Chapter 5
Smart Development of Ahmedabad-Gandhinagar Twin City Metropolitan Region, Gujarat, India

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Abstract With India transforming as matured democracy, the government is focusing upon improving quality of life of citizens by urban renewal and infrastructure development vide ambitious smart cities project. Energy, the electrical power in particular, has been the most crucial and the resource always in scarcity in India and proving itself as a major bottleneck. Therefore, India has been transforming legacy conventional non-smart non-intelligent unidirectional electrical power grids into modern smart grids which are bidirectional and intelligent in nature by leveraging ICT, IoTs, e-Governance and e-Democracy. Smart grids are likely to serve as energy backbones of smart cities and involve high interactive participation of citizens in energy management, based on humanitarian and customer centric approach. Different types of Prosumers (Producers + consumers), their different energy requirements at different timings, different types of energy resources and their switching feasibilities considering different aspects have been integrated. The Ahmedabad-Gandhinagar twin city metropolitan region (Naroda area) has been considered as region of interest and study. The region is surrounded by reputed industrial, commercial, educational-research organizations, heritage monuments and demonstrates extremely encouraging potential for creative research and technological developments with variety of Prosumers in particular. To study existing economic and spatial strategies and recommend suggestions for smart metropolitan region development have been main objectives of the work presented. Useful approach for smart metropolitan region development has been presented by effective energy management, active citizen participation and e-governance by proposing deployments of smart grid and smart buildings with integration of

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renewables, ICT and IoTs. Ensuring 24 × 7 electricity with limiting carbon footprint has been the major challenge.

Keywords Electricity · Smart buildings · Smart city · Smart grid
Smart metropolitan region development · Information and communication technology (ICT) · Internet of things (IoT)

List of Abbreviations

AMI	Advanced Metering Infrastructure
AT&C	Aggregate Technical and Commercial
BAS	Building Automation System
BPO	Business Process Outsourcing
CCTV	Closed Circuit Tele Vision
CO_2	Carbon Dioxide
CT	Communication Technology
DDU	Dharmsinh Desai University
DISCOM/DisCom	DIStribution COMpany/Distribution Company
DR	Demand Response
DSM	Demand Side Management
GAV	Gandhinagar-Ahmedabad-Vadodara
GDP	Gross Domestic Product
GEDA	Gujarat Energy Development Authority
GERMI	Gujarat Energy Research and Management Institute
GHG	Green House Gas
GIDC	Gujarat Industrial Development Corporation
GIFT	Gujarat International Finance-Tec city
GoG	Government of Gujarat
GoI	Government of India
GUI	Graphical User Interface
HAN	Home Area Network/Home Automation Network
ICT	Information and Communication Technology
IMRB	Indian Market Research Bureau
IOT/IoT	Internet of Things/Internet of Things
ISGF	India Smart Grid Forum
IT	Information Technology
ITES	Information Technology Enabled Services
M2M	Machine to Machine
MRD	Metropolitan Region Development
NAN	Neighborhood Area Network
NASSCOM	National Association of Software and Services Companies
NCR	National Capital Region
NCRB	National Crime Record Bureau
NITC/NIT-C	National Institute of Technology Calicut
NRI	Non Resident Indian

O&M	Operations and Maintenance
PDPU	Pandit Deendayal Petroleum University
PHEV	Plug-in Hybrid Electric Vehicle
PLCC	Power Line Carrier Communication
Prosumer	Producer + Consumer
PV	Photo Voltaic
R&D	Research and Development
RAPDRP/R-APDRP	Restructured Accelerated Power Development and Reforms Programme
RBI	Reserve Bank of India
RCP	Representative Concentration Pathway
RF	Radio Frequency
RTP	Real Time Pricing
SCADA	Supervisory Control And Data Acquisition
SEZ	Special Economic Zone
SG	Smart Grid
SGCT	Smart Grid Communication Technology
SPV	Special Purpose Vehicle
STPI	Software Technology Parks of India
SWOC	Strengths, Weaknesses, Opportunities, Challenges
T&D	Transmission and Distribution
TCS	Tata Consultancy Services
TOU	Time Of Use
UGVCL	Uttar Gujarat Vij Company Limited
UNESCO	United Nations Educational, Scientific and Cultural Organization
V2G	Vehicle to Grid
WAN	Wide Area Network

5.1 Introduction [1–8]

Transforming lifestyles and rising population eventually causing rising expectations for better quality life and steadily driving people towards urban areas, resulting in the growth of megacities across the globe. Against problems such as rapid rise in population, fast urbanization, sustainable livelihood, employment creations, and rising migration from rural to urban areas, smart cities are emerging as novel solutions [1, 2].

Cities are engines of growth for the economy of every nation, including India. Nearly 31% of India's current population lives in urban areas and contributes 63% of India's GDP (Census 2011). With increasing urbanization, urban areas are expected to house 40% of India's population and contribute 75% of India's GDP by 2030. This requires comprehensive development of physical, institutional, social and economic infrastructure. All are important in improving the quality of life and attracting people and investments to the city, setting in motion a virtuous cycle of growth and development. Development of Smart Cities is a step in that direction [1, 2].

Around 90% of the world's urban population growth will take place in developing countries, with India taking a significant share of that. Between 2015 and 2030, India's GDP is expected to multiply five times, with over 70% of new employment generated in cities. Close to 800 million m^2 of commercial and residential space needs to be built to serve this population. Urban areas of India contributed and are expected to continue contributing a higher share of the GDP. While the urban population is currently around 31% of the total population, it contributes over 60% of India's GDP. It is projected that urban India will contribute nearly 75% of the national GDP in the next 12–15 years. Therefore, cities are referred to as the '**engines of economic growth**', and ensuring that they function as efficient engines is critical to our economic development. This trend of urbanization that is seen in India over the last few decades will continue for some more time, in fact it is likely to pick up further. In this context, the government of India has decided to develop 100 smart cities in the country [1, 2].

In such context, reliable electricity supply is essential and vital for development of any metropolitan region or a smart city. Therefore, as suggested by [2], smart grids—as energy backbones, are observed being essential and mandatory at the core of smart city developments globally.

Referring to our earlier works, in [3], detailed technical review of smart grid along with identification of critical applications and parameters, while in [4], e-governance of rooftop based solar photo voltaic rooftop system has been covered with special focus on Gandhinagar solar city project. Next, in [2], smart grid pilots along with interesting applications have been discussed including various initiatives of UGVCL and GERMI. This work presents interesting details of smart metropolitan region development of Ahmedabad-Gandhinagar twin city metropolitan region by smart grid installation with Naroda area at the focus.

5.1.1 The 'Smart City' Concept [1–7]

People migrate to cities primarily for employment. To support their happy and comfortable living, people also need good quality housing; cost-effective physical and social infrastructure, such as water, sanitation, electricity, clean air, education, healthcare, security, entertainment, etc.

The first and most basic need people have is the need for survival: their physiological requirements for food, water, and shelter. If any of these physiological necessities is missing, people are not motivated enough to meet the growth needs [1]. Seven categories of basic needs common to all people have been identified and represented as a hierarchy in the shape of a pyramid in [1] as shown in Fig. 5.1. This hierarchy is an arrangement that ranks people or concepts from lowest to highest. According to [1], individuals must meet the needs at the lower levels of the pyramid before they can successfully be motivated to tackle the next levels. The lowest four levels represent deficiency needs, and the upper three levels represent growth needs [1].

Fig. 5.1 Maslow's hierarchy of needs [1]

One will need to fulfill growth needs once their deficiency needs are fulfilled. In India, many cities have the infrastructure where deficiency needs are fulfilled and Smart City concept will fit in, while in other cities citizens are even struggling for their deficiency needs to be fulfilled. Due to dense population and lack of streamlined civic facilities and processes, such deficiencies remain unattended leading to complex problems in cities. To overcome this difference, the Government needs proper strategy that helps in successful implementation of smart city concept. India is at a point of transition where the pace of urbanization will speed up. The relatively low base allows us to plan our urbanization strategy in the right direction by taking advantage of the latest developments in technology especially in ICT [1].

There is no universally accepted definition of smart city [5]. The conceptualisation of smart city, therefore, varies from city to city and country to country, depending on the level of development, willingness to change and reform, resources and aspirations of the city residents.

According to the Smart Cities India Foundation [6], a 'Smart City' is defined as a developed urban area that creates sustainable economic development and high quality of life by excelling or becoming "smart" in multiple key areas; economy, mobility, environment, people, living, and government. Excelling in these key areas can be done through strong human capital, social capital, and/or Information Communication Technology (ICT) infrastructure.

As described by Wikipedia [7], a smart city is an urban area that uses different types of electronic data collection sensors to supply information used to manage assets and resources efficiently. This includes data collected from citizens, devices, and assets that is processed and analyzed to monitor and manage traffic and transportation systems, power plants, water supply networks, waste management, law enforcement, information systems, schools, libraries, hospitals, and other community services.

It is a well-planned and well-developed urban area where sustainable economic development and high quality of life are provided to its citizens by enhancement in different key areas; such as economy, mobility, environment, people, living, government, etc. through strong human capital, social capital, and/or Information Communication Technology (ICT) infrastructure. The new internet and smart technologies have opened new ways for collective action and collaborative problem solving.

India is at a point of transition where the pace of urbanization will speed up. In this context, the Government of India has launched the Smart City Mission in 2014 and has decided on developing 100 smart cities in the country, which are planned to provide a very high quality of life to citizens, i.e. good quality but affordable housing, cost efficient physical, social and institutional infrastructure (water, sanitation, 24/7 electricity), clean air, quality education, cost effective health care, security, entertainment, high speed connectivity and efficient mobility; it must also attract investments, experts and professionals. The 100 smart cities are to be developed in different population ranges of up to one million, one to four million and over four million.

The smart city concept integrates ICT and various physical devices connected to the network (popularly known as IoT) to optimize the efficiency of city operations and services and connect to citizens. Smart city technology allows city officials to interact directly with both community and city infrastructure and to monitor what is happening in the city and how the city is evolving. ICT is used to enhance quality, performance and interactivity of urban services, to reduce costs and resource consumption and to increase contact between citizens and government. Smart city applications are developed to manage urban flows and allow for real-time responses. A smart city may therefore be more prepared to respond to challenges than one with a simple “transactional” relationship with its citizens.

