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Research paper

A Study on Future City Models through Domestic and Foreign Cases -Focusing on the Zero-energy Town and Smart City-

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Abstract

Recent increases in population, carbon emission, and energy consumption have led to the placement of greater emphasis on the application and development of new and renewable energy technologies and the securing of alternative fuels. In light of this, several institutions in South Korea have undertaken preliminary studies that include literature reviews and case studies related to smart cities and the development of zero-energy complexes as solutions to these issues. However, these studies in most instances are non-comprehensive and focused on specific cases. Several cities in South Korea lack adequate preparations to realize future cities. In light of this, through the study of domestic and foreign cases regarding smart cities and the concept of zero-energy towns, new and renewable energy and ICT technology applications centered on methods of realizing future cities were analyzed and in doing so, basic materials necessary for the effective realization of future cities in South Korea were established.

Keywords: *Future City, Zero-energy, New and Renewable Energy, Zero-energy Town, Smart City*

1. Introduction

1.1. Background and Purpose of Research

According to the United Nations Development Programme, approximately 55% of the world's population in 2010 was concentrated in cities. This indicated that the process of urbanization was occurring rapidly in regional units. Despite the formation of mega cities, in accordance to this trend has resulted in some positive aspects such as greater economic activity and the development of infrastructure. However, such positive elements have come at the expense of a variety of urban challenges associated with traffic congestion, city-wide overcrowding, energy shortages and environmental pollution. (1) With this in mind, several cities across the globe have established a trend in which smart cities are being applied as a means of responding to such urban challenges that have recently developed. Although the concepts of smart cities are applied differently according to the respective economic and social conditions the focus city, smart cities largely regard cities that apply a variety of complex technological elements in addition to being cities that vie for self-sustainability through the use of Information and Communication Technologies (ICT). (2) Of the various problems that have occurred in mega cities of the past, the consumption of energy by buildings has been highlighted as an extremely important issue concerning the process of city operations. According to a report published by the International Energy Agency in 2001, energy consumption in the building sector constituted 38% of the total energy consumption. As carbon emissions and energy-related problems have become recognized as important issues affecting cities, such issues have accordingly emerged as key issues in architecture as well as urban development and urban regeneration projects. Even until recently, the issue of environmental friendliness has been accepted as a key issue that has been adopted worldwide and in line with such trends. Moreover, the reduction of energy consumption and carbon emissions has become recognized as a key issue that has necessitated the reduction of fossil fuel consumption in buildings. In light of this, zero-energy and zero-energy urban planning have emerged as important issues. Upon recognizing the importance of reducing carbon emissions and the importance of zero-energy, the methods of city operations in South Korea have entailed, for example, in the case of Seoul Metropolitan City (SMC), an announcement to reduce greenhouse gas (GHG) emissions by 40% and increase the supply of new and renewable energy up to 20% through the "Seoul City Low Carbon Green Growth Master Plan." (٣(

In light of this, the aim of this study was to survey smart city zero-energy complex plans that are being applied in South Korea in accordance to the Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy. In addition, this study also aimed to develop the basic materials for the application of energy self-sustaining smart city complexes to be applied in South Korea in the future. To meet this objective, the technological applications and new and renewable energy applications through case analyses of South Korean complexes based on smart city zero-energy technological elements applied in overseas countries were analyzed.

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1.2. Scope and Method of Research

Based on prior literature reviews and domestic and foreign case studies, this study undertook research regarding the means of developing a future city. Although the introductory background, cause, and objective of zero-energy towns and smart cities are considered to be similar, there are differences in each of the processes from the standpoint of the introductory period and planning mechanisms. These differences have been presented in the form of applying elements such as the application of new and renewable energies and smart grids, the application government-led models, and the application of ICT. In light of this, to draw an image of plans regarding a future city, the analyses were undertaken upon limiting cases to zero-energy towns that have achieved net-zero-energy and smart cities that applied advanced ICT infrastructure as a new urban trend. (3) A framework was then established for each case and applied to the case analysis. In addition, the characteristics presented in each of the cases were analyzed and examined. Specifically, the implications of each element were evaluated to explore the future direction of city model developments.

Theoretical Review	Summary of smart cities and zero-energy towns based on literature reviews and case studies
Development of Framework	Development of framework for the case analysis of zero-energy towns and smart cities
Case Analysis	Summary of implications regarding the direction of development and each of the applied technologies through case analyses

Fig. 1: Research Flowchart

2. Zero-energy and New and Renewable Energy

2.1. Definition of a Zero-energy Building

The Ministry of Land, Infrastructure, and Transport defines the concept of a zero-energy building (ZEB: Zero-energy Building or EZB: Energy Zero Building), as a building that approaches zero-energy consumption due to the consumption of energy by a building being at lower levels than the total amount of energy that is self-produced by the building itself. A zero-energy building entails methods of raising the energy efficiency of a building through passive technologies. Such technologies minimize energy loss through means such as the adoption of highly air-tight windows and high-performance minimal heat exchanging insulation. Active technologies that apply new and renewable energies are also employed. (4) Although it would be ideal to establish a method that does not involve the supply of fossil fuel energy to buildings, methods that utilize fossil fuel energy and return new and renewable energy according to peak times and seasons are common methods.

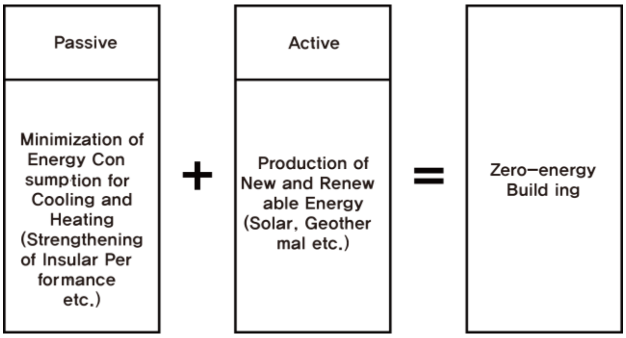


Fig. 2: Concept Map of a Zero-energy Building

2.2. Definition of a Zero-energy Town

A zero-energy town is a concept that expands upon the zero-energy building concept in which an entire complex self-generates energy and thus approaches zero-energy dependence on external sources of energy. (5) Zero-energy towns have advantages that are not limited to the buildings themselves, such as zero-energy buildings, but also have advantages that may be found with respect to the site of the town, the buildings, and the utilization of energy produced from external sources. As shown in <Table. 1> zero-energy towns are classified into five categories.

