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SCALING UP CIRCULAR ECONOMY THROUGH SUSTAINABLE INFRASTRUCTURE

Case Study from China
Japan and Korea

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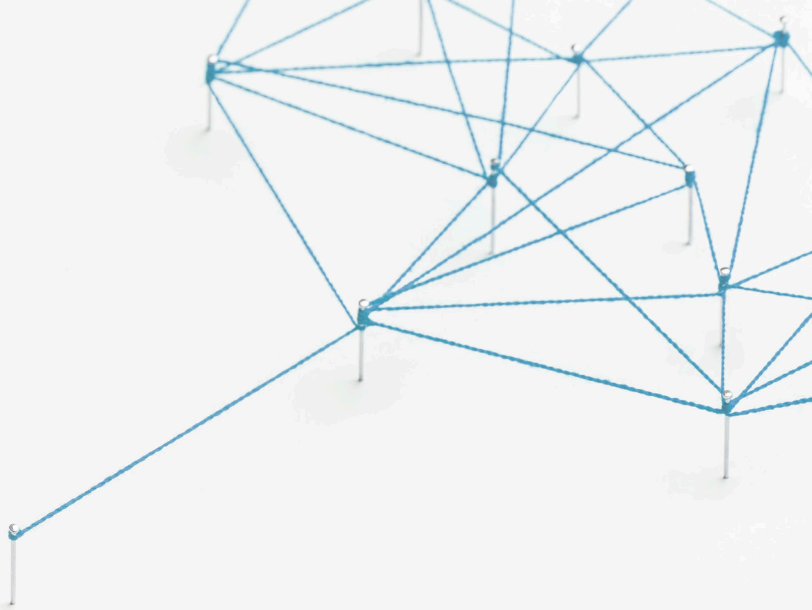

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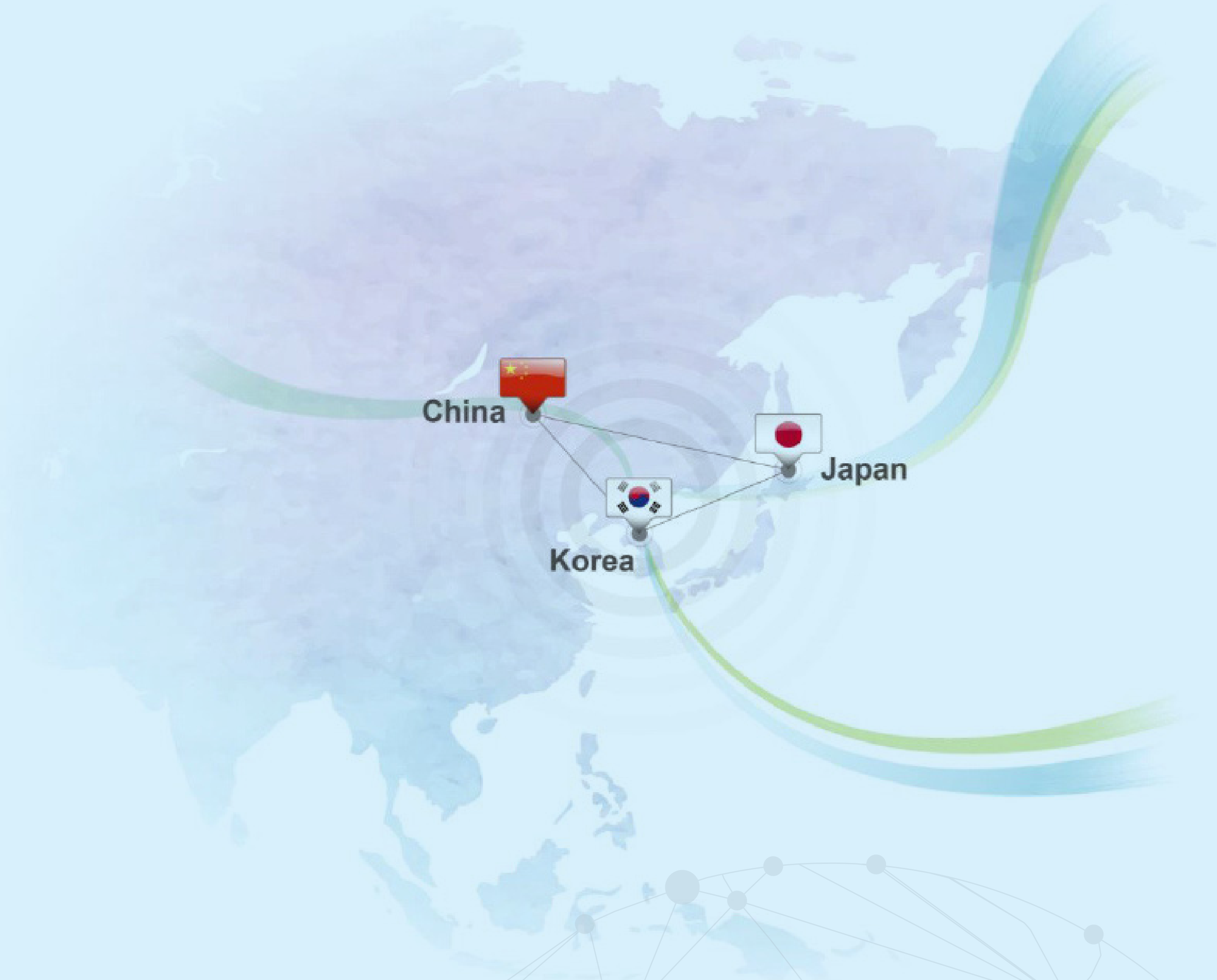
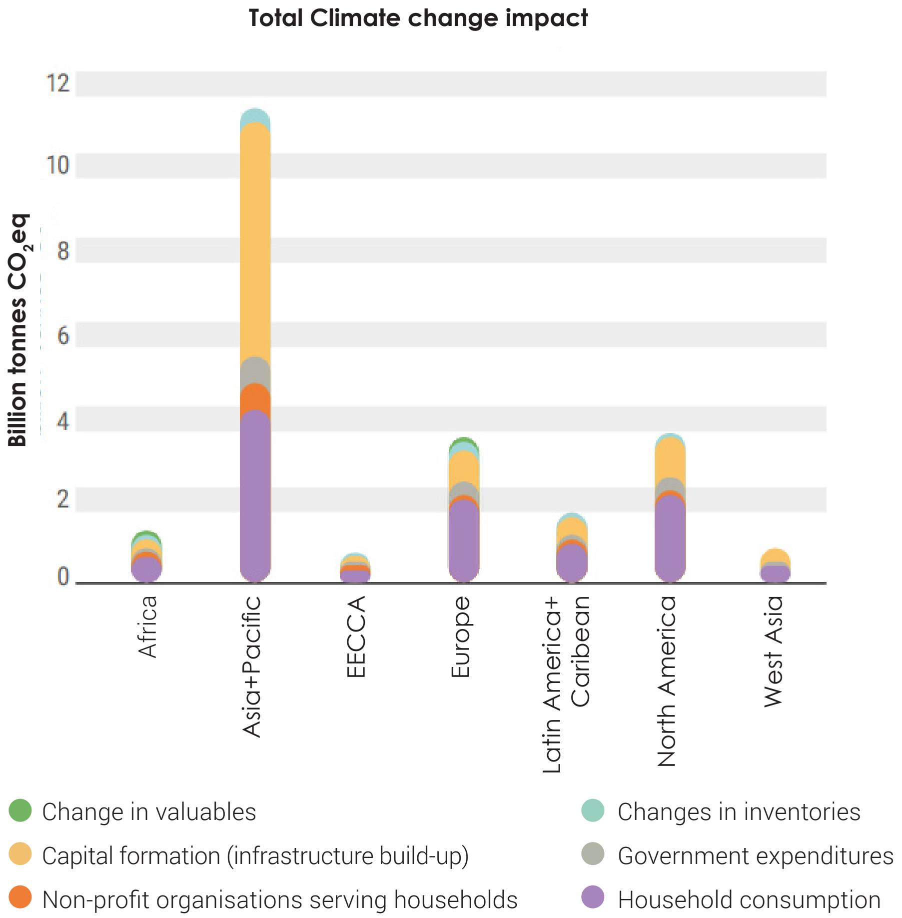


INTRODUCTION

Economic growth in many countries has, up until now, been based on the linear economic “take, make, and dispose” model. This has led to a tremendous increase in the extrac-tion of natural resources (biomass, fossil fuels, metals, and non-metallic minerals) on a global level in recent decades. In 2017, more than half of global natural resources demand originated in Asia and the Pacific . While hav-ing contributed to strong economic growth and improved welfare, resource extraction and processing have had adverse effects on the planet and its people. Resource extrac-tion and processing are responsible for more than 90 percent of both global biodiversity loss and water stress, and are major drivers of climate change. In emerging economies, particularly in Asia and the Pacific, the rapid increase in material resource extraction is mainly driven by the expansion of infrastruc-ture. This massive infrastructure build-up ac-counts for the largest share of total climate change impacts in Asia and the Pacific (see Figure 1-1).

