index of the city. The main pillars that constitute the Liveability index of a city are shown in Figure 1[2].

As a part of this program, ULBs need to adopt Smart solutions which would have following features.

- World-class benchmark Liveability Index by providing 24x7 Water supply, 100% Power supply and Solid waste management facilities
- Environmentally sustainable technology to minimize pollution levels of air, water and land
- Minimum 10% of city's power demand met from renewable energy source
- Robust IT and digitization framework
- Affordable housing for urban poor
- e-Governance with citizen participation
- Urban mobility and public transport
- Pollution free urban transport by adopting Electric Vehicles
- Health and Education
- Safety and Security of Citizens

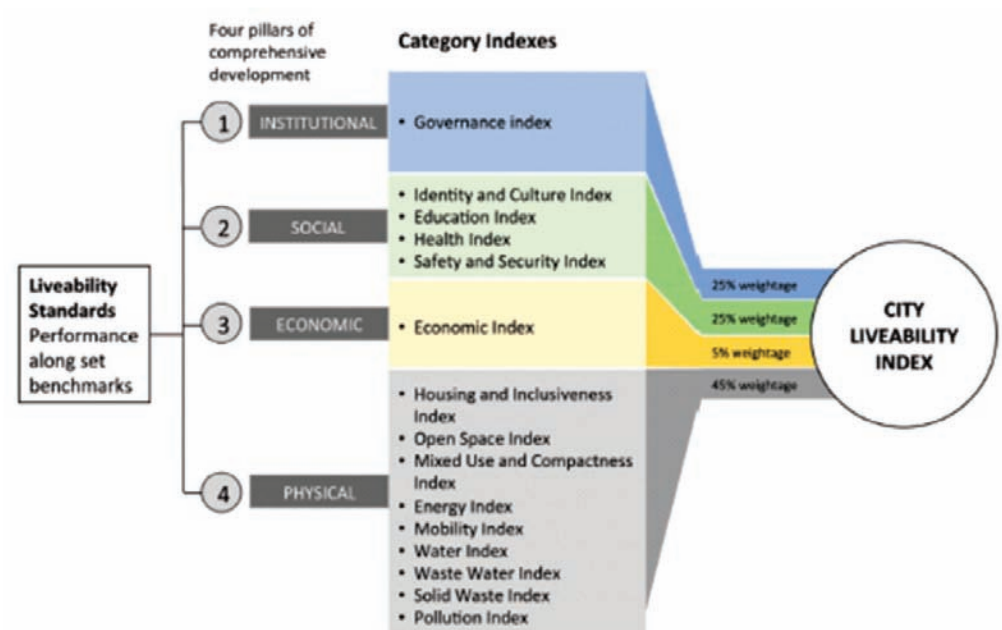

Figure 1: Factors impacting Liveability Index[2]

Total allocation of funds for Smart city projects by Government is Rs. 100,000 Cr. Smart city projects are classified into two categories, viz., Pan City Projects and Area Based Development (ABD) Projects. Key features of Pan city projects are related to Information and Communication Technology (ICT) – that includes laying of optical fiber cables, Integrated Traffic Management System (ITMS), e-Governance, Automated city level waste collection system, Utility Management System, City Level Command and Control Centre, etc. Further, roof top solar on the Government Buildings also forms a part of these projects. In ABD projects, a small area within the city is identified and the infrastructure in this area is developed with identified smart solutions so that this area becomes a benchmark for Infrastructure and develops as a Role model for other parts of the city in Infrastructure development. The ABD projects are classified broadly into 3 categories:

City Improvement projects (Retrofitting) – a minimum area of 500 acres (202.3 hectares) is identified for which a holistic improvement of infrastructure is worked out adopting smart solutions.

City Renewal projects (Redevelopment) – a minimum area of 50 acres (20.23 hectares) of existing area inside the city is identified. Old and dilapidated structures are removed and new layout is developed in the same space with extra Floor Space Index (FSI) and Smart Infrastructure.

City Extension projects (Greenfield) involve developing a vacant area available in the city with higher FSI and world class infrastructure.

3. SMART CITIES PROGRAM

The Smart Cities program could be considered to have begun in 2010 with the GIFT (Gujarat International Financial Tech city) city project at Gandhinagar, Gujarat. It is a green field project developed with mixed land use catering for the purposes of an International Financial Business hub. It is planned to occupy 800 acres (323.75 hectares) of land with a total built-up area of 8.5 million m^2 catering to a population of 900,000.

