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Smart Sustainable Cities: An Integrated Planning Approach towards Sustainable Urban Energy Systems, India

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***Abstract*—**Cities denote instantaneously a challenge and an opportunity for climate change policy. Cities are the place where most energy services are needed because urbanization is closely linked to high population densities and concentration of economic activities and production (Urban energy demand). Consequently, it is critical to explain about the role of cities within the world's energy systems and its correlation with the climate change issue. With more than half of the world's population already living in urban areas, and that percentage expected to rise to 75 per cent by 2050, it is clear that the path to sustainable development must pass through cities. Cities expanding in size and population pose increased challenges to the environment, of which energy is part as a natural resource, and to the quality of life. Nowadays, most cities have already understood the importance of sustainability, both at their local scale as in terms of their contribution to sustainability at higher geographical scales. It requires the perception of a city as a complex and dynamic ecosystem, an open system, or cluster of systems, where the energy as well as the other natural resources is transformed to satisfy the needs of the different urban activities. In fact, buildings and transportation generally represent most of cities direct energy demand, i.e., between 60 per cent and 80 per cent of the overall consumption. Buildings, both residential and services are usually influenced by the local physical and social conditions. In terms of transport, the energy demand is also strongly linked with the specific characteristics of a city (urban mobility).The concept of a "smart city" builds on statistics as seven key axes of a city's success in moving towards common platform (brain nerve)of sustainable urban energy systems.

With the aforesaid knowledge, the authors have suggested a frame work to role of cities, as energy actors for smart city management. The authors have discusses the potential elements needed for energy in smart cities and also identified potential energy actions and relevant barriers. Furthermore, three levels of city smartness in cities actions to overcome market /institutional failures with a local approach are distinguished. The authors have made an attempt to conceive and implement concepts of city smartness by adopting the city or local government as nerve center through an integrated planning approach. Finally, concluding with recommendations for the organization of the Smart Sustainable Cities for positive changes of urban India.

***Keywords*—**Urbanization, Urban Energy Demand, Sustainable Urban Energy Systems, Integrated Planning Approach, Smart Sustainable City.

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I. Introduction

SMART. Everything is or should be "Smart". There is virtually no energy or city conference that does not include at least one session entitled "Smart Grids" or "Smart Cities" or a combination of both. "Smart Grids - Smart Cities" has become a recurrent theme, thus acquiring a magical power that has turned the concept into a generally agreed opinion whose rightfulness is not usually questioned. The European Commission has launched an initiative entitled "Smart Cities and Communities". A number of large Information and Communication Technologies (ICT) companies are very much involved in ''Smart'' issues. The "Smart" concept originally came from the integration of ICT in products and systems with the proclaimed aim of optimizing their efficiency. "Smart meters" integrate additional metering functions: information, load management, load shedding, dynamic pricing, energy efficiency, etc. Complementary "Smart Grids" provide a flexible, bidirectional way of managing power grids by combining embedded power distribution and collection. The concept of "Smart Cities" aims to optimize urban systems, notably by metering, monitoring and managing energy, water, traffic, passenger, discharge, emission and effluent flows from urban activities.

The 21st century cities faces the challenges of climate change, unprecedented population growth, demographic change, contemporary process of urbanization and resource depletion mean that the world's great cities need to adapt to survive and thrive over the coming decades. Lowering greenhouse gas emissions to prevent catastrophic climate change while maintaining or increasing quality of life could be a costly and difficult process. There is an increasing interest, therefore, in the role that information and communications technologies could play in transforming existing power-crazy metropolises into low-carbon cities of the future. In the past decade concepts that capture the idea of how to future-proof our cities have arisen worldwide: livable cities, livable winter cities, sustainable cities, intelligent cities, smart cities, resilient cities, energy cities, eco cities, now a step down to eco districts and so on. The world cities are diverse, vibrant and accommodate large numbers of the global population, but they are the main contributors to environmental degradation. Almost 70 per cent of global greenhouse gases are being emitted in urban areas. However, there is great potential to make cities a better place through innovative projects and better management of local resources to enhance energy efficiency for creating a sustainable environment for the community. Smart cities can be recognized along with seven

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key dimensions. They are: (i).smart economy; (ii).smart mobility ;(iii).smart environment; (iv).smart people; (v).smart living; (vi).smart governance and, finally (vii)“smart technologies”. In particular, these dimensions are based on theories of regional competitiveness, transport and ICT economics, natural resources, human and social capital, quality of life, and participation of citizens in the governance of cities. According to State of Green, Climate Consortium Denmark, 2011[24], by 2050, more than 6 billion people will live in urban areas. This development calls for ‘smart’ approaches to ensure that cities are optimized for economic activity, energy consumption, environmental impact and improved quality of life.

II. An Overview of Global Urbanization and Urban Energy Demand

Urbanization is one of the major demographic and economic trends occurring in developing countries, with important consequences for development, energy use, and well-being. Long term projections of future energy use, land use, and greenhouse gas emissions have typically focused on the role of technological change and economic growth as the principal drivers of future emissions. Less attention has been given to changes in the composition of the population by demographic or socio-economic characteristics [20]. Urbanization is a major demographic trend in much of the world, particularly in Asia and Africa [18], with potentially major consequences for development and the environment [10]. It is particularly important for energy policy and planning. Urbanization plays a key role in what has become known as the “energy transition” [16]:the observation that the process of economic development is generally accompanied by a shift within developing country households toward an increasing use of modern fuels, and decreasing reliance on biomass, even in the absence of policies explicitly aimed at achieving this outcome [21] . The design of effective policy interventions, and the anticipation of future demand necessary for planning supply options, depends on understanding the determinants and consequences of this transition. Lately, analysts have begun to investigate the role of urbanization, and differences in energy-related consumption between urban and rural households [14], as part of long-term scenario analyses [4], [20], [35]. We build on these initial studies by carrying out an assessment of the implications of a plausible range of urbanization pathways for smart urban energy use and emissions regulator to navigate towards smart sustainable urban system of India.

According to World Urbanization Prospects-United Nations, 2012 [32], world urban population is expected to increase by 72 per cent by 2050, from 3.6 billion in 2011 to 6.3 billion in 2050. By mid-century the world urban population will likely be the same size as the world’s total population was in 2002. Virtually all of the expected growth in the world population will be concentrated in the urban areas of the less developed regions, whose population is projected to increase from 2.7 billion in 2011 to 5.1 billion in 2050. Over the same period, the rural population of the less developed regions is expected to decline from 3.10 billion to 2.9 billion. In the more developed regions, the urban population is projected to increase modestly, from 1 billion in 2011 to 1.10 billion in 2050.

The rate of growth of the world urban population is slowing down. Population growth of World by development group between 1950 and 2050 is summarized in Table I. This table reveals that between 1950 and 2011, the world urban population grew at an average rate of 2.6 per cent per year and increased nearly fivefold over the period, passing from 0.75 billion to 3.6 billion. During 2011-2030, the world urban population is projected to grow at an average annual rate of 1.7 per cent, which, if maintained, would lead to a doubling of the urban population in 41 years. During 2030-2050, the urban growth rate is expected to decline further to 1.1 per cent per year, implying a doubling time of 63 years.

Globally, the level of urbanization is expected to raise from 52 per cent in 2011 to 67 per cent in 2050. Urban growth scenario of World by development group between 1950 and 2050 is presented in Table II.

The table depicts that more developed regions are expected to see their level of urbanization increase from 78 per cent to 86 per cent over the same period. Further, in the less developed regions, the proportion urban will likely increase from 47 per cent in 2011 to 64 per cent in 2050.

The world urban population is not distributed evenly among cities of different sizes. Over half of the world’s 3.6 billion urban dwellers (50.9 per cent) lived in cities or towns with fewer than half a million inhabitants. Such small cities account for 55 per cent of the urban population in the more developed regions and for 50.2 per cent of that in the less developed regions.

The Urban growth scenario of World in the major area between 1950 and 2050 has been analyzed and presented in Table III. Among the less developed regions, Latin America and the Caribbean have an exceptionally high level of urbanization (79 per cent), higher than that of Europe. Africa and Asia, in contrast, remain mostly rural, with 40 per cent and 45 per cent, respectively, of their populations living in urban areas. Over the coming decades, the level of urbanization is expected to increase in all major areas of the developing world, with Africa and Asia urbanizing more rapidly than the rest. Despite its low level of urbanization, in 2011 Asia was home to about half of the urban population in the world.

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TABLE I
POPULATION GROWTH OF WORLD BY DEVELOPMENT GROUP BETWEEN 1950 AND 2050

S.No.	Development Group	Population (billions)					Average annual rate of change (%)			
		1950	1970	2011	2030	2050	1950-1970	1970-2011	2011-2030	2030-2050
1	**Total Population of World**	**2.53**	**3.70**	**6.97**	**8.32**	**9.31**	**1.89**	**1.55**	**0.93**	**0.56**
2	More developed regions	0.81	1.01	1.24	1.30	1.31	1.08	0.51	0.23	0.06
3	Less developed regions	1.72	2.69	5.73	7.03	7.99	2.23	1.85	1.07	0.65
4	**Urban population of World**	**0.75**	**1.35**	**3.63**	**4.98**	**6.25**	**2.98**	**2.41**	**1.66**	**1.13**
6	More developed regions	0.44	0.67	0.96	1.06	1.13	2.09	0.89	0.52	0.29
7	Less developed regions	0.30	0.68	2.67	3.92	5.12	4.04	3.33	2.02	1.34

Source**:** Compiled by the Authors based on the World Urbanization Prospects: The 2011 Revision

TABLE II
URBAN GROWTH SCENARIO OF WORLD BY DEVELOPMENT GROUP BETWEEN 1950 AND 2050

S.No.	Development Group	Percentage of Urban					Rate of Urbanization (%)			
		1950	1970	2011	2030	2050	1950-1970	1970-2011	2011-2030	2030-2050
1	**World**	**29.40**	**36.60**	**52.10**	**59.90**	**67.20**	**1.09**	**0.86**	**0.74**	**0.57**
2	More developed regions	54.50	66.60	77.70	82.10	85.90	1.01	0.38	0.29	0.23
3	Less developed regions	17.60	25.30	46.50	55.80	64.10	1.81	1.48	0.95	0.69

Source: Compiled by the Authors based on the World Urbanization Prospects: The 2011 Revision

TABLE III
URBAN GROWTH SCENARIO OF WORLD BY MAJOR AREA BETWEEN 1950 AND 2050

S.No.	Major Area	Percentage of Urban					Rate of Urbanization (%)			
		1950	1970	2011	2030	2050	1950-1970	1970-2011	2011-2030	2030-2050
1	Africa	14.40	23.50	39.60	47.70	57.70	2.47	1.27	0.98	0.96
2	**Asia**	**17.50**	**23.70**	**45.00**	**55.50**	**64.40**	**1.52**	**1.57**	**1.10**	**0.74**
3	Europe	51.30	62.80	72.90	77.40	82.20	1.02	0.36	0.31	0.30
4	Latin America and the Caribbean	41.40	57.10	79.1	83.4	86.6	1.61	0.8	0.28	0.19
5	Northern America	63.90	73.80	82.2	85.8	88.6	0.72	0.26	0.22	0.16
6	Oceania	62.40	71.20	70.7	71.4	73	0.66	-0.02	0.05	0.12

Source: Compiled by the Authors based on the World Urbanization Prospects: The 2011 Revision

Over the next four decades, Africa and Asia will experience a marked increase in their urban populations. In Africa the urban population is likely to treble and in Asia it will increase by 1.7 times. The overall and urban population growth of World by major area between 1950 and 2050 has been compiled and summarized in Table IV. By mid-century, most of the urban population of the world will be concentrated in Asia (53 per cent) and Africa (20 per cent).The world urban population is highly concentrated in a few countries. In 2011, about three quarters of the 3.6 billion urban dwellers on Earth lived in 25 countries, whose urban populations ranged from 31 million in Ukraine to 682 million in China. China, India and the United States accounted for 37 per cent of the world urban population. Most of the 25 countries with the largest urban populations are highly urbanized, but eight have levels of urbanization ranging from 28 per cent to 51 per cent and they include some of the most populous countries in the world: Bangladesh, China, India, Indonesia, Nigeria and Pakistan.