Table 1: Zero-energy Town Classification Types

Category	Energy-providing
Independent Type	Buildings within town
Hybrid Type	Buildings and sites within town
Resource Inflow Type	External new and renewable resources
External Direct Investment Type	External new and renewable facilities
External Indirect Investment Type	Externally generated electricity

First, the independent type regards a method of producing and supplying energy by installing new and renewable energy facilities in buildings within a town. (6) This type can be adopted in small towns that comprise of buildings with small floor areas. Second, the hybrid type regards a method of producing and supplying energy by installing new and renewable energy facilities in buildings and land lots within a town. This method concerns the installation of new and renewable energy facilities that are expanded into land lots in the case in which energy density demands are higher compared to the independent type. Third, the resource inflow type concerns the production and supply of energy by introducing new and renewable energy sources to a town by utilizing externally produced new and renewable resources such as biomass to account for energy shortages that cannot be supplied through the production and supply of energy through new and renewable energy sources applied in buildings and land lots within a town. (7) Fourth, the external direct investment type concerns the production and supply of energy by installing new and renewable sources of energy in a location external to a town. This arrangement is proposed in the event that shortages or limitations concerning the installation of new and renewable energy facilities within a town become an issue. (8) Fifth, the external indirect investment type concerns the supply of energy by purchasing new and renewable energy from external sources rather than directly investing in new and renewable energy facilities when developing a town.

2.3. Definition of New and Renewable Energy

New and renewable energy refers to energy that is capable of substituting primary sources of energy such as coal, petroleum, and natural gases. The phrase 'new and renewable energy' combines the notions of new energy and renewable energy. As shown in <Table. 2>, according to Article 2 of the 'Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy' and as designated by the Ministry of Trade, Industry and Energy, new and renewable energies in South Korea have been designated into 11 different categories to respond to the depletion of energy and manage the problems of environmental pollution. These energy types are not regarded as primary sources of energy.
The types of new and renewable energies that are easily applicable to multi-unit residences and general residential buildings include solar, geothermal, and hydrogen energy sources. Hydroelectric, wind power, and cogeneration (CHP) energy sources are difficult to apply to individual households due to the scale of their production facilities and energy production volumes.

Table 2: Classification Standards of New and Renewable Energy

Category	Type
New Energy	Fuel Cells, Hydrogen Energy, Coal Liquid Gasification and Gasification of Heavy Residual Oil
Renewable Energy	Solar Photovoltaic, Solar Heat, Bio, Wind, Hydro, Maritime, Waste, Geothermal

2.4. Definition of a Smart City

The necessity of the development of a smart city came about as a means of responding to a rise in the global population. According to 'World Urbanization Prospects: The 2014 Revision' by the United Nations, the global urban population will increase by 1.6% each year and will exceed 5 billion by 2030. The report also expects the ratio of urbanization to exceed 60%. This indicates an increase in the number of mega cities with a population of over 10 million in which the count of 27 such cities in 2014 is expected to increase to 41 by 2030. Such an increase in the number of mega cities results in a proportionate rise in carbon energy consumption and high economic activity within a restricted area, which in turn become the key causes of negative environmental impacts. The necessity of smart cities has gradually emerged as a solution to address such problems. Moreover, the importance of efficient resource consumption across the mega cities in each country of the world has become ever more emphasized.
Smart cities have been highlighted as being part of a new urban trend associated with the 4th Industrial Revolution and may be presented in the form of various concepts according to the urban environment, economic standpoint, and social factors of a country. However, the general definition of a smart city is a systematic network system that is capable of city operations and city management through the application of ICT technologies. Nevertheless, a smart city is defined according to different standpoints associated with the development speeds, possible level of technical applications, and economic differences of each city.