The Key Infrastructure features developed at GIFT city include Integrated underground utility tunnel which carries power cables, optical fibre cable (OFC), solid waste collection pipes, chilled water, treated water, potable water etc.; District cooling system, Automatic waste collection system, Reuse of treated water for HVAC system, flushing, etc., Sustaining buildings meeting all green building norms and no DG back up for buildings by providing reliable power supply system, taking dedicated power supply from 2 different source substations, ring main underground cable distribution network, compact distribution substation, etc.

The green field industrial townships at 8 nodes for DMICDC (Delhi Mumbai Industrial Corridor Development Corporation) at Dholera, Manesar-Bawal, Pithampur-Dhar-Mhow, Shendra-Bidkin, Khushkhera-Bhiwadi-Neemrana, Dadri-Noida-Ghaziabad, Jodhpur-Pali-Marwar and Dighi Port Industrial Area / Investment Regions in the states of Gujarat, Haryana, Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh are also considered as Smart cities. As per DMICDC's official website [3] 'Delhi - Mumbai Industrial Corridor (DMIC) is India's most ambitious infrastructure program aiming to develop new industrial cities as "Smart Cities" and converging next generation technologies across infrastructure sectors. The objective is to expand India's Manufacturing & Services base and develop DMIC as a "Global Manufacturing and Trading Hub". The program will provide a major impetus to planned urbanization in India with manufacturing as the key driver [3].

For all of the above projects, some of the key infrastructure components considered include 24x7 water supply with minimum NRW (non-revenue water) losses in distribution system meeting international bench mark; Reuse of treated water for flushing and gardening; and providing dual plumbing system in buildings; All buildings are constructed meeting green building norms; Roof top solar on all buildings with net metering; 24x7 power supply with power quality meeting global standards considering smart grids, energy storage, ring underground cable distribution system, etc.; Automatic waste collection system and complete processing of waste generated; Integrated utility corridors; District cooling system; Energy efficient street lighting; SCADA system for utility management; Smart metering for water and power; CCTV cameras for safety and disaster management and OFC cables, city level command and control center for city management, traffic management and e-Governance.

The Ministry of Housing and Urban Affairs (MOHUA) initiated the process for selecting 100 smart cities all over India in 2016. The selection process had two stages: Stage – 1, that involved selection at each state level and selected entries forwarded to Central Government; and Stage – 2, a challenge round, in which the potential city is expected to prepare a proposal document by studying the city conditions in a holistic manner for development. The proposals by the participating cities were evaluated and the wining cities were included in the list of 100 smart cities and accordingly allocated funds for development.

Consulting Engineers were actively involved in supporting various Municipalities in preparing the Challenge Proposals. The time duration for preparing the challenge was typically 3 months. The budget allocation for each city varied from Rs.1,000 to Rs. 2,000 crores approximately.

The Cities which qualified to enter the 100 smart cities list formed a Special Purpose Vehicle (SPV) and floated tenders for Project Management Consultancy (PMC) to execute the projects. The main task of these PMC's is to support the SPV's to execute the projects on the ground as identified in Smart City Challenge Proposals.

4. ENERGY CONSERVATION IN BUILT ENVIRONMENT IN SMART CITIES

The Energy Conservation Act was enacted in 2001 and the Bureau of Energy Efficiency (BEE) was created in 2002. Due to various measures initiated by BEE, 2.8% of total energy consumption could be saved by the year 2013, which avoided generation of 36 GW.

Bureau of Energy Efficiency has revised the Energy Conservation Building Code (ECBC) in 2017 [4] which is a step towards achieving energy neutrality in commercial buildings. This establishes minimum performance standards for buildings. ECBC 2017 defines performance levels and incorporates advanced technologies, integration of renewable energy and passive design strategies (using local resources and climatic conditions in design). It defines mandatory requirements, prescriptive requirements and whole building performance method for ease of compliance.

In the following sections, some of the measures adopted by the authors in the design of smart cities are described.

Typical break up of Power demand for a Built Environment consisting of Residential and Commercial complexes is indicated in Table 1.

Description	Break up in %
Lighting & all socket loads	60%
HVAC	30%
Others	10%

Table 1: Breakup of Power Demand in a typical Built Environment [5]

As is evident from Table 1, significant Power Demand in Built Environment is shared by Lighting and HVAC systems. Hence various measures, as listed below, need to be deployed in these areas to achieve energy conservation.

4.1 HVAC System

In an HVAC system, some of the reasons for high power consumption are:

- Oversized Equipment
- Variable Load
- Manually Operated System
- Inefficient / aged system
- Inefficient preventive maintenance

The technologies to address these challenges and bring down the power consumption are discussed below.