Similarly, the increases in the world urban population are concentrated in a few countries, with China and India together projected to account for about a third of the increase in the urban population in the coming decades. Between 2011 and 2030, the urban areas of the world are expected to gain 1.4 billion people, including 276 million in China and 218 million in India, which account together for 37 per cent of the total increase. Nine additional countries are projected to contribute 26 per cent of the urban increment, with increases ranging from 22 million to 76 million. The countries involved are: Nigeria and the Democratic Republic of the Congo in Africa; Bangladesh, Indonesia, Pakistan and the Philippines in Asia; Brazil and Mexico in Latin America, and the United States of

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America. Among them, those in Africa and Asia will experience high rates of urban population growth, usually surpassing 2 per cent or even 3 per cent per year. This phenomenal increase in population growth of developing and less developed regions of the world would require vast transformation of resources in to goods and services and massive infrastructure for their sustenance. These transformations of natural resources in to goods and services and all kinds of infrastructure (i.e., Physical, Social and Economic infrastructures) to cater the economic needs of growing population would stimulate the surge of urban energy demand. Eventually, the rise of urban energy demand is highly responsible for excessive Greenhouse emissions in the system, which leads to environmental deterioration.

TABLE IV
OVERALL AND URBAN POPULATION GROWTH OF WORLD BY MAJOR AREA BETWEEN 1950 AND 2050

S.No.	Major Area	Population (millions)					Average annual rate of change (%)			
		1950	1970	2011	2030	2050	1950-1970	1970-2011	2011-2030	2030-2050
A	**Total Population**									
1	Africa	230	368	1046	1562	2192	2.35	2.55	2.11	1.69
2	**Asia**	**1403**	**2135**	**4207**	**4868**	**5142**	**2.10**	**1.65**	**0.77**	**0.27**
3	Europe	547	656	739	741	719	0.91	0.29	0.01	-0.15
4	Latin America and the Caribbean	167	286	597	702	751	2.69	1.79	0.85	0.34
5	Northern America	172	231	348	402	447	1.49	0.99	0.76	0.53
6	Oceania	13	20	37	47	55	2.16	1.57	1.25	0.80
B	**Urban Population**									
1	Africa	33	87	414	744	1265	4.82	3.82	3.09	2.65
2	**Asia**	**245**	**506**	**1895**	**2703**	**3310**	**3.62**	**3.22**	**1.87**	**1.01**
3	Europe	281	412	539	573	591	1.92	0.65	0.33	0.15
4	Latin America and the Caribbean	69	163	472	585	650	4.29	2.59	1.13	0.53
5	Northern America	110	171	286	344	396	2.21	1.26	0.98	0.70
6	Oceania	8	14	26	34	40	2.82	1.56	1.30	0.91

Source: Compiled by the Authors based on the World Urbanization Prospects: The 2011 Revision

A. World Energy Demand and Energy Related CO_2 Emissions Scenario

According to report on Exxon Mobil 2012 [25], the World energy demand has been estimated as 522 Q-BTUs (Quadrillion BTUs) for the year 2010 and projected to 705 Q-BTUs for the year 2040. The World energy demand and percentage of change by development regions between 1990 and 2040 were analyzed and summarized in the Table V. This Table clearly explains that the energy demand for Non-OECD regions contributes 56 per cent in the year 2010 and increased to 69 per cent for the year 2040. Out of total energy demand of Asia Pacific regions i.e., 316 Q-BTUs, China and India accounts for the more than two-third and major contributors in peak energy demand by 45 per cent and 22 per cent respectively. Further, it is clear evident from this table that India and China are the dominant players in energy demand followed by the Africa in the Non-OECD regions, which accommodates world's major share of population. On the contrast the regions like Europe, Russia and United Sates are showing their negative growth of energy demand from the year 2000 to the projected year 2040.

Furthermore, the Global energy scenario of primary energy type between 1990 and 2040 also examined by the authors and summarized in Table VI. This table reveals that out of total global primary energy demand the Oil demand for the projected year 2040 is highest share nearly one-third (32 per cent) followed by Gas and Coal which accounts less than one-third i.e., 27 per cent and 19 per cent respectively. Further, it clearly depicts that the biomass/waste, other renewables and Hydro are lowermost contribution which shares only about 8 per cent, 4 per cent and nearly 3 per cent respectively for the same year. It is clear evident from these analysis one can conclude that among the global primary energy demand oil, gas and coal consumption are highly responsible for the excessive energy-related CO_2 emissions of the world.

In Non-OECD region considerable increase in CO_2 emissions has been observed from 21.30(Billion Tons) to 36.30 (Billion Tons) between 1990 and 2011World energy-related CO_2 emissions has been estimated as 30.50 (Billion Tons) for the year 2010, and projected to 36.30 (Billion Tons) for the projected year 2040. The World energy-related CO_2

emissions and percentage of change by development regions between 1990 and 2040 were analyzed and summarized in the Table VII. This Table depicts those CO_2 emissions for Non-OECD region contributes 58 per cent in the year 2010 and increased to 73 per cent for the year 2040. Out of total CO2 emissions of Non-OECD regions i.e., 26.30 (Billion Tons), the Asia Pacific alone accounts for the more than two-third and major contributor for 69 per cent and Europe for 13 per cent, followed by the African region which contributes 10.64 per cent. Further, it is clear evident from this table one can easily conclude that Asia Pacific regions are chief contributors for energy related- CO_2 emissions of the world regions. Europe, Russia and United Sates regions are showing their negative growth of energy demand from the year 2000 to the projected year 2040 and as consequence the considerable reduction in energy related- CO_2 emissions has been observed in the system.

TABLE V
WORLD ENERGY DEMAND BY DEVELOPMENT REGIONS BETWEEN 1990 AND 2040

S.No.	WORLD Regions	Energy Demand (Quadrillion BTUs)					Average Annual Change (%)			Percentage of Change (%)		
		1990	2000	2010	2025	2040	2010-2025	2025-2040	2010-2040	2010-2025	2025-2040	2010-2040
1	**World**	**360**	**416**	**522**	**654**	**705**	**1.5**	**0.5**	**1.0**	**25.0**	**8.0**	**35.0**
2	OECD	190	225	230	234	223	0.1	-0.3	-0.1	2.0	-5.0	-3.0
3	**Non OECD**	**170**	**190**	**292**	**420**	**482**	**2.5**	**0.9**	**1.7**	**44.0**	**15.0**	**65.0**
4	**Africa**	**17**	**22**	**29**	**44**	**61**	**2.7**	**2.2**	**2.4**	**49.0**	**38.0**	**106.0**
5	**Asia Pacific**	**90**	**125**	**201**	**289**	**316**	**2.5**	**0.6**	**1.5**	**44.0**	**10.0**	**58.0**
6	China	33	44	97	146	142	2.8	-0.2	1.3	51.0	-3.0	47.0
7	**India**	**13**	**19**	**28**	**49**	**68**	**3.7**	**2.2**	**3.0**	**74.0**	**39.0**	**141.0**
8	Europe	74	78	81	82	77	0.0	-0.4	-0.2	0.0	-6.0	-6.0
9	European Union	68	72	73	72	66	-0.1	-0.5	-0.3	-2.0	-8.0	-10.0
10	Latin America	15	20	26	36	45	2.1	1.5	1.8	37.0	26.0	73.0
11	**Middle East**	**11**	**18**	**30**	**43**	**53**	**2.4**	**1.4**	**1.9**	**44.0**	**22.0**	**76.0**
12	North America	95	114	113	116	112	0.2	-0.3	0.0	3.0	-4.0	-1.0
13	United States	81	96	94	94	89	0.0	-0.4	-0.2	0.0	-5.0	-6.0
14	Russia/Caspian	58	38	42	45	43	0.4	-0.4	0.0	7.0	-5.0	1.0

Source: Compiled by the Authors based on the report of World Energy Outlook, 2012

TABLE VI
GLOBAL ENERGY DEMAND SCENARIO OF PRIMARY ENERGY TYPE BETWEEN 1990 AND 2040

S.No.	*Energy by Type-WORLD*	Energy Demand (Quadrillion BTUs)					Average Annual Change (%)			Percentage of Change (%)		
		1990	2000	2010	2025	2040	2010-2025	2025-2040	2010-2040	2010-2025	2025-2040	2010-2040
	PRIMARY	**360**	**416.0**	**522.0**	**654.0**	**705.0**	**1.5**	**0.5**	**1.0**	**25.0**	**8.0**	**35.0**
1	Oil	137.0	158.0	178.0	208.0	223.0	1.1	0.5	0.8	17.0	7.0	26.0
2	Gas	72.0	89.0	115.0	160.0	189.0	2.2	1.1	1.7	39.0	18.0	65.0
3	Coal	86.0	90.0	134.0	156.0	131.0	1.0	-1.2	-0.1	17.0	-16.0	-2.0
4	Nuclear	21.0	27.0	29.0	41.0	59.0	2.4	2.5	2.4	42.0	45.0	106.0
5	Biomass/Waste	36.0	41.0	49.0	55.0	55.0	0.8	0.0	0.4	13.0	0.0	14.0
6	Hydro	7.0	9.0	12.0	16.0	19.0	2.3	1.1	1.7	40.0	18.0	66.0
7	Other Renewables	1.0	3.0	7.0	18.0	29.0	6.4	3.3	4.8	152.0	63.0	311.0

Source: Compiled by the Authors based on the report of World Energy Outlook, 2012

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TABLE VII
GLOBAL ENERGY DEMAND SCENARIO OF PRIMARY ENERGY TYPE BETWEEN 1990 AND 2040