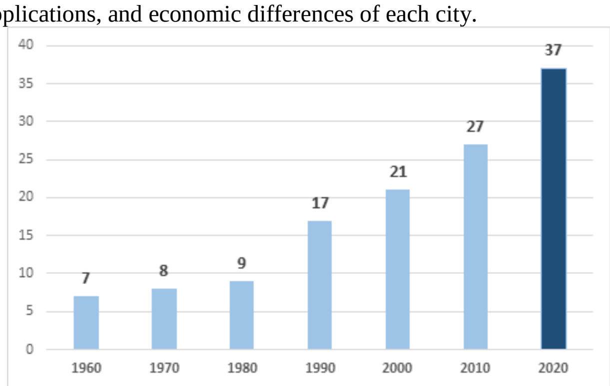


Fig. 3: Projected Increase in the Number of Mega Cities Worldwide

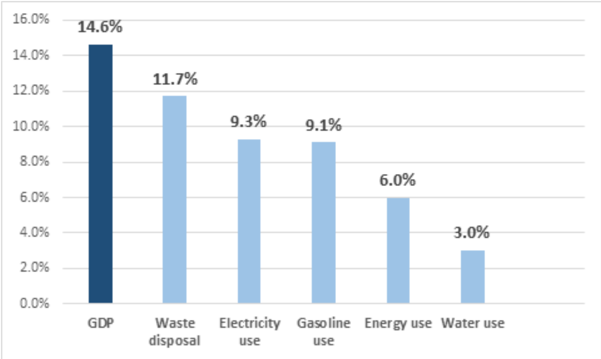


Fig. 4: Ratio of Resource Consumption by Mega Cties across the World

Table 3: Various Definitions of a Smart City

Item	Content
International Telecommunications Union (ITU)	“A smart city is a city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, and environmental aspects.”
UK Department for Business, Innovation and Skills (BIS)	“There is no absolute definition of a smart city, no end point, but rather a process, or series of steps, by which cities become more 'liveable' and resilient and, hence, able to respond more quickly to new challenges.”
Accenture	“A smart city is a city that is capable of leading a nation’s economy and improving the quality of life of urban citizens through intensive approaches to its citizens, enterprises, and efficient city operations.”
IBM	“A smart city is a city that utilizes information and communication technologies to collect and analyze information and applies this information as core technical elements.”
European Commission	“A smart city is a city in which its efficiency has been raised by combining new digital technologies with existing networks used to manage a city whereby smart traffic systems, smart light adjusting systems, and adjustable water and sewage systems achieve carbon emissions reductions. This is in addition to being a system that enables the sustainability of a city through city management practices that are based on governance systems that address matters such as aging city populations and urban safety.”
Northstream	“A smart city refers to a city where a concept of hyper-connectivity exists by applying ubiquitous technologies across a city to achieve object-to-object, human-to-object, and ultimately human-to-human connections.”

Furthermore, as shown in <Table. 3>, the definitions have largely developed in a manner of fitting the needs of cities under different titles such as ‘sustainable cities,’ ‘ICT applied cities,’ and ‘low carbon cities.’ Smart cities are not simply referred to as intelligent cities that apply ICT technology. They are also referred to as an integrated network in which social elements interact in a complex manner. That is, by utilizing complex social relations of urban citizens based on this network in addition to the application of ICT technologies, what was once considered impossible and difficult to manage in existing city operations has become possible for the efficient adjustment and realization in a city.

2.5. ICT for the Development of Smart Cities

Although several factors are at play for the establishment of smart cities, it is necessary to establish technologies that are capable of efficiently resolving the problems arising from urbanization. Information technologies capable of being utilized in smart cities as presented in the literature review include technologies associated with AI, Big Data, IOT, Smart Home, Spatial Information, Health Care, Smart Grid, Cloud Computing, and i-Robots, as shown in <Table. 4>

Table 4: Smart City Information Technologies

Category	Content
AI	Concerns intelligence created by machines. Research efforts to utilize neural networks, such as those used in the Deep Learning process of AlphaGo, have recently been actively pursued.
Big Data	Data created in a digital environment on a more massive scale than analog methods.
IOT	Technologies that communicate information between an object and another object or between a person and an object through the Internet. Short for Internet of Things.
Smart Home	Technologies that enable the control and connection to all electronic devices, including household electronic appliances, using a smartphone
Spatial Information	Information necessary for decision-making and spatial recognition related to the location information of an artificial object that exists in a space

Health Care	Short for Ubiquitous Health Care (a.k.a. Ubiquitous Health Management). Medical services unrestricted by space and time
Smart Grid	A next-generation intelligent electrical grid that optimizes energy efficiency by exchanging real-time information in both directions between consumers and suppliers of electricity by incorporating information technologies to existing electrical grids
Cloud Computing	A computing environment that enables the one-stop use of IT-related services such as the use of content networking and data storage through servers on the Internet
i-Robot	Also known as a humanoid, a robot that autonomously executes necessary tasks and, like humans, self-detects the external environment using vision and hearing

3. Selection and Analysis of Domestic and Foreign Cases of Zero-energy Town Applications

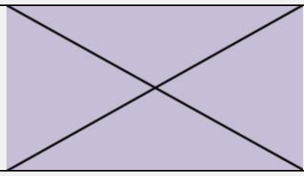
3.1. Site Selection

Sites that conform to the zero-energy town concept were selected from among cities in each country and cases analyses were undertaken upon consideration of the level of technical applications and potential for excellent performance as well as the domestic and foreign zero-energy-related pilot complexes.
The classification standard of the case subject site as defined in this study was established based on the sustainable new city standard data of the Ministry of Land, Infrastructure and Transport, as presented in <Table. 3>. For the specific case subject site selection, the sites were classified into per ha densities of 100 people, 150 people, and 200 people.

Table 5: Standard Density Classifications

Density Classification	Per ha Standard
Low-density	Within 100 people / ha
Mid-density	Within 150 people / ha
High-density	Within 200 people / ha

Table 6: Zero-energy Town Case Analysis Framework

Item		Content
Photo		
Location		
No. of Households		
Comparative Analysis of Government Policies	Collective Energy	
	Resident Participation	
	Public Private Partnership	
	Private Sector Innovations	
	Government Policies	

3.2. Low-density Category Case Analysis (Viikki, Pal Town)

(1). Viikki

As new buildings were no longer allowed within the city limits of Helsinki due to the ‘Sustainable Building Act’ enacted in 1990, Eco-Viikki announced design plans for a zero-energy town to accommodate its growing population by holding an international open competition.
Following the establishment of a master plan in 1990, two urban design open competitions were held in 1994. Thereafter, the development of the Eco-Viikki ecological residential complex, which features a finger-shaped design in which buildings and green spaces were alternately arranged, began making accelerated progress. Following this, self-developed guidelines (PIMWAG) were established following many discussions that were carried out over a long period of time.
The ecologically sustainable urban environment of Viikki was achieved as a result of two urban design competitions. Currently, various pilot projects for ecological buildings are being initiated in Viikki. Compared to Helsinki, Viikki was able to reduce fossil fuel-based heating energy consumption by 50%, atmospheric emissions by 40%, tap water use by 1/3, and waste discharge volumes by 1/3. In addition, solar collectors and active solar energy collection devices were installed to supply half of the heated water for 400 households thereby achieving zero-energy through solar energy.