4.1.1 Variable Speed Chillers

In most of the buildings in Indian cities, the type of air conditioning used is of air cooled type which consumes power in the range of 1.3kW per ton refrigeration (TR). As per study conducted by ASHRAE in 2001, it is possible to bring down the power consumption to 0.5kW per TR through utilization of Variable Speed Chillers and real time sensing of temperature, humidity and automation for varying the speeds accordingly.

Figure 2 below shows graphical representation of how the power demand for HVAC system can be optimized by using various techniques [6].

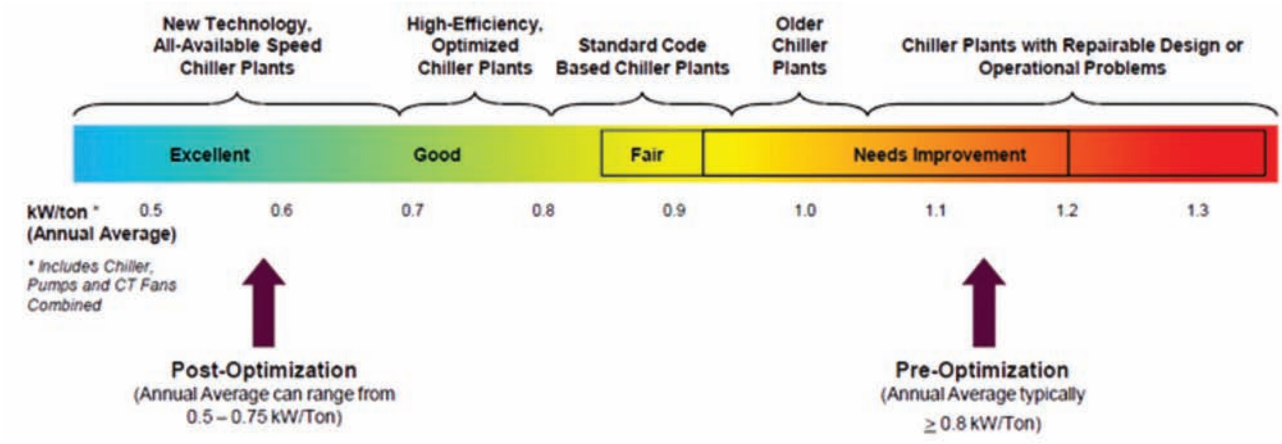

Figure 2: Optimization of HVAC system [6]

4.1.2 Reuse of Byproducts from HVAC system

Effectively using the byproducts of a HVAC plant would result in overall energy efficiency. HVAC plant generates hot water and buildings such as hotels and hospitals require hot water. During planning and design stages of HVAC system for such buildings, utilization of hot water generated should be considered.

4.1.3 Sustainable Planning for Buildings

Sustainable planning involves carrying out thermal modeling of a particular site and the built environment to analyze the path of sunlight and then optimize its shape and orientation so that the building is exposed to optimum heat minimizing the temperature difference between outside and inside of the building thereby minimizing overall HVAC requirement. External cladding and glazing could also be planned and designed to minimize heat gain/ loss as well increase natural ventilation in and around the building, as desired. Some of the BIM (Building Information Modeling) tools have this capability.

Another approach involves 100% natural HVAC system which is developed by studying the wind patterns, velocity and direction. This is known as Passive Downdraught Evaporative Cooling (PDEC). For this wind towers are built at strategic locations of building to capture the wind and channelize the wind through ducts which are sprayed with water. The Hot air entering from outside evaporates the water and during the evaporation process the air gets cooled and the same is circulated inside the building.

Further, buildings with glass facades can be provided with double glazed glass which is having better thermal insulation properties. The glazing could also be designed to get minimum direct solar heat.

DISCOMS may implement time of the day metering system with lower power costs during nonpeak hours. Buildings with centralized chiller plants may be provided with thermal storage facility for chilled water in the basements or in underground holes. Most of the commercial complexes require the HVAC system during day time, so the buildings with thermal storage can operate their chiller plants during nonpeak hours and store the chilled water and same could be utilized during day time.

4.1.4 City Level Infrastructure Planning

In green field projects with mixed land use, i.e., built up area consisting of residential and commercial spaces, with large requirement of HVAC systems, the design may be carried out as city level Centralized District Cooling System (DCS). This could also be implemented in existing urban areas which are being redeveloped or space available to suitably locate a DCS plant.