S.No.	WORLD Regions	Energy CO_2 Emissions(Billion Tons)					Average Annual Change (%)			Percentage of Change (%)		
		1990	2000	2010	2025	2040	2010-2025	2025-2040	2010-2040	2010-2025	2025-2040	2010-2040
1	**WORLD**	**21.3**	**23.6**	**30.5**	**36.7**	**36.3**	**1.2**	**-0.1**	**0.6**	**20.0**	**-1.0**	**19.0**
2	OECD	11.3	12.8	12.8	11.9	9.9	-0.5	-1.2	-0.8	-7.0	-17.0	-22.0
3	**Non OECD**	**10.0**	**10.7**	**17.7**	**24.8**	**26.3**	**2.3**	**0.4**	**1.3**	**40.0**	**6.0**	**49.0**
4	**AFRICA**	**0.7**	**0.9**	**1.1**	**1.9**	**2.8**	**3.5**	**2.6**	**3.1**	**68.0**	**48.0**	**148.0**
5	**ASIA PACIFIC**	**5.3**	**7.4**	**13.2**	**18.2**	**18.1**	**2.2**	**-0.1**	**1.1**	**38.0**	**-1.0**	**37.0**
6	EUROPE	4.5	4.3	4.3	4.1	3.4	-0.4	-1.3	-0.8	-5.0	-17.0	-22.0
7	LATIN AMERICA	0.7	0.9	1.2	1.6	2.0	2.0	1.4	1.7	35.0	24.0	67.0
8	**MIDDLE EAST**	**0.7**	**1.1**	**1.8**	**2.4**	**2.7**	**1.9**	**1.0**	**1.5**	**33.0**	**16.0**	**54.0**
9	NORTH AMERICA	5.6	6.6	6.4	6.0	5.1	-0.4	-1.2	-0.8	-6.0	-16.0	-21.0
10	RUSSIA/CASPIAN	3.9	2.3	2.5	2.5	2.2	0.0	-0.8	-0.4	0.0	-12.0	-12.0

Source: Compiled by the Authors based on the report of World Energy Outlook, 2012

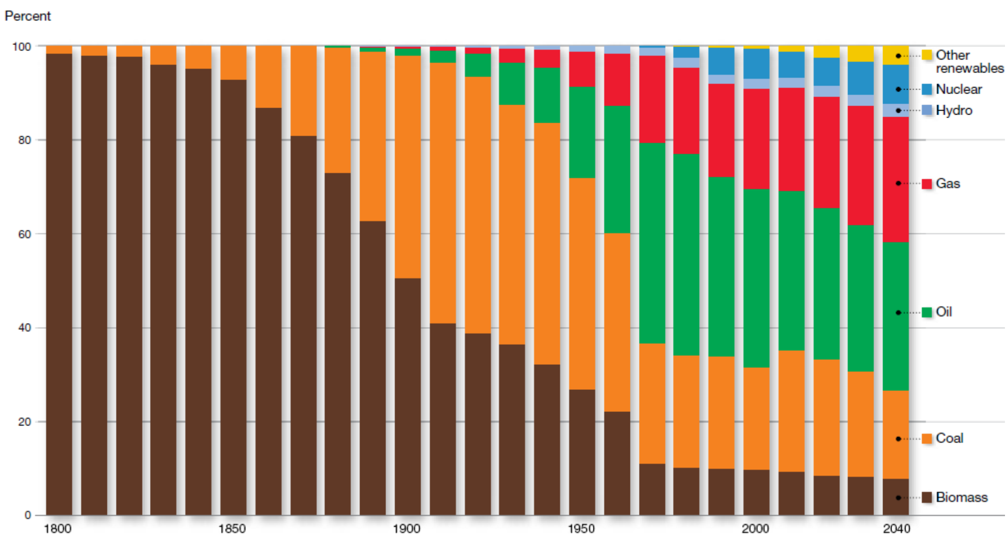

Fig. 1 Decadal Global Fuel mix scenario between 1800 and 2040
Source: Smil, Energy Transitions (1800-1960)

According to the report of Smil, Energy Transitions [30], the global decadal fuel mix situation was observed from 18th century, 19th century and also projected for 21st century up to the year 2040. The Global fuel mix scenario has been analyzed and presented in the Fig. 1. This figures demonstrates that there was almost 100 per cent biomass utilized in the year 1800 and it started declining in midst of 18th century i.e., 1850, further sharp decrease in the second half of 18th century(1850-1900). During the decades 1850-1900, the coal begins to increase its share with biomass of almost 50 per cent in the year 1900. Furthermore, it has been observed from this figure that in the decades of 1900-1950, utilization of oil and gas started and shared its combined contribution of nearly one-third to the global fuel mix. The share of oil and gas was sharply increased and biomass and coal were considerably reduced in the decades 1950-2000. During these decades, additionally utilization of hydro, nuclear and other renewables started and also shared its contribution to global fuel mix. Further, it has also been observed that for the projected year 2040, the biomass and coal usage has declined to one-third its usage drastically and on the other side the contribution of oil and gas has increased sharply to tow-third of its usage along with reasonable share of hydro, nuclear and other renewables in the system. From this analysis one can easily understand that consumption of oil and gas would be more in coming decades followed by coal. It clearly indicates that oil, gas and coal are the more contributors for excessive emissions and can be concluded that these primary energy are highly responsible for global energy related CO_2 emissions in the system. Additionally, the authors have also analyzed the energy demand by end-use sectors of world. The end-use sector which includes,

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residential, commercial, transportation, industrial, electricity generation and electricity demand respectively and summarized in the Table VIII. The Table clears idea of sect oral demand of end-use sectors. For the residential/commercial sectors, the demand of electricity will be high and contributes 42 per cent and 23 per cent respectively for the year 2040. In Transportation sector, oil has highest share of 89 per cent and for industrial sector the oil, gas and electricity topping the list by 30 per cent, 26 per cent and 21 per cent respectively. The generation of electricity accounts the demand in the order of coal, gas, and nuclear which shares about 33 per cent, 29 per cent and 20 per cent respectively in the system. From these analysis of one can conclude that oil and gas are dominant players and followed by electricity generation and modern nuclear energy in the system.

TABLE VIII
GLOBAL ENERGY DEMAND SCENARIO OF DIFFERENT END-USE SECTORS BETWEEN 1990 AND 2040

S.No.	Energy by Type-WORLD	Energy Demand (Quadrillion BTUs)					Average Annual Change (%)			Percentage of Change(%)		
		1990	2000	2010	2025	2040	2010-2025	2025-2040	2010-2040	2010-2025	2025-2040	2010-2040
End-Use Sectors -WORLD												
RESIDENTIAL/COMMERCIAL												
	Total	**87**	**98**	**116**	**138**	**148**	**1.2**	**0.5**	**0.8**	**19.0**	**7.0**	**28.0**
1	Oil	13	16	15	16	16	0.4	-0.2	0.1	7.0	-3.0	4.0
2	Gas	16	21	25	31	33	1.4	0.5	0.9	23.0	7.0	31.0
3	Biomass/Waste	26	29	33	33	28	-0.1	-1.0	-0.5	-1.0	-13.0	-14.0
4	Electricity	16	23	32	47	61	2.6	1.7	2.2	48.0	30.0	92.0
5	Other	15	9	11	12	11	0.6	-0.6	0.0	9.0	-8.0	0.0
TRANSPORTATION												
	Total	**65**	**81**	**99**	**124**	**141**	**1.5**	**0.9**	**1.2**	**25**	**14**	**43**
1	Oil	64	79	94	114	125	1.3	0.6	1.0	21	10	33
2	Other	**1**	**1**	**4**	10	16	5.2	3.5	4.3	114	68	258
INDUSTRIAL												
	Total	**138**	**149**	**189**	**240**	**250**	**1.6**	**0.3**	**0.9**	**27**	**4**	**32**
1	Oil	45	51	58	70	75	1.3	0.5	0.9	21	8	30
2	Gas	31	37	43	57	66	1.8	1.0	1.4	31	17	53
3	Coal	29	25	42	47	34	0.8	-2.1	-0.7	13	-27	-18
4	Electricity	18	21	30	46	53	2.8	1.1	1.9	52	17	78
5	Other	15	14	17	21	21	1.4	0.2	0.8	23	4	27
ELECTRICITY GENERATION-WORLD												
PRIMARY		**118**	**144**	**192**	**258**	**292**	**2.0**	**0.8**	**1.4**	**34**	**13**	**52**
1	Oil	15	12	10	8	7	-1.5	-1.0	-1.2	-21	-13	-31
2	Gas	24	31	45	69	84	2.9	1.3	2.1	53	21	85
3	Coal	48	61	88	105	95	1.2	-0.7	0.2	20	-10	8
4	Nuclear	21	27	29	41	59	2.4	2.5	2.4	42	45	106
5	Hydro	7	9	12	16	19	2.3	1.1	1.7	40	18	66
6	Wind	0	0	1	5	10	10.5	4.4	7.4	346	90	746
7	Other Renewables	3	4	7	13	19	4.1	2.5	3.3	84	45	166
	ELECTRICITY DEMAND (Terawatt Hours)						**Average Annual Change (%)**			**Percentage of Change(%)**		
	WORLD	**10149**	**13175**	**18332**	**27490**	**34198**	**2.7**	**1.5**	**2.1**	**50**	**24**	**87**
1	OECD	6657	8603	9578	11237	12154	1.1	0.5	0.8	17	8	27
2	Non-OECD	3492	4572	8754	16254	22044	4.2	2.1	3.1	86	36	152

Source: Compiled by the Authors based on the report of World Energy Outlook, 2012

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Cities are one of the key element contributions towards global sustainability. A high population density and massive consumption open up several options to effectively utilize natural resources and promote efficient urban infrastructural development. For example, compact settlement and a high population density in a city may reduce per capita the infrastructure and distribution costs and open up opportunities for economies of a large scale. This can be seen in Hong Kong, which is a very densely populated city. Thus, cities can greatly facilitate the implementation of measures, which reduce energy use and stress upon the environment. Cities and their energy consumption bring two major environmental issues to the forefront for policy-makers. The first is the massive consumption of energy and materials that affects natural systems and, ultimately, areas and peoples outside the boundaries of cities and even the next generation of residents. The second is the exposure of a large and concentrated urban population to worsening air, water, and waste pollution. It is well recognized that the bulk of the world’s energy consumption is within cities, and much of the rest is used for producing and transporting goods and people to and from cities. It is thus crucial to develop strategies for the use of sustainable energy. The major factors influencing energy use in cities include patterns of urban settlement, transportation systems, incomes and lifestyles, the energy efficiency of technologies, industrial processes, building technologies, climate and methods of waste disposal. Therefore, the 21st century urbanization and urban effects on energy consumption reveals that there is an inevitable requirement of smart pathway to integrated approach towards sustainable urban energy system.