Figure 1-1_ Climate change impacts according to final demand categories and regions



Source: International Resource Panel (2019)

[1] Bringezu, S., Ramaswami, A., Schandl, H., O’Brien, M., Pelton, R., Acquatella, J. et al. Assessing Global Resource Use: A systems approach to resource effi-ciency and pollution reduction. Nairobi, Kenya: Inter-national Resource Panel and United Nations Envi-ronment Programme; 2017. Available from: https://www.resourcepanel.org/reports/assessing-global-resource-use.

[2] Oberle, B., Bringezu, S., Hatfeld-Dodds, S., Hellweg, S., Schandl, H., Clement, J. et al. Global Resources Outlook 2019 - Natural Resources for the Future We Want. Nairobi, Kenya: International Resource Panel and United Nations Environment Programme; 2019. Available from: https://www.resourcepanel.org/reports/global-resources-outlook.

In addition to driving climate change through greenhouse gas (GHG) emissions, construction and operation of infrastructure is also responsible for the significant fraction of various other forms of waste generation and pollution. For instance, the building sector alone accounts for around 40 percent of sol-id waste generation in developed countries[3].

Decoupling natural resources use and waste generation from economic growth is, there-fore, essential to reduce pressure on ecosystems, the climate, and human well-being. Since this decoupling is the fundamental goal of a circular economy, implementing national and global circular economies is at the heart of achieving the aims of the Paris Agreement and the Sustainable Development Goals (SDGs). A circular economy can be defined as "one in which the value of prod-ucts, materials and resources is maintained in the economy for as long as possible"[4]. The circular economy concept aims to mini-mize resource extraction and waste genera-tion by closing the resources loop through reusing, repairing, refurbishing, remanufacturing, repurposing, and recycling[5] products, materials, and assets, and by increasing re-source efficiency.

Many countries around the world and, in particular, in Asia and the Pacific region which is increasingly experiencing the limits and adverse effects of the linear economic model and are gradually recognizing the substantial benefits of a circular economy. Countries such as China, Japan, and South Korea proactively established policy frameworks and regulations promoting the necessary shift towards a circular economy.

China started to incorporate circular econo-my principles in its 11th five-year plan (2006-2010). In 2009, China passed the "Circular Economy Promotion Law" which was "enacted for the purposes of facilitating [a] circular economy, raising resources utilization rate, protecting and improving [the] environment and realizing the importance of sustainable development"[6]. Moreover, the law presents the Chinese understanding of a circular economy that comprises "the activities of reducing, recycling and resource recovery in production, circulation and consumption". It also introduces circular economy principles designed to be considered in the building sector. The implementation of a circular economy in China extends, for example, from eco-designs, and product reuse and recycling systems at the micro (enterprise) level, to eco-industrial parks and industrial symbioses at the meso (inter firms) level, to urban symbiosis or renting services established at the macro (provincial regional, state and city) level. Despite these exemplary measures, public awareness on circular economy activities in China[7] is still relatively low.

Japan started to establish enabling laws for a circular economy and advancing the 3Rs (Reduce, Reuse, Recycle) in the early 2000's. Its circular economy transition is characterized by effective and very close

collaboration between consumers and manu-facturers and includes educational courses on environmental issues in schools, communities and companies. The implementation of a circular economy is mainly carried out at three levels: enterprises, industrial parks, and society in particular. Circular economy practices in Japan can even be described as a "lifestyle, making it not only an economic behavior, but also a social one"[8]. This holistic approach to a circular economy is also very much reflected in the concept of "Regional Circular and Ecological Sphere" (RCES), which was proposed in the Fifth Basic Envi-ronment Plan in 2018 and presented in detail in the Japanese case study included in this report.

In the 2000's, the Republic of Korea expand-ed its focus from recycling policies to broader resource circulation frameworks by announcing the "Act on Resource Circulation of Electrical and Electronic Equipment and Vehicles" in 2007 and the "Framework Act on Resource Circulation" (FARC) in 2018. While placing high importance on waste manage-ment regulations, Korea tries to increasingly promote society-wide participation in estab-lishing a circular economy and promoting sustainable consumption and production[9].

As outlined above, rapid infrastructure ex-pansion is a major driver of resource extraction, climate

[3] Bringezu, S., Ramaswami, A., Schandl, H., O'Brien, M., Pelton, R., Acquatella, J. et al. Assessing Global Resource Use: A systems approach to resource efficiency and pollution reduction. Nairobi, Kenya: International Resource Panel and United Nations Environment Programme; 2017. Available from: https://www.resourcepanel.org/reports/assessing-global-resource-use.

[4] Oberle, B., Bringezu, S., Hatfeld-Dodds, S., Hellweg, S., Schandl, H., Clement, J. et al. Global Resources Outlook 2019 - Natural Resources for the Future We Want. Nairobi, Kenya: International Resource Panel and United Nations Environment Programme; 2019. Available from: https://www.resourcepanel.org/reports/global-resources-outlook.

[5] UNEP Circularity Platform. Understanding circularity. Available from: https://buildingcircularity.org/ [Accessed 16 December 2020].

[6] Government of China. Circular Economy Promotion Law. 2009. Available from: https://www.greengrowthknowledge.org/national-documents/china-circular-economy-promotion-law.

[7] Ogunmakinde, O.E. A Review of Circular Economy Development Models in China, Germany and Japan. Recycling. 2019; 4(3): 27.

[8] Ogunmakinde, O.E. A Review of Circular Economy Development Models in China, Germany and Japan. Recycling. 2019; 4(3): 27.

[9] Korean Ministry of the Environment. Major Policies for Circular Economy in Korea and Global Cooperation Approach for Environmental Industry. Presentation at the 2020 Korea-World Bank Environmental Cooperation Forum; 2020. Available from: https://olc.worldbank.org/system/files/1.%20WBG%20KOREA%20WEEK_MOE%20PRESENTATION.pdf.

change and pollution in many countries. However, infrastructure underpins the entire economy and society as a whole, and is essential for human well-being. Therefore, incorporating the principle of circularity in infrastructure development can unlock great potential to not only make infrastructure more sustainable in general, but also to demonstrate and accelerate circular economy transitions around the world. Deploying inte-grated approaches to infrastructure planning using synergy between infrastructure systems, can lead to substantial economic and environmental benefits in terms of resource savings and waste reduction.

From 2021 through to 2030, an annual investment of US$ 6.9 trillion in infrastructure is estimated to be required to achieve the SDGs of the world's nations[10]. The economic stimulus packages developed and imple-mented by nations in response to the COVID-19 crisis present a valuable opportunity to direct investment towards greener growth and sustainable infrastructure, but these investments have so far fallen relatively short of what is necessary to fully embrace a transition towards a green and circular economy. Green investments support the economic recovery from the COVID-19 crisis in the short and medium term, but also ad-dress societal infrastructure needs in the long-run, while scaling-up a circular economy with its numerous benefits for the planet and people.

This collection of case studies presents exemplary frameworks and measures in China, Japan, and the Republic of Korea that mainstream circular economic principles through sustainable infrastructure in the building, transport and energy sectors. It outlines how these countries incorporate the principle of circularity in policy frameworks and infra-structure development, and how they are building the sustainable infrastructure that is necessary to establish circular economies. The report analyzes the development of green buildings in Shenzhen, China, elaborates on the Japanese "Regional Circular and Ecological Sphere" concept by providing a case study on the development of an inte-grated lightrail transit system in Utsunomiya City, and presents insights into the Korean "Future Waste Recycling System" for used electric vehicle batteries and decommissioned solar PV panels.

Together, these three case studies are aimed at encouraging other countries in the region and worldwide to proactively promote sustainable infrastructure development and circular economy frameworks, regulations, concepts, and laws.

[10] OECD. Investing in Climate, Investing in Growth: A Synthesis. Paris, France: OECD; 2018. Available from: https://www.oecd.org/environment/cc/g20-climate/synthesis-investing-in-climate-investing-in-growth.pdf.

Chapter **01**

Green Buildings in Shenzhen, China

EXECUTIVE SUMMARY

Achieving a Circular Economy is considered by Chinese decision makers to be a pathway to Ecological Civilization, the Chinese national strategy for sustainable development. Under the broader national policy framework of a Circular Economy, green buildings are promoted as a main focus area and include considerations of efficient land use, renewable energy supply, energy saving, water saving, resource efficiency, green construction materials, and construction waste management among others.