Utilizing some of the concepts listed above, the power demand for HVAC system can be optimized to about 0.9 kW per TR. Another tangible benefit that can be achieved with this system is utilization of recycled water from Sewerage Treatment Plants (STPs) for make-up water in cooling towers of the District cooling systems.

The overall Schematic Diagram of DCS for a typical city project is shown in Figure 3 below [7]:

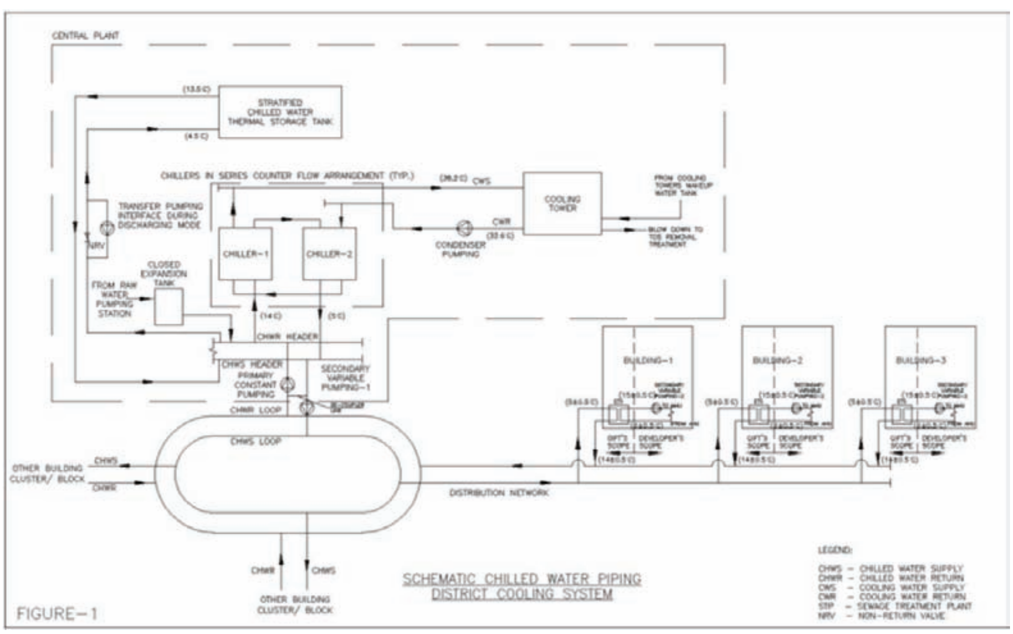

Figure 3: Overall schematic of a District Cooling System [7]

4.2 Lighting System

Lighting system includes building lighting, all socket loads such as refrigerators, fans, etc., area lighting and street lighting and is the prime energy consumer in a city. Some of the best practices followed to achieve energy efficient lighting designs are:

- Use of energy efficient control gears

- Integration of lighting system design with day light using BIM tools
- Use of occupancy sensors for switching on/ off or dimming the light
- Use of fixtures with photometric characters suitable for specific task for which lighting is used
- Avoidance of wastage of light by selecting proper cut-off angle of luminaire
- Use of LED lamps instead of conventional lamps
- Use of LED lamps for street lighting instead of high pressure sodium vapor (HPSV) lamps
- Design of Intelligent Street Lighting Management system which turns on/ off based on traffic as well as day light

Table 2 below gives a comparison between LED lamps and conventional lamps [8].

Light Technology	High Pressure Sodium Light	Compact Florescent Light	Florescent Light	LED Light
Life Time (approx.)	12000	6000 – 15000	10000	50000
Lumens per watt	45 – 130	50 – 70	60 – 100	70 – 150
Color Temperature	2000K	3500K	2700K – 6200K	4000K – 6400K
Color Rendering Index	25	80	70 – 80	85 – 90
Ignition Time	Minutes	Second	Instant	Instant
Drawback	Mercury & Lead	Mercury	UV Radiation	High Initial Cost

Table 2: Comparison of LED lamps with conventional lamps [8]

4.3 Energy Efficient Pump Drives

In a typical city, water supply, waste/ sewage water and storm water management requires considerable amount of power. The systems since they consists of intake water pumping stations, treatment plants, sewage pumping stations and sewage treatment plants, pumping for disposal or reuse, storm water pumping stations & plants, treatment plants and disposal or reuse. Many of these assets in Indian cities are more than 30 years old and are working on out- dated equipment and hence require efficiency improvements.