Recent interest in smart cities is motivated by major issues and challenges, including climate change, economic restructuring, the move to online retail and entertainment, ageing populations, and pressures on public finances.

As mentioned by [1], growth and deficiency needs can be classified under smart city characteristics as shown in Table 5.1.

Obviously as mentioned in Table 5.1, the energy grid (smart grid) forms not only the most primary and basic smart city component under the classification of ‘Growth Needs’, but it also serves as mandatory and fundamental requirement as to

Table 5.1 Classification of smart city components according to Maslow's hierarchy [1]

	Domain	Objective
Growth needs	Energy grids	Automated grids that employ ICT to deliver energy and enable information exchange about consumption between providers and users, with the aim of reducing costs and increasing reliability and transparency of energy supply systems
	Public lighting, natural resources and water management	Managing public lighting and natural resources. Exploiting renewable resources, such as heat, solar, cooling, water, and wind power
	Waste management	Applying innovations in order to effectively manage the waste generated by people, businesses, and city services. It includes waste collection, disposal, recycling, and recovery
	Environment	Using technology to protect and better manage environmental resources and related infrastructure, with the ultimate goal of increasing sustainability. It includes pollution control
	Transport, mobility, and logistics	Optimizing logistics and transportation in urban areas by taking into account traffic conditions and energy consumption. Providing users with dynamic and multi-model information for traffic and transport efficiency. Assuring sustainable public transportation by means of environmental friendly fuels and innovative propulsion systems
	Office and residential buildings	Adopting sustainable building technologies to create living and working environments with reduced resources. Adapting or retrofitting existing structures to gain energy and water efficiency
	Healthcare	Using ICT and remote assistance to prevent and diagnose diseases and deliver the healthcare service. Providing all citizens with access to an efficient healthcare system characterized by adequate facilities and services
	Public security	Helping public organizations to protect citizens' integrity and their goods. It includes the use of ICTs to feed real-time information to fire and police departments
Deficiency needs	Education and culture	Capitalizing system education policy, creating more opportunities for students and teachers using ICT tools. Promoting cultural events and motivating people participation. Managing entertainment, tourism, and hospitality
	Social inclusion and welfare	Making tools available to reduce barriers in social learning and participation, improving the quality of life, especially for the elder and disabled. Implementing social policies to attract and retain talented people

(continued)

Table 5.1 (continued)

	Domain	Objective
	Public administration and (e-) government	Promoting digitized public administration, e-ballots, and ICT-based transparency of government activities in order to enhance citizens' empowerment and involvement in public management
	Economy	Facilitating innovation, entrepreneurship, and integrating the city in national and global markets

provide sustainability of other components in both 'Deficiency Needs' as well as 'Growth Needs' [1].

5.1.2 *The Smart Cities Framework*

An integrated smart city component interconnection presented in Fig. 5.2 comprising the key enablers like **Smart Governance, Smart Living, Smart People, Smart Mobility, Smart Environment, and Smart Economy** to serve conceptual smart city objectives and to facilitate implementation [1].

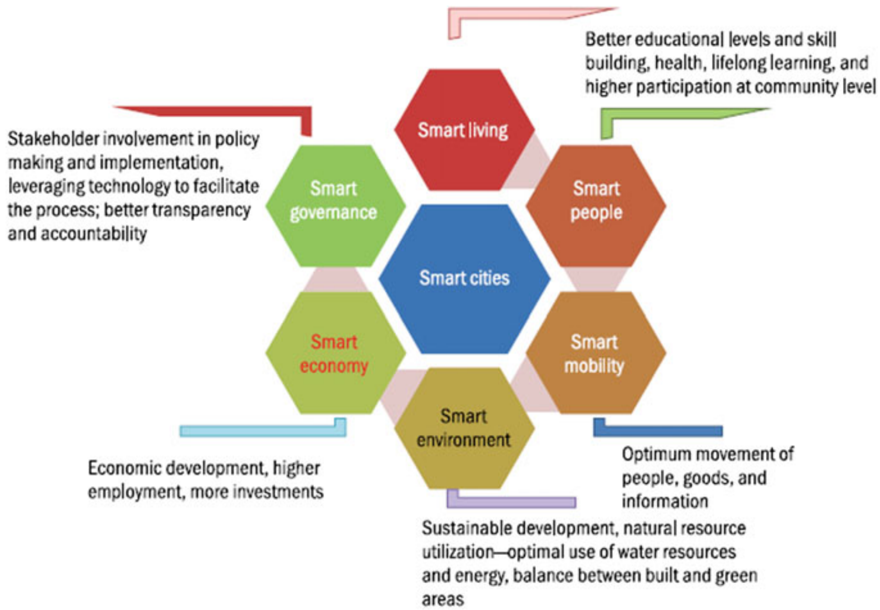

Fig. 5.2 Smart city components [1]

A key enabler is **Smart Environment**, which includes optimal use of water resources and energy, to maintain balance between built and green areas. Smart grid could be proved a game changing mechanism here [1].

5.1.3 Conversion of Existing City to Smart City [8–10]

The genesis of smart cities in India is linked to the post economic liberalization and reform since 1991. Indian economy is going through a process of significant structural change between 1991 and 2011, with the declining share of agriculture in the GDP, stagnating manufacturing sector and leap-frog growth of service sector with its contribution to GDP rising from 44.1 to 56.4%. The improved economic performance is powered by the growth of urban based knowledge intensive services (e.g. IT-ITES-BPO, education and healthcare), automobiles, pharmaceuticals, biotechnology, garments, hotels and recreation sector activities. Initially seven big urban agglomerations in the cities of Bengaluru, Hyderabad, Chennai, Mumbai, Pune, Kolkata and Delhi NCR started due to growth of ICT sector, and subsequently, more grandiose vision of smart cities has become integral to the idea of industrial corridor being launched for economic turnaround of the nation through development of green-field industrial cities, where high-end infrastructure, sensors, smart grids, big data and analytics considered as the elementary tools for urban governance [8].

As depicted an illustration in Fig. 5.3 [1], for successful conversion of an existing city into smart city, fulfillment of certain features have been expected and desired. It could be observed that while 'Energy' forms the core feature along with 'Sustainable transport', 'Water management' and 'Spatial programming', ICT remains as vital connecting link to all the four core features.

The smart city infrastructure is mentioned as the introductory step for establishing the overall smart city framework and architecture. A smart city is a city that uses digital technologies to improve the quality of life and standard of living of its citizens. Smart cities anticipate and mitigate current and future challenges by using the power of the communication network, distributed wireless technology and intelligent business management system [9].

A rapid urbanization increases day by day because of which there has been a steady increase in migration from rural to urban areas. It is expected that around 70% of the global population will be living in cities by the year 2050. This needs about 500 new cities to accommodate the inundation.

The announcement of '100 Smart Cities' by government of India falls in line with the vision of providing ample living space in the urban regions. This also allows for investment opportunities in the infrastructure sector in India. In a smart city, the information technology plays a pivotal role in providing the essential services to its residents. The information technology is the major infrastructure of these cities. Automated sensor networks and data centers are the examples of technological platforms involved in such smart cities. These smart cities have

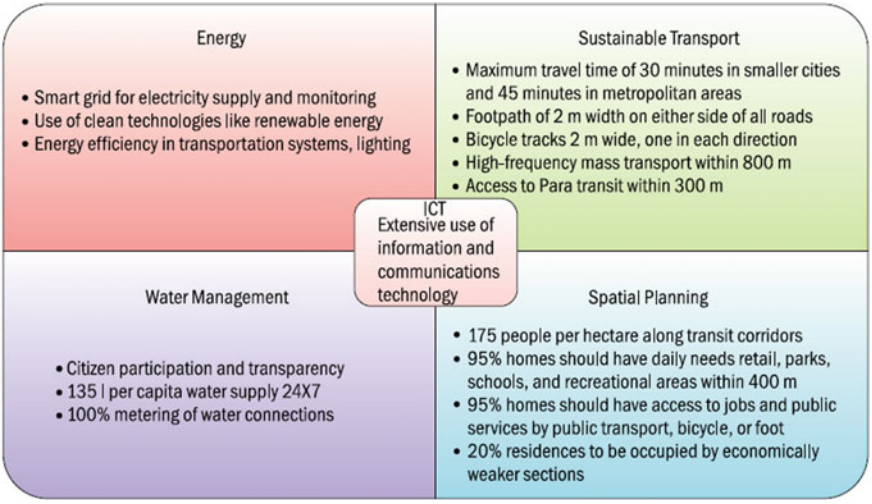

Fig. 5.3 Features required for smart cities [1]

sustainable economic development, which benefits everyone, including citizens, businesses, the government and the environment.

Challenges remain, especially in relation to access to financing of large scale reforms like smart grid in the electricity sector [10].

Also, due to issues such as electricity theft, etc. energy management is emerging as one of the major challenges in the growth of smart cities in India. Government of India has started various initiatives to provide smart energy solutions via smart grid and finalized following initiatives:

(i) Establish smart grid test bed and smart grid knowledge centre
(ii) Implementation of eight smart grid pilot projects in India with investment of USD 10 million
(iii) Addition of 88,000 MW of power generation capacity in the 12th Five Year Plan (2012–17)
(iv) The Power Grid Corporation of India Limited has planned to invest USD 26 billion in the next five years
(v) Installation of 130 million smart meters by 2021

5.2 Smart Regional Development [9]

There are under mentioned six dimensions of development of a smart city or smart metropolitan region [9]:

5.2.1 Smart Governance

City is a private and civil organization that works at its best as one organism fuelled by infrastructure, hardware, software and data mining. Smart governance is about transparency and can be achieved from government enabled applications in terms of citizen decision making and e-public services. It includes involvement of the public in decision-making, public and social service and government transparency.

5.2.2 Smart People

It includes a culture of life-long learning, social and ethnic diversity, flexibility, creativity and community participation. People fed since childhood by e-skill that promotes creativity, critical thinking, and independence fostering innovation by all means.

5.2.3 Smart Mobility

Smart mobility means integrated transport and logistics system supported by wise infrastructure, hardware, software, and data mining. It includes local and national accessibility, safe and sustainable transportation systems, and access to ICT infrastructure.

5.2.4 Smart Economy

E-business process and E-commerce are to boost sustainable growth and productivity. It also includes entrepreneurship and productivity, economic progression, flexibility in the labor market, and an overall culture of innovation.