In the COVID-19 context, infrastructure investment is a dominant component of the stimulus package in China. Ensuring that infrastructure is sustainable is of vital importance for a green recovery. Green buildings, as a form of sustainable infrastructure, are one of the cross-cutting innovations that have the potential for a resilient economic recovery and decent jobs creation, and at the same time contribute to the circularity and sustainability of the socio-economy.

Shenzhen was the first city to develop green buildings in China in 2008. To date, it has become one of the few cities with the largest scale and density of "green buildings" in the country. The city's efforts in promoting green buildings include a holistic regulation and policy framework formulated over the years. Economic incentives, green and digital technology development, capacity building and international cooperation also play important roles in enabling the proliferation of green buildings in Shenzhen.

However, challenges persist: there is a lack of economic incentives and some are not easily accessible; construction waste management is still relatively inefficient; green buildings operations are difficult to realize due to higher costs; and consumers are not fully engaged in the green buildings industry.

To tackle these challenges and further boost the industry, Shenzhen is strengthening policy implementation through integrated approaches such as targeted support, subsidy reform, private sector engagement, and the integration of green buildings into sustainable urban planning.

This case study showcases the successful story of Shenzhen's development of green buildings, including good practices and lessons learned, as well as the exchange of knowledge and experience with other cities, provinces and countries. The study aims to inspire broader domestic and international audiences, especially policymakers, to help scale up the Circular Economy through sustainable infrastructure.

INTRODUCTION

The traditional linear economic growth model has created and exacerbated planetary chal-lenges such as climate change, land degra-dation and environmental pollution. In the context of social and economic recovery from the impacts of the COVID-19 pandemic, large-scale infrastructure investment is a common and traditional economic recovery mechanism that can stimulate investment and create jobs. Two keys to solving the afore-mentioned planetary challenges in China are: 1) ensuring the sustainability of infrastructure during its life cycle, and 2) changing the economic growth model to achieve a circular economy is one of the keys in solving these problems in China.

The term "circular economy" in this case study refers to China's National Development and Reform Commission's definition: "The Circular Economy is an economic growth model that conforms to the concept of sustainable development, with efficient and recycling use of resources at its core. It is based on the principle of reducing[11], reusing[12], and recycling[13], with low consumption, low emission and high efficiency as the basic characteristics."

According to the Ellen MacArthur Foundation's "The circular economy: a transforma-tive Covid-19 recovery strategy", investing in sustainable infrastructure will promote the circular economy as a pathway to achieve sustainable development. The document identifies 10 circular economy investment opportunities in 5 major sectors, and sustainable infrastructure cross sectors and ac-counts for more than half of them, including the renovation and upgrade of buildings, building materials reuse and recycling infra-structure (Ellen MacArthur Foundation, 2020).

Sustainable infrastructure is a very broad topic. The purpose of this case study is not to define sustainable infrastructure, but to use a type of sustainable infrastructure—green buildings—as an entry point to explore its various contributions to the realization of a circular economy. According to the "Assessment standard for green buildings (2019)" issued by the Ministry of Housing and Urban-Rural Development, green buildings are defined as high-quality buildings that save resources[14], protect the environment, reduce pollution, provide people with healthy, applicable and efficient use of space, and maximizes the realization of har-monious coexistence between human and nature.

Shenzhen is selected due to its pioneer sta-tus for green buildings in China, as well as its achievement of advanced progress - being one of the cities with the largest scale and density of green buildings in China. It's hoped that Shenzhen's success will stimulate further actions in green buildings and broad-er sustainable infrastructure at the domestic and global level to promote a Circular Econ-omy, and finally achieve the United Nations 2030 Sustainable Development Goals (SDGs).

This case study is divided into three major parts

1. National policy background
2. Shenzhen Green Building Case Study
3. Summary and Outlook

[11]The term "reducing" refers to reducing resource consumption and the production of waste in the production, circulation and consumption pro-cess,

[12]The term "reusing" refers to using wastes as products directly, using wastes after repair, re-newal or reproduction or using part or all wastes as components of other products.

[13]The term "recycling" refers to using wastes as raw materials directly or after regeneration.

[14]Land, energy, water and materials

1. NATIONAL POLICY BACKGROUND

China's urbanization and industrialization may have boosted the economy, but it was also responsible for acute problems that later emerged, including urban land use, greenhouse gas emissions, environmental pollution, and a decline in biodiversity. The continued urbanization process also promoted large-scale urban development and renovation activities. Correspond-ingly, the scale of construction waste continued to expand, from 1.6 billion tons in 2013 to 1.9 billion tons in 2017, accounting for 30%-40% of total municipal solid waste, while the recycling rate of construction waste was lower than 10% in 2017 (Qiu, Deng & Sun, 2017). The energy consumption of the building industry continues to rise. By 2020, China's building energy con-sumption had been projected to reach 1.09 billion tons of standard coal, more than three times the level in 2000.

1.1 POLICIES AND REGULATIONS

Since Chinese policymakers realized that circular economy surpasses the traditional end-of-pipe pollution control and can contribute to achieving ecological civilization[15] and sustainable development, China has been promoting the development of the Circular Economy on a large scale (Zhu, 2017).

In 2006, the Circular Economy concept was first included in China's 11th Five-Year Plan for National Economic and Social Development (2006-2010), where various pilot projects of Circular Economy were promoted, including green construction, green building material, and building energy and water efficiency. In January 2009, the "Circular Economy Promotion Law" was for-mally implemented, providing legal protection for the development of the Circular Economy. The Law also stipulates the entire life cycle of building materials and buildings, involving energy saving, water saving, land saving, and material saving. The Law encourages the use of renewable energy, the use of solid waste to produce building materials, better building maintenance and management to extend the service life of buildings, and the comprehensive utilization of construction waste.

In the 13th Five-Year Plan (2016-2020), Section 5 of Chapter 43 (Promote Economic and Inten-sive Resource Utilization) is focused on developing a Circular Economy. The Plan also recog-nizes the positive role of green buildings in green urbanization, resource and energy efficiency,

[15] Ecological Civilization" is a Chinese concept for a sustainable development framework. It is defined as: "a resource efficient and environmental-friendly society, based on the carrying capacity of the environment, observing the law of nature and aimed at realizing sustainable development".

and environmental protection. In the 14th Five-Year Plan (2021-2025), Section 2 of Chapter 39 (Accelerate the Green Transformation of Development Mode) is focused on promoting the Cir-cular Economy and establishing a resource recycling system. Green buildings are integrated in the broader concept of urban planning, resource efficiency, low carbon development, waste management, and construction safety.

1.2 GOALS AND RESULTS

To date, China has made significant achievements in the development of the Circular Economy. The upstream policy design has been formed, the institutional framework has been continuously improved, and the economic system has been established at an accelerated pace, showing benefits in terms of natural resources, the environment, and socio-economy.

As of 2016, there were 20 million employees in the recycling industry, and nearly 260 million tons of various wastes were recovered or recycled in that year. Compared with the use of primary resources, nearly 200 million tons of standard coal were saved, and 9 billion tons of wastewater and 1.2 billion tons of solid waste were reduced.

According to the National Bureau of Statistics, the output value of the resource recycling indus-try increased from 1.5 trillion yuan in 2014 to 2.3 trillion yuan in 2016 (National Bureau of Statis-tics, 2017). In 2017, 14 Ministries including the National Development and Reform Commission and the Ministry of Science and Technology jointly issued the "Initiative to Guide Circular Development", with the target that the output value of the resource recycling industry will reach 3 trillion yuan by 2020.

Furthermore, the Initiative includes a series of important indicators. For example, by 2020, the comprehensive utilization[16] rate of general industrial solid waste will reach 73%. According to the 2020 Statistical Yearbook, this rate was 53% in 2017.

The Initiative also sets the goal of developing sustainable infrastructure and green buildings, aiming to increase the utilization of construction waste; and implement green building standards in government buildings.

In July 2020, The Ministry of Housing and Urban-Rural Development and 7 other departments jointly issued the "Green Building Establishment Action Plan". This specified that "By 2022, the proportion of green buildings out of the total of newly-constructed urban buildings will reach 70%. The energy efficiency level of buildings will be continuously improved, and the applica-tion of green building materials will be further expanded (Ministry of Housing and Urban-Rural Development, 2020)."

If the green building standard is fully implemented, it is estimated that by 2020, 420 billion kWh of electricity and 260 million tons of standard coal will be saved each year, and 846 million tons of greenhouse gas emissions will be avoided. Moreover, in China, compared with traditional building construction, the operation and maintenance cost of buildings with circular architectural design is estimated to be reduced by 10% by 2030 and 28% by 2040 (Ellen MacArthur Foundation, 2018).