In such situations, energy audits must be conducted on existing assets and pumping systems must be redesigned with energy efficient motors for pumps along with deployment of variable frequency drives (VFD's) wherever required. Redesign of the water distribution networks with proper zoning and design of the systems with gravity flows minimizing pumping requirement would result in energy efficiency. Similarly, sewage systems may be redesigned with decentralized package STPs which can minimize the sewage pumping requirements. Further, all treatment plants and pumping stations can be automated with SCADA system along with deployment of IOT sensors in distribution networks, pumping stations and treatment plants with necessary control logics in place to ensure energy efficiency. Same applies to storm water management as well.

5. RENEWABLE ENERGY INTEGRATION IN SMART CITIES

As mentioned earlier, the share of renewable energy sources (RES) in country's installed generation capacity is about 20% and Ministry of Power has set a target of achieving 37% share by year 2022; the targeted quantum is 175 GW. Out of this, the targeted share of roof top solar is 40GW. Therefore, MOHUA has set guidelines that in all Smart

Cities, 10 % of city power demand needs to be met from renewable energy sources. Considering the Indian cityscape, following are some of the practicable renewable energy sources that could be planned in the city.

- Roof top solar units
- Power generation from municipal waste
- Cogeneration in sewage treatment plants

5.1 Roof Top Solar Plants

The concept of roof top plant is based on grid connected solar panels installed on terraces of various buildings in urban areas. A typical concept diagram is shown below in Figure 4.

1kW generation through solar panels would typically need an area of 10 to 12 m^2. In order to encourage installation of roof top solar units in the cities, the state needs to implement a net metering policy and conventional energy meters need to be replaced with net meters at each consumer end.

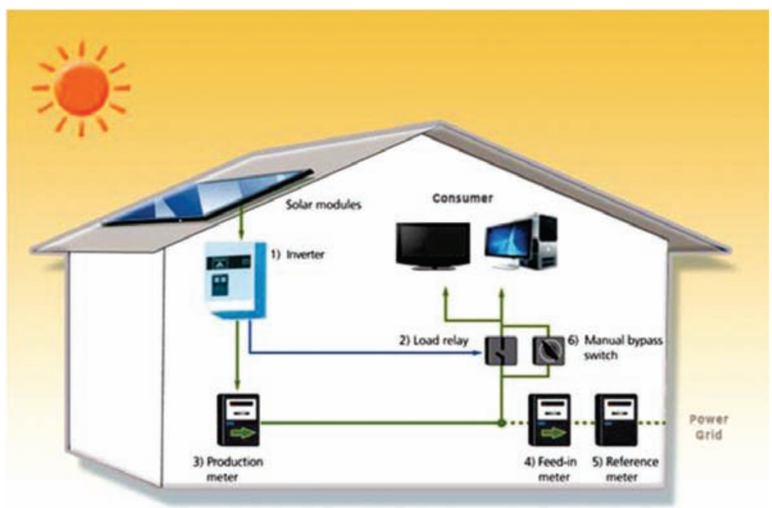

Figure 4: Typical Concept Diagram for Roof Top Solar Unit

In all Smart cities, the authorities have planned to implement roof top solar units in following spaces:

- Terrace areas of all government buildings
- Top of canals
- On the sides of roads above cycle tracks
- Solar trees in open areas and gardens
- Bus stops (top of shelters) and top of skywalk roofs
- Opens spaces available in sewage treatment plants, water treatment plants and pumping stations
- e-Vehicle charging stations

As per existing energy policy in many states, each consumer can export power to grid starting from 10% to 100% of existing contract demand as per regulatory norms of each state.

In most of Smart city projects, roof top solar units are planned on PPP mode in which the Municipal authorities are facilitating providing space at public areas and government buildings. Private operators install the Solar panels and have agreement with space owners for installing the panels. Space owners would have separate agreements with electricity boards for installing net metering and agreement for selling excess power. Some cities have proposed tendering through EPC mode in which the city authorities are identifying places such as top of canals, treatment plants, along roadsides, on top of skywalk, etc., and are using that power either to meet power demand or to sell excess power.

5.2 Power Generation from Municipal Waste

In all cities, solid waste management is a major challenge and all smart cities have planned a robust solid waste management system and processing of the waste after collection. A typical Waste to Energy (WTE) plant requires minimum 300 TPD solid wastes as input to make the system economically viable. 1 MW Waste to Energy plant requires 100 TPD waste as input.

There are broadly two types of waste processing technologies used – thermal process and biological process. Figure 5 gives an overview of various technologies [9].