B. Urbanization Trend on Indian Perspective

According to United Nations, India has the highest rate of change of the urban population among the BRIC nations, which will remain above 2 per cent annually for the next three decades. At this rate, an estimated 854 million people will live in Indian cities by 2050, a figure which is the combined population of present day USA, Brazil, Russia, Japan and Germany. Even in the coming decade (2011-2020), India will add 95 million people to its already dense urban fabric, nearly one-fourth of its current urban population. India needs more cities, and it is a mere understatement to say that we might be misjudging the dimensions of the situation. With a land area of one third the size of USA, India harbors nearly four times the population i.e., present Indian has population of 1,210,193,422 (2011) as against the USA of 314,982,000 (2012). Unsurprisingly, Indian cities are not only the most populous but also among the densest urban agglomerations of the world, which poses unique challenges to the development of infrastructure and real estate. Creation of dense informal settlements within the city, impractical low cost housing at the exurbs or high-rising verticals are nothing but a manifestation of this inevitable immigration of people from rural to urban areas. Growth Scenario of urbanization of India between the year 1901 and 2011 are compiled and is presented in the Table IX.

India is one of the least urbanized countries in the world because between 1951 and 2001, the level of urbanization increased by 13 percentage points only. The urban population in India at the beginning of 20th century was only 25.85 million constituting 10.84 per cent of India's population in 1901, which increased to 285.35 million comprising 27.78 per cent of total population in 2001. Though urbanization in India is 27 per cent its urban population exceeds the total population of USA and Brazil. Today India has the second largest urban population in the world and more than two thirds of it lives in the 393 cities that have a population of more than a lakh. During the last 50 years, the rate of growth of urban population of India has been double that of the rate of growth of population. It took nearly 40 years between 1971 and 2008 for India's urban population to rise by 230 million and it could take only half that time to add the next 250 million. According to Mckinsey Report [17], [26] Indian cities are likely to house 40 percent of the urban population by 2030. India has seen a phenomenal increase in the number of its metropolitan towns. More than half of the total urban population of India lives in small and medium towns. In the beginning, the country had only one metropolitan city, which had increased to 35 in 1991. These 35 million plus cities account for 107.9 million urban populations in the country. Selected Indian Cities and Urban Agglomerations between the 1901 and 2011 are presented in Table X. This table reveals that the concentration of population in million plus cities increased significantly in the last two decades to almost two-fifth of the urban population. The four mega cities viz. Delhi, Mumbai, Kolkata, Chennai, with a population of 15.72 million, 16.43 million, 13.20 million and 6.56 million respectively in 2001 Census year account for almost one fourth of the population living in the cities. As per Census of India 2011, these four megacities accommodates with increased population of 21.75 million, 20.74 million, 16.50 million and 8.91 million respectively. As per the projections of Government of India, the urban population of the country would be 553.04 million in 2021. Thus around one third of population is expected to live in urban areas. Another striking feature of India's urbanization has been the concentration of urban population in Class I cities. The number of Class I cities has grown from 24 in 1901 to 423 in 2001. It is clear evident that there has been more than fivefold increase in the number of Class I cities since 1951. The startling fact is that the proportion of population living in smaller towns has shown declining trend over the period while there is massive growth in population of larger towns. The least-developed states such as, Madhya Pradesh, Bihar, Orissa, Rajasthan, and Uttar Pradesh have urbanized faster than national average. Furthermore, the number of census towns has considerable increase from 1827 to 5178 between the year 1901 and 2001, and during the last decade (2001-2011) census towns rose to 7936 by 35 per cent respectively.

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TABLE IX
URBANIZATION TREND OF INDIA BETWEEN 1901 AND 2011

S.No	Census Year	Number of Urban Agglomeration/Towns	Total Population	Urban Population	Percentage of Urban Population	Rural Population	Percentage of Rural Population
1	**1901**	**1827**	23,83,96,327	2,58,51,873	10.84%	21,25,44,454	89.16%
2	**1911**	**1825**	25,20,93,390	2,59,41,633	10.29%	22,61,51,757	89.71%
3	**1921**	**1949**	25,13,21,213	2,80,86,167	11.18%	22,32,35,046	88.82%
4	**1931**	**2072**	27,89,77,238	3,34,55,989	11.99%	24,55,21,249	88.01%
5	**1941**	**2250**	31,86,60,580	4,41,53,297	13.86%	27,45,07,283	86.14%
6	**1951**	**2843**	36,10,88,090	6,24,43,709	17.29%	29,86,44,381	82.71%
7	**1961**	**2363**	43,92,34,771	7,89,36,603	17.97%	36,02,98,168	82.03%
8	**1971**	**2590**	59,81,59,652	10,91,13,977	18.24%	48,90,45,675	81.76%
9	**1981**	**3378**	68,33,29,097	15,94,62,547	23.34%	52,38,66,550	76.66%
10	**1991**	**3768**	84,43,24,222	21,71,77,625	25.72%	62,71,46,597	74.28%
11	**2001**	**5178**	1,02,70,15,247	28,53,54,954	27.78%	74,16,60,293	72.22%
12	**2011**	**7936**	**1,21,01,93,422**	**37,71,05,760**	**31.16%**	**83,30,87,662**	**68.84%**

Source: Compiled by the researcher based on the report of Census of India, 2011, [2].

TABLE X
SELECTED INDIAN CITIES & URBAN AGGLOMERATIONS OF MORE THAN 5 MILLION INHABITANTS, 2011

S.No.	Name	**YEAR** (Population in thousands of inhabitants)							
		1901	**1951**	**1961**	**1971**	**1981**	**1991**	**2001**	**2011**
1	**Delhi**	240	1 537	2 527	3 941	5 783	8 723	15 725	21 753
2	**Mumbai**	813	2 967	4 152	6 592	9 422	12 572	16 434	20 748
3	**Kolkata**	1 503	4 761	5 903	7 421	9 914	10 916	13 206	16 509
4	**Chennai**	541	1 416	1 729	3 170	4 290	5 361	6 560	8 917
5	**Bangalore**	162	786	1 207	1 664	2 922	4 087	5 701	8 728
6	**Hyderabad**	449	1 130	1 251	1 815	2 562	4 280	5 742	7 749
7	**Ahmadabad**	186	877	1 206	1 752	2 558	3 298	4 525	6 352
8	**Pune**	164	600	738	1 135	1 686	2 485	3 761	5 049

Source: Compiled by the researcher based on the report of Census of India, 2011, [2].

In 1901 the urban population was only 10.81 per cent which increased to 27.78 per cent of the total population in 2001. Between1901 to 2001 the total population increased by about 322 per cent from 238 million to 1027 million and the urban population increased by 996 per cent from about 26 million to 285 million, while the corresponding increase in rural population was less than 250 per cent. The percentage of annual exponential growth rate of urban population reveals that in India it grew at a faster pace in 1921-1931 and until 1951. This reflects a net movement of people from villages to towns and cities associated with non-agricultural employment; especially during the Second World War. The other factors in the decade 1941-1951was the urban influx of refugees from Pakistan following the partition of British India. Thereafter it registered a sharp drop in 1951- 61. The sharp drop in urban rate during 1951-61 was due to the declassification of a large number of towns during that period. The data indicates that the process of rapid urbanization began during the inter-war years. This was also the period of growth of industry. However the process seems to have really accelerated in the post-independence period. There has been considerable growth in industry during this period but it is the service sector which has expanded the fastest. The decades 1961-1971 and 1971-1981 have showed the significant improvement in growth this has thereafter steadily dropped to the present level. Number of urban agglomerations has grown from 1827 in 1901 to 5161 in 2001. A majority of settlements now classified as towns since long have displayed urban characteristics for a very long time and then got elevated to the status of a town. According to Census of India 2011 out of total population of 1210 million about 377 million live in urban areas and 833 million live in rural areas. Indian cities fall well short of delivering even a basic standard of living for their residents. Though the rate of population may slow down but the rate of urbanization cannot be arrested. This unprecedented urbanization stimulates the rise in urban energy

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demand and excessive emission in the system, ultimately end up with environmental chaos. An integrated approach to new smart sustainable urban development is very much essential through brain nerve of sustainable urban energy system to navigate towards the smart sustainable cities.

C. Smart Sustainable City as a System

Why smart sustainable cities? Against the background of economic and technological changes caused by the globalization and the integration process, cities face the challenge of combining competitiveness and sustainable urban development simultaneously. Evidently, this challenge is likely to have an impact on issues of urban quality such as housing, culture, economic, social and environmental conditions. Even though the vast majority of the urban population lives in cities, the main focus of urban research tends to be on the 'global' metropolises. As a result, the challenges of medium-sized cities, which can be rather different, remain unexplored to a certain degree. Medium-sized cities, which have to cope with competition of the larger metropolises on corresponding issues, appear to be less well equipped in terms of critical mass, resources and organizing capacity. In this connection, Indian cities are not an exemption and there is inevitable requirement to insert city smartness in the system to attain sustainable urban development.

Contemporary thinking about the integrated smart sustainable city as a system can only be turned into reality with a smart, integrated approach to both delivery and strategy. In an interconnected urban system, trees and green walls naturally cool streets and buildings; their green waste can be transformed into energy via anaerobic digestion or similar biological treatment; this energy can be used to power a fleet of street cleaning vehicles; the vehicles can make use of the recycled grey water from nearby apartments; the organic waste from the apartments can be used in greenhouses on the roof; and this can deliver food back to the apartments or the café at street level, and so on. Nutrient cycles are closed, water cycles are closed, energy is transferred from one system to another, and communities are engaged. Benefits are environmental, social and economic. So the idea of the smart city has become important not simply due to the emergence of the internet over the last two decades but also due to political, organizational, social, cultural and spatial challenges now facing city governments. While smart city thinking can address almost every walk of life, as indicated by the internet's extraordinary reach, climate change has substantially focused the thinking around smart cities in terms of reducing greenhouse gas emissions through low energy life styles, for navigating towards smart sustainable cities.

III. Cities as Energy Systems for Smart Sustainability

Given the rapidly changing world and the ever increasing demands on our resources we need now, more than ever before, to be making decisions today that will ensure long-term delivery of our needs. SMART sustainability helps to make decisions that reduce overall demand and consumption of urban energy which leads to SMART sustainable urban future of contemporary urbanizing world. It is estimated that currently more than half of the world's population is living in cities, and urbanization is expected to continue worldwide for the coming years [33], [19]. Within the European Union (EU), high levels of population density and urbanization are common characteristics in most countries, where over 70 per cent of the population lives in cities. Urbanization is closely linked with concentration of economic activities and production [19]. In fact all resources aim directly or indirectly to reach people, the natural dynamic is that a large share of the available resources necessary to the development and well-being (such as energy, water, food etc.,) converge to cities. Thus, cities are responsible for the bulk of the world's energy use and, consequently, for a significant share of the world's greenhouse gas (GHG) emissions. Within the European Union, cities are responsible for about 70 per cent of the overall primary energy consumption, and this share is expected to increase to 75 per cent by 2030[11].Cities expanding in size and population pose increased challenges to the environment, of which energy is part as a natural resource, and to the quality of life. Nowadays, most cities have already understood the importance of sustainability, both at their local scale as in terms of their contribution to sustainability at higher geographical scales. A trend exists to encourage cities to establish an informal accountability, e.g. through rankings of CO_2 emissions per capita per year. This accountability is likely to be refined in the future. The fact that cities gather a large share of the population makes them responsible for also a large part of the CO_2 emissions and therefore makes cities crucial elements to achieving the EU energy policy targets.