5.2.5 Smart Living

Smart living means healthy and safe living through smart technologies. It also includes cultural and educational facilities, quality health conditions and public safety, accessibility to quality housing, tourists' attractions and social integration.

5.2.6 Smart Environment

It means renewable and clean energy managed by ICT. The main objective is a clean environment with pollution and trash disposal under control. It also includes

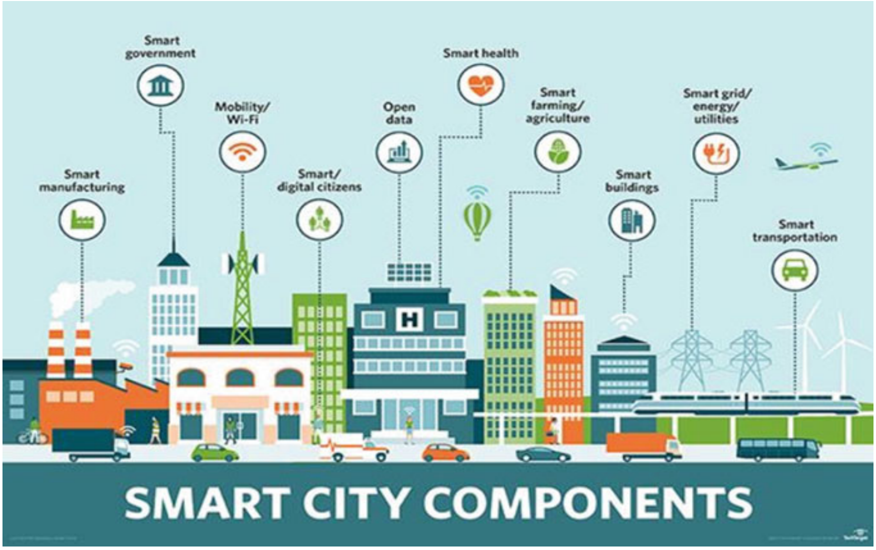

Fig. 5.4 Smart city components [9]

attracting natural conditions, reduction in pollution, and increase in environmental protection and sustainable resource management.

ICT is serving as vital interconnecting link between all the smart city components mentioned above and shown in Fig. 5.4 [9].

5.3 Drivers of Growth [10–13]

According to [10], India's smart grid top market rankings have been improving by a fast-growing economy and electricity sector. Growing electricity consumption and ambitious government policies for energy access, renewable resources deployment and "development of smart cities" are among major strengths for the smart grid developments.

Comparing the smart city initiatives by China and India, [11] pointed out various differences in methodologies adopted by both countries, and indicated that to meet huge demands of electricity, China has already started smart grid development in 2012, with targets of installing smart meters by 2017 to enable time based electricity pricing which complements smart cities mission, on the other hand, India is still working with pilot projects in experimental stages.

The challenging physical, economic and technological environment across the globe necessitates smart cities which help to enhance livability, workability and sustainability. Such powerful drivers which are responsible for growth of smart cities are identified by authors in [12] as presented below:

5.3.1 Growing Urbanization

Cities deliver many benefits—greater employment opportunities, easier access to healthcare, education, entertainment, culture and the arts. As a result, people are moving to cities at an unprecedented rate. In India, over 200 million people will be added to urban populations over the next 15 years.

5.3.2 Rapidly Improving Technology

Improvement in technology has made things much easier than before, and will go a long way in making cities smart. In many developed countries, the installation of millions of smart meters and smart sensors will produce data of value to a smart city. The adoption of smart thermostats and building management systems in many cities is resulting in smart buildings. Other smart technologies such as intelligent transportation management software, roadway sensors, smart parking apps, navigation apps and equipment displaying real-time traffic are effectively planning and managing traffic. The use of electric vehicles helps reduce pollution levels. High-bandwidth networks worldwide connect one billion computers and four billion cell phones approximately.

5.3.3 Growing Environmental Challenges

Cities house half of the world's population but use two-thirds of the world's energy and generate three-fourths of the world's CO_2 emissions. Every city has to learn to proactively mitigate the effects of such environmental concerns and other climate changes. Smart technologies can help to do this, and to spread awareness.

5.3.4 Rising Expectations

Accustomed to instant, anywhere, anytime, personalized access to information and services via mobile devices and computers, citizens are now expecting the same kind of access to city services. In developed countries, ICT plays an important role in all type of city services, from governance to smart management of buildings. This helps increase transparency between the government and citizens. Easy access to all city services causes citizens to interact more and participate in the long term development and maintenance of their city.

5.3.5 Increasing Economic Competition

Cities across the world are competing to secure investments, jobs, businesses and talent. This may lead to a transition in the workforce and migration of people from one city to another. Cities will increasingly need to focus more on physical infrastructure and social infrastructure to meet the needs of a growing population.

5.3.6 Inadequate Infrastructure

Urbanization is putting a significant strain on city infrastructure that was, in most cases, built for populations a fraction of their current size. Currently, most cities, towns, districts, and states in India lack adequate base infrastructure such as roads, power, water supply, sewerage, and sanitation. The need for base infrastructure to be addressed to prepare the foundation for 'Make in India' a major new national program, designed to facilitate investment, foster innovation, enhanced skill development, protect intellectual property. and build best-in-class manufacturing infrastructure.

5.3.7 Rising Stress

The challenges and competitions from increasing population, increased costs, increase in travel distances, unemployment, unavailability of quality time with family, increase in crime rates have led to many physical and psychological problems. Hence, the city should have good transportation, public amenities and leisure facilities, public security, smart technologies etc. to mitigate the growing stress.

In the Indian context, following are identified as key drivers of growth of smart grids in [13]:

(i) Reduction in AT&C losses
(ii) Demand side management (TOU Tariff—Dynamic pricing based for peak demand and peak supply)
(iii) 24 × 7 Power for all
(iv) Outage reduction
(v) Renewable energy integration
(vi) Improved energy efficiency
(vii) Reliable grid stability
(viii) Faster restoration of electricity after fault or disturbances
(ix) Grid flexibility (backup power)

(x) Reduction in peak demand
(xi) Reduction in power purchase cost

5.4 Needs and Impacts of the Grid [14, 15]

5.4.1 Needs [14]

Following needs and requirements of the smart grid have been outlined [14]:

(i) *Primary energy shortage*: Energy should be transmitted from external place to city in a distant way in the form of coal, gas or electric power. Relying on long distance transmission channels is indeed expensive and non-reliable.
(ii) *Imperfect network structure*: The capacity to accept power from external generations needs to promote. Substations are over loaded and in low automation level. The distribution system has a high density of lines, a high fault rates, low efficiency and operates inflexibly.
(iii) *More requires*: Consumers in city, residents and industries, require more in service quality and varieties.
(iv) *Great damage risk*: Once blackout occurs, it will cause a great damage to people's daily life and economics, even to the national security.
(v) *Limited land*: With the processes of urbanization and modernization, the capacity is still expanding, but the land needed to build new substations and lines is getting limited.

5.4.2 Impacts [15]

In [15], following impacts of the smart grids have been presented:

5.4.2.1 Environmental Impact

By enabling distributed generation, smart grid can work with fewer generating plants, fewer transmission and distribution assets in order to cater the growing demand of electricity. With the possible expectation of wind farm sprawl, landscape preservation is one of the evident benefits. Since maximum generation today results in emission of greenhouse gas, a smart grid reduce air pollution and plays a significant role in combating global climate change issue.

A smart grid has the capability to accommodate technical difficulties of integrating renewable resources like wind and solar to the grid, providing further reduction in greenhouse gas emissions.

5.4.2.2 Cost

The ability to bypass the cost of the plant and grid development is a major advantage to both the utilities and customers. Further with the aid of smart grids less generating units would be required in order to fulfill the energy demand of the growing population and cost of setting up more and more plants can be deferred. At that point of time, more emphasis will be on overall development of T&D efficiency based on demand response, load control, and many other technologies.

Energy efficiency would be the second priority in order to save cost with reference to the customers. With timely and detailed information provided by Smart Grids, customers would be encouraged to limit waste, adopt energy-efficient building standards, and invest more and more in energy efficient appliances.

5.4.2.3 Utility Operations

Smart Grids can assist the utilities, as the principal focus of the utilities is to improve business processes. Many utilities have an extensive list of projects that they would like to fund in order to improve the customer service or to ease workforce's burden of repetitive work. Calculating smart grid benefits by the cost/benefit analysis it puts emphasis in favor of the change and can also significantly decrease settlement/payback periods.

Mobile workforce group and asset management group work collectively to organize assets and then maintain, renovate, and replace them. This can result in increased productivity and fuel saving from superior methods.

Similarly, smart grid provides customers with real time information and encourages them to do online payments, thus lowering billing costs.

5.4.2.4 Theft Control

This is not an issue in developed countries like US, but in developing countries like India as well, where people have a little insight of the grid and higher poverty rate, power theft is quite common. With development of smart grid, power theft can be controlled to a greater extent, thereby improving the efficiency of distribution system. Thus, grids will provide higher quality and reliable power supply, and there will be fewer blackouts.

5.5 Benefits of Smart Grids [6, 16–20]

According to [16], various anticipated benefits of smart grid are as follows:

(i) Better power quality as well as reliability by better matching of demand-supply and improvement in grid congestion

(ii) Reduction in spinning reserves and improved ancillary service
(iii) Increased efficiency, security and capacity utilization of grid
(iv) Power disruption management and analysis
(v) Integration of renewable energy resources, ultimately leading to reduction of greenhouse gases in the anticipated climate change
(vi) Opportunity for new markets
(vii) Energy management savings in the monthly electricity bills, improved efficiency of appliances
(viii) Self-healing nature of the grid, which will improve the maintenance of the grid and will also allow the islanded operation whenever required
(ix) Demand response will enable various choices of utility generated power and green power with differential pricing for consumers
(x) Transparency in operation of the utility grid and optimization of its asset utilization
(xi) Reduction in expenditure spent on the maintenance and operation of the utility grid
(xii) Innovative decision assistance and business intelligence will be available at both automatic and manual monitoring level through optimization tools
(xiii) PHEV and V2G integration would help in peak shaving and valley filling
(xiv) Improved electric load forecasting through data mining of the information collected from two-way M2M communication of utility grid
(xv) Encourages energy independence
(xvi) Enables distributed generation
(xvii) Allows customers to manage their consumption level and to take benefit of pricing and supply options
(xviii) Better catering of environmental issues

As presented in [17], Real Time Pricing (RTP) based tariff is more advantageous to the flat rate tariff as it encourages customers to use their appliances during off-peak period. By applying this type of tariff, peak load on the power plant reduces and amount of monthly bill of customers also reduces.