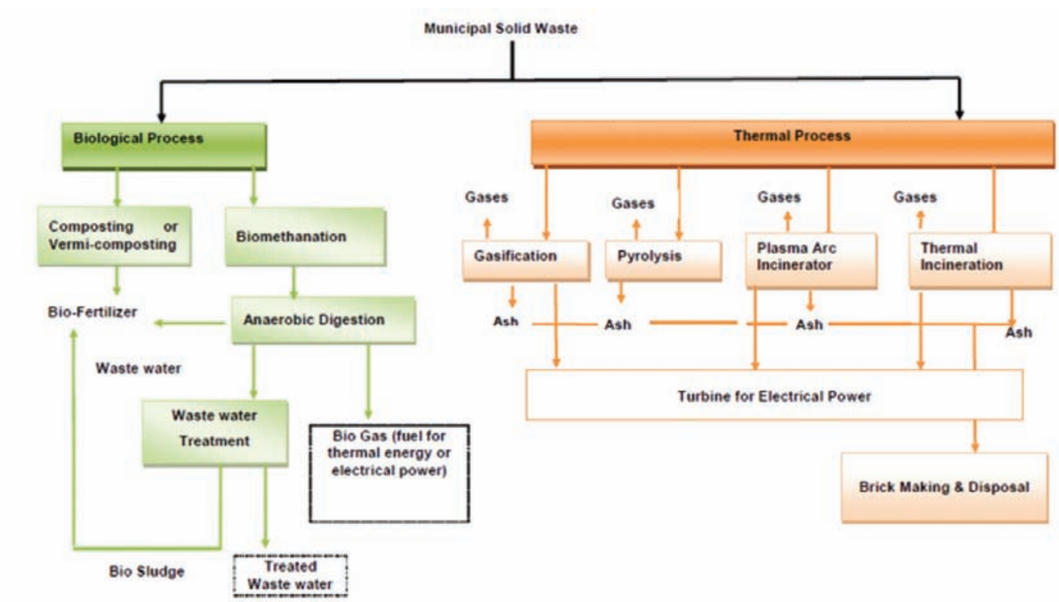

Figure 5: Waste to Energy Technologies [9]

5.3 Cogeneration in Sewerage Treatment Plants

STP consumes high power based on the type of process being used. There are two options in which cogeneration can be harnessed from STPs:

Option-1: Burning of Methane Gas Generated from Process. This is based on BOD content of sewage and ambient temperature, and approximately 8 to 10kW of Power can be generated per MLD of installed capacity of STP. This can recover approximately 30 to 40 % of power demand of STP operation. This option is economically viable for STPs with capacity of 50 MLD and above.

Option-2: Installing Solar Panels in Open Spaces & Roof Tops in Treatment Plant. This is based on open spaces and roof tops available in each STP. Roof top solar panels can be installed at the rate of 10 to 12 m^2 per kW, as mentioned earlier.

The CPCB has classified the cities based on their population. Approximate capacity of STP's, its potential for power generation and space requirement (assuming Sequential Batch Reactor – SBR technology for waste water treatment) for the same is depicted in Table 3 [10].

Sr No	City Category	Approximate STP capacity in MLD	Potential for Cogeneration in MW	Space Requirement based on SBR technology in m^2
1	Class-1 Cities having population > 10 Lakhs	346	3.46	190,300
2	Class-1 Cities having population 5 - 10 Lakhs	120	1.2	66,000
3	Class-1 Cities having population 2 - 5 Lakhs	40	Economically Unviable	22,000
4	Class-1 Cities having population 1 - 2 Lakhs	18	Economically Unviable	9900
5	Class-2 Town having population 0.5 - 1 Lakhs	6	Economically Unviable	330

Table 3: Cogeneration potential in Sewerage Treatment Plants [10]

Considering 50% of space is available for installation of roof top solar units, there would be a potential for generation of at least 8MW solar power in addition to what is stated in Table 3.

6. BEYOND THE BUILT ENVIRONMENT

All smart cities are provided with an integrated City level Command and Control Center, which is a city level management system with e-Governance and physical infrastructure.

A typical Block diagram of City Management System is shown in Figure 6.

The broad components of City Management System are shown below:

- Command and Control Center consisting of video wall and data center
- City wide Optical fiber network
- IOT sensors for collection of data
- Interface with SCADA system of utilities

This management ecosystem would collect huge amounts of data from various city level activities; the collected data would be analyzed using data analytics and utilized for activities mentioned below.