Cities are the place where most energy services are needed and are therefore ultimately responsible for the use of energy resources. Even though these resources are natural, i.e. part of the environment, they are not all of the same nature neither do their uses have the same impact on the environment. Some are available locally or within the traditional city hinterlands, while others are taken from large distances; some are of renewable nature and others are of exhaustible nature and usable through pollutant processes, such as the combustion of all fossil fuels. This context prompts the prime relevance that shall be given to the exercise of matching energy supply and demand in cities. It requires the perception of a city as a complex and dynamic ecosystem, an open system, or cluster of systems, where the energy as well as the other natural resources is transformed to satisfy the needs of the different urban activities [8], [9]. In fact, buildings (including residential and services) and transportation generally represent most of cities' direct energy demand, i.e., between 60 per cent and 80 per cent of the overall consumption. The amount of energy demanded from both sectors is strongly linked to characteristics, such as the climatic conditions, the urban density and morphology, the practices of the building construction, the main economic activities and cultural habits, which are particular for each city [15]. Buildings, both residential and services are usually influenced by the local

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physical and social conditions. Buildings in cities make streets and squares and modify the climate in the urban environment contributing to the creation of microclimates of higher polluted ambient air and with the so called 'heat island', a local increase of the ambient temperature that can go up to 10ºC, compared to the temperature on the periphery of the city. Those phenomena together with the street noise may lead to tighter buildings and the adoption of heavy mechanical systems for acclimatization, representing an additional and somehow unsuspected burden regarding the contribution of the building stock to climate change.

In terms of transport, the energy demand is also strongly linked with the specific characteristics of a city (urban mobility). Urban density and CO_2 emissions tend to have a direct, inverse correlation: in general, the lower the density of a city, the higher its emissions from the transport sector, suggesting that more compact cities are more energy-efficient regarding transport. This may be both because compact cities require inhabitants to travel lower distances but also because compactness is essential to create critical mass for efficient collective transport systems. Urban planning and its impact on the urban tissue is thus a key factor in the demand for transport. Furthermore the planning is responsible by zoning different services and conditions the movement of people and, consequently, also the need for transport. Moreover, the suitability of different mobility modalities, such as walking and cycling, depends on the morphology and dimensions of the city. Hence, the management of energy demand benefits from being done at a city level, which allows a tailored choice of the specific set of actions to undertake based on the local characteristics and expertise.

IV. Smart Cities as Energy Actors for Sustainable Development

Denser cities, with more people using resources and services more efficiently, is a key element in sustainable development. Currently, it is estimated that while 70-80 per cent of global Gross Domestic Product emanates from cities, so do 70-80 per cent of greenhouse gas emissions. The concept of a "smart city" builds on statistics such as those, key indicators of a city's success in moving to a sustainable growth path. From an historical point of view, many European cities evolved from medieval towns, according to the human and physical factors that surrounded them. Thus, though having different characteristics associated to their own specificities, European cities are usually compact. The urban form of these cities is strongly constrained by their past, which in terms of form has positive consequences on their energy demand when compared, e.g., with American towns that grew essentially after the spreading of the automobile led by cheap oil. In the contrast, Indian cities are being experienced with sprawling effect led to transport dependent, which stimulate the increase of urban energy demand and ultimately end up with environmental chaos due to excessive emissions.

Major events such as the First and Second World War, that affected all of Europe, also strongly influenced the current issues of cities. Various cities were devastated and a large share of the existing building stock was destroyed. This prompted to the construction of entirely new city blocks and the complete renovation of large urban areas during the 50s and 60s. Many of these buildings and open spaces were not significantly modified until today. Meanwhile many other cities followed a similar path while planning new urban extensions in the 50's and in the 60's. During these two decades, there was also a boom of social housing constructions, both in the former Western and Eastern Europe, often without proper urban planning with very low thermal performance. European cities face great challenges in terms of energy needs when facing the renovation of the existing building stock, challenges that are very similar to building stock of Indian cities. Furthermore, there are governance issues that prompt the city level as an appropriate level for action, the role of cities as energy actors along with refereed stakeholders are presented in the Fig. 2. Local authorities have responsibilities regarding land-use planning and management of resources (such as soil, water and waste) that interfere with the main activities in a city, its urban form and the use of resources [3]. It influences directly the needs for transportation and establishes a pre-condition for the potential of energy efficiency of buildings. The municipalities are typically in charge of the buildings' licensing. They are at first instance responsible for checking if the new and retrofitted buildings comply with international or local requirements, and in some cases they may even require performance levels for new buildings stricter than the national standards and create favorable conditions. Regarding the transport sector, they can have an important role in their management too.

For example, cities often manage directly the buses and train fleets, they decide on corridors for buses and other collective or soft transportation modes, etc. Cities may also condition private traffic, e.g., through paid parking and entrance fees for vehicles coming from outside the city's boundaries. Therefore, since city authorities directly affect the sectors responsible for the largest share of energy use (buildings and transportation), their responsibilities must also include the management of the energy demand. The electricity mix is measured at a national level, and so, two different cities, one belonging to a country whose electricity is mainly produced from fossil fuels and other with electricity mostly generated from hydro, with the same level and patterns of energy use may end up with very different levels of CO_2 emissions per capita. That would require that due account of the primary energy balance for each country or city must be considered, in line with the balance of the CO_2 emissions and in parallel with the balance of the final energy. The non-clarification of this issue is also a barrier to the establishment of proper policies and to the adoption of the most suitable practices for the sustainable use of energy. Research into smart cities shows that cities are smarter where government, industry, and universities work together. Therefore, city planning and management should have access to universities to acquire appropriate solutions. Eventually, the authors suggested that the city management should have partnership with refereed stakeholders through the brain nerve of

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sustainable energy systems to attain the sustainable urban future in the system.

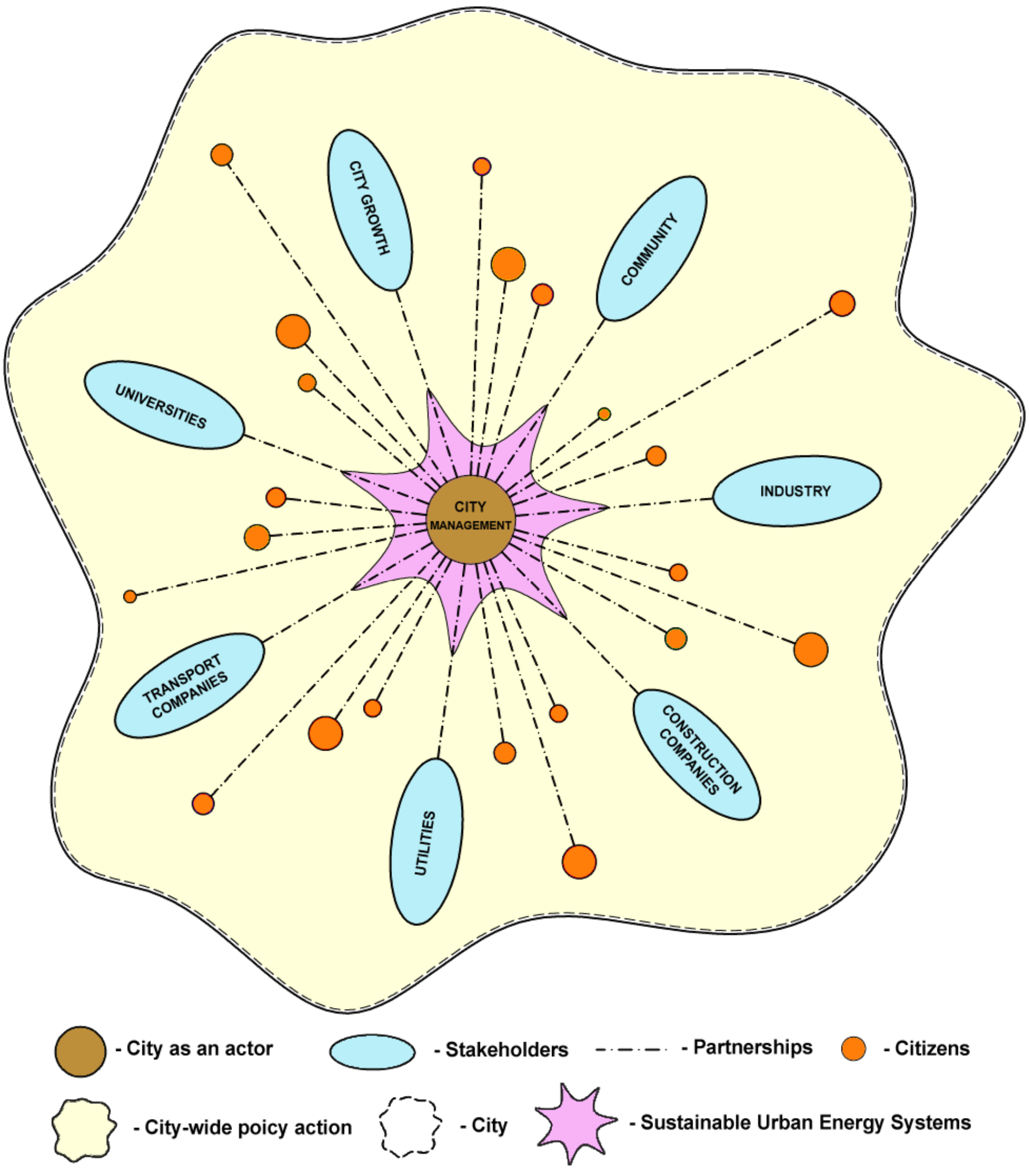

Fig. 2 Framework to Role of Cities as Energy Actors along with Refereed Stakeholders
Source: Compiled by the Authors

V. What Exactly is a Smart Sustainable City?

The strategic objective of smart sustainable cities would be : *"To expose the feasibility of rapidly progressing towards our energy and climate objectives at a local level while proving to citizens that their quality of life and local economies can be improved through investments in energy efficiency and reduction of carbon emissions"*

Information and Communication Technology (ICT) can play a significant role to improve the carbon footprint of cities by moving to a more intelligent use of energy (European Commission). An integrated and intelligent approach to urban development is needed to address the complexity of a smart sustainable city, aiming at improving the quality of life of all its citizens. The authors have made an attempt to establish the system's complexity by understanding the functional integrity along with subsystems of smart sustainable city. Smart sustainable city comprises the seven subsystems as summarized below:

1) Smart Economy:

SMART Economy focuses on value-added production and generates green products that will be in demand in tomorrow's markets. A smart economy is efficient. It relies on non-polluting systems and energy sources.

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2) Smart Mobility:

SMART Mobility is meeting the transportation needs of people and freight, while enhancing city's economic, environmental, and human resources. Smart mobility promises nothing more than a mobility revolution; with clean energy fuelling the drive technologies of the future.