These results and figures reflect the contribution of green buildings to the transition into a Circular Economy in China, and to eventually achieving ecological civilization and sustainable de-velopment, especially SDG 12: responsible consumption and production. In addition, it also contributes to SDG 6: Clean water and sanitation; SDG 7: Affordable and clean energy; SDG 8: Decent work and economic growth; SDG 9: Industry, innovation, and infrastructure; SDG 11: Sustainable cities and communities; SDG 13: Climate Action, etc.

[16] Through recycling and processing, solid waste is converted into usable resources, energy and other raw materials such as agricultural fertilizers, building materials, and road construction materials.

1.3 GREEN BUILDINGS AND THE CIRCULAR ECONOMY IN THE CONTEXT OF THE COVID-19 PANDEMIC IN CHINA

At the beginning of 2020, as the novel coronavirus disease swept across China causing market demand and production to plummet, almost all industries were significantly affected. To ease economic pressure and maintain GDP growth, the Chinese government introduced plans to stimulate investment through public financial expenditure, especially infrastructure investment. According to China Economic Weekly, the total scale of cumulated major investment projects in China in 2020 would reach 49.6 trillion yuan, of which the newly planned investment for 2020 alone would be 7.6 trillion yuan, with infrastructure investment comprising the majority (Xie, 2020).

In the context of COVID-19, green buildings have better air quality, water supply and sanitation, waste separation and barrier-free accessibility which have a positive impact on overall well-being and health. (Wang et al, 2020). Green building ventilation and air quality requirements can reduce the health risk from indoor air pollution and COVID-19 contamination. Clean water fol-lowing national standards is also essential, and water sealing in the drainage systems prevents harmful substances and viruses in the gases from escaping into the atmosphere. Waste sepa-ration and collection systems can ensure the separate collection, transportation, and treatment of household COVID-19 medical waste, preventing and controlling the secondary spread of viruses. The passages in green buildings are usually barrier free, directly connected to the out-side of the building, making it easier for medical crews and ambulances to manoeuvre during an emergency (Dai & Meng, 2020).

From the socio-economic recovery point of view, investment in green buildings is expected to bring opportunities for a greener recovery. In China, the market size of green buildings is esti-mated to be as high as 15 trillion yuan in 2016 and up to 200 jobs can be created for every one million US dollars invested in transforming existing buildings (Yang, 2018). The scale of China's construction waste treatment and recycling industry increased from 27 billion yuan in 2017 to 30 billion in 2018, with still less than a 10% recycling rate. There's a huge missed opportunity. Meanwhile currently in China, green building materials only account for 10% of all building ma-terials, with an estimated market size of 350 billion yuan. There is still significant potential for growth, which will, in turn, benefit and stimulate the construction industry's green technology research and development, green industrial design, etc. In this national context, Shenzhen's green buildings represent an important example for analysis and advancement.

2. SHENZHEN GREEN BUILDINGS

2.1 POLICIES AND MEASURES OF GREEN BUILDINGS IN SHENZHEN

In 2008, Shenzhen put forward the goal of "creating a city of green buildings". Since then, it has been undertaking national pilot tasks in large-scale public building energy consumption monitoring, renewable energy building applications, construction waste reduction and utilization, public building energy-saving renovation, and prefabricated building applications. In addition, Shenzhen has issued a series of policies to help the development of green buildings, shown below in Table 1-1.

Table 1-1_ policy and regulation framework of green buildings in Shenzhen

Name	Year
Shenzhen Building Energy Conservation Regulations	2006
Shenzhen Implementation Plan of Systems Development of Circular Economy	2006
Action plan for building a city of green buildings	2008
Shenzhen Construction Waste Reduction and Utilization Regulations	2009
Twelfth Five-Year Plan" for Building Energy Efficiency and Green Buildings in Shenzhen	2011
Shenzhen Green Building Promotion Measures	2013
Shenzhen Construction Waste Management Measures	2013
Notice on the full implementation of green building standards in newly-constructed housing projects	2013
Shenzhen's 13th Five-Year Plan for a Circular Economy	2016
Shenzhen's 13th Five-Year Plan for Building Energy Efficiency and Green Buildings	2016
Shenzhen's Green Building Quantity and Quality Upgrade Three-year Action Plan (2018-2020)	2018
Green Building Evaluation Standard	2018
Shenzhen Construction Waste Reduction and Comprehensive Utilization Incentive Measures	2020

2.2 ECONOMIC INCENTIVES OF GREEN BUILDINGS

The Shenzhen Green Building Promotion Measures included major economic incentives. The Shenzhen Municipal Finance Department has set up a special fund to support the development of green buildings. The fund has a dedicated green building technology development section. In addition, Shenzhen has set up a green building and construction technology innovation award every three years to reward, highlight, and accelerate regional innovation. Buildings can also undergo a free evaluation by the City of Shenzhen to determine if they can be called "green". Green buildings that have passed the assessment can apply for financial subsidies from the national and municipal level at the same time. Green building technology and green building materials, especially locally-produced materials, are included in the priority public pro-curement list.

On the other hand, if construction fails to meet the Assessment Standard for Green Buildings (2019), or when indoor pollutant concentration and/or energy consumption are not properly monitored after delivery of construction, the responsible parties may be fined 20,000 to 300,000 yuan.

In construction waste management, financial subsidies, land use arrangements, rent reduction and exemption, public procurement and other incentive measures are applied to promote the development and growth of the construction waste recycling industry. The estimated budget for the annual construction waste reduction and recycling economic incentives is 375.8 million yuan, with 4.8 million yuan allocated for capacity building (Shenzhen Housing and Construction Bureau, 2019).

2.3 MEASURES AND RESULTS OF GREEN BUILDINGS

2.3.1 Overall status

Shenzhen has implemented the green building standards for all new buildings as of 2018. In 2018 alone, 20 million square meters of green buildings were newly-built (China Construction News, 2019). By the end of the year, a total of 1,030 projects in Shenzhen passed the green building assessment, with a total area of over 93.4 million square meters.

At present, Shenzhen has formed a green building industry cluster with a scale of over 100 bil-lion yuan. The business of local enterprises expanded to the regional Guangdong-Hong Kong-Macao Greater Bay Area on a national and international level, sharing Shenzhen's achievements in the field of green buildings.

Box 1-1 Shekou Cruise Center

Shenzhen Shekou Cruise Port is a high-rise building with internal functions integrating land transportation, customs clearance services, offices, commercial spaces, coastal leisure activi-ties, and supporting services. The concept of green and environmental protection is run through the whole life cycle of project design, construction and operation.

Considering the building envelope, air conditioning equipment, lighting equipment, energy-saving elevator, water-saving appliances, water-saving irrigation, light pipe technology and oth-er green building measures, this building can save 1,735,400 kWh of energy and 89,000m³ of water per year, reducing consumer and commercial expenditures of 2.13 million yuan annually. Compared to baseline building scenarios, these measures can save 701.1 tons of standard coal, reduce CO_2 emissions by 1730.2 tons, reduce SO_2 emissions by 52.06 tons, and reduce NO_x emissions by 26.03 tons.

Source: Shenzhen Green Building and Building Energy Efficiency Development Annual Report (2018)

Government Key Performance Indicators

The local government plays a significant role in advancing the development of Green Buildings in the Chinese context. To this end, the Shenzhen Government has established a mechanism to incorporate the progress of local Green Buildings development into government performance assessment. This includes a set of 23 green building indicators to quantitatively measure the progress, as part of criteria in implementing Ecological Civilization strategies locally.

Table 1-2_ Green building indicators in the local government performance assessment

Type	No.	Entry			Unit
Energy saving and emissions reduction	1	Proportion of energy saved in buildings compared to total energy saving in the city			%
	2	Energy saved			10,000 tons of standard coal
	3	Water saved			10,000 tons
	4	Land use saved			10,000 mu
	5	Building materials saved			10,000 tons
	6	Construction waste reduction			10,000 tons
	7	CO2 emissions reduction			10,000 tons
Energy saving and green develop-ment	8	Building energy efficiency	Energy efficiency compliance rate of new build-ings		%
	9		Energy-saving renovation area of existing build-ings		10,000 m^2
	10		Energy-saving supervision system	Energy auditing	/
	11			Energy consumption monitoring	/
	12			Data center	/
	13	Green building	Green building ratio	Government invested building	%
	14			Public building	%
	15		Green building area		10,000 m^2
	16		Green property management	Existing building area	10,000 m^2
	17			New construction area	10,000 m^2
	18	Green Industrial Parks			/
	19	Renewable energy building applications	Application area of solar thermal system in new buildings		10,000 m^2
	20		Application area of solar thermal system in existing buildings		10,000 m^2
	21		Increased installed capacity of solar photovoltaic systems		MW
	22	Recycling rate of construction waste			%
	23	Capacity building			/

Energy saving

In 2011, Shenzhen was approved as one of the first cities in the country for piloting energy-saving renovation of public buildings, under the guidance of the Ministry of Housing and Ur-ban-Rural Development and the Ministry of Finance, focusing on office buildings, medical and health care infrastructure, shopping malls, supermarkets, and hotels. Specific renovations in-clude double-paned windows, better insulation, more efficient lighting, passive cooling sys-tems, etc. As of 2018, 187 energy-saving projects at public buildings have been implemented in Shenzhen, with a renovation area of 8.32 million square meters. It is expected that after the completion of all the projects, 80 million kWh of energy will be saved each year, with an annual reduction of 76,000 tons of carbon dioxide (Qianzhan Industry Research Institute, 2019).