- Forecasting of Physical Utility Infrastructure
- e-Governance
- Disaster Management
- Safety and Security
- Health and Education

An integrated command center can be programed with control logics to ensure energy efficiency at the city level.

Energy Management System at the level of public built utilities as well as utilities beyond built environment (public spaces) can be a part of either a local command center or an integrated command and control center at the city level.

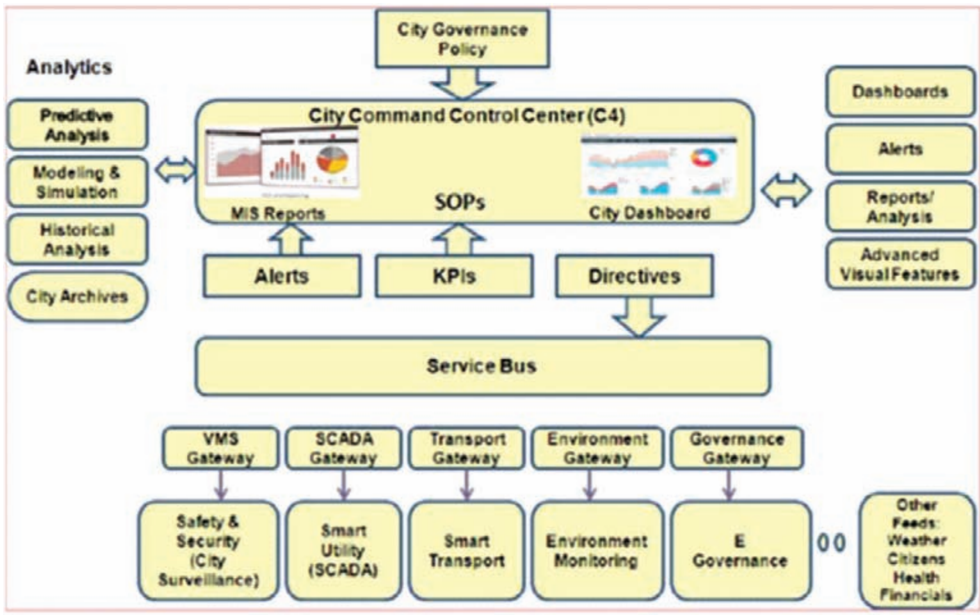

Figure 6: City Management System

7. ROLE OF BIM IN ENERGY CONSERVATION

Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. BIM can be utilized during the complete Life Cycle of any Built Environment Project.

3D tools are available to develop integrated 3D models which may be located on a GIS platform enabling development of accurate thermal models of a building. Based on the thermal model of a building, an optimized HVAC system could be designed and by leveraging the natural light, the building lighting design can be optimized ensuring energy efficiency.

BIM is utilized to design advanced Building Management System (BMS) where the digital twin of the building can be located at a Central Monitoring Station and utilized for real time monitoring of climatic conditions, access control, security monitoring, utility tracking, lighting management, outage management and maintenance requirements. Energy efficiency is ensured through the monitoring stations.

In green field projects, where a new master plan is developed on a GIS platform integrated with BIM, and necessary energy efficiency measures are a part of the design using Industry 4.0 principles. In brownfield projects, the area to be developed is digitized by conducting Drone Surveys and laser scans of underground utilities and the data is integrated on a GIS platform. This digitized GIS maps are used in City level Command and Control Center for City Management activities.

8. INDUSTRY 4.0 AND ENERGY CONSERVATION

Cities of the future would be smart and connected. Electricity value chain that has traditionally been one way (generation, transmission, distribution, devices and consumer) is maturing into a two-way distributed resources regime in which every consumer is a generator as well. Information is collected at every instant and based on need; anyone can consume or share energy from their roof top or their electric vehicle. Access to energy gets decentralized. Smart transportation systems including electric vehicles with charging infrastructure, energy storage facilities, micro-grids with renewable integration, smart grids, smart water and waste water systems, public spaces, built utilities and commercial spaces, homes, parks, buildings, all can get connected with each other with sensors and instrumentation in place generating and transmitting huge amount of data which gets analyzed; analytics ensures decisions are taken to becoming more and more 'smarter' day by day in energy consumption. Artificial intelligence plays a key role in making these smarter and self-learning. Necessary information and communication infrastructure needs to be in place and the future is all about utilizing minimum amount of energy efficiently and ensuring sustainability.