3) Smart Environment:

Environment which ensures pollution prevention, sustainable resource management and environmental protection. 'Smart' approaches to ensure that cities are optimized for economic activity, energy consumption, environmental impact and finally improved quality of life.

4) Smart People:

SMART People are that the choice that individuals make about their lives and behaviors is a significant contributory factor in levels of carbon emission. Developing sustainable behaviors in people, from smart policies which 'nudge' people towards more sustainable living, to online applications and tools which support smart citizens, in the classroom, at home and on the move, are central to the smart and sustainable functioning of a city.

5) Smart Living:

SMART Living seeking wholeness and balance in everyday life. Smart living and its associated campaign guide people on how to be resource-efficient and sustainable in their daily lives and practices.

6) Smart Governance:

SMART Governance is about the future of the public services, it's about greater efficiency, community leadership, mobile working and continuous improvement through innovation. Smart Governance is about using technology to facilitate and support better planning and decision making. It is about improving democratic processes and transforming the ways that public services are delivered. It includes e-government, the efficiency agenda and mobile working.

7) Smart Technologies:

SMART Technology provides innovative and interactive solutions for Education; Business and Government .Smart technology is more than just clever: it takes inputs, processes them, and then creates outputs. A recent aspect to the energy-efficient real estate industry is "smart technology" for buildings and is now even cities. But even though there may be an advantage to such technology and focus, it leaves out a critical ingredient. In order for anything to be truly smart people and their motivations must be included in the equation.

All the subsystems of smart sustainable system (city) are interconnected and interdependent to each other towards common platform (brain nerve) of sustainable urban energy systems. By understanding the interconnectedness among the these seven subsystems and functional linkages the authors have developed Integrated Conceptualized Frame Work of Smart Sustainable City which is summarized in Fig. 3. The city smartness and sustainability can be achieved together in the system by understanding cause-and-effect relationships among the subsystems through reduction of energy demand (RED) and convergence of energy efficiency (EE) towards sustainable urban energy system. The 21st Century's modern cities of developing world call for new forms of urban development which coupled with city smartness and sustainability to attain the smart sustainable system. Therefore, one can easily conclude that the integrated planning approach transition towards local sustainable urban energy system which is inevitable requirement to achieve the smart sustainable city and eventually as nerve center for the smarter planet.

VI. Desired Elements for Energy in Smart Sustainable Cities

A. Smart City Concept

The term "Smart City" has been used in academic research and also as a marketing concept used by companies and cities, but a definition has not yet been established [1]. There are three main characteristics that seem to be common to most uses of the expression, which are i) friendliness towards the environment; ii) use of information and communication technologies as tools of (smart) management and iii) ultimate goal of sustainable development. In this case, a Smart City is implicitly defined as a city that improves the quality of life and local economy, through moving towards a low carbon future. Investments in energy efficiency and local renewable energy, with consequent radical reductions of primary fossil forms of energy and of CO_2 emissions, are seen as tools that help achieving sustainability and quality of life in a city.

The key elements listed below are grouped in three categories of opportunities: i) the building stock; ii) the transport and mobility; and iii) the city management opportunities. The order by which they are listed bears in mind some rationality in terms of priority of intervention versus its impact on the objectives of energy efficiency and/or CO_2 reduction.

1) Building Stock

In the building stock, a city of today may have to consider three major components with specific aspects to be addressed. First group are the new and great rehabilitated buildings, of institutional, office and other services character. All those cases may need, depending on the climate, full climatic and other special energy intensive features thus offering a wide spectrum of challenges for innovative energy technologies to reduce the energy needs and the demand from the energy networks ('net zero energy building' concept) as well as for reduction of CO_2 emissions. The second group is the new residential buildings, where passive and other solar derived technologies can be used to approach for lowering the energy needs. The third group presents the existing housing buildings, to be retrofitted. This is a major task for Indian cities, where solutions must be somehow in between those relating to the other two groups, if significant energy and CO_2

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reductions are to be reached without jeopardizing comfort and healthy environment indoors.

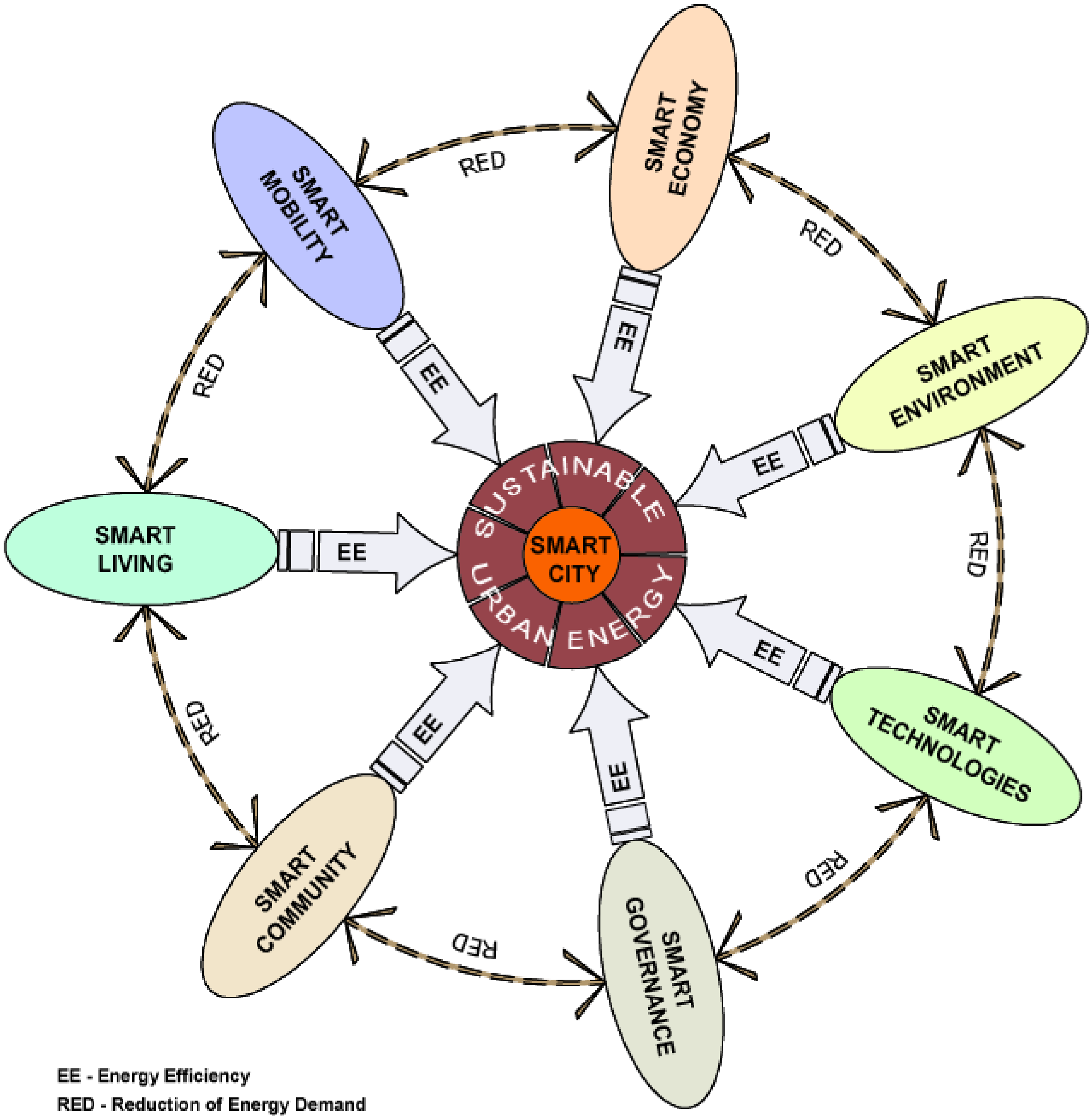

Fig. 3 Integrated Conceptualized Frame Work of Smart Sustainable City
Source: Compiled by the Authors

2) Transport and Mobility

The transport sector is, after the building sector, the second main originator of energy consumption and cause of CO_2 emissions in a city.

a).Lowering the mobility needs: The first measures to consider when aiming at the reduction of energy use within the transport sector should be the reductions of the transportation needs. There are several factors that influence these needs: some are social characteristics, such as population's age, average income and wealth; others regard physical specificities, such as climate conditions and city's topology; others, such as the distribution of different activities among the territory and city's density, are mainly linked to urban planning issues.

b).Shift from individual to collective transport: Additionally to the reduction of the demand for transport, it is possible to reduce the energy intensity associated to transportation, i.e., to reduce the amount of energy needed to perform a certain journey. Concerning passenger transportation the shift from private to collective transportation modes seems to be the most effective in achieving this goal. Besides the decrease in energy use for transport purposes, the increase on the number

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of citizens choosing collective modes of transport instead of individual motorized vehicles might also lead to an improvement in the quality of life. This could be achieved by the use of Information and Communication Technology (ICT) infrastructure to predict journeys and common movements within the city, leading to a better balance between supply and demand. Besides being an improvement by itself, this could also work as a motivation for people to shift to collective modes of transport.

c).Soft modes of transport: Enabling the use of soft modes of transport, such as cycling and walking, within the city is a way of improving quality of life whilst reducing air pollution. These are individual modes of transport, i.e. they still have the independency of route and schedules of the individual vehicles, but, at the same time, they do not require fossil energy and are not harmful to the environment.

3) City Management

Shift among energy carriers: There are several forms of bringing energy or providing energy services to the end-users: electricity, gas, heated or cooled water, solar radiation, etc. These are the so-called energy carriers or forms of final energy. However, these carriers must be produced from primary sources available in nature, or harvested from renewable flows sometimes with relatively low efficiencies as in the case of conversion into electricity. Therefore, the efficiency of the conversion from primary to final energy (and then to useful energy) strongly depends on the energy carrier used. If the resource is a fuel, the inefficiency means pollution burden at all environmental scales and, if the resource is renewable the inefficiency may represent just a (temporary) barrier to its economic feasibility. A system approach requires the search of the best match between energy service and energy carrier, and often this is achieved by shifting to the most suitable sector to provide a specific end-use.

VII. Key Barriers and Snags

In general, the barriers are not the same for all the technical options and are further commonly interrelated, i.e. with the cumulative occurrence of some difficulties others may become more relevant. The key difficulties corresponding to the uptake of technical energy measures by urban actors (market failures). Second, the causes and profiles of the disincentives of city authorities to move towards sustainability are identified (institutional failures).

A. Market Failures

A possible way to categorize the barriers designated 'market failures' is to divide these into two categories according to their type or character i) economical; and ii) informational and behavioral.

1) Economic Type of Barriers

Economic factors are believed to be very influential on the success or failure of the wide-scale implementation of most of the technical energy measures. Often, this implementation can occur naturally without the use of promotion mechanisms other than information, if the cost-benefit analysis is clearly favorable, the upfront cost is low and the return-on investment period is short. But the usual situation is not that simple and transparent, due several reasons such as (i) Price distortions, (ii) Cost-effectiveness perception, (iii) High-risk of investments, (iv)High upfront costs, and (v) Long payback periods respectively.