Table 7: Viikki Case Analysis

Category		Content
Photo		
Location		Finland Viikki
No. of Households		900 Households
Comparative Analysis of Government Policies	Collective Energy	Solar Heating, Local (District) Heating
	Resident Participation	✕
	Public Private Partnership	Establishment of regulations
	Private Sector Innovations	✕
	Government Policies	Environmentally Friendly Pilot Complex Project

(2). Pal Town

Pal Town is a small city with a population of approximately 220,000 located in the southeastern area of Gunma Prefecture in Japan. The city has initiated the introduction of solar power generation facilities since the year 2000. As Pal Town was not initially planned as a zero-energy town, the city was once considered unconducive to building energy efficiency improvements. However, the city became designated as a zero-energy model city and was continually subject to projects to achieve zero-energy goals. Through this progress, the New Energy and Industrial Technology Development Organization (NEDO) of Japan in 2003 established a plan for 553 households in the Gunma Prefecture of Japan. Ota City was selected for a pilot project as part of the ‘Model Project of a Town in which Its Environment and Economy are Sustainable’ by the Ministry of Environment of Japan. The project subjected over 20 public facilities to energy-conserving remodeling efforts and Ota became a zero-energy town by achieving a reduction of approximately 1,000 tons of CO2 emissions and 35 million yen of costs per year.

Table 8: Pal Town Case Analysis

Category		Content
Photo		
Location		Japan Ota (Pal Town)
No. of Households		900 Households
Comparative Analysis of Government Policies	Collective Energy	Solar Heating, Local (District) Heating
	Resident Participation	✕
	Public Private Partnership	Technological Research
	Private Sector Innovations	✕
	Government Policies	Solar Photovoltaics Pilot Project

The Pal Town Project mainly aimed at installing, grid-linking, and using solar generation facilities in its housing developments. The initiative was heavily invested by private enterprises led by Kandenko, a leading infrastructure firm of Japan. Pal Town has achieved zero-energy status in which each household has, on average, a 3.84 kW capacity to produce energy and is capable of self-producing household electricity at a 100% rate.

3.3. Mid-density Category Case Analysis (Vauban, Upton)

(1). Vauban

Vauban is a zero-energy town with a population of 5,500 over an area of 41 ha and is located in Freiburg, Germany. Upon the withdrawal of the French army in 1991, the government began developing the area upon purchasing lands for the purpose of developing housing complexes. In addition to the self-government policies, a group of 30 citizens led an initiative to transform Vauban into an environmentally friendly energy town. In doing so, experts were recruited, and the Vauban Self-Governing Civilian Forum led the initiative. The core areas of renovations concerned greater insulation of walls, windows, and cellars. Such efforts transformed Vauban into a zero-energy town that reduced annual energy consumption for heating purposes from 200~300 kW/h per 1 ㎡ to 50~100 kW/h per 1 ㎡.

Table 9: Vauban Case Analysis

Item		Content
Photo		
Location		Freiburg, Germany (Vauban)
No. of Households		2000
Comparative Analysis of Government Policies	Collective Energy	Local (District) Heating
	Resident Participation	Forum Vauban
	Public Private Partnership	Solar Photovoltaic Pilot Complex
	Private Sector Innovations	✕
	Government Policies	Urban Development Measures Act

The project involved the installation of a cogeneration power generation system fueled by wood pellets (80%) and natural gas (20%) as a community facility used to supply regional heating to the town. The town also applied a 500 m^2 solar heat collector and a 2500 m^2 sunlight module to achieve energy independence. These applications were in addition to the town consisting of passive houses and zero-energy buildings.

Vauban is currently actively being subject to private investments and is experiencing a particularly rapid hike in investments for the high-cost Schiller Solar Complex from enterprises and individual investors that are highly interested in new and renewable energies. Vauban sells a portion of the new and renewable energy it produces, which provides the town an average annual income of 4,000 euros. In addition, the town has been selected as a case of excellence by the international community.

(2). Upton

The Upton new city residential complex was developed to resolve issues regarding housing supply in light of the economic growth and increases in population in Northampton, which is located in the East Midlands region of the UK. The area concerned a new development which, unlike other cases, prioritized the resolution of housing supply in addition to addressing the energy issue. One thousand, three hundred and eighty households over a 44-ha area were planned for development in steps. An interesting item of note was that the foundation of the Crown Prince participated and established the plans and regulations known as the Upton Design Code. The foundation of the Crown Prince introduced “Enquiry by Design,” a decision-making tool and a method of urban planning. The Upton Design Code applied in Upton minimizes the need for wastewater systems, energy and utilities, and resource consumption. The code advocates conservation of energy, water resources, and building materials, and minimized waste.

Upton established goals with high standards from the outset in the energy sector. All homes in Upton had the goal of fulfilling BREEAM/EcoHomes at a grade level of excellent or higher. In addition, the standards were set to be even higher during the development stage to encourage the construction of some residences to be absent of carbon emissions.

Energy production was actively pursued in a manner of solar energy use. Both solar heat and solar photovoltaics were used to produce heated water and electricity. Small-scale cogeneration power generators were installed in certain zones to compensate for lacking energy and heat supplies.

From the standpoint of its overall high-energy standards, Upton’s residences are considered an example of a successful case. From a policy standpoint, the Upton Design Code during the development of Upton served as an important element that reflected technologies with realistic feasibility for realization by civilian participants.