9. SUMMARY

With the thrust on renewable energy by the Government of India on the generation side, several measures are initiated also on utilizing available energy smartly and efficiently on the demand side. 40% of India's population is expected to be in urban environment by 2030 and Smart cities program is intended to make the cities more livable and energy efficient. Various energy conservation measures adopted in built environment in these smart cities is discussed in detail with respect to HVAC, lighting, water and waste water management, etc. Renewable integration in smart cities is described focusing on roof top solar, power generation from municipal waste and cogeneration from sewerage treatment plants. Role of BIM and Industry 4.0 are stated in making our future cities smarter and self-learning with respect to energy conservation.

10. TCE's contribution to growth of Smart Cities

TCE started their work on Smart Cities with the GIFT (Gujarat International Financial Tech city) city project at Gandhinagar, Gujarat. Three of the townships for DMICDC (Delhi Mumbai Industrial Corridor Development Corporation) at Dholera, Dadri-Noida-Ghaziabad, and Vikram Udyogpuri in Ujjain are conceptualized by TCE. The Vikram Udyogpuri township is planned over an area of 1096 acres (443.54 hectares) as an industrial township. The city is planned for mixed used development with a manufacturing hub for non-polluting industries, higher education hub and residential development. The Industrial Township at Dadri is developed on an area of 755 acres (305.54 hectares) with 50% area earmarked for industries which mainly include Hitech industries, Biotech and R&D setups. In Dholera TP-2 (West) is an industrial township at Dholera, Gujarat. The total area of this township is 43 sq km.

The successful cities for which TCE assisted in preparation of proposals were: Vadodara, Rajkot, Dahod, Gandhinagar, Amritsar, Chennai, Puducherry, Tiruchirapally, Aligarh, and Moradabad.

A snapshot of TCE's engagement as PMC in execution of Smart City projects is shown in Figure A. At present, out of 100 cities, TCE is involved as PMC for 13 cities across 7 states in India and is responsible for a capital expenditure of more than Rs. 22,000 crores. Out of this, execution is in progress for Rs. 1,500 crores. Tenders have been floated for about Rs. 8,000 crores. Further work is in progress and this engagement would continue till 2023.

Tata Consulting Engineers is also involved in several WTE projects including 3000TPD project at Deonar for Municipal Corporation of Greater Mumbai and Refuse Derived Fuel (RDF) based WTE project at Kancheepuram in Tamil Nadu.

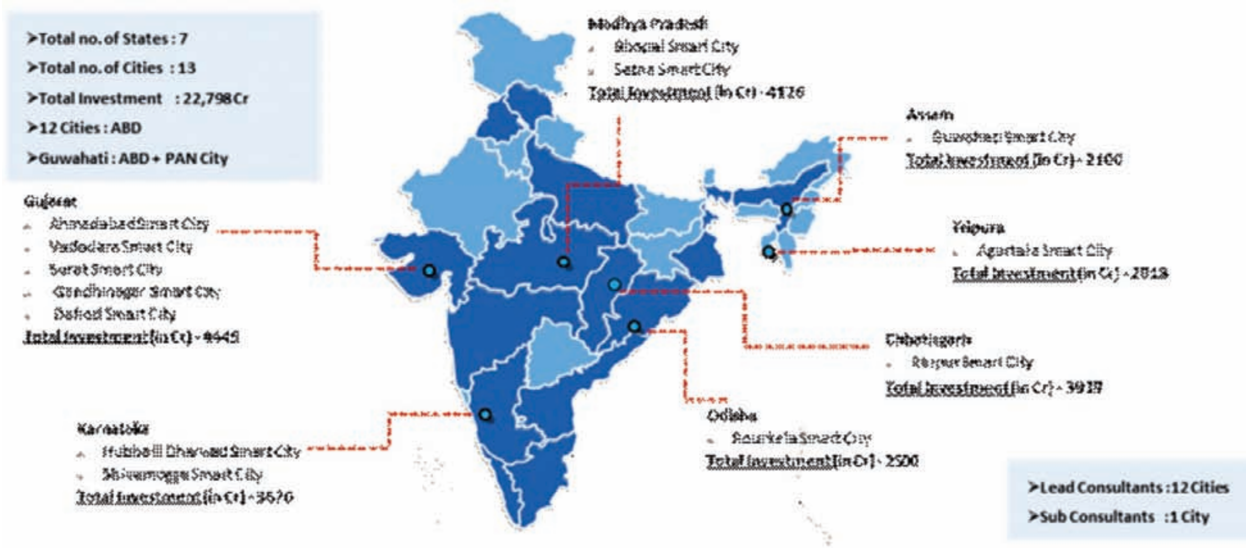

Figure A: TCE's involvement as PMC for Smart Cities

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