5.5.1 Economic Benefits [6, 18, 19]

References [6] and [18] mentioned that no standardized method currently exists for assessing the economic and environmental impacts of SG systems. Therefore, the context, boundaries, and ICT technologies included should be made very clear so that comparison and extrapolations can be made. Significant variation exists among studies in their estimates of SG systems, so the precise costs, benefits, and GHG emission reductions are uncertain. Standardizing some methodologies and key assumptions (time horizon, discount rates for costs), as well as scrutinizing some key input data (e.g. data related to electricity losses), can result in more consistent estimates of costs, benefits, GHG emission reductions, and energy savings

estimates. Despite these variations, the analysis shows that SG systems may not results in cost-savings but contribute to energy and GHG savings due to the large deployment of renewable energies.
Reference [19] identified following economic benefits of smart grids:

(i) Improved asset utilization
(ii) T&D capital savings
(iii) T&D O&M savings
(iv) Theft reduction
(v) Energy efficiency
(vi) Electricity cost savings
(vii) Power quality

5.5.2 Employment Generation Capabilities [20]

In [20], nine different types of renewable power generation technologies have been compared for their employment generation capabilities, particularly comparing installation and O&M works, summarized in Table 5.2 [20].

From the data presented in Table 5.2, it is evident that after biogas, solar PV (residential + large scale PV) has been second largest employment generator [20].

From charts in Fig. 5.5 [20], it is interesting to note that as compared to biomass-the highest employment generator, the second highest employment generator-solar PV provides more employment opportunities in installation and relatively lesser employment opportunities in O&M.

5.5.3 Social Benefits [19]

Reference [19] identified following social benefits of smart grids:

(i) Offering flexibility to reschedule operation of consumer appliances via DSM
(ii) Detailed feedback of energy consumption patterns to consumers via smart meters
(iii) Enhancement in quality of lifestyle
(iv) Simplicity, transparency and convenience
(v) Improved user awareness and sharing of resources

5.5.4 Environmental Benefits [19, 20]

Reference [19] suggested that due to under-mentioned environmental benefits of smart grids, the living environment and lifestyle quality enhances:

Table 5.2 Breakdown of lifecycle employment factors (persons-years per GWh) for the nine different renewable power generation technologies [20]

	Construction stage			Operation & maintenance stage			Total
	Direct	Indirect	Subtotal	Direct	Indirect	Subtotal	
Residential PV	0.67	1.43	2.10	0.33	0.30	0.63	2.73
	(24.6%)	(52.4%)	(77.0%)	(12.0%)	(11.0%)	(23.0%)	(100.0%)
Large-scale PV	0.59	1.12	1.71	0.89	0.23	1.13	2.84
	(20.8%)	(39.5%)	(60.3%)	(31.5%)	(8.2%)	(39.7%)	(100.0%)
Wind	0.24	0.70	0.94	0.50	0.45	0.95	1.89
	(12.7%)	(36.9%)	(49.7%)	(26.5%)	(23.8%)	(50.3%)	(100.0%)
Large-scale geothermal	0.27	0.40	0.67	0.15	0.20	0.35	1.01
	(28.1%)	(36.0%)	(64.1%)	(23.2%)	(12.7%)	(35.9%)	(100.0%)
Small-scale hydro	0.56	0.71	1.27	0.46	0.12	0.58	1.85
	(30.0%)	(38.6%)	(68.6%)	(25.0%)	(6.4%)	(31.4%)	(100.0%)
Wood biomass	0.22	0.17	0.39	0.65	2.85	3.50	3.89
	(5.7%)	(4.4%)	(10.1%)	(16.6%)	(73.3%)	(89.9%)	(100.0%)
Sewage sludge biogas	0.41	0.88	1.30	0.91	0.80	1.72	3.01
	(13.7%)	(29.3%)	(43.0%)	(30.3%)	(26.7%)	(57.0%)	(100.0%)
Animal waste biogas	1.01	0.95	1.96	1.14	1.78	2.92	4.88
	(20.7%)	(19.4%)	(40.1%)	(23.4%)	(36.4%)	(59.9%)	(100.0%)
Food waste biogas	0.63	0.98	1.61	0.95	2.48	3.43	5.04
	(12.5%)	(19.4%)	(31.9%)	(18.9%)	(49.2%)	(68.1%)	(100.0%)

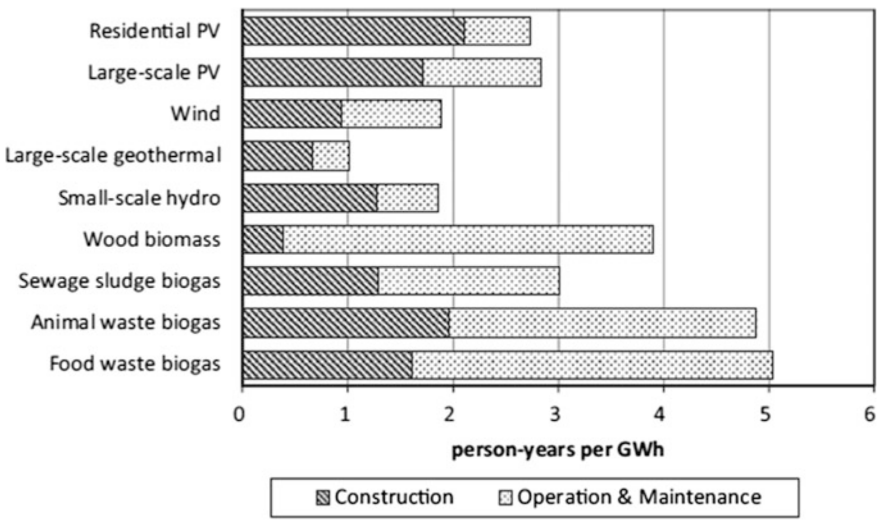

Fig. 5.5 Life cycle employment factors (person-years per GWh) for the nine different renewable power generation technologies [20]

(i) Cleaner air, reduced CO_2 emissions
(ii) Reduction in Green House Gas (GHG) emissions by reducing fossil fuels and encouraging renewables
(iii) Reduction in COx, NOx, and PM-10 emissions

5.6 Challenges and Solutions [9, 15, 21]

5.6.1 Challenges

As described by [21], there are several challenges during the execution & post execution of the smart grid pilot project like transition of legacy equipment/system, lack of standard & interoperability, policy & regulatory framework, lack of awareness, cyber security & data privacy etc., the government should encourage financial and technical development of smart grid standards including pilot models, for the expected key benefits from these projects like lowering of peak demand, differed capital investment by avoiding network capacity cost, reduction in outage duration & outage restoration costs, increased efficiency of network & empowerment of consumers. There are various inherent risks involved in restructuring the utility grid, which are required to be addressed for the modernization of utility grid: Information integration across all units of the smart grid is a necessity.

Non-conventional sources of energy may have critical impact on the reliability of smart grid such as faulty forecasting of load, distribution and transmission congestion, little correlation with requisite load profiles and so on, making it more vulnerable to failures. Further, absence of policies, regulations and standards for smart grid, cyber-attacks on smart grid, such as theft of important information or manipulation of the whole or part of system through smart meters, AMI, supervisory control and data acquisition control, energy storage subsystem, V2G infrastructure, etc. may cause impairment of the vital units of smart grid.

Integration and information security (interoperability, encryption, data protection, cyber terrorism) pose a major challenge for the implementation of smart grid and extensive requirement of capital for ICT, smart meters, communication infrastructure, etc. Energy markets have a constraint of minimum production, which makes it impossible for the electricity produced from renewable sources to participate in the energy market. Lack of knowledge regarding smart meters, its usage and literacy related to power rating of appliances, peak load, etc. make this technology less lucrative. Large information will be generated on a real-time basis. If any wrong decision is made by the consumer due to some incorrect information or due to lack of needed information, it may lead to power outages.

One of the major challenges involved in the implementation of smart grid is investment. Generation of electricity through non-conventional sources of energy needs extensive capital and large lead times. A huge cost would be incurred for the automation of whole grid. The investment required would need contribution from government, utilities and also through credits and issuance of bonds.

Some other ill effects are inherent, such as the communication infrastructure for smart grid would lead to the formation of electro smog; exposing individuals to continuous RF radiation; emitted vampire energy, which would ultimately lead to various health hazards. These RF radiations may interfere with the ecosystem, thus disrupting the movement of birds, butterflies, marine animals and so on who use electromagnetic radiations as a guide for their migrations.
Mentioned below are some more challenges identified in [9]:

(i) Retrofitting existing legacy city infrastructure for making it smart

There are a number of latent issues to consider when reviewing a smart city strategy. The most important is to determine the existing city's weak area that needs utmost consideration i.e. 100% distribution of water supply and sanitation. The integration of formerly isolated legacy system to achieve citywide efficiencies can be significant challenge.

(ii) City development plan

Most of our cities do not have good master plan or development plan, which is important to smart city planning and implementation.

(iii) Governance

There should be successful implementation of smart city solution needs effective horizontal and vertical coordination between various institution providing various municipal amenities as well as effective coordination between central govt., state government and local government agencies.

(iv) Building program

To build 100 smart cities is not an easy task and most ambitious project is delayed owing to lack of quality manpower, both at the state and central level. In terms of funds only around 5% of the central allocation may be allocated for capacity building program that focus on training. Investment in capacity building program have a multiplier effect as they help in time bound completion of project and in designing program.

