Chapter 2
Planning Models for Climate Resilient and Low-Carbon Smart Cities: An Urban Innovation for Sustainability, Efficiency, Circularity, Resiliency, and Connectivity Planning

Abstract This chapter provides planning models for climate resilient and low-carbon smart cities as an urban innovation for sustainability, efficiency, resiliency, circularity, and connectivity of cities. The models incorporate strategic urban growth while keeping under control (or reducing) GHG emissions and vulnerability to climate change, bringing about growth benefits, in particular with the use of automation and Internet control system technology development. The complexity of a low-carbon smart urban development can be addressed and managed through connected networking and information sharing with ICT applications in areas such as transport, land-use planning, energy, water, and waste management under an integrated holistic approach.

Keywords Planning models · Reverse carboning · Sustainability · Efficiency · Resiliency · Circularity · Connectivity · GHG emissions · Vulnerability · Internet · ICT · Connected networking

2.1 Context and Relevance of ICT and Urban Form

The global warming is considered as a serious threat to the very survival of mankind and other living creatures. The full complexity of the carbon-smart urban development can be addressed and managed in the areas of transport and land-use planning, energy, water, and waste in an integrated holistic manner. This type of development can be done through connected networkings and information sharing with ICT and sustainable technology applications.

ICT helps city build resilience to adapt to changing conditions as we move into the era of rapid climate change. The need for a climate resilient and low-carbon smart city

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with Intelligent Digital Connections (IDC) has been demonstrated by existing World Bank programs. The World Bank has an active work program in the areas of cities and climate change, ICT, and also more broadly in the areas of sustainable cities.

2.1.1 A Package Program for Low-Carbon Smart City Development Plans

Cities can serve as living laboratories for innovative techniques and complementary climate policy package. While low-carbon smart city innovation can have significant impacts on economic growth, the ICT applications for low-carbon city in many developing countries are very limited. Many inspiring smart city ideas never make them into their comprehensive low-carbon city development plans which include climate action plans.

Therefore, it is necessary for them to understand why this is the case, and how to improve the situation in a total holistic manner. At the same time, it is necessary to ensure that a complete package is developed for humanware, infoware, and orgaware for a healthy, easy, simple, practical, and structured technology transfer and diffusion.

2.1.2 Reverse Carboning (RC)

Ideas such as reverse engineering (RE) and reverse mortgage have been implemented, respectively, in new product design and rescheduling of acute financial amortization. Similar possibilities can be explored for the development of low-carbon smart cities as it is impossible to destroy all the cities and rebuild them again from scratch. Reverse Carboning (RC), a new concept introduced in this model, can be defined through appropriate methods, procedures, planning, and development (MP^{2}D). The MP^{2}D, therefore, entails supplemental and advanced research studies. The MP^{2}D for RC differentiates the low-carbon smart city from the existing smart city in a practical manner in that transdisciplinary systems-of-systems (TD_SoS) approaches are considered vital.

The current version of MP^{2}D for smart cities lacks these approaches. Furthermore, the existing methods or projected approaches considered "what" it is and "how" to deal with the situation, but do not address "why" the steps to be taken. As a matter of fact, we currently have a less-awareness society. Needless to say, only a small percentage of global population knows "Why." All should critically think about the endangered situation ahead: not just for thinking about it on a 4/5-year governmental term basis but for sustainably global term basis, say 100 years, 500 years, or 1000 years. By appropriate MP^{2}D, we should be able to decarbonize the globe the way we want.

The "Why" variables in the proposed TD_SoS approach are distinct as compared to the existing approach.

2.2 Model for Comprehensive Climate Resilient and Low-Carbon Smart City Planning

2.2.1 Definitions

This is the digital age. Due to the breath of ICTs that have been implemented under the smart city label, it is difficult to distill a precise definition of a smart city. The Smart City Council defines a smart city as one that has simple, easy, and practical digital technology embedded across all city functions.

A smart city is defined by Dr. S. Himesh as follows:

> A smart city is an intrinsically sustainable city which recognizes the physical limits to its growth without compromising the quality of life of the present and future generations.

In the context of climate change, planning processes have to recognize the need for ongoing adaptation, flexibility, and resilience.