Box 1-2 China Construction Steel Structure Building

The project is a super high-rise building integrating underground parking, ground-level commercial spaces and high-rise offices. A heat recovery system was one of the 20 technologies used in this project. The use of the heat recovery system for air conditioning and ventilation in the project can save about 288,437 kWh of electricity throughout the year. Building lighting mainly uses energy-saving and high-efficiency fluorescent lamps that can be centrally-controlled by an intelligent lighting system. The building also uses a solar photovoltaic power generation system with a total capacity of 68.15kW. In total these measures reduced operating costs by about 1.2 million yuan per year.

Source: Shenzhen Green Building and Building Energy Efficiency Development Annual Report (2018)

Renewable energies

In 2009, Shenzhen became one of the first demonstration cities for renewable energy in build-ings, as approved by the Ministry of Finance and the Ministry of Housing and Urban-Rural Development. Shenzhen has since explored renewable energy production and usage technolo-gies, primarily with solar energy, but also biomass and geothermal energies. Promotion measures include using policy and economic incentives (see chapters 2.1 and 2.2), publishing technical standards, adopting lifecycle management of operations and communication strate-gies to the public.

The application area of solar-heated water buildings in Shenzhen increased from 7 million square meters in 2016 to 15 million in 2018, with installed capacity of solar photovoltaic power of 46.8 MW in 2018. According to an energy efficiency evaluation conducted by the Shenzhen Academy of Construction Sciences, these specific solar-heated water projects can result in annual savings of 19,000 tons of standard coal, 47,000 tons of carbon dioxide emissions, 383.1 tons of sulfur dioxide emissions, and 191.6 tons of particulate matter emissions (Shen-zhen Special Zone Daily, 2017).

Greenhouse Gas Emissions

The Government's drive to encourage energy conservation and the deployment of renewable energies would lead to greenhouse gas (GHG) emissions reduction through a reduction in energy consumption and a change of energy mix. In addition, Shenzhen is the first city in China to compile, publish and implement energy consumption quota standards and technical specifica-tions and guidance documents. These include "Specifications and Guidelines for Quantification and Reporting of Greenhouse Gas Emissions in Buildings (Trial)" and "Verification Specifica-tions and Guidelines for Building Greenhouse Gas Emissions (Trial)". By 2018, carbon verifica-tion of 913 government office buildings and large public buildings in the city was completed, and 315 building carbon quotas were issued.

Waste management

As of 2018, Shenzhen has built 5 projects that include the comprehensive utilization[17] of construction waste, with a total treatment capacity of 5.2 million tons. As of 2019, Shenzhen has built 15 construction waste recycling facilities, with a total processing capacity of 14.65 million tons/year (Li, et al, 2019).

According to the "Shenzhen Construction Waste Management Measures", the Department of Housing and Urban-Rural Development of Shenzhen will coordinate and manage the disposal of construction waste. Previously, the default action was to dispose of construction waste in city landfills. Today, measures include transition with water transport, comprehensive utilization, engineering backfill, temporary and fixed disposal in landfill sites, with new management meth-ods such as disposal approval, transport and landfill records and electronic manifests to real-ize tracking of construction waste information along the entire chain.

[17] Through recycling, processing, recycling, or exchange, extract from solid waste or convert it into usable resources, energy and other raw materials, such as agri-cultural fertilizers, production of building materials, and road construction.

Green and recycled building materials

Specialized enterprises use construction waste generated from demolition and construction entities as raw materials to produce recycled building materials. These recycled materials are certified and prioritized for procurement in public buildings and are encouraged in private ones, through the policies and incentives mentioned in chapters 2.1 and 2.2.

Besides recycled materials, other raw building materials that have lower carbon emissions or higher energy and resource performance are also included in the whitelist of certified green building materials that are promoted through policies and incentives.

Box 1-3 Horizontal Skyscraper – Vanke Center

The Horizontal Skyscraper, completed in 2009, is a mixed-use building on the outskirts of Shenzhen, consisting of offices, a conference center, restaurants, an auditorium, a hotel, apartments and a large public park. It is one of the first batch of green building demonstration projects in Shenzhen.

Materials saving is realized through the use of high-performing reinforced concrete and the recycling (45%) of construction wastes during construction. 29.4% of the materials used for construction were recycled from previous buildings. Interior designs also include sustainably-sourced bamboo.

source: "Shenzhen Green Building Case Selection"

Water saving and recycling

Water efficiency is integrated in the planning, design, construction, operation, maintenance, and decommissioning of a green building's life cycle. For example, green buildings should be equipped with water-saving appliances (Shenzhen Housing and Construction Bureau, 2012).

Box 1-4 Shenzhen Kehua School

This building integrates green building technology from the planning and design stage to create a green school that includes many efficiency measures that include multi-layered greening, re-claimed water recycling, rainwater utilization, energy-saving, efficient air conditioning and light-ing, material saving optimization designs, natural ventilation and lighting, and indoor pollutant concentration monitoring.

The building uses water-saving appliances. Water-saving high-pressure water guns are used for garage work and road-cleaning operations, while a micro-sprinkler irrigation system is used in outdoor landscaping. Two non-traditional water sources, rainwater and reclaimed water, are also integrated and comprise 51.97% of total water used. The former is used for underground gar-age flushing, irrigation and road and square watering; the latter is used for toilet flushing in the classroom, restaurants, and the dining room.

Source: Shenzhen Green Building and Building Energy Efficiency Development Annual Report (2018)

The water recycling system for green buildings in Shenzhen can also ease the burden of munic-ipal water use. The water used for landscape irrigation within or around green buildings is main-ly rainwater collected from rooftops, saving 45,700 tons of water annually, and is supplement-ed by recycled water. Constructed wetlands around green buildings are a compelling example of a nature-based solution, as they collect sewages and purify them through biodegradation, recycling up to 200 tons of water per day. The recycled water can be used for local irrigation, cleaning, and other purposes.

Digital solutions

Shenzhen has built a real-time online platform for monitoring the building energy consumption of 599 public buildings (Shenzhen Housing and Construction Bureau, 2019). Since 2017, Shen-zhen has released an annual report analyzing energy consumption data at public buildings, providing targeted energy-saving renovation suggestions, promoting measures such as stand-ardizing energy use behavior, optimizing systems operations, and improving operational man-agement systems to reduce building operations energy consumption.

In addition, the Municipal Housing Construction Bureau of Shenzhen also developed the "Shen-zhen Construction Waste Smart Supervision System" based on a GPS positioning system of dump trucks and the input of electronic data of construction waste. Through this system, the entire life cycle of construction waste - including discharge, transportation, transfer, backfill, acceptance, utilization, etc. - can be monitored to realize a closed loop starting from the source of construction waste through transportation routes to end with disposal management.

Figure 1-2_ a snapshot of the monitoring system

Source: Shenzhen Housing and Construction Bureau

The system's data sharing mechanism covers all levels of supervision departments, including housing construction, transportation, water affairs, traffic police, etc., and other users such as construction agencies, waste treatment agencies, and vehicle transportation agencies. This en-sures multi-departmental data sharing and interconnection.

Meanwhile, enterprises in the green buildings sector are encouraged by the government policies to increase the R&D, application, and promotion of information technologies such as Building Information Modeling, the Internet of things (IoT) and virtual simulation technologies to increase efficiency. The industry is also encouraged through government policies to transform itself towards design digitalization, production automation, intelligent operation, electronic businesses, service customization to improve information interaction efficiency, and comprehensive man-agement of the entire industry chain.

2.3.2 Professional development and capacity building

The government of Shenzhen promotes and offers professional skills training and qualification management for green building practitioners and enterprises. It co-organizes energy-saving and green building business training courses with the provincial and municipal construction bureaus. Additionally, it carries out special training for construction teams of green buildings, technical personnel, design, supervision personnel, energy equipment management personnel, govern-ment managers and related enterprises, so that employees and enterprises can upgrade their technology competency to improve the effectiveness of their work.