(v) Reliability of utility services

For any smart city in the world, the focus is on reliability of utility services, whether it is electricity, water, telephone or broadband services. Smart city should have universal access to electricity 24 × 7, this is not possible with the existing system. Cities need to shift towards renewable sources and focus on green building and green transport to reduce the need for electricity

As identified by [15], the challenges for smart grid development are:

(i) Policy and regulation

The current policy and regulatory frameworks were typically designed to deal with the existing networks and utilities. To some extent the existing model has encouraged competition in generation and supply of power but is unable to promote clean energy supplies. With the move towards smart grids, the prevailing policy and regulatory frameworks must evolve in order to encourage incentives for investment. The new frameworks will need to match the interests of the consumers with the utilities and suppliers to ensure that the societal goals are achieved at the lowest cost to the consumers. Generally, governments set policy whereas regulators monitor the implementation in order to protect the consumers and seeks to avoid market exploitation. Over the last two decades, the trend of liberalized market structure in various parts of the world has focused the attention of policy-makers on empowering competition and consumer choice. The regulatory models have evolved to become more and more effective to avoid market abuse and to regulate the rates of return. Moving forward, the regulatory model will have to adopt the policy which focuses much on long term carbon reduction and security of supply in the defined outcomes and they need to rebalance the regulatory incentives to encourage privately financed utilities to invest at rates of return that are commensurate to the risk. This may mean creating frameworks that allow risk to be shared between customers and shareholders, so that risks and rewards are balanced providing least aggregate cost to the customer.

(ii) Business scenario

The majority of examples results in negative business cases, undermined by two fundamental challenges:

a. High capital and operating costs
   Capital and operating costs include large fixed costs linked to the chronic communications network. Hardware costs do not cause in significant growths in economies of scale and software integration possess a significant delivery and integration risks.
b. Benefits are constrained by regulatory framework
   When calculating the benefits, organizations tend to be conservative in what they can gather as cash benefits to the shareholders. For example, in many cases, line losses are considered to be put on to the customer and as a result any drop in losses would have no net impact on the utility shareholder. The smart grid benefits case may begin on a positive note but, as misaligned policy and regulatory incentives are factored in, the investment becomes less attractive. Therefore regulators are required to place such policies and regulations in place which could provide benefits both to the utilities and the consumers. Therefore the first factor to be considered is to provide incentives to the utilities in order to remove inefficiencies from the system. They should be aptly remunerated for the line losses on their networks. On the budget side of the calculation, there is no avoiding the fact that smart technologies are expensive to implement, and at the

present level it is right to factor in the risk associated with delivery. But the policy makers and regulators can mitigate that risk by seeking economies of scale and implementing advanced digital technologies.

(iii) Technology maturity and delivery risk

Technology is one of the essential constituents of Smart Grid which include a broad range of hardware, software, and communication technologies. In some cases, the technology is well developed; however, in many areas the technologies are still at a very initial stage of development and are yet to be developed to a significant level. As the technologies advances, it will reduce the delivery risk; but till then risk factor have to be included in the business situation.

On the hardware side, speedy evolution of technology is seen from vendors all over the world. Many recently evolved companies have become more skeptical to the communications solutions and have focused on operating within a suite of hardware and software solutions. Moreover the policy makers, regulators, and utilities look upon well-established hardware providers for Smart Grid implementation. And this trend is expected to continue with increasing competition from Asian manufacturers and, as a consequence, standards will naturally form and equipment costs will drop as economies of scale arises and competition increases.

On the software and data management side, the major challenge is to overcome the integration of the entire hardware system and to manage high volume of data. With multiple software providers come multiple data formats and the need for complex data models. In addition, the proliferation of data puts stresses on the data management architecture that are much similar to the telecommunications industry than the utilities industry. Many of these issues are currently being addressed in pilots such as smart grid task force and, as a consequence, the delivery risk will reduce as standards will be set up.

(iv) Lack of awareness

Consumer's level of understanding about how power is delivered to their homes is often low. So before going forward and implementing Smart Grid concepts, they should be made aware about what Smart Grids are? How Smart Grids can contribute to low carbon economy? What benefits they can drive from Smart Grids? Therefore:

a. Consumers should be made aware about their energy consumption pattern at home, offices … etc.
b. Policy makers and regulators must be very clear about the future prospects of Smart Grids.
c. Utilities need to focus on the overall capabilities of Smart Grids rather than mere implementation of smart meters. They need to consider a more holistic view.

(v) Access to affordable capital

Funds are one of the major roadblocks in implementation of Smart Grid. Policy makers and regulators have to make more conducive rules and regulations in order to attract more and more private players. Furthermore the risk associated with Smart Grid is more; but in long run it is expected that risk-return profile will be closer to the current situation as new policy framework will be in place and risk will be optimally shared across the value chain.

In addition to this, the hardware manufacturers are expected to invest more and more on mass production and R&D activities so that technology obsolescence risk can be minimized and access to the capital required for this transition is at reasonable cost.

(vi) Skills and knowledge

As the utilities will move towards Smart Grid, there will be a demand for a new skill sets to bridge the gap and to have to develop new skills in analytics, data management and decision support. To address this issue, a cadre of engineers and managers will need to be trained to manage the transition. This transition will require investment of both time and money from both government and private players to support education programs that will help in building managers and engineers for tomorrow. To bring such a change utilities have to think hard about how they can manage the transition in order to avoid over burdening of staff with change.

(vii) Cyber security and data privacy

With the transition from analogous to digital electricity infrastructure comes the challenge of communication security and data management; as digital networks are more prone to malicious attacks from software hackers, security becomes the key issue to be addressed.

In addition to this; concerns on invasion of privacy and security of personal consumption data arises. The data collected from the consumption information could provide a significant insight of consumer's behavior and preferences. This valuable information could be abused if correct protocols and security measures are not adhered to.

If above two issues are not addressed in a transparent manner, it may create a negative impact on customer's perception and will prove to be a barrier for adoption.

5.6.2 Solutions [15]

In [15], following solutions have been proposed to overcome challenges identified in earlier sections:

5.6.2.1 Forming Political and Economic Frameworks

Policy makers and regulators have to implement a framework which optimally spread the risk over the whole value chain i.e. to guard the investors from risk and to yield the result at lower cost to the customers. They have to form a robust incentive model in order to attract more and more private investment. Also rate of return should be based on the output generated. Rewards and penalty mechanism should be considered in order to monitor the performance of the utilities and to encourage them to deliver the outcomes in the most efficient manner.

Technological and delivery risk associated with Smart Grid are significant. And this can be overcome over a due course of time as more issues arise and are addressed. Risks associated with Smart Grid have to be shared by every member across the value chain. While making the framework regulators must consider how much of that risk a utility can pass on to the contractors, suppliers and consumers. By maintaining the proper balance, there will be an improved alignment of the incentives. And further they have to tackle numerous policy disputes and recommend potential solutions.

5.6.2.2 Moving Towards a Societal Value System

The major challenge for the transition from analogous to digital infrastructure will be to move from utility-centric investment decision to societal-level decisions which determine wider scopes of the Smart Grid. This would help in the accelerated adoption of Smart Grid Technology by the society.

5.6.2.3 Achieving Greater Efficiency in Energy Delivery

Smart Grid Technology should consider building greater efficiency into the energy system which would result in reduction of losses, peak load demand and thereby decreasing generation as well as consumption of energy. New regulatory framework which incentivizes utilities for reducing the technical losses would help utilities to perform more efficiently.

5.6.2.4 Enabling Distributed Generation and Storage

Smart grids will change where, when and how energy is produced. Each household and business will be empowered to become a micro-generator. Onsite photovoltaic panels and small-scale wind turbines are the predominant examples; developing resources consist of geothermal, biomass, hydrogen fuel cells, plug-in hybrid electric vehicles and batteries. As the cost of traditional energy sources continues to rise and the cost of distributed generation technologies falls, the economic situation for this evolution will build.

5.6.2.5 Increasing Awareness on Smart Grids

There is an imperative need to make the society and the policy makers aware about the capabilities of a Smart Grid. The main step is to form a perfect, universal description on the common principles of a smart grid. Beyond agreement on a characterization, the matter also needs to be debated more holistically as a true enabler to the low-carbon economy, rather than as an investment decision to be taken within the meeting room of distinct utilities. The importance of consumer education is not to be under estimated. The formation of user-friendly and state-of-the-art products and services will play a significant role in convincing the society about Smart Grids.

Also the utilities are required to scrutinize the major challenges in implementation of Smart Grid and their impact on their business model and operations.

5.6.2.6 Creating a Fresh Pool of Skills and Knowledge

Successful implementation of the smart grid will require a large number of highly skilled engineers and managers mainly those who are trained to work on transmission and distribution networks. As a result to on-job training and employees development will be vital across the industry. Simultaneously, there is a requirement for investment in the development of relevant undergraduate, postgraduate and vocational training to make sure the availability of a suitable workforce for the future. The investment in T&D should not be limited and neither in research and knowledge development, which would be essential for the development of this sector.

5.6.2.7 Addressing Cyber Security Risks and Data Privacy Issues

Smart Grid success depends on the successful handling of two major IT issues: Security and Integration and data handling.

With increase in computers and communication networks comes the increased threat of cyber-attack. The Government should look into this matter because consumer's consumption data can be misused by the utilities and the third party. Utilities have to give assurance to the consumers that their valuable information is handled by authorized party in ethical manner. The government has to adopt high standard level in order to withstand cyber-attacks.

5.7 Study Area Information [22–30]

5.7.1 Historical Perspectives

Ahmedabad [22–25]:

The historic city of "Ahmedabad" or "Amdavad" or "Ahmadabad", the largest city of Gujarat, has been declared as *India's first UNESCO World Heritage City* in July, 2017.

Ahmedabad has been the fifth most populous city and seventh most populous urban agglomeration in India. Currently, with a population of more than 6.3 million and an extended population of 7.8 million, it is the sixth largest city and seventh largest metropolitan area of India. According to the 2011 census, the urban agglomeration of Ahmedabad was 6,361,084.

Ahmedabad is located on the banks of the Sabarmati River, 30 km (19 mi) from the state capital Gandhinagar, which is twin city of Ahmedabad forming Ahmedabad-Gandhinagar twin city metropolitan region, focused in this chapter.

The Ahmedabad city, founded by Sultan Ahmad Shah in 1411 AD, lies on the banks of the Sabarmati river, is amongst the major metropolitan cities in India. The history of Ahmedabad stretches as far back as in the 11th century and linking itself with old towns of Ashaval and Karnavati about 1000 years ago. In the year 1411 AD, Sultan Ahmed Shah built citadel and encouraged development of trade and commerce. In 1456 AD, an enclosing wall was constructed defining a periphery to the city-limits. The city within this wall got structured into wards, organized by 12 main roads each terminating at a gate in the wall.