2) Information and Behavior Type of Barriers

In addition to the above, there are difficulties associated with lack of proper information .The informational deficit can include the lack of customized information and the lack of public awareness on climate change issues, but also the insufficient qualification of staff for complex integrated tasks at the public entities and service provider's levels. They are: (i) Lack of information and information asymmetry, (ii) Lack of expertise, (iii) Perception of quality of life, and (iv). Divergence of interests between different actors involved obstacle to the sustainability in a city.

B. Institutional Failures

This section deliberates the difficulties and disincentives city authorities can have in undertaking action towards sustainability, i.e. institutional failures are mainly of political and administrative nature. The main institutional failures are: (i). Political Thought: "not in my term"; and (ii). Political Occupation: "not my business".

1) Political Thought: "Not in My Term"

Politicians are concerned over their re-election, and hence, tend to think and act on the short term. Actions and money spent need to demonstrate clear benefits and added value for their voters, while the transformation towards a sustainable city might take decades. This might turn city officials reluctant to invest in measures that do not immediately show benefits, and rather opt for short term 'patched' solutions. A quick transition towards local sustainable energy systems implies that typically shorter term measures will be demonstrated. Still, the importance of longer term urban planning should not be overlooked as it has only recently been integrating concepts of sustainability, taking into account issues such as local and global environment, social equality, quality of life, public health, etc. [36].

Local governments have a diversity of priorities, as social issues, public health and ensuring economic growth, amongst others. Therefore, if climate action and sustainability is to be put on the agenda, it will have to compete with these other priorities, as the local resources (both human and financial) are limited. Furthermore, also in wealthy cities, examples exist of climate policy having to compete with local environmental problems, e.g., cities suffering from pollution of small particles from diesel engines, might promote a shift to gasoline engines, which emit more CO_2.

2) Political Occupation: "Not My Business"

Mayors are not necessarily energy experts. Quite often, the people elected still have little introduction and appetite for the concepts of local sustainability and the related new culture of a new energy paradigm made of diversification, decentralization of sources and conversion facilities and of priority to the demand approach. Given the cross-cutting nature of climate change, and the corresponding wide variety of relevant issues i.e., energy and all activities that are strongly dependent on energy, (e.g., transport, buildings, industry, leisure, normal citizen life), it is everything but straightforward to have the required expertise at all these levels. Hence, climate action and sustainability involve a wide range of elements and are intrinsically multidisciplinary in nature. Integrated solutions are required covering urban planning, buildings licensing, energy infrastructures, transport, water and waste management. However, these domains are often classified under different departments, all having their own targets/constraints. For instance, in the absence of internal coordination, a city may have an energy agency to promote local sustainable energy systems.

Based on the desired elements of Building stock, Transportation and City management, the authors have examined energy actions in urban activities and identified the possible energy barriers are summarized in the following Table XI, Table XII and Table XIII respectively. These barriers are in energy actions must be deactivated through integrated city smartness approach by the pathway of local sustainable energy systems.

TABLE XI
ENERGY ACTIONS ALONG WITH POSSIBLE BARRIERS IN CITY MANAGEMENT

City Management Scenarios		
S.No	**Energy Actions**	**Key Barriers**
1	Shift among energy carriers	▪ Price distortions (best match between use and carrier is not always the cheapest) ▪ Divergence of interests ▪ High upfront costs (undesired costs to perform the shift)
2	Upgrade of street and traffic lighting	▪ High upfront costs (compared to the financial capacity of the municipality)
3	Combined heat and power(CHP) with district heating and cooling	▪ Price distortions (on the final energy and inappropriate CO_2 accounting) ▪ Costs-effectiveness perception ▪ Lack of cooperation (among neighbourhood municipalities)
4	Development of smart grids	▪ High upfront costs ▪ Lack of expertise (on how to take advantage of ICT to reduce energy consumption)
5	Information and Communication Technology (ICT)	▪ High upfront costs ▪ Lack of expertise (on how to take advantage of ICT to reduce energy consumption)

Source: Compiled by the Authors based on report [6]-[8] and [22]

TABLE XII
ENERGY ACTIONS ALONG WITH POSSIBLE BARRIERS IN CITY'S TRANSPORTATION AND MOBILITY

Transportation and Mobility Scenarios		
S.No.	**Energy Actions**	**Key Barriers**
1	Lowering mobility needs	▪ Urban planning (impossibility of designing the city from scratch) ▪ Regulatory frame work (most transport planning is done at the national level) ▪ Lack of cooperation (among neighbourhood municipalities)
2	Shift from individual to collective transport	▪ Regulatory frame work (most transport planning is done at the national level) ▪ Lack of coordination (between different transport modes / inter modality
3	Soft modes of transportation	▪ Lack of information (walking and cycling are usually not seen as transport modes) ▪ Cultural barriers ▪ Perception of quality of life (Example, necessary to change the perception of comfort)
4	Integration of Electric Vehicles in the urban environment	▪ Early-stage (10 years are not enough for a strong impact) ▪ Regulatory framework (its success is dependent on the electricity mix) ▪ High upfront costs (to build the infrastructure and to buy the cars)

Source: Compiled by the Authors based on the report [5], [7], [8], [28] and [29]

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TABLE XIII
ENERGY ACTIONS ALONG WITH POSSIBLE BARRIERS IN CITY'S BUILT ENVIRONMENT

Building Stock Scenarios		
S.No.	**Energy Actions**	**Key Barriers**
1	Thermal upgrade of the envelope of existing buildings	▪ Divergence of interests (costs to the landlord and benefits to the tenant) ▪ Long payback periods ▪ Lack of information (no additional costs if the building is undergoing major renovation
2	Upgrade of lighting in buildings	▪ Lack of information (regarding its importance on the overall consumption and potential for improvements) ▪ Lack of expertise (on the opportunities of daylight and proper efficient control) ▪ High upfront costs (associated with control devices and designing process.
3	Mechanical ventilation with heat recovery and free cooling	▪ Lack of expertise (absence of trade-off analysis between savings of heating/cooling and energy used to move the fans) ▪ High upfront costs (without the guarantees of proper results)
4	Efficient electrical appliances	▪ Lack of information(to incentivize a quicker stock turnover) ▪ Lack of motivation (due to the lack of incentive's programs)
5	Passive buildings	▪ Asymmetry of information (misleading terms as Net Zero Energy Building -NZEB and passive building) ▪ Regulatory framework (absence of national mandates to stricter building codes) ▪ Lack of expertise (non-diffused best practice)
6	Smart metering	▪ Divergence of interests (regarding who supports the costs) ▪ Lack of information (the user needs to know how to take advantage of it)

Source: Compiled by the Authors based on the report [4], [8], [23], [27], [31] and [34]

VIII. SUGGESTED SMART SUSTAINABLE CITIES INITIATIVE

A. Disabling Market Failures with a Local Approach: Three Levels of City Smartness

Based on the suggested barriers in energy actions and detailed discussions, the authors have identified that there are three levels of city smartness in city's actions to overcome market failures with a local approach are distinguished, which is depicted in Fig. 4 and also summarized in Table XIV, They are: (i).leading by example, (ii).governing the private urban actors, and (iii).conceiving and implementing an integrated approach at the local level.

1) First Level of City Smartness: Leading by Example

When managing them, the public budget will accrue both costs and benefits, e.g. higher upfront payment for savings on future energy bills. Two examples are given of how the city authority as a public actor over time can lead by example to overcome the market failures are (i) public buildings; and (ii) public procurement at the local level.

First example is public buildings, such as offices, schools, hospitals, social housing, etc. Buildings are responsible for about 40 per cent of the final energy use in the EU and about 50 per cent of this value corresponds to the demand for space heating and cooling [5]. Even though public buildings only represent a fraction of the total building stock, they can lead by example stimulating local businesses to develop, making it easier for private actors to follow. Second example is public procurement at the local level, such as the purchase of appliances, joint procurement of energy efficient lighting bulbs for schools, the choice of electricity supplier, etc. Public procurement is a considerable share of GDP, even though the figures differ depending on the source. Even though public procurement at the local level is only a fraction of the total public procurement, over period of time, it can create a local demand for new and innovative products and services so that a market can develop.

2) Second Level of City Smartness: Governing the Private Urban Actors

Conceiving and implementing second level of city smartness concepts are more challenging than the first level, but they have a potentially larger impact. In what follows, three examples are given of how the city authority as a local policy maker can govern private urban actors to take action and overcome the market failures are (i) building codes; (ii) city entrance or parking charges; and (iii) land-use regulations over time.

First example is building codes [12]. The municipalities are typically in charge of the buildings' licensing. They are at first instance responsible for checking if the new and retrofitted buildings comply with international or local requirements. A well-known example is the Merton rule in the UK where 10 per cent of the energy consumed by new buildings has to be locally produced with Renewable Energy System (RES). Another example is Barcelona that requires the installation of solar thermal collectors for the hot water supply. In Freiburg, the municipality even created a network between energy companies and citizens, so the latter can rent their roofs to promoters interested in investing in photovoltaic.

Second example is city entrance or parking charges [12]. A well-known example of the first is the creation of a congestion charging scheme in London, i.e. all the commuters entering and leaving the city have to pay a municipal fee; this action led to a significant decrease of traffic in central London. Other cities, such as Stockholm, have followed this example. A good example of the second is the case of Copenhagen where the local government has recently decided to reserve five hundred parking slots exclusively for electric cars to give an additional incentive to their purchase.

Third example is land-use regulations, the lower the density of a city, higher its emissions from the transport sector. This may be both because compact cities require inhabitants to travel smaller distances but also because compactness is essential to create a critical mass for efficient collective transport systems. Copenhagen is an interesting example where the city authority planned densely developed fingers sticking out of the city with green areas in between to allow for a better development of the public transport system.