Resilience is defined by Walker et al. (2004) as the ability of an ecosystem to withstand or recover from disturbance or stress. Disturbances such as drought, heat, cold, flood, and disease and changes in species all influence or impair an ecosystem's capacity to perform specific functions and provide ecosystem services.

Climate resilient and low-carbon smart cities can be defined as ones that have digitalized connections of all sectors and functions, in which everything is connected, supporting sustainability, resiliency, circularity, efficiency, and connectivity of the city. It incorporates climate change mitigation and adaptation policy goals at each stage of planning process and in urban policies.

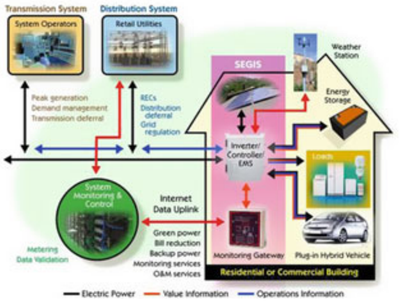
2.2.2 Connectivity of Climate Change Actions and Plans

Though cities and communities around the world have elaborated a wide variety of climate change actions and plans, their development and implementation often follow a project-based approach with no networked connections between projects. The increasing number of urban responses to climate change highlights the need for carbon-centered comprehensive (3Cs) smart planning model which incorporates climate change mitigation and adaptation policy goals at each stage of the process.

Such a model aims for digitalizing solutions for individual actions and viability decisions in a holistic manner, and, therefore, the model needs to combine a very high number of different ICT uses that are relevant to climate change mitigation and adaptation measures which will be described in this book later. Lots of institutional capacity is needed in installment of execution of smart ICT uses networks.

In order to visually show efficient development of GHG reduction technologies with ICTs, it is essential to use digital overlay technique and carbon overlay technique as well in the model. The carbon overlay is a quantitative index of the relative importance of individual credits associated with the construction and operation of buildings and various infrastructures based on the carbon footprint (Figs. 2.1 and 2.2).

Diagram showing the integration of PV with the smart grid



SEGIS diagram showing the integration of PV with the smart grid
source: www1.eere.energy.gov/solar/images/segis.jpg

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Diagram showing the integration of PV with other renewable energy

Illustrative development of GHG reduction activities on the masterplan: Strategic urban plan for climate change

Fig. 2.1 Illustration of the package program for the digitalizing connections of smart city and low-carbon city

Digitalized Network of Existing plus New Energy Suppliers and Consumers

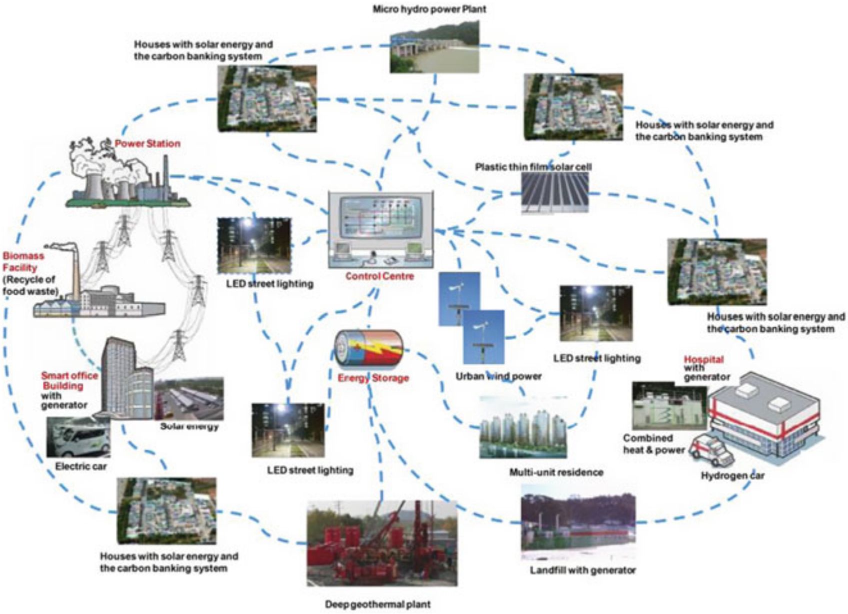

Fig. 2.2 Conceptual urban 100% renewable energy grid system which can be expanded to include carbon capture and utilization, and carbon sink technologies: to become a low-carbon smart city to switch to 100% renewable energy

These figures show the future direction of the digitalized connectivity from information and ICT perspective.