In 2014, the Shenzhen Green Building Association established the Professional Qualifications Evaluation Scheme for granting professional titles for green building engineers. This has filled the gap in the evaluation of green building technical personnel. As of 2018, 277 technical per-sonnel have earned accreditation, with 90 accredited in 2018 alone. This has encouraged the professionals in the green building sector to improve the overall level of technical knowledge and experience and also cultivated young talents.

The Shenzhen Construction Science and Technology Committee has recruited 18 green building experts in the field of architecture, HVAC, electrical automation, water supply and drainage, structure, and building physics. These experts are responsible for providing much-needed de-cision-making and technical support to the government. The Shenzhen Green Building Associa-tion also recruited over 300 experts since it established its expert committee in 2016, offering opportunities for peer learning.

2.3.3 Collaboration and outreach

Shenzhen takes the lead in organizing, participating in, and carrying out major domestic and international exchange activities including the International Green Building and Building Energy Conservation Conference and New Technology and Product Expo, the China International High-tech Achievement Fair, and the International Low Carbon City Forum. For example, the Shen-zhen International Green Building Industry Exhibition is co-organized by the central, provincial, and local governments every year, covering the entire value chain of green buildings and offer-ing a platform to exchange information and create business opportunities on the green design of buildings, green building parts and materials, and green construction technology, products and services.

Shenzhen also works to strengthen exchanges and cooperation with green building organiza-tions in other cities, provinces, surrounding regions as well as internationally, including with the British Building Research Institute (BRE) and German Energy Agency (dena).

Through energy conservation week and other activities, various forms of publicity and promo-tional activities have been carried out. Various media and organizations also reported on Shen-zhen's work in green buildings promotion and other fields, introducing the latest developments in the industry to practitioners and the public to raise awareness on green buildings.

2.3.4 Integrated urban planning

The development of green buildings in Shenzhen is forming a trend from point to surface, from single unit to areas such as ecological industrial parks and sustainable districts. Shenzhen is establishing a policy and technical support system for green city construction as a key direc-tion for the next step of green development, to improve the level of sustainable urban con-struction.

2.4 CHALLENGES AND OPPORTUNITIES

Construction waste recycling

In Shenzhen, construction waste recycling projects are usually built next to construction waste landfills, mainly utilizing inert materials such as waste concrete and waste bricks. However, construction waste is not disposed of separately, and construction workers on the whole do not have proper training on environmental impact and resource consumption. Other garbage such as peels, plastics, wood, metal, etc. are mixed with construction waste, making the sort-ing and reuse process difficult and inefficient. Adding to the challenge, construction waste re-cycling plants are relatively small and a lot of energy is needed to crush waste. All these fac-tors make the costs of recycled building materials relatively high, hence the price lacks com-petitiveness. Meanwhile there is no mature price compensation mechanism, e.g. subsidies, for these products. At present, most companies that handle recycled building materials are still operating at a loss.

Shenzhen's policies to promote the comprehensive utilization of construction waste include a special grant for the development of energy-saving and environmental protection industries, special support measures for green building development, and detailed industrial development special funds to support green development. However, the incentives and policy support for emissions reduction and comprehensive utilization of construction waste are relatively on a macro public policy level. Due to a lack of specific implementation methods and coordinated management and supervision which makes it difficult to implement at ground level, these policies have not been well-executed.

There is still a gap between the provisions of the provincial regulations and the municipal-level utilization management methods. Addressing this gap would help enterprises in the industry to comprehensively access reductions, exemptions, and preferential treatment in terms of finance, tax and land use as intended. Tax refunds are difficult to carry out due to the lack of a com-prehensive catalogue of tax incentives. Land use approval and environmental assessment for construction waste recycling projects are perceived as additional challenges to the industry's development.

Shenzhen's policymakers continue to establish city standards and systems for construction waste reduction and recycling. The city also aims to increase green building materials demand through policy enforcement or incentives, and by promoting circular economy models in the construction process. This includes refining management policies for source control (construc-tion waste regulations, special plans, government KPI, review and auditing systems, fees and fines policies), recycling (land use policy, recycled goods standards, demonstration projects) and recycled material use (product certification and promotion, green public procurement). Stronger and more targeted economic incentives in various forms are also needed to continue the efforts in supporting this industry.

Green Buildings Promotion

Green buildings certifications can be categorized for green building design and green building operations. Currently, there are much fewer buildings in Shenzhen certified as green operations than those certified as a green design due to higher costs and management requirements as-sociated with the former. Meanwhile, operations account for 80% of energy consumption during a building's lifespan and increasing green operations is one of the major areas that need to be improved. However, in 2019, three project developers in Shenzhen reportedly preferred to give up green buildings subsidies than continue green building operations, such as using solar panels and reclaimed water facilities. This reflected the high operational cost of green buildings, but also highlighted the potential issues of the subsidies lacking economic theory and technical systems support.

Discussion on subsidy reform is ongoing in Shenzhen, as direct payment transfer may not always be the best solution. Areas of potential reform include scope, focus, amount, and variety. Options could be loan discount funds, price risk funds, or focusing on industry R&D. Further-more, consumers are not perceived as playing a meaningful role in this industry. There is a general lack of awareness, and residents cannot properly experience the benefits of green op-erations of these buildings because there are so few of them. The driving force of the industry still lies on the government policies and incentives to the project developers.

Shenzhen is considering improving the green operation of schools, hospitals, and community projects that are more accessible to the people, while - at the same time - focusing on cultivat-ing and creating a portfolio of high-standard "small and beautiful" green building projects. These could become Shenzhen's green city "business card", strengthening publicity through public awareness activities. In the meantime, Shenzhen is exploring opportunities to encourage participation in private sector investment through Public Private Partnerships (PPP) and other instruments.

3. SUMMARY AND OUTLOOK

In the past 15 years, the development of green buildings in Shenzhen has shown multiple synergetic benefits in economic growth, social inclusion, jobs creation and environmental protection—including pollution prevention, resource efficiency and GHG emissions control. These have contributed to Shenzhen's transition to a Circular Economy and the city's efforts to con-struct an ecological civilization, the Chinese framework for Sustainable Development.

In the COVID context, in order to ensure that the government's fiscal stimulus plan for socioeconomic recovery will be consistent with ecological civilization, the 2030 Agenda for Sustain-able Development and the Paris Agreement, these plans should encourage the use of the latest green technologies, invest in environmentally-friendly industries, make reasonable adjustments to existing infrastructure and built facilities that reduce disaster risk. Shenzhen's promotion of green buildings brings further opportunities to break through traditional linear infrastructure business models, in order to fundamentally strengthen the compatibility of society and the economy with the environment, making the region more resilient to natural disasters and global crises.

Shenzhen's endeavor in green buildings development has also had spillover effects on neigh-boring cities or provinces, incentivized by the growth of the industry and the market. Other cit-ies and provinces in China have also learned from Shenzhen's experiences and lessons, and have replicated this development model, including a comprehensive policy and regulation framework supported by economic incentives, capacity building, the raising of public awareness and regional and international cooperation. The green buildings development progress is also included in the local government KPI, integrating criteria such as energy saving, renewable energies supply, GHG reductions, waste management, green and recycled building materials, water conservation and recycling, etc., which are also assessment criteria in the green buildings standards. Digital solutions were also adopted by different stakeholders in various stages of the value chain of the green building industry, ranging from online energy monitoring and con-struction waste supervision by the local government, to Information and Communications Tech-nology (Building Information Modeling, the Internet of Things, Artificial Intelligence, Augmented Reality, simulation, etc.) by the industry.

Challenges remain, including insufficient or inaccessible economic incentives; relatively inefficient construction waste management; difficult and expensive green building operations; and a lack of engagement with consumers and the private sector. Shenzhen is exploring multiple pathways to tackle these challenges and further boost the industry through strengthening policy implementation with integrated approaches, including targeted support, subsidy reform and private sector engagement of various kinds, while integrating green buildings into wider sus-tainable urban planning.

Chapter **02**

Achieving the Regional Circular and Ecological Sphere in Japan: A case study on the development of a light-rail transit system in Utsunomiya City

EXECUTIVE SUMMARY

Japan is facing demographic challenges of declining birth rates, an aging population and an uneven population distribution concentrated mainly in megacities. These trends have weakened local economic growth and the capacity of local governments in the conservation of ecosystems and their ser-vices. To address the social, economic and environmental issues, the concept of Re-gional Circular and Ecological Sphere (RCES) was proposed in the Fifth Basic Environment Plan (2018). RCES is a new model of economic growth aimed at building an environmentally-sound and economically-viable sphere through the circulation of natu-ral, human and financial resources across neighboring regions.