Table 10: Upton Case Analysis

Item		Content
Photo		
Location		UK Northampton (Upton)
No. of Households		1,500 Households
Comparative Analysis of Government Policies	Collective Energy	Small-scale cogeneration
	Resident Participation	✕
	Public Private Partnership	Technical Development, Establishment of Regulations
	Private Sector Innovations	✕
	Government Policies	Growth Area Designation

3.4. High-density Category Case Analysis

(1) Bo01, Malmö

Bo01 of Malmö City was neglected and suffered from severe ground pollution following the withdrawal of an automobile factory. In 1996, the project began after Bo01 was selected as the initial hosting site for the European Housing Expo. Following its selection, the Government of Sweden and the EU launched tests regarding new methods and technologies for the development of sustainable cities of the future. Malmö City took these opportunities to recover its urban economy. One thousand, five hundred people secured residence through the project following the completion of construction of some housing units during the first development phase in 2001. The Bo01 project was completed following the completion of construction of 599 housing units in 2003. Malmö was created with the full backing of the Swedish government in a dilapidated shipbuilding complex following industrialization. The initial energy consumption goal was set to 105 kWh/㎡ per year. However, in reality, the consumption volumes reached between 120~150 kWh/㎡. This translated to a 25% to 40% lower energy consumption than that of the average household in Sweden.

Table 11: Malmö Case Analysis

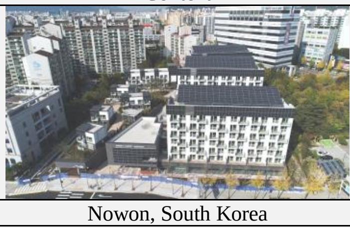
Item		Content
Photo		
Location		Malmö, Germany (Bo01)
No. of Households		1200 Households
Comparative Analysis of Government Policies	Collective Energy	Wind Power Generation, Wave Power Generation, Cogeneration
	Resident Participation	×
	Public Private Partnership	×
	Private Sector Innovations	×
	Government Policies	Housing Expo

Bo01 makes use of new and renewable sources of energy associated with the region, such as wind and seawater, to raise the energy efficiency of buildings. Bo01 primarily satisfies its energy demands using wind and seawater sources of energy that produce local energy. The remaining energy needs are supplied through a 120 ㎡ solar photovoltaic facility. Approximately 15% of the heating energy needs are supplied through solar heat and the size of the collection panels installed in the area is 1400 ㎡. In addition, the project realized the zero-energy goal by using cogeneration-based methods of collective energy.

(2). Nowon-gu, Hagye-dong Zero-energy Testbed Complex

In 2013, the Seoul Metropolitan Government announced a plan to construct a zero-energy testbed in Nowon-gu, Seoul. These plans were attempted approximately 20 years behind other overseas countries. A 1 ha area across the entirety of 251-9, Hagye-Dong, Nowon-gu was used to construct a 122-unit complex that included various types of residences, including single unit residences, shared wall residences, townhouses, and apartments. This was the first step taken in South Korea to achieve the mandate for zero-energy housing by 2025. The land was provided free of charge from the Office of Nowon-gu and the project entailed total expenses of 44.2 billion won. The Seoul Metropolitan Government invested 20.2 billion won, the Ministry of Land, Infrastructure and Transport invested 18 billion won in research and development, and private enterprises invested 6 billion won in the project.
As passive elements were incorporated to conserve energy, all buildings were arranged to face due south and all windows were installed with triple layered glass window systems. Air-tight tape and heat-exchange inhibitors capable of insulating the building from cold and hot temperatures were also applied. In addition, heat recovery systems, ventilation systems, and motor-driven shades were installed. Energy production was carried out via solar photovoltaic power generation using the roof and window surface areas, which yielded 5,200 kWh of electricity per year. A geothermal heat pump was applied as the source of heat energy.
The Nowon-gu testbed regards a plan whereby a zero-energy town concept was applied for the first time in South Korea. The case also carries significance in that it proposed rental apartments and greater energy welfare for working-class citizens.

Table 12: Nowon Case Analysis

Item		Content
Photo		
Location		Nowon, South Korea
No. of Households		122
Comparative Analysis of Government Policies	Collective Energy	Solar Heat, Geothermal Heat Pumps
	Resident Participation	×
	Public Private Partnership	×
	Private Sector Innovations	×
	Government Policies	Zero-energy testbed construction plan

4. Analysis of Selected Implementation Strategies of Domestic and Foreign Cases of Smart Cities

4.1. Site Selection

The smart city implementation strategies select strategic goals according to the content demanded by each country. Thus, variations are present in the nature of implementation by each country. The classifications of the smart city implementation goals by each continent were as presented in <Figure. 5>. The smart city implementation goals of advanced countries are largely focused on increasing energy efficiency, technological developments, and the open data sector. Based on this objective, smart cities are being used as a means to respond to climate change. Led by the European Commission under the European Union, policies that accelerate the introduction of smart cities across Europe have also been implemented. In the case of Asia, the implementation goals of smart city concepts proposed in developing countries are presented. This regards the expansion of the smart city market in India and China and the entry of foreign advanced countries and global enterprises into the market. Smart city projects in Asia are focused more on enhancing the competitiveness of a city as well as economic vitalization. This is in contrast to other advanced countries, whose project objective is to respond to climate change. Project sectors were presented in order of traffic systems, infrastructure establishment, and environment and administration. The priority of traffic systems and infrastructure establishment was set higher than the environmental aspects.
In light of this, in this research, as a method of classifying the case sites to study smart cities from a macroscopic standpoint, the smart city implementation strategies in Asia, including South Korea and cases in Europe, which were considered to consist of advanced countries in terms of smart cities, were compared and analyzed. From a microscopic standpoint, the application periods of smart cities were classified to set the range of pre-applied cities and post-applied cities.