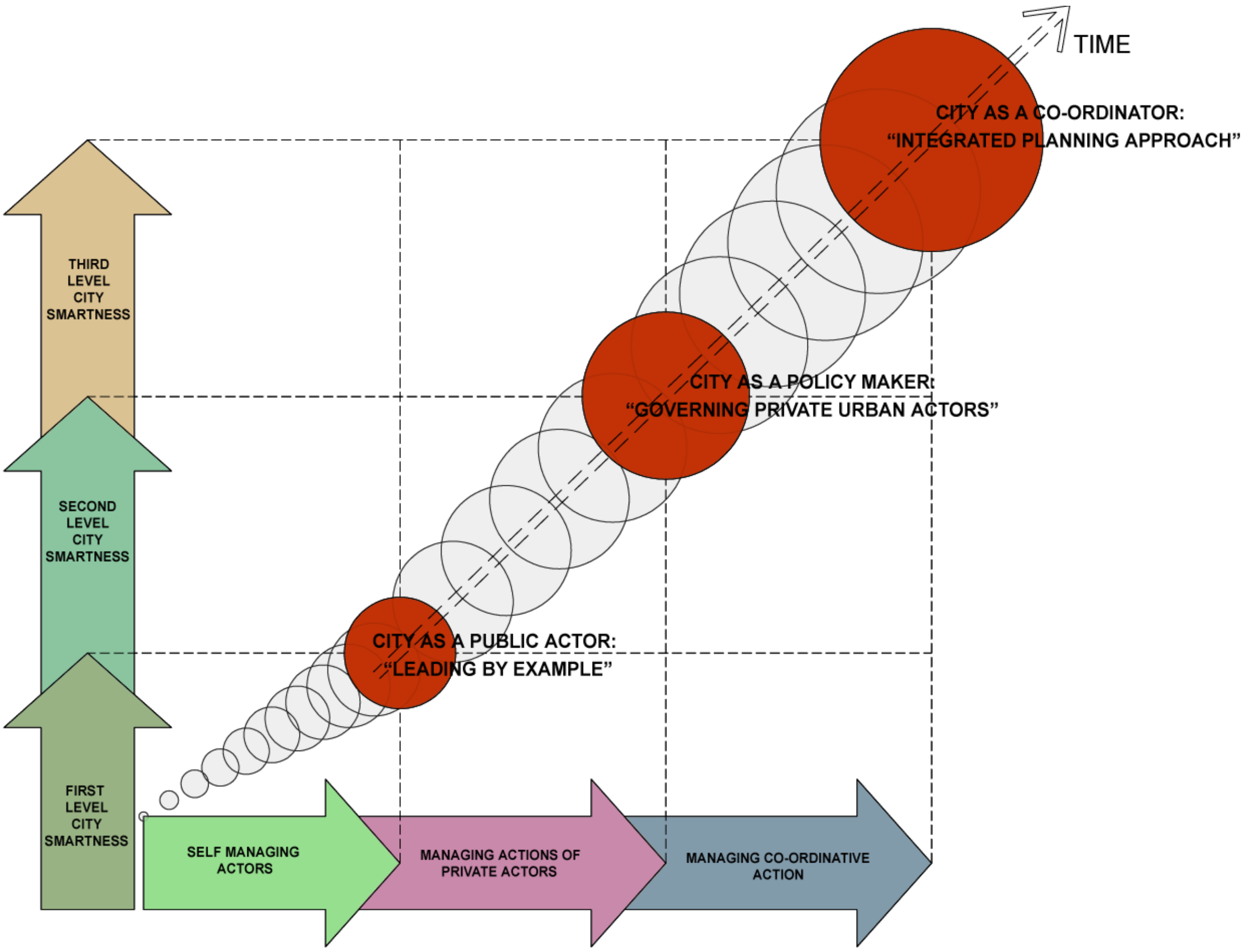

Fig. 4 A Collaborative Notion Graph for City smartness in urban actions with localized approach
Source: Compiled by the Author

3) Third Level of City Smartness: Integrated Planning Approach

When managing coordinative action, the city as a coordinator can help overcome the complexity of the action at the local level involving a high number and diversity of actors that can also have diverging interests. In what follows, two examples are given of how the city authority as a coordinator can promote an integrated approach to overcome the market failures: They are (i) conceiving and (ii) managing the implementation of such an approach over time.

First is to conceive an integrated planning approach, i.e. to design an energy action plan. A good example is the so called Sustainable Energy Action Plan (SEAP) that signatories of the Treaty of Mayors need to elaborate to reduce their carbon dioxide emissions with at least 20 per cent by 2020. Under the Treaty, cities are required to develop a baseline emissions inventory, set targets, and list a set of actions to reach the targets, with the build environment, the local energy networks,

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and the urban transport systems integrated in one plan. Already more than two thousand cities in Europe have voluntary signed the Treaty and SEAPs have already been produced showing the enormous potential offered to the cities as protagonists on energy for sustainability.

Second is to manage the implementation of an integrated planning approach over time, i.e. to involve urban actors, local business, and urban infrastructure service providers. A good practice is to involve stakeholders already at the planning stage with public consultations. The city authority is also well-placed to ensure the involvement of service providers. The service provider can implement city-scale demonstrations of innovative infrastructures, and the city authority can ensure there is then a demand for the associated services because they are users themselves in the system.

TABLE XIV
SUMMARY AND ILLUSTRATION OF THE DIFFERENT LEVELS OF CITY SMARTNES

Summary and illustration of the different levels of City smartness				
S.No	**Stages**	**Conceptualization**	**Samples**	**Smartness**
1	**First level** of city smartness	Self-managing actions by *city authorities* and *seen through the lens of* **Public actor** over time	Public buildings (Examples, schools, social housing infrastructures, etc.,) Street lighting, municipal fleet	**Lead by example**
2	**Second level** of city smartness	*City authorities* managing private actors reluctance to act and *seen through the lens of* **Local policy maker** over time	Regulation land-use (urban planning), building codes, city entrance charges Facilitation information centers, trainings, subsidies	**Manage the private urban actors**
3	**Third level** of city smartness	*City authorities* managing coordinative actions and *seen through the lens of* C**oordinator** over time	Combined action with city-scale demonstration of innovative infrastructures that enable a smarter use of energy, in combination with actions from city authorities to promote the use of the associated services	**Integrated Planning Approach**

Source: Compiled by the Authors based on the report

IX. RECOMMENDATIONS

City smartness essentially stands for integrating concepts of sustainability in every policy decision that is made on the local level so that cities will become institutions that accelerate rather than slow down the uptake of sustainable energy measures.

Organization of the Smart Cities Initiative

i. Carefully select and support a portfolio of smart cities to increase the excellence of the current pioneers, while also giving opportunities to cities in parts of India where there is a promising potential, but pioneers have not yet emerged. A well balanced portfolio of smart cities that represents the population of Indian cities needs to include cities with different energy fundamentals, a different political economy, and different institutional capacities.

ii. Promote concepts of city smartness. Within the three levels of city smartness we have identified in this research article, especially the third level is challenging so that this is where city excellence can be further promoted by the Smart Cities Initiative, i.e. to conceive and implement an integrated approach over time, for instance combining city-scale infrastructure demonstrations that enable a smarter use of energy with actions by city authorities to ensure the use of the associated services.

iii. Establish a strict performance reporting methodology for smart cities. A set of rules and tools is needed to set targets at the local level, prioritize actions to reach these targets, and measure progress and performance during the implementation stage (taking into account that there are different groups or clusters of cities). Performance can be a combination of ambition (in reducing CO_2 or energy use), innovation (infrastructures that enable a smarter use of energy), cooperation (performance of a twin city), etc.

iv. Make support for smart cities conditional to signing the agreement of Mayors. The agreement includes a reporting methodology for cities to navigate towards local sustainable energy systems.

v. Municipal administrations should make transparent and consistent all aspects of their urban planning: building permits, zoning regulation, and urban development planning. In cities of multiple municipalities, those policies should be made standard across municipalities.

vi. States and Municipalities should increase property tax and do more to enforce collection so that they are resourced to fund more effective training programs and sustainable urban development that benefit the majority of residents.

vii. Urban planning and housing agencies should be incentivized to promote sustainable urban development that promotes density and public transit rather than horizontal expansion and traffic.

viii. Centralized financial transfers to municipalities should include criteria that incentivize smart urban development.

ix. Charge fees for congestion, parking, and the real costs of driving. Remove oil subsidies and use the money on better urban development.

x. Introduce the role of "urban administrator" to coordinate

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urban policies across multiple municipalities and this post should be separate from electoral cycles.

X. Final Thoughts

Whereas the previous centuries were dominated first by empires and next by nation states, the 21st century belongs to the Cities. The growing economic, social and environmental importance of cities has led to a global wave of Sustainable Urban Development. The Smart City is heart of this wave, and is defined in this research article as "a city which systematically makes use of ICTs to turn its surplus into resources, promote integrated and multifunctional solutions, and improve its level of mobility and connectedness. It does all this through participatory governance based on collaboration and open source knowledge." What makes the Smart Sustainable Cities differ from 'Sustainable Cities' or 'ECO cities' is its emphasis on creating connections and systems, not only between the millions of smart devices present in modern day cities, but also between the businesses, the public sector, the knowledge institutions, and the inhabitants of the city and their functional integrity with brain nerve of sustainable urban energy systems.

The differentiation criterion between "good" and "poor" commercial offers as regards "Smart technologies'' should always be the empowerment of local authorities, citizens and socioeconomic stakeholders. Any technology or set of technologies that increases the power to influence both individual and collective fates has a good future. A "Smart Sustainable City" is a city that has found ways of combining "smart economy", "smart mobility, "smart environment", "smart living", "Smart governance", "smart technologies" with, last but not least, "smart people "are moving towards common platform (brain nerve) of sustainable urban energy systems and city as nerve center for attaining the smarter planet. When developing this notion, one can observe that it goes well beyond purely technical issues. Therefore, the contemporary process of urbanization and surge of urban energy demand transition towards Energy Smart Cities, which prefers the "low energy city with a high quality of life for all" concept with all the technologies needed to make it happen. "Agenda setting at the global, continental, and even national scale will miss a lot of the most important needs… the transcendent challenge is to help promote the relatively 'local' dialogues from which meaningful priorities can emerge, and to put in place the local support systems that will allow those priorities to be implemented" [13]. In a context where Indian citizens feel that "everything is being taken out of their hands", what we need is an energized, rather than a computerized, democracy. We must move cautiously, opening horizons for everyone and not just a few, even if this means yielding to the delights of exciting technologies. In fact, local authorities should clarify possible contradictions in this field while adopting participatory approaches. In order to permit this, their participation in legislative directives at national level is essential. Additionally, local communities often lack the expertise to interpret the recommendations contained in local energy regulation and planning instruments. Multiple local initiatives, for example, have to be coordinated with respect to legislative, policy and economic aspects. In this respect, communication, capacity building and policy learning in decision-making processes play a fundamental role. In the transition toward local sustainable energy systems cultural/cognitive legitimacy may be stronger than normative/regulative one for marching towards the Smart Sustainable Cities for India.

In general, the authors have made an endeavor to define the Smart Sustainable Cities as "*Smart development that transforms our resources in to infrastructures, goods and services with energy efficiency, to cater the needs of present masses without compromising the sustainable ability of future generations to meet their economic needs and enhances the quality of life for all*". Eventually, the authors' perception concluded that the city smartness coupled with sustainable development through sustainable urban energy would pave the way to advance sustainable development at local level, and certainly lead to build smart sustainable state, nation, and planet in future.

Glossary

BTU: British thermal unit. A BTU is a standard unit of energy that can be used to measure any type of energy source. It takes approximately 400,000 BTUs per day to run the average North American household. (Quad refers to quadrillion BTUs).

Watt: A unit of electrical power, equal to one joule per second. A 1-gigawatt power plant can meet the electricity demand of more than 500,000 homes in the U.S. (Kilowatt (KW) = 1,000 watts; Gigawatt (GW) = 1,000,000,000 watts; Terawatt (TW) = 1012 watts). Three hundred terawatt hours is equivalent to about 1 quadrillion BTUs (Quad).

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