In the RCES, mountainous, agricultural and fishing villages provide natural resources and relevant ecosystem services to cities. Through consumption and providing human and financial resources, cities support the production and ecological conservation in the rural areas. Self-reliant and decentralised economic development is expected to be achieved through local production for local consumption and strengthening partnership between rural areas and cities.

Local governments have developed various approaches and pilot projects for achieving RCES which can be summarized in three major areas. These include: i) supply and use of renewable energy to support public services, including governmental organisations, schools, hospitals, and public transportation; ii) building recycling systems and utilisation of recyclable resources; and iii) utilisation of various ecosystem services that are formed by forests, villages, rivers, and the sea. De-pending on the actual situation, circularity can be achieved within a specific rural area, within a city, or through collaboration between cities and rural areas.

In this paper, the development of a light-rail transit (LRT) system in Utsunomiya City is selected for a case study to demonstrate how sustainable infrastructure and related services play a key role in achieving the RCES. The LRT system has gained a high strategic position in both the 6th Utsunomiya Comprehensive City Plan (2018-2027) and the 2nd Utsunomiya Urban Transportation Strategy (2019-2028) for achieving a network-type compact city. The LRT is a next-generation public transport system powered by local renewable energy generated from waste. With improved services and enhanced con-nections with other public transport systems and other means of transportation, the LRT system will enable access for everyone, particularly senior citizens, and meet their mobility needs. The LRT project including connect-ed public transport systems will introduce

MaaS (mobility as a service) and CASE (IOT and AI-based connection, autonomous driving, sharing and electrification) to optimize transport services and make mobility more comfortable and convenient, and emitting less carbon. This service which will link various functional areas of Utsunomiya City together, including industrial parks, central ur-ban areas and tourism areas, and the con-struction of transit centres with multiple functions, will no doubt help to create jobs and revitalize the local economy.

While providing convenient, comfortable and sustainable mobility services for achieving SDG Target 11.2 on sustainable transport system, the LRT project will help achieve other SDG targets including the promotion of renewable energy

(Target 7.2), decarbonisa-tion (Target 13.2), sustainable tourism (Target 8.9), sustainable industrial development (Tar-get 9.2), women's employment (Target 10.2), living conditions (Targets 9.1 and 11.1), sus-tainable infrastructure (Targets 9.1), waste generation and reduction (Targets 12.3 and 12.5), public participation in community de-velopment (Target 17.7) and access to all levels of education (Targets 4.3, 4.7).

Financially supported by the national gov-ernment, similar LRT projects are under de-velopment in many other cities in Japan which can learn the experiences from the LRT project in Utsunomiya City. Some important factors for the development of sustainable infrastructure based on the experiences learned from this case study are summarized as follows:

- Development of sustainable infrastructure based on a shared long-term vision or relevant governmental development plans and strategies is a success factor.
- Linking infrastructure projects with other services/activities and urban planning to create multiple synergies beyond individual construction projects is the key to maintaining economic sustainability.
- Governmental financial support for nurturing the development of new models and innovations is important to promote pioneer projects.

INTRODUCTION

With Japan's declining birth rate and its aging population, the decreasing population is being unevenly distributed throughout the country, with a high population density in mega-cities. These trends have weakened the local economy and hindered the proper func-tioning of local governments, including eco-logical conservation areas. Due to the de-crease in the number of farmers and forestry workers, the number of abandoned cultivated land have increased and forests have been poorly maintained. Together with a decrease in the number of hunters, damages from wild birds and animals to villages and agriculture are becoming more serious[18]. Many areas have become more vulnerable to natural dis-asters. Nature-rich areas, such as Satochi and Satoyama, have been lost, leading to a decline in biodiversity and deterioration of ecosystem services. Challenges of these interlinked environmental, economic and social issues are becoming more complex (MOEJ, 2019a).

In Japan's Fifth Basic Environment Plan (2018), the concept of Regional Circular and Ecological Sphere (RCES) was proposed to address the existing social, economic and environmental challenges in Japan and respond to the global trend in achieving a de-carbonised society and Sustainable Devel-opment Goals (SDG), as well as the devel-opment of emerging technologies such as artificial intelligence (AI), Big Data and the Internet of Things (IOT). The RCES demonstrates how to achieve a self-reliant, decentralised, economically sustained, environmentally sound and hazard-resilient society by leveraging local resources, including natu-ral, human and financial resources, and strengthening collaboration across the regions. RCES hopes to contribute to the revitalization of the regional economy, circulation of material flows and capital flows, the enhancement in productivity and the creation of jobs (MOEJ, 2019a).

RCES is beyond the scope of material flow circulation and waste reduction in the life cycle of products and is broader than the intercorporation material circulation and exchange within the ecological industrial parks. RCES stands for the idea of building an environmentally-sound and economically viable sphere through the circulation of natural, hu-man and financial resources across neighboring regions. In the RCES, regions will both contribute to and benefit from the de-velopment of an optimal regional growth model that can best use local resources, particularly untapped resources which are unique to each region. Realizng the RCES will nurture the synergies of economic growth, ecological conservation and improved wellbeing and promote the innovation and development of new businesses and business models.

This paper introduces a case study in Japan for achieving the RCES through the development of sustainable infrastructure and re-lated services. The development of a lightrail transit (LRT) system in Utsunomiya City, which is selected by the Ministry of the Envi-ronment of Japan (MOEJ) as a model project for the promotion of RCES, to demonstrate how sustainable infrastructure development and related services play a key role in achieving the RCES. LRT is a next-generation public transport system with excellent fea-tures such as ease of getting on and off, punctuality, speedy delivery, and comfort by utilising low-floor vehicles and improved tracks and tram stops. Not being developed just as a single construction project, the LRT project in Utsunomiya City will provide an integrated public transportation

[18] According to MATT (2019), the amount of damage to agriculture caused by wild birds and beasts has been around 20 billion JPY per year in recent years. About 70% of the total damages are caused by deer, wild boar, and monkeys. Total damaged forest area was about 6,000 ha in 2017, of which about 3/4 was damaged by deer. In the period of 1989-2016, deer and wild boar populations in-creased by 10 times and 3 times, respectively, while the number of hunters (with a hunting li-cense) decreased from about 300,000 to 200,000.

network link-ing the city with the existing public transport system and private transportation together with new services, which will enhance the city's functions to meet the needs of sustainable urban development.

The LRT project is one of its kind in Japan and has attracted huge attention locally. It aims to build a new regional decarbonised transportation model that utilises locally-produced renewable energy and E-mobility, including electric vehicles (EV), electric mo-torcycles, electric buses, and Green Slow Mobility[19]. In the automobile industry, IOT and AI-based connection, autonomous driv-ing, sharing and electrification (CASE) is a global trend. The LRT project including the connected public transport system will oper-ate E-mobility together with CASE to opti-mise transport services in the region. Pow-ered by electricity produced locally from re-newable energy, it will also contribute to the GHG reduction from transportation while meeting the mobility needs for the first and the last mile in the region.

Section 2 introduces relevant policies for building a sound material-cycle society and the promotion of RCES in Japan. Section 3 introduces a case study of a RCES model project on the development of the LRT sys-tem in Utsunomiya City and Section 4 pro-vides a summary of the success factors of the LRT project in terms of the role of sustainable infrastructure in the promotion of RCES

[19] Electric vehicles that run at a speed lower than 20km/h and transports the elderly

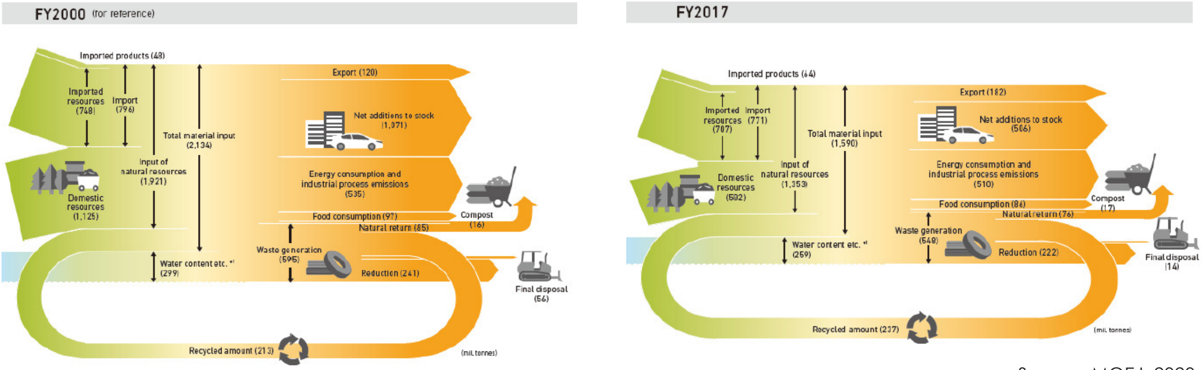
1. RELEVANT NATIONAL POLICIES ON THE PROMOTION OF RCES