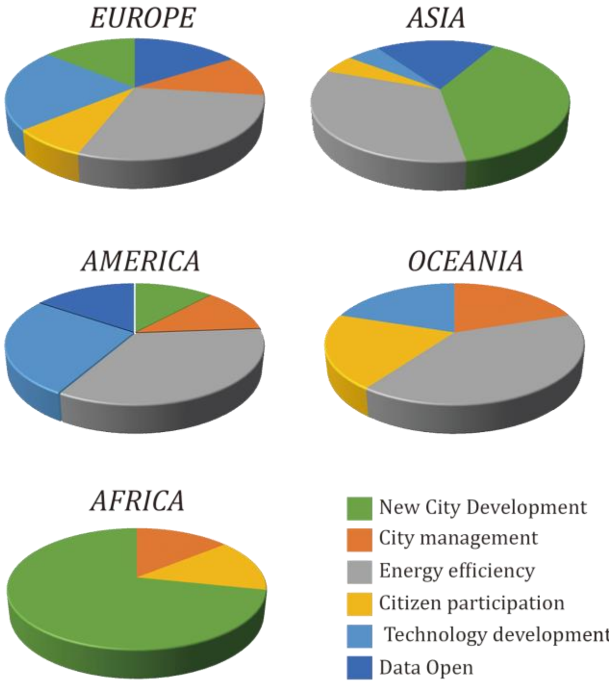
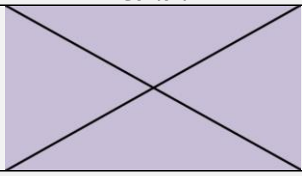


Fig. 5 Implementation Goals of Smart Cities by Continent

Table 13: Smart City Case Analysis Framework

Item	Content
Photo	
Location	
Initiative Objective	
Key Participants	
Key Activities	
Characteristics	

4.2. Analysis of European Cases

(1). Copenhagen, Denmark

The smart city strategy of Copenhagen aims to achieve carbon neutrality by 2025 to raise the quality of life of its citizens. In doing so, the City of Copenhagen designated five sectors including smart mobility, energy and climate change, smart citizens, health, and smart learning as its design and operational policies. For efficient operations, the local government, businesses, and research institutions came together to establish Gate 21. This organization functions both as a network platform present across the entire city and as a community union that provides successful solutions regarding traffic systems, energy use, smart cities, green growth, and economic circulation.

Through this platform, Copenhagen managed lighting technologies through a central control system within the testbed complex to perform multi-faceted analyses regarding energy use and peak load monitoring, which resulted in the reduction of unnecessary energy consumption. It also encouraged participation by the local community through the interaction and cooperation among various local community members, including the local government, global corporations, and small- and medium-sized businesses.
Such processes of the project carry significance in that a systematic system that is capable of being developed and verified by businesses through a testbed was designed. Moreover, by testing the performance alongside the experiences of local urban citizens who make actual purchases, the achievement of developments, to an extent that product purchase and standardization were being regarded, carries great significance.

Table 14: Case Analysis of Copenhagen, Denmark

Item	Content
Photo	
Location	Copenhagen, Denmark
Initiative Objective	Attempt at standardized design of product through a light testbed complex
Key Participants	Local Governments, Enterprises, Universities, Non-profits
Key Activities	Smart city planning involving horizontal environment and centered on lighting
Characteristics	Technological developments to resolve the issues have been explored and commercialization of a business model has been attempted

(2). Helsinki, Finland

Helsinki is a leading city with respect to resident-participated smart city applications that emphasizes public participation in its city operations. According to the European Parliament, Helsinki is a representative city having declared the smart city initiative and ranks 6th among 468 of such cities. City officials, architects, parliamentary members, and the general public form a communal group that hosts public hearings to continually establish city operation policies.
Through such processes, the City Government of Helsinki has proceeded with the Kalasatama Initiative. The Kalasatama project, which was launched to resolve urban problems due to an increasing population, currently provides homes to 3,000 citizens following the first open call for homeowners in 2013. Despite the vision of the project being centered on the maximized use of smart technologies, the project aims to achieve a complex approach to smart cities that does not solely depend on technical elements such as smart power grids. As a successful solution to issue, the city supports a cooperative environment between the public, private, and civilian sectors. Such cooperative attitudes among these groups have resulted in the operation of a communal club of which its members include academics, city officials, civil groups, and activists. The club provides overall solutions for a city through smart solution prototypes regarding city operations that are established during regularly held meetings.
This is significant in that a method of conflict resolution through debate, which opens the possibility of social acceptance of technologies across multiple sectors, including energy, the environment, and traffic systems was adopted. Through such resolution methods, IoT, self-driving systems, and the active adoption of new and renewable energies, such as wind power and solar heat, was applied naturally to the local community without resistance. This community acceptance is also a point that carries significance.

Table15: Case Analysis of Helsinki, Finland

Item	Content
Photo	
Location	Kalasatama, Helsinki, Finland
Initiative Objective	Tests through various attempts for smart city developments
Key Participants	Citizens, Local Government, Enterprises
Key Activities	Establishment of smart-based infrastructure, the operation and design of portfolios such as smart metering
Characteristics	Proceeded to resolve discovered problems according to demand upon recruiting residents and planning the area

(3). Amsterdam, The Netherlands

The 1993 Digital City provided an opportunity for continued discussions regarding smart cities in Amsterdam. In addition, a method in which urban innovations based on the region's rich history can naturally blend into the lives of its citizens and society was emphasized. The Amsterdam smart city was established in 2009 and established goals to improve the quality of life of its citizens, education, technologies regarding basic facilities, circular economy, mobility, and energy. An open platform for citizens to suggest and implement various ideas to resolve city problems to realize a smart city through various interest groups was proposed.

Table 16: Amsterdam Case Analysis

Category	Content
Photo	
Location	Amsterdam, Netherlands
Initiative Objective	Discovery and implementation of projects according to the items of demand by citizens from an urban standpoint
Key Participants	Citizens, Local Government, Enterprises
Key Activities	Energy Mobility, Circular Economy Infrastructure, Technical Enhancement, Governance and Training through an Online Platform
Characteristics	Establishment of a civilian participated platform based on a living lab

In particular, an online and offline platform provided a means for a citizen-led exchange of ideas and a number of technologies to estimate required demands were tested. The online and offline platform was led by the private sector and a smart city was aimed to be established based on the platform. Efforts were concentrated in the energy and traffic sectors due to the goal of reducing CO2 emissions volumes to 40% relative to emissions volumes during the 1990s by 2025. To achieve this goal, various projects, including Sustainable Neighbors, Cargo Hoppers, and City-zen were undertaken. Through such projects, a traffic ecosystem regarding traffic and the distribution of goods was established. This case is significant in that it approached problems by establishing a close cooperation among the city government, private enterprises, universities, and citizens. The traffic ecosystem was also noteworthy as it established an infrastructural system that enables the use of cargo vehicles that use environmentally friendly sources of energy.