The Ahmedabad city is the administrative headquarter of Ahmedabad district and is the judicial capital of Gujarat as the Gujarat High Court is located here.

With a population of more than 5.8 million and an extended population of 6.3 million, it is the fifth largest city and seventh largest metropolitan area of India. With the increasing opportunities for trade and commerce and as a center for higher education, this heavy growth continues.

In 2003, Ahmedabad has the *lowest crime rate* of the 35 Indian cities with a population of more than one million according to the National Crime Records Bureau (NCRB) report. In 2010, Forbes magazine rated Ahmedabad as *one of the fastest-growing city in India and the world*. In 2011, Ahmedabad was rated *India's best megacity to live in* by leading market research firm IMRB. Again in 2012, The Times of India chose Ahmedabad as *India's best city to live in* (Fig. 5.6).

Gandhinagar [26, 27]:

Gandhinagar is the capital of the state of Gujarat in Western India. Gandhinagar is located approximately 23 km north of Ahmedabad, on the west central point of the Industrial corridor between Delhi, the political capital of India, and Mumbai, the financial capital of India.

Gandhinagar, Gujarat's new capital city, lies on the west bank of the Sabarmati River, about 545 km (338 miles) north of Mumbai, the financial capital

Fig. 5.6 Panoramic view of Ahmedabad city [24]

Fig. 5.7 Panoramic view of Gandhinagar city [26]

of India and 901 km (560 miles) southeast of Delhi, the political capital. Built with parks, extensive plantation and recreational areas along the river, Gandhinagar has a green garden-city atmosphere (Fig. 5.7).

Naroda [28, 29]:

Naroda is fast growing area in northeast side in Ahmedabad city, situated on the emerging Gandhinagar-Ahmedabad-Vadodara (GAV) corridor. With the establishment of the Naroda industrial area in the 1980s, it progressed well as separate town and later incorporated into Ahmedabad in 1996. Being eight km from Ahmedabad international airport and located on the SP Ring Road, Naroda has over the last two years transformed from a neglected industrial area to desirable location for homes. The Naroda GIDC industrial park hosts national and multinational corporations. Several major township projects are being developed along the Ahmedabad-Vadodara expressway with Naroda being at the center of the development. In the recent Vibrant Gujarat summit, 24 projects worth more than Rs. 1000 Crore were slated to be developed in this part of city and along the Ahmedabad-Vadodara expressway including hospitals, hotels and clubs, educational institutions, NRI residential colonies, business parks, etc. In the satellite map of Fig. 5.8, Naroda's strategic presence surrounded by diversified types of locations has been depicted which is region of our research study interest in the Ahmedabad-Gandhinagar smart twin city metropolitan region (Table 5.3).

5.7.2 Regional Contexts [23, 29]

5.7.2.1 Demographic Attributes [23]

Ahmadabad District is the central region district of Gujarat with its administrative headquarters located at Ahmadabad city. Naroda area is located in Ahmadabad city on the junction of Ahmedabad-Gandhinagar cities, in Ahmedabad district of Gujarat state of India.

Fig. 5.8 Satellite map of Naroda area [29]

Table 5.3 Details of diversified locations surrounding Naroda in satellite map [29]

Sr. No.	Highlighting colour	Location classification	Examples in the map
1		Main location	Naroda
2		Residential area	Naroda, Nava Naroda, Asarwa, Bapunagar, Gomtipur, Amraiwadi
3		Heritage monuments	Sabarmati Ashram (Gandhi Ashram), Hathising Jain Temple, Shree Swaminarayan Temple, Siddi Saiyad Jali Mosque, Khadia
4		Industrial area	GIDC Naroda, Nikol, Kathwada, Vastral
5		Other important location	Sardar Vallabhbhai international airport, Sardar Vallabhbhai National Memorial, World Vintage Car Museum, Kamla Nehru Zoological Garden

Geographical area: 8107 km^2 (total cropped area 6410 km^2, forest area 149 in sq km (as per 2015 data)
Population: total 72,14,225, 37,88,051 males and 34,26,174 females (according to 2011 census)
Sex ratio: 904 females for every 1000 males
Literacy rate: 85.31% persons, 90.74% males and 79.35% females
Spoken languages: Gujarati (77.05%), Hindi (12.41%) and Urdu (5.14%)
Labour force participation rate: 36.25%
Year of Establishment: 1411 A.D.
Commencement of the municipal works by 'Town wall fund committee': 1834.
Establishment of Municipality—1858
Establishment of Municipal Corporation—1950

Area of the city: 464.16 km^2.
Languages spoken Gujarati, Hindi, English
Urban Population of the State is 42.6%, which used to be at 37.4% in 2001. Rural population in the state in 2011 fell to 57.4% from 62.6% in 2001.

Ahmedabad is the most populated District in the State, with 7.20 million people, up 11.94% from 2001, followed by Surat with 6.07 million people, up 10.07%, as per Gujarat's Directorate of census operations.

5.7.3 *Physical Aspects (Climatic and Weather Conditions Including Rain, Etc.) [23, 30]*

Latitude—22° 58N, Longitude—72° 35EN, Altitude—49 Mts. above MSL
Average annual rainfall—750 mm (July to September)
Climate: Summer—24–39 °C (May exceed 42 °C or above.)
Winter—10–24 °C (It may dip to 5 °C)

From Figs. 5.9 and 5.10 of [30], it could be observed that average temperature in the region is continuously rising every year causing rapid rise in the electrical energy being consumed every summer as compared to monsoon in both residential as well as commercial areas.

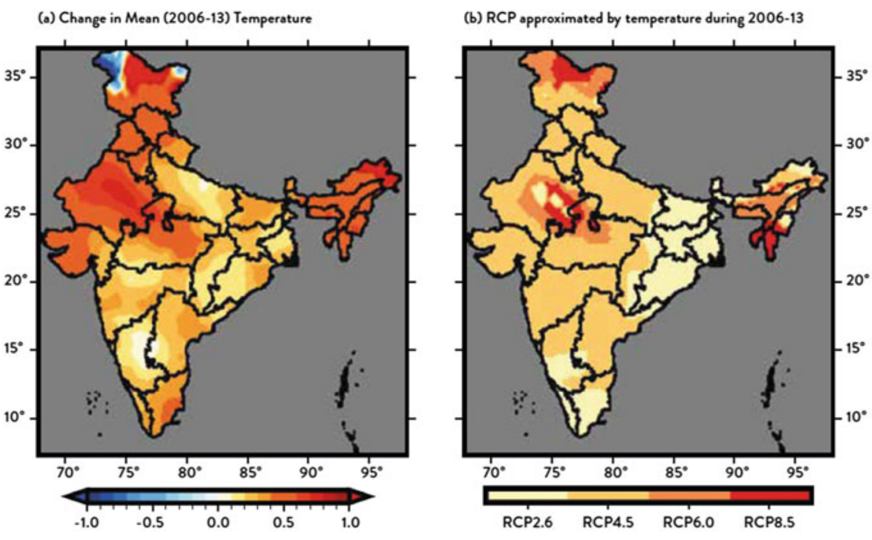

Fig. 5.9 **a** Change in mean (2006–13) annual temperature as compared to historical (1951–2005) period and **b** Representative Concentration Pathway (RCP) [30]

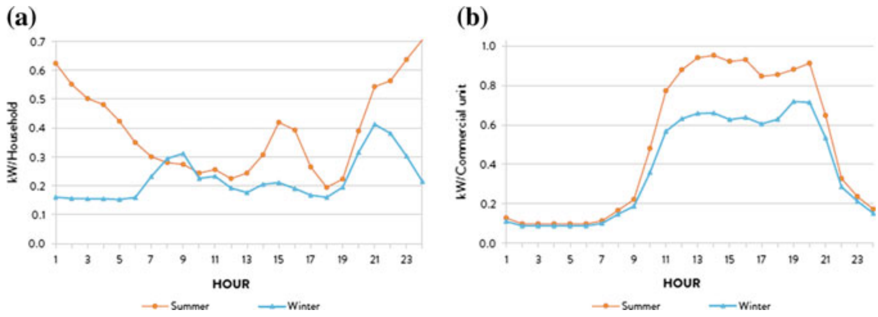

Fig. 5.10 **a** Load analysis curve for Gujarat—residential area and **b** Load analysis curve for Gujarat—commercial area [30]

5.7.4 Rise in the New Economy and Post-liberalization Growth [22–24]

The GDP of Ahmedabad was estimated at US$64 billion in 2014. The RBI ranked Ahmedabad as the seventh largest deposit centre and seventh largest credit centre nationwide as of June 2012. In the 19th century, the textile and garments industry received strong capital investment.

On 30 May 1861, Mr. Ranchhodlal Chhotalal founded the first Indian textile mill, the Ahmedabad Spinning and Weaving Company Limited, followed by the establishment of a series of textile mills. The textile industry further expanded rapidly during the First World War, and benefited from the influence of Mahatma Gandhi's Swadeshi movement, which promoted the purchase of Indian-made goods. Ahmedabad was known as the "Manchester of the East" for its textile industry. The city is one of the largest suppliers of denim and exporters of gemstones and jewellery in India. In 1966, Mr. Dhirubhai Ambani incorporated Reliance Textiles Industries Private Limited in Maharashtra and established a synthetic fabrics mill at Naroda in Gujarat. In 1975, the company expanded its business into textiles, with "Vimal" becoming its major brand in later years.

Post independence, Ahmedabad has emerged as an important commercial, enterprising and industrial hub in India. It has been one of the largest producers of cotton in the country, and with the country's second oldest stock exchange. Impacts of liberalization of the Indian economy have nurtured economy of this city towards various diversified sectors finance, trade, communication, housing, construction, etc.

The automobile industry also flourished in the city with Tata, Ford and Maruti Suzuki established their plants near Ahmedabad. IT industry significantly developed in Ahmedabad, with presence of giant IT companies such as Tata Consultancy Services (TCS). Ahmedabad was ranked fifth among the top nine most competitive cities in the country in 2002 NASSCOM survey on the "Super Nine Indian Destinations" for IT-enabled services. Indian as well as foreign students and young skilled workers have been attracted by educational and industrial institutions of the city.