The features of a digitalized network of existing and new energy suppliers and consumers (Fig. 2.2) are as follows:

- Integrate new renewable energy sources into the existing energy system with ICT;
- At present, the energy system in many cities already has a relatively high share of renewable energy and plans for further large-scale integration as clean natural energy sources are available. The large-scale integration of renewable energy is shown in Fig. 2.2;
- The system is an example of flexible energy systems, in which many cities decide to make each building energy independent and carbon neutral through the use of renewable energy, primarily solar but also geothermal and wind power, as well as storage devices and distributed renewable solar thermal energy system, while other buildings, private businesses, and homes are connected to central power grid through the control center; and
- The design of future 100% renewable energy system with ICT is a very complex process. However, the variety of benefits both to the city and to the citizens makes it worthwhile. A cost-benefit analysis may be needed to justify this idea.

Figures 2.1 and 2.2 are illustrative examples of the deployment of GHG reduction technologies. Some technologies are practical for deployment in the near future.

These conceptual development plans show how to achieve the ultimate goal of the "climate resilient and low-carbon smart cities". The actual deployment of GHG reduction technologies for innovation is presented in Fig. 2.3.

Fig. 2.3 GHG reduction technologies for innovation for a better life. *Source* LG Group blog (lgblog.co.kr)

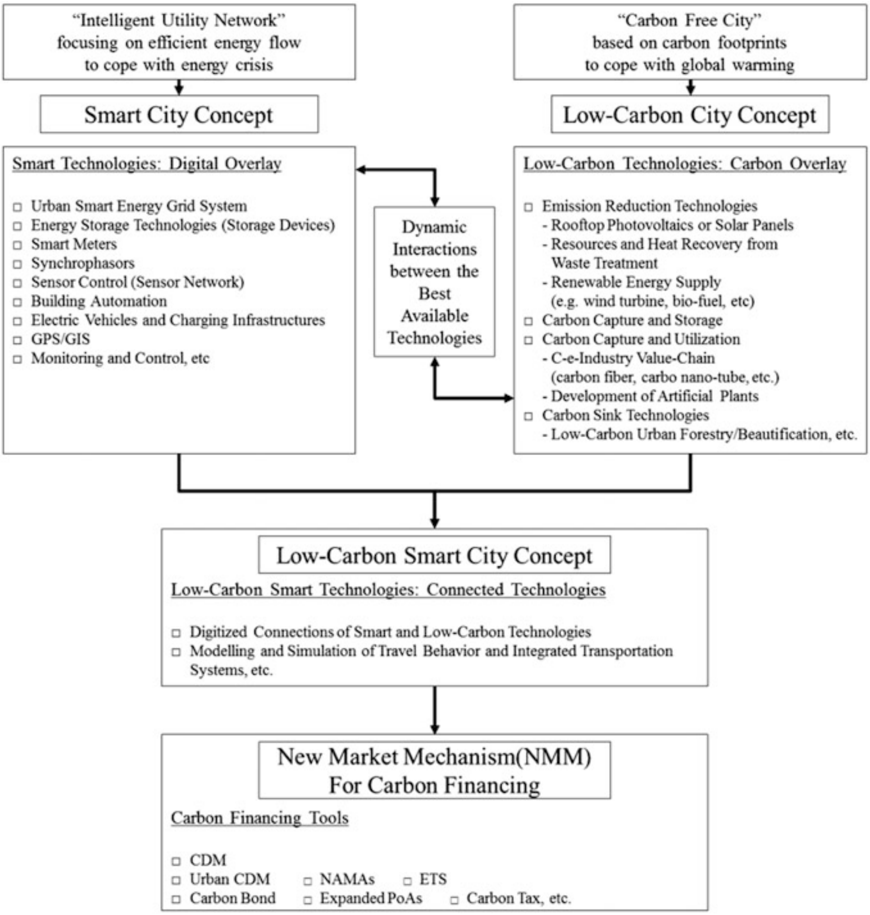

Fig. 2.4 Technologies for the digitalizing connections of smart city and low-carbon city

In Fig. 2.4, the carbon overlay is a quantitative index of the relative importance of individual credits. The score for each LEED credit is estimated based on the carbon footprint for a typical LEED building. A building's carbon footprint is the total greenhouse gas emissions associated with its construction and operation, including the following:

- Energy used by building systems;
- Building-related transportation;
- Embodied emissions of water (electricity used to extract, convey, treat, and deliver water);
- Embodied emissions of solid waste (life cycle emissions associated with solid waste); and
- Embodied emissions of materials (emissions associated with the manufacture and transport of materials) (US Green Building Council).