4.3. Analysis of Asian Cases

(1). Sejong City, South Korea

The smart city planned policies of South Korea expanded upon the concept of U-City and has proceeded with projects for smart city applications. The aim was to conserve financial resources used for city operations through the integration and linking of systems. The plan was to increase the convenience of urban citizens as they relate to traffic systems, prevention of natural disasters, and energy use. This concerns exploring the direction in which developments are to be pursued based on the existing U-City infrastructure and concerns the establishment of methods to vitalize industry by focusing on environmentally friendly technologies and IoT.

Table 17: Case Analysis of Sejong City, South Korea

Item	Content
Photo	
Location	Sejong City of the Republic of Korea
Initiative Objective	Testbed construction planning through the utilization of existing U-City-based infrastructure
Key Participants	Local Government, Civilians, Enterprises
Key Activities	Public Bikes, BRT Priority Signals, 3D Spatial Information of Underground Facilities, Smart Streetlights, Smart Parking Information System
Characteristics	Provision of information specialized services and the establishment of citizen-participated modules through the establishment of ICT infrastructure and an extensive Internet network

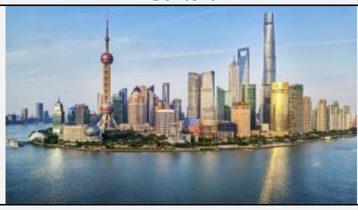
(2). Shanghai, China

The rate of urbanization in China reached 54% in 2014. Rapid increases in population have resulted in complex urban problems regarding the energy, housing, traffic, medical, education, and public safety sectors. To resolve these problems, the Chinese government invested 90 trillion won over a period of 5 years beginning in 2011 for the establishment of smart cities and plans to invest an additional 2 trillion yuan by 2025. Although the initiatives were individually undertaken by local governments on the outset, the projects began to be managed directly by the central government after 2013. The City of Shanghai, in particular, has undertaken preparations to establish smart cities with Tencent and aims to realize public services centered on a mobile platform.

In terms of 2010 revenues, the IT industry in Shanghai is sized at 153 trillion yuan. Such rapid developments of the IT industry have affected the smart city implementation goals of Shanghai. With the aim of establishing an intelligent city based on IoT, super computer, and cloud computing technologies, the project aimed to realize human-to-human and object-to-human communications among residents within the city.

The smart city goals of China were found to have a tendency to prioritize focus on the integration of smart technologies, the advanced development of the smart industry, and the enhancement of the living standards for its citizens.

Table 18: Case Analysis of Shanghai, China

Item	Content
Photo	
Location	Shanghai, China
Initiative Objective	Review the feasibility of applying advanced technologies and test the necessity of smart cities
Key Participants	Central Government, Enterprises
Key Activities	Establishment of Intelligent Cities by focusing on Cloud Computing, Super Computer, and IoT technologies.
Characteristics	Expansion of public services centered on a mobile platform

(3). Yokohama, Japan

Following the Great East Japan Earthquake of 2011, Japan began making concentrated efforts to engage in smart city developments as a means of recovering areas affected by natural disasters. Despite the country's entry into smart city development being later compared to that of Europe, Japan aims to enter foreign markets by developing successful smart city models. In stark comparison to South Korea, as Japan began transitioning to an aging society early on, policies related to the establishment of energy infrastructure are being prioritized for implementation.

The Japanese government has invested a total of 840 million USD from 2011 to 2014 for smart city testbed projects in the energy sector. Furthermore, key government ministries and agencies are separately implementing smart city-related policies. The three goals of Japanese smart cities include the efficient use of energy, the vitalization of local development, and the strengthening of global competitiveness. The testbed complex to realize these goals is the Yokohama Smart City Project. A smart grid to manage energy for residences, buildings, and the local community was applied, and a next-generation traffic system was established. In addition to utilizing renewable energy, the project enabled the reduction of electrical consumption through energy use management. In addition, 7 Japanese companies have been actively involved and have led the project.

Table 19: Case Analysis of Yokohama, Japan

Item	Content
Photo	
Location	Yokohama, Japan
Initiative Objective	Establish plans for a smart city as a means of recovering areas affected by natural disasters
Key Participants	Local Government, Enterprises
Key Activities	Efficient use of energy, vitalization of local development, strengthening of global competitiveness
Characteristics	Establishment of urban infrastructure actively reflecting social issues as well as energy issues

5. Analysis of the Urban Operational Goals of Smart Cities and Zero-energy Towns

5.1. Operational Goals of Zero-energy Towns

Through the cases of zero-energy towns home and abroad, the application of new and renewable energy technologies was analyzed focusing on plans to create zero-energy towns as shown in [Table 18]. The standards for the analysis assessed 11 new and renewable energies and each region was set up by density. Although the types of new and renewable energy applied to zero-energy towns vary in size according to the density related to energy consumption, solar power generation was applied in all of the regions, as shown in [Table 4], and there were also application cases by local climate and environment such as wind power and wave power generation. In the case of Eco-Viikki, which was planned in 1994, we could see the characteristics of applying district heating using large-scale solar heating. Cogeneration using new energy was applied to towns that were planned afterward, and the insufficient heat source was supplemented by individual hot water using solar heat. In the cases of Paltown and Nowon, which were planned after 2000, solar power generation dramatically improved in comparison with the same area.