Software Technology Parks of India (STPI) was established at Infocity, Gandhinagar. Gujarat International Finance Tec-City (GIFT-City) is an under-construction central business district between Ahmedabad and Gandhinagar. It will be built on 359 ha (886 acres) of land with core objective is to provide high quality physical infrastructure (electricity, water, gas, district cooling, roads, telecoms and broadband), so that finance and tech firms can relocate their operations there from Mumbai, Bangalore, Gurgaon etc. where infrastructure is either inadequate or very expensive. It will have a special economic zone (SEZ), international education zone, integrated townships, an entertainment zone, hotels, a convention centre, an international techno park, units, shopping malls, stock exchanges and service units.

5.7.5 Importance and the Role of the Region

Ahmedabad-Gandhinagar twin city has been already selected as potential smart city in phase-I under Government of India's flagship Smart Cities Mission. As the smart grid is the energy backbone of this upcoming smart city, well established and successful smart grid pilot has been conducted at Naroda area at the junction of the twin city by utility UGVCL. This project has been funded by Government of India funding under R-APDRP scheme.

5.8 Scope Analysis [30, 31, 32]

As the cities are becoming smart, citizen and governance support applications are rising in quantities and complexities. This has direct impact on overall electrical energy requirements. Production, transmission and distribution of electricity are getting expensive. Higher dependencies on fossil fuel based thermal power stations as well as low penetration of renewables has been resulting in rising costs. Bad habits, lack of discipline of citizens, heavy wastages, etc. are also important factors.

Therefore, it is an urgent need of today to transform all smart city homes into smart homes with smart HANs and relevant solutions, which would result into effective and optimal utilization of electricity.

5.8.1 Potential

In India, home automation sector is largely unexplored and rarely any full-scale installations could be found.

In general, popular understanding of home automation is believed as security solution with CCTV and detectors for smoke-fire-gas leak only.

Integration of technologies like IoT, HAN, BAS, Green buildings, Solar PVs and Smart Grid has strong potential to build up 'Sustainable and Energy Efficient Smart City', which result in effective and convincing justification for investment.

5.8.2 Feasible Applications

(i) Advanced Metering Infrastructure (AMI)
(ii) Monitoring and automation of substations
(iii) Home Automation Network (HAN)
(iv) Power network monitoring
(v) Demand Response (DR)
(vi) Integration of renewables
(vii) Supervisory Control And Data Acquisition (SCADA) system
(viii) Plug-in Hybrid Electric Vehicles (PHEV)

5.8.3 Technological Advancements

5.8.3.1 IoT Based Smart Buildings [30]

Smart buildings are realized by technologies such as HAN and/or BAS. Home Area Network (HAN) is the network within the premises of a home enabling devices and electrical loads to communicate with each other and dynamically respond to externally sent signals (e.g. price, etc.) Building Automation System (BAS) is a data acquisition and control system that incorporates various functionalities provided by central control system of a building.

Figure 5.11 presents conceptual architecture of AMI containing integration of different electricity and communication networks and sub-systems. Figure 5.12 provides modified version of AMI architecture of Fig. 5.11 after deployment of IoT components with wireless connectivity at necessary points.

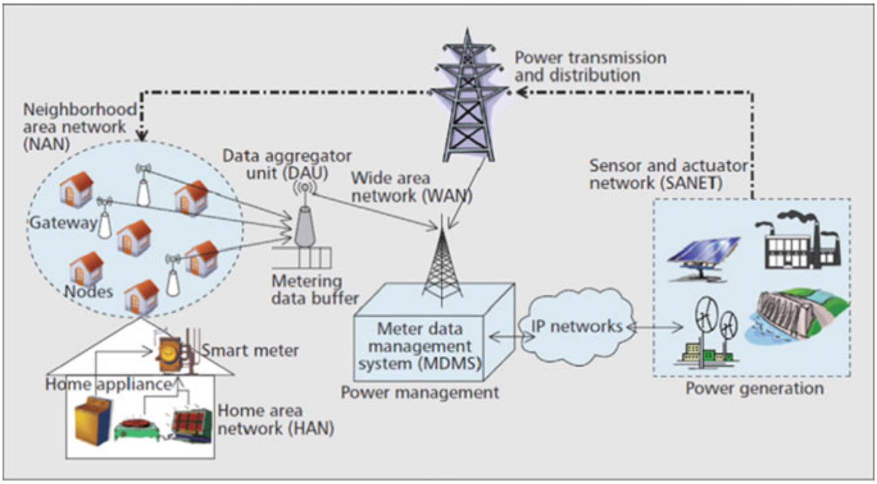

Fig. 5.11 Automated Metering Infrastructure (AMI) [31]

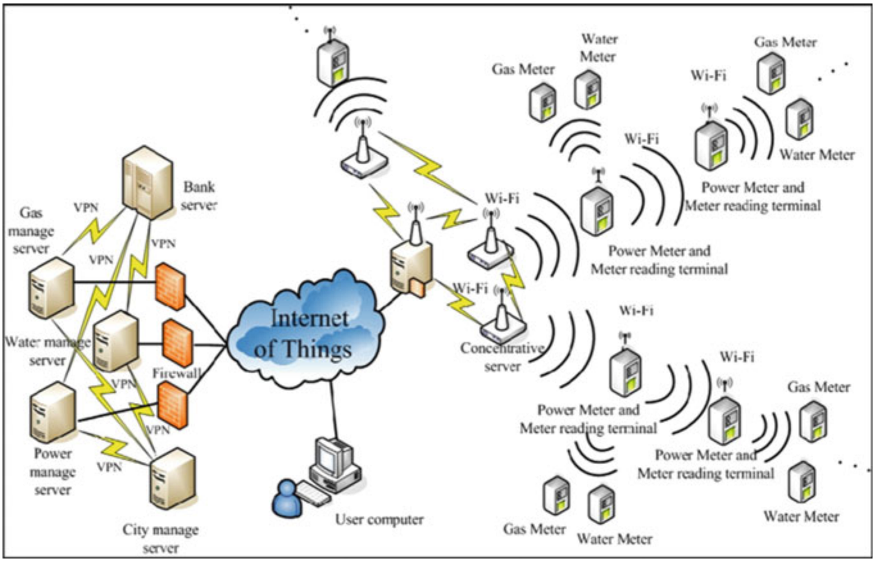

Fig. 5.12 IoTs and AMI [32]

5.9 Present Situation [8]

Referring [8], data related to Naroda smart grid pilot are as mentioned below:

Consumers: 39,422 (Residential, Commercial and industrial)

Input energy: around 1700 GWh approx.
Total Project Cost: Rs. 48.78 Cr approx.

Benefits/objectives/Expected outcomes:

(i) Effective and efficient utilization of energy
(ii) Reduction in energy wastage
(iii) Reduction in AT&C losses
(iv) Savings in peak power purchase cost by reduction of peak load
(v) Reduction in meter reading cost, cost of payment collection, etc.
(vi) Reduction in transformer failures
(vii) Reduction in number of outages
(viii) Reduction in overall carbon footprint

Features of smart grid proposed to be installed:

(i) AMI R: AMI for residential consumers focusing on Demand Response (DR)
(ii) AMI I: AMI for industrial consumers focusing on Demand Side Management (DSM)
(iii) OM: Outage Management
(iv) PLM: Peak Load Management

Unmetered consumers were accounting for input energy of around 1700 MU approx. The functionalities of Peak load management, Outage Management, Power Quality Management are proposed by implementing Automated Metering Infrastructure (AMI) for Industrial, Commercial and Residential Consumers. Some additional functionalities like Load forecasting and Asset Management are also proposed and functionalities of load forecasting, peak power management and outage management are also considered at utility level which will impact all consumers of utility (i.e. 27 Lac consumers) indirectly. Renewable energy integration has also been proposed to be carried out at Patan Solar Park and few roof top installations at some of the universities. The funding scheme for the programme is RAPDRP, Part-C.

Naroda is ready with successful pilot of smart grid with smart meters already installed and NAN-WAN connectivity already tested. Meters are fetching sampled data and proper interpretation and analysis are efficiently being carried out at UGVCL head end. Citizens in the area have been found satisfactory with the setup and ready to participate at next level of development.

5.9.1 SWOC Analysis

5.9.1.1 Strengths

(i) Preliminary level of foundation work completed
(ii) Pilot has been successful
(iii) Participant citizens are cooperative

5.9.1.2 Weaknesses

(i) Connectivity and ICT infrastructure

5.9.1.3 Opportunities

(i) The work itself
(ii) Motivation and support from central and state governments
(iii) Training of citizens for upcoming changes
(iv) Possible employment and commercial opportunities for everyone

5.9.1.4 Challenges

(i) Costing and revenue sharing, subsidies, etc.
(ii) Security of data and access authentication

5.10 Proposed Workplan [3, 5, 33–35]

Naroda area of smart grid pilot is ready for the next stage in which data received from consumer is being analyzed and post-AMI applications shall be implemented-integrated.

Plan of [33] shown in Fig. 5.13 could serve as valuable reference for preparation of the way ahead. While writing this, the region at the start of 2018 is exactly in the middle of the plan, wherein step 1 seems almost completed, work for steps 2 and 3 is undergoing and likely to continue till end 2020. Next and final phase of the work plan for 2021–2024 shall begin.

5.10.1 Solution Approach

First, existing economic and spatial strategies and recommend suggestions for smart development of the metropolitan region have been studied. Then after, a solution approach has been prepared for metropolitan region development by effective energy management, active citizen participation and e-governance. This is carried out by recommending deployments of smart grid and smart buildings with integration of renewables, ICT and IoTs. To ensure 24 × 7 electricity supply along with limiting carbon footprint has been observed as the major challenge and connectivity has been found major bottleneck in the process.