Fig. 2.5 Image of a smart/connected city. *Source* Gordon Fellor, Internet of everything: revitalizing cities, citizens, and urban systems, June 6, 2016, unpaged

On the other hand, the term "smart grid" defines a self-healing network equipped with dynamic optimization techniques that use real-time measurements to minimize network losses, maintain voltage levels, and increase reliability and improved asset management (Momoh 2012). The smart grid environment requires the upgrade of tools for sensing, metering, and measurements at all levels of the grid (Fig. 2.5).

Climate resilient and low-carbon smart cities and the digital and carbon technology behind them hold much promise and other interesting opportunities for new markets, services, and practices to the cities' stakeholders. These opportunities will be discussed in Chaps. 5 and 7.

2.3 Low-Carbon Smart Sectors with ICT Applications: Sectoral Platform Planning Models

2.3.1 Low-Carbon Smart Transportation System and Land-Use Planning

Energy consumption in the transportation sector in the city of developing countries currently is not monitored via technology systems. As a matter of fact, no information (past, current, and predicted traffic) is available to maintain and control GHG emissions. There is no control of usage of vehicles from any categories, although energy consumption in the transportation sector in the city of developing countries currently accounts for more than 10% of total GHG emissions. There are lots of benefits of smart transportation.

Urban authorities make decisions that influence the transportation systems which may have negative impacts on the sustainability of the city. Hence, actions have to be taken to get solutions through ICT application that help more environment-friendly and sustainable transportation networks, change the human behavior for the use of mode of transport with low-energy demand, reducing GHG emissions, decrease operational costs, move toward better congestion, parking lots and traffic lightings, and integrate new transportation systems. ICT coverage allows individuals to travel less and be more protective via communication.

Land-use zoning and land adjustments in many countries are very critical issues. Although cities only make up 2% of the earth land surface, they are responsible for 67% of global energy consumption and 60–70% of the global GHG produced. Many cities in developing countries are associated with unbalanced growth, fragmental spaces, social segregation, lack of infrastructure, and lack of access to key resources which are quite often related to urban land use.

Therefore, there is great necessity for innovative solutions to maximize the operational performance of transportation and environmental infrastructure, and to move toward more sustainable flow of energy and materials through better land-use planning with digitalized connections based on GIS/GPS techniques.

2.3.2 Energy

Urban energy flow and distribution in many countries are not analyzed as part of urban knowledge base. Hence, it is necessary to understand the interrelations between energy suppliers and consumers, and energy flows between built form, urban infrastructure, and open spaces, as described in section "Design for Energy Conserving Cities".

Another key area is an innovation in the urban smart grid system which is integrated with low-carbon green technologies in a total holistic manner.

The low-carbon smart city requires an urban renewable energy grid system which can be expanded to include carbon capture and utilization, and carbon sink technologies.

2.3.3 Water Supply

The water industry is one of the fast-growing energy users which is a main source of CO_2 emissions. With the rise in water demand, there is a great necessity for innovations driven by ICT applications, with the potential to achieve significant system efficiency improvements.

New technologies are crucial for securing water resources and sustainable integrated management systems that enhance public safety, health, and quality of life in all its communities. Such a utility as water needs to be produced and delivered more efficiently with well-connected networks in terms of electricity used to extract, convey, treat, and deliver water. New technologies for treatment, and processing of "wastewater" streams would recover heat and energy, and valuable raw materials for agriculture and manufacturing, further reducing carbon use.

Water authorities must consider connecting water companies with energy producers to create more effective partnerships for tackling emissions based on the water and energy nexus.

2.3.4 Solid Waste

With urban concentration, cities use a significant proportion of the world's material goods and produce an increasingly large proportion of global solid wastes.

There are many opportunities for us to reduce our GHG emissions, including reduction of waste volume at landfills and the promotion of waste-to-energy may also, in the future, offer potential revenues from the sale of renewable energy credits and carbon credits in emerging new carbon financing mechanisms, including the Urban CDM and emissions trading programs.

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