Table 20: Analysis of Zero-energy Town-Applied Technologies

Item	Low-density		Mid-density		High-density	
Item	Viikki (1994)	Pal Town (2002)	Vauban (1996)	Upton (2004)	Bo01 (1996)	Nowon (2013)
Fuel Cells						
Hydrogen Energy						
Coal Liquified Gas						
Solar Photovolta-ics	PV system	PV system	PV system	PV system	PV system	PV system
Solar Heating	Local (District) Heating		Individual Heated Water Supply	Individual Heated Water Supply	Individual Heat-ed Water Supply	
Bio			Cogeneration	Cogeneration	Cogeneration	
Wind Power					Wind Power	
Hydroelectric						
Maritime power generation					Wave power generation	
Waste						
Geothermal						Heat Pumps

5.2. Operational Objective of Smart Cities

Upon examining the domestic and foreign smart city cases, the implementation goals of pre-applied cities and post-applied cities were analyzed. Due to the possibility of the standards of smart cities, as presented in "Chapter 2 Theoretical Review," being presented differently, the proposed urban planning implementation strategy announced by each country was used as the basis.

The case analysis presented both advanced and emerging country types where all types initiated smart cities as a new model of urban innovation as part of the 4th Industrial Revolution. The cases of Amsterdam, Helsinki, and Copenhagen regarded pre-applied models of smart cities where civilian government cooperation was undertaken to establish an ICT-centered infrastructure to provide various solutions. Recently, according to the economic features of a city and the social factors, processes in which various strategies and content were being provided in the form of urban platforms, living labs, and citizen experience-based pilot complex establishments have been presented. In the cases of South Korea, Japan, and China, compared to the European cases, the applied cities demonstrated a tendency to implement smart policies led by public actors to strengthen national competitiveness. This presented results concerning an environment in which both the problems of urbanization were rapidly resolved, and the focus was placed on supporting the economy.

Table 21: Smart Cities Case Analysis in Europe

Category	Europe		
Location	Copenhagen, Denmark	Helsinki, Finland	Amsterdam, Netherlands
New City development		●	
Data Open	●	●	
City manage-ment			●
Energy effi-ciency	●		●
Development Technology		●	
Initiative Ob-jective	Attempt at standardized design of product through a light testbed com-plex	Tests through various attempts for smart city developments	Discovery and implementation of projects according to the items of demand by citizens from an urban stand-point
Key Partici-pants	Local Governments, Enterprises, Uni-versi-ties, Non-profits	Citizens, Local Government, Enterprises	Citizens, Local Government, Enterprises

Table 22: Smart Cities Case Analysis in Asia

Category	Asia		
Location	Sejong City of the Republic of Korea	Shanghai, China	Yokohama, Japan
New City development	●		●
Data Open	●	●	
City management			●
Energy efficiency			●
Development Technology	●	●	
Initiative Objective	Testbed construction planning through the utilization of exist-ing U-City-based infrastructure	Review the feasibility of apply-ing ad-vanced technologies and test the neces-sity of smart cities	Establish plans for a smart city as a means of recovering areas affected by natural disasters
Key Participants	Local Government, Civilians, Enterprises	Central Government, Enter-prises	Local Government, Enterprises

5.3. The Implication of Zero Energy Towns and Smart Cities

Although zero energy towns and smart cities emerged at different times, the fundamental cause was planned as part of a solution to address population problems and energy depletion due to rapid urbanization. As one can see from each case, each can be viewed as a development activity through public-private participation for efficient city operation and operational development through energy production. In terms of zero energy towns, public-private participation is limited to the early stages of the plan as the entire city is operated through the primary production of new and renewable energy. On the other hand, the percentage of citizen participation is high in smart cities because the city is operated by regular public participation rather than by the priority production of energy. This is viewed as a result of the differences between the application of technology and social factors. In the case of zero energy towns where energy production is the main factor, there are positive aspects such as easy implementation with simplicity and large-scale support, and easy housing management for each module unit. However, as public-private participation is limited to the initial planning stage and as the role of the community in managing the town gradually decreases, plans are needed to supplement these issues. In the case of smart cities, while it is favorable to build ICT infrastructure and configure urban modules for each situation through continuous public-private participation, most of the plans are limited to presenting experimental models through new town planning.

6. Conclusion

This study performed the basic research on the trends of zero energy town and smart city application technologies both domestically and abroad for implementing future cities. Through each category, this study identified the correlation between energy production and public-private participation, and performed a case analysis for future city module design. The results are significant as data that can help people identify and prepare in advance for potential urban problems that may occur in existing cities.
First, the case of zero energy towns was classified by population density and the classification type was established according to the density. The correlation between energy production and public-private participation of zero energy towns was then derived by analyzing applicable new and renewable energy cases.
Second, this study compared and analyzed smart city cases based on the urban planning promotion strategies by continent, and derived the relationship between the smart city promotion goal and the major participants through the trends of plans and development of urban problems in each country.
Third, although zero energy towns and smart cities emerged at different times, the fundamental cause is considered to be due to urban problems. Therefore, this study analyzed the strengths and weaknesses of both cases to analyze the direction of future city models.
Fourth, zero energy towns seem to have a structure where the use of new and renewable energy is essential and public-private participation is limited to the early stage. On the other hand, as the efficiency of PV systems increase over time, it is possible to solve high-density energy with minimum equipment.
Fifth, smart cities have a high percentage of citizen participation because they operate the city through the management of ICT infrastructure and regular public-private participation rather than by the production of new and renewable energy.
This study compared and analyzed domestic and international cases of zero energy towns and smart cities, which were proposed as solutions to address existing urban problems. It also performed the basic research for the implementation of future cities by deriving their strengths and weaknesses. However, the limitations of this study are that most of the cases are focused on Europe, and that the domestic standard was applied as the density standard. Therefore, the data needs to be supplemented by related research. This study can find significance as basic research data for implementing future cities based on this analysis.

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