A five step methodology has been suggested for the implementation of recommended approach:

TABLE III.
PLAN TO IMPEMENT SG

Main steps	Up to 2015		2016 to 2020		2021-2024	
	Case	Action/ implementation	Case	Action/ implementation	Case	Action/ Implementation
1	Deploy base Technology	• Smart meter installed • OMS/DMS system • Micro grid pilot	Automated outage detection, restoration customer notification	• Expanded SCADA& line devices • Both way information • Self-healing grid technology in place	Customer supply side and storage decisions	• Significant DER penetration • Additional micro grids where cost effective • Customer as a resource
2	Customer program offered by utilities	• Dynamic pricing • EE demand response • HAN, energy management	Mature new services for customers	• Load control with DR • Bundled services • DER aggregation	PHEV adoption rises	• PHEV adoption emerges as a critical component of DER • Charging in frame structure in place • PHEV rates in place
3	Many smart grid components are initially deployed	• Self-healing grid technologies • Micro grid technology& self-sustaining community concept • PHEV infrastructure pilots	Major regulatory issues	• Data ownership and access • Cross jurisdictional conflicts • T&D renewable strategy	Advanced grid technology	• CBM cable Diagnostics • Advanced energy storage to support RPS goals • Self-healing grid is a reality

Fig. 5.13 Tabular plan to install smart grid [33]

(i) Integration of renewables

This has been covered in [5] with interesting case of Gandhinagar Solar Photo Voltaic Rooftop Program in by including case-study of application of hybrid communication technologies deployed to serve need based data along with *Development of Remote Energy Parameter Monitoring System*. The proposed and implemented system has distinct features such as an affordable cost, scalability and *anytime-anywhere* monitoring, to encourage inclusion of more sensors for enhanced data acquisition, improved spatial resolution for more fine-grained measurements and better monitoring of critical regions.

(ii) Smart energy (Deployment of Smart Grid)

In [3] presented democratic and citizen-centric approach of design-implementation of architectural details along with presenting a useful framework in order to make Smart Grid more inclusive, effective and comprehensive. Descriptions on communication technologies in form of instrumentation telemetry deployed to timely serve need based bidirectional information between utility and end users have also been included.

(iii) Smart People (Prosumers) and their participation

In [3], smart grid has been presented as an energy backbone of Smart City is immensely vital and serving at the core of Smart City realization. Evolving e-Democracy, smart grid includes highly interactive participation of citizens in energy consumption domain, based on humanitarian and customer centric approach. Different types of customers, their different energy requirements at different timings, different types of energy resources and their switching feasibilities considering different aspects have been integrated. Critical smart grid subsystems (such as BAS, HAN, AMI, DR, etc.), ICT integration and GUIs have been identified as some of the major design considerations. 'Transformation of Conventional Consumer into Smart Prosumer' has been major outcome of the work presented, since the customer has been now enabled as producer of electricity, thereby contributing to the grid and getting credits which is adjustable against consumption.

(iv) Smart buildings with energy efficiency

In [34] and [35], indicating the transformation of legacy stand-alone security systems into intelligent computerized-network based building automation systems, authors presented design-development of IoT based working models for security and HAN-BAN. Development of web-based virtual instrument to run-time couple local/remote monitoring and control of the building has been major outcome. The presented proof-of-concepts of IoT systems could be employed with suitable ICT for converting existing buildings into smart buildings with improved energy efficiency.

(v) Implementation with minimal financial implication

Massive national level awareness campaigns should be organized for citizens' awareness and encouragement for enthusiastic participation. Funding could be arranged from The World Bank, IMF, United Nations and developed countries to government of India, which could be sent to state governments via Special Purpose Vehicles (SPV) such as RAPDRP. State governments should encourage the Prosumers via various state level programs in form of subsidies and other techno commercial support mechanisms. Under 'Make in India', indigenous manufacturers (SME and entrepreneurs in particular) should be encouraged for local manufacturing of devices, systems, software and engineering integration-maintenance supports. Entire mechanism should be operated as single integrated system with single window clearance and e-governance.

5.11 Institutional Collaboration Setup

5.11.1 Gujarat Energy Research and Management Institute (GERMI), Gandhinagar

Gujarat Energy Research and Management Institute (GERMI), Gandhinagar, is a centre for excellence in industry learning and is set up to develop human resource assets to cater to the renewable as well as non-renewable energy sectors, improve knowledge base of policy makers and technologists and provide a competitive edge to leaders to compete in the global arena. GERMI is a Scientific and Industrial Research Organization recognized by the Department of Scientific and Industrial Research (DSIR), Govt. of India; and an ISO 9001:2008 certified by Bureau Veritas, France.

5.11.2 Dharmsinh Desai University (DDU), Nadiad

Dharmsinh Desai University (DDU), Nadiad, is a progressive and one of the leading universities of India, excelling in research and education in the fields of Engineering-Technology, Management, Dental Science, Pharmacy, Information Science, and Commerce. DDU is a Scientific and Industrial Research Organization recognized by the Department of Scientific and Industrial Research (DSIR), Govt. of India; DDU is approved institution under 2(f) and 12(B) of the UGC Act, 1956; DDU is western India's Premier Education Institution established in 1968, ISO 9001:2008 certified by ISOQAR, Manchester, UK.

5.11.3 Association for Collaborative Research

Under Vibrant Gujarat 2013, GERMI and DDU signed a Memorandum of Understanding (MoU) for a collaborative research project 'Solar City-Smart Grid Project'. During 2013–2016, Phase-I of the said research project with detailed title "Development of a City-Level Smart Communication System for Monitoring, Recording, Assessment and Forecasting of Power from Distributed Source of Generation" has been already executed. The MoU has been extended for 2016–2019, wherein phase-II of the research project with detailed title "Undertaking joint research project in Smart Grids and Microgrids for Smart communication system for monitoring, recording, assessment and forecasting of power from distributed sources of Generation" is currently in progress.

5.12 Excerpts from Research Group Activities

5.12.1 International Consultative Meeting, 17–18 December, 2016 at NITC

International Consultative Meeting on 'Design of Spatial and Economic Strategy for Smart Metropolitan Region Development', 17–18 December, 2016, was organized at Department of Architecture and Planning, National Institute of Technology Calicut (NITC), Calicut, Kerala, India. The main objective of this meeting was to follow up the ideas expressed earlier and share-encourage discussions regarding smart metropolitan regional development as well as to exchange-evolve novel perspectives of views and opinions for the future research works.

Considering convenience of participant teams representing different countries across the world, two different modes of presentation have been offered: Physical and Virtual. The virtual mode of presentation was by A-VIEW Video conferencing software platform developed and supported by Amrita University, while entire arrangements for this 2-days workshop were provided by NITC. On day-1 post inauguration, Indian teams representing Calicut, Surat, Bhopal and the team from Naples, Italy made their presentations. Similarly, on day-2, teams representing Hong Kong-China, Dakar-Senegal, Johannesburg-Africa, Ahmedabad-Gandhinagar-India, Abuja-Nigeria, Nairobi-Kenya, Conakry-Guinea, Jaipur-India made their presentations. Each day ended with concluding sessions with valuable comments and suggestions for enhancement of future works.

On day-2, 18/12/2016, 10.30 to 11.15 a.m., authors of this chapter made presentation as research team representing Ahmedabad-Gandhinagar twin city metropolitan region development. Our presentation was made using virtual mode and based upon smart grid and its contribution to spatial-economic development of Ahmedabad-Gandhinagar twin city smart metropolitan region with a special focus Naroda pilot project as case study. After presenting details of need and scope, region identification and its present state, SWOC analysis, etc., a methodology along with workplan and envisaged outcomes has been proposed for smart MRD of region. The presentation ended with review comments, useful guidelines and suggestions for enhancement of the work in progress.

5.12.2 Bulletin Contribution

Out of total three bulletins published, teams representing Pittsburg, Stuttgart and Naples contributed articles to first bulletin; teams representing Dakar, Conakry, Abuja, Johannesburg and Nairobi contributed articles to second bulletin and Ahmedabad-Gandhinagar, Bangalore, Chandigarh, Hong Kong, Kozhikode, New Delhi, Jaipur and Surat contributed articles to the third bulletin.

Our article ‘Ahmedabad-Gandhinagar, Gujarat, India: Towards sustainable growth by energy reliability’ was contributed to Bulletin-3. The article has been in line with earlier contributions as well as post-presentation suggestions in the international consultative meeting.

5.12.3 Summary of Outcomes

Proposed approach for metropolitan region development by effective energy management, active citizen participation and e-governance has been major outcome this book chapter. This is achieved by proposing deployments of smart grid and smart buildings with integration of renewables, ICT and IoTs. The approach suggested is useful, adaptive and simple, but effective for implementation, if applied with suitable customization as necessary.

5.13 Recommendations

5.13.1 For Regulators

(i) Create a regulatory framework which aligns incentives of each member in the value chain.
(ii) Allocation of risk and reward efficiently, considering both utilities and customer while making policies.
(iii) Adopt output based regulatory system (Reward/Penalties) which stresses on utilities to perform better.

5.13.2 For Utilities

(i) Adopt more holistic approach about Smart Grids, so that they can convey its future benefits to the customers.
(ii) Reduce the risk of technology obsolescence by R&D activities.
(iii) Undertake large scale pilot projects and analyze the benefits.
(iv) Transformation from utility-centric investment decision to societal-level decisions.

5.13.3 For Vendors

(i) Required to play important role in policy making process.
(ii) To help utilities to adopt flexible design and compatibility of Smart Grid fast.
(iii) To convince customers about the acceptance of changing trend by product and service offering.

5.13.4 For Customers

(i) Plays critical role by demanding for more flexible service.
(ii) To encourage more players to enter in this field and in order to make the market competitive.
(iii) To help utilities and regulators to set goals and make conducive policies.
(iv) To increase the awareness in society.

5.14 Summary and Conclusions

5.14.1 Summary

(i) Proposal regarding HAN-BAS development in the region presented for smart grid development
(ii) Feasible applications suggested
(iii) Earlier works cited
(iv) Ubiquitous and effective usage of different ICT technologies integrating IoT and WSN
(v) Significant optimization in overall energy consumption and efficient utilization
(vi) Advancements like demand response could be made possible

5.14.2 Conclusions

Smart grids are energy backbones of smart cities. Without smart grids implemented, smart cities cannot be realized. However, in case where existing city like Ahmedabad-Gandhinagar twin city are being transformed into smart cities, existing grids are operational and they are to be converted into smart grid while their operation is continued, this is a challenging task considering technical complexities involved as well as cost implications and many humanistic-socialistic issues involved. Therefore, rather than converting complete grid, area wise pilot installations such as Naroda could be planned out and phase wise conversion can be carried out. Continuously feedback from all the stakeholders, Prosumers in particular, should be acquired and required customizations should be made in the solution approach for easy adaptability of the change.

Proposed approach for metropolitan region development should be utilized for effective energy management and could be realized by deployments of smart grid, smart buildings with integration of renewables, ICT and IoTs.

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