Japan is one of the most advanced countries in the world for promoting a Circular Economy based on the 3Rs namely reduce, reuse and recycle. Several legal acts and governmental regu-lations, plans and guidelines were developed to support efforts to build a society based on a Circular Economy both in Japan and in Asia. In this section, two national plans closely related to achieving a circular society deliberated by the Government of Japan in 2018 will be intro-duced. These two plans are the Fourth Fundamental Plan for Establishing a Sound Material-Cycle Society (briefly called the Fourth Fundamental Plan hereinafter) and the Fifth Basic Envi-ronment Plan (Government of Japan, 2018; MOEJ, 2018). Both plans share the overall objec-tives for addressing the existing social, economic and environmental challenges in Japan in an integrative way through the circulation and sustainable use of resources, taking advantage of advanced technologies and building partnerships. The concepts of a sound material-cycle so-ciety and RECS were integrated in both plans. MOEJ is responsible for the implementation of both plans in collaboration with other relevant ministries, while the Fourth Fundamental Plan focuses more on the circulation of resources through the 3Rs and the utilisation of renewable energy. The Fifth Basic Environment Plan has a broader scope covering six cross-cutting priority strategies. These include: i) formulation of a green economic system for realizing sustainable production and consumption; ii) improvement of the value of lands as national stocks; iii) sus-tainable community development using local resources; iv) realisation of a healthy and pros-perous life; v) development and dissemination of technologies that support sustainability goals; and vi) demonstration of Japan's leadership through international contributions and building strategic partnerships.

1.1 JAPAN'S FOURTH FUNDAMENTAL PLAN FOR ESTABLISHING A SOUND MATERIAL-CYCLE SOCIETY

In May 2000, Japan's Basic Act on Establishing a Sound Material-Cycle Society was enacted aimed at making Japan a recycle-based society in the 21st Century. In a "sound material-cycle society", consumption of natural resources is reduced and the environmental load is minimized. Based on the Basic Act, the Fundamental Plan for Establishing a Sound Material-Cycle Society was formulated under which policy measures were developed and implemented for building a sound-material cycle society (Government of Japan, 2018). Various efforts made by different sectors and actors to create a sound material-cycle society has led to the substantial improve-ment in resource productivity and recycling rate, as well as significant reduction in final disposal (see Figure 2-1). Compared with the status of material flows in 2000, the total inputs of natu-ral resources, including both imported resources and domestic resources, were reduced by around 30% from 1,921 million tons (2000) to 1,353 million tons (2017). At the same time, recy-cled materials increased by more than 10% from 213 million tons (2000) to 237 million tons (2017). As a result from the reduction in total domestic consumption (including total energy consumption) and increased recycling, the burden of final disposal was greatly reduced by 75% from 56 million tons (2000) to 14 million tons (2017). In contrast, exports greatly increased by more than 50% from 120 million tons (2000) to 182 million tons (2017).

Figure 2-1_ Progress in Japan's material flows for achieving a Sound Material-Cycle Society



Source: MOEJ, 2020.

However, progress has been stagnant in recent years and there is a need to strengthen efforts in enhancing resource productivity through the 3Rs. In addition, in the recovery and reconstruc-tion from the Great East Japan Earthquake disaster, the removal and disposal of radioactive materials discharged from the nuclear power plant accident was much-needed. The Fourth Fun-damental Plan was issued in June 2018 to address these challenges.

In light of the current status of the development of a Sound Material-Cycle Society, while keep-ing the core issues the same as included in the Third Fundamental Plan—such as quality development and integrated efforts for building a Sound Material-Cycle Society, a low-carbon socie-ty, and a harmonious co-existent society—the Fourth Fundamental Plan has expanded the scope of activities to incorporate economic and social considerations (Government of Japan, 2018). Socially, these include the issues of the declining population, low birthrate, and an aging population which have weakened regional vitality. In economic terms, innovations and technologies from the fourth industrial revolution which will have an impact on industries and people's lives have been reflected in the efforts for achieving a Sound Material-Cycle Society in the Fourth Fundamental Plan.

1.2 JAPAN'S FIFTH BASIC ENVIRONMENT PLAN

According to Japan's Basic Environment Act (1993), the Basic Environment Plans, which stipu-late the outline of comprehensive long-term measures on environmental conservation, have been revised every six years since the first Plan was issued in 1994. The latest Plan - the Fifth Basic Environment Plan - was decided by Japan's Cabinet on 17 April 2018. Based on Japan's traditional wisdom to respect, adapt and coexist with nature using the best science and tech-nology such as ICT, the plan provides a vision for achieving a sustainable society which sup-ports sustainable economic growth, minimizes environmental impact, realizes a circular material cycle, maintains healthy ecosystems and their services, achieves coexistence between human and nature and decouples economic and social activities from carbon emissions. Such a socie-ty will be an advanced civilized society in which human and nature coexist in a symbiotic rela-tionship.

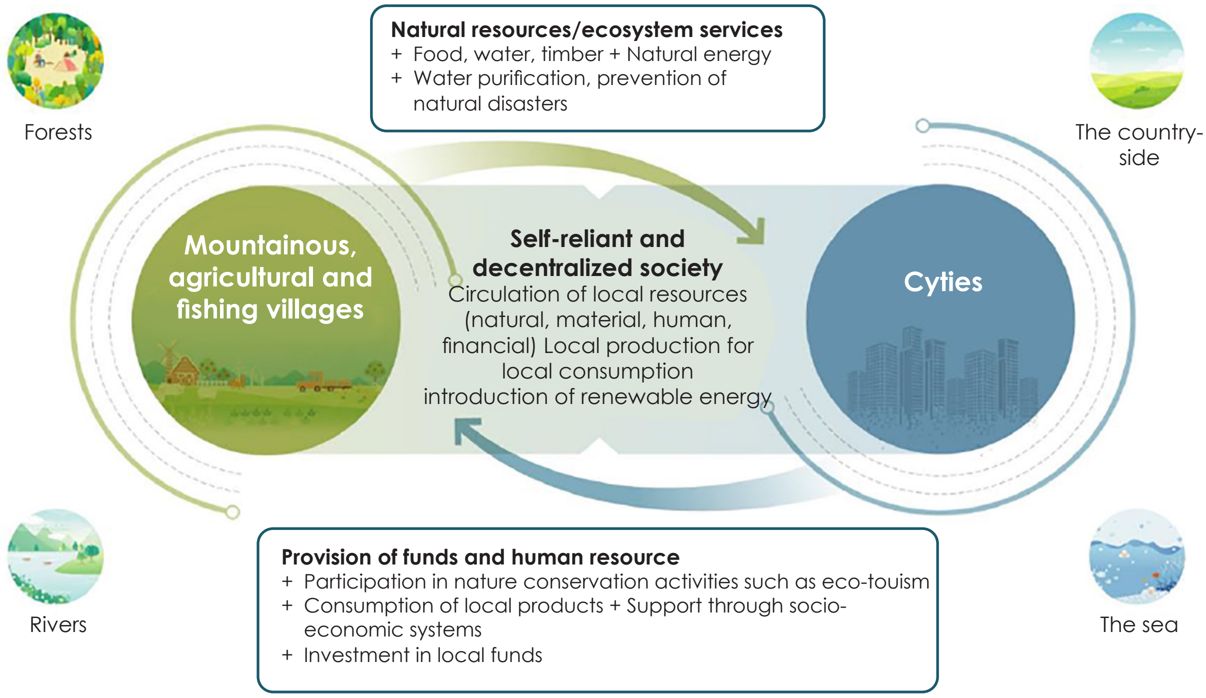
Towards achieving a sustainable society envisioned in the Fifth Basic Environment Plan, a new growth model based on the concept of RCES is provided, aiming at developing a self-reliant and decentralized society in Japan by leveraging regional natural resources and strengthening the collaborations across neighboring areas (MOEJ, 2019a).

Through the establishment of the RCES based on the unique characteristics of individual re-gions, it is expected to revitalize the regional economy, create new businesses and improve the well-being of locals. RCES will contribute to achieving an integrated management of society, economy and the environment and the SDGs.

RCES is described as a circular and ecological economy at the regional level (see Figure 2-2). Circularity is achieved through the circulation of local resources, i.e. natural resources, materi-als, human resources and financial resources, across different administrative areas. Mountain-ous, agricultural and fishing villages provide natural resources including food, water, timber and energy, and relevant ecosystem services such as water purification and prevention of natural disasters, to the cities. Through the consumption of products provided by the rural areas and providing human resources and financial resources, cities support the production and natural conservation activities, such as eco-tourism, in the rural areas. A self-reliant and decentralized economic development will be achieved through local production for local consumption and strengthening the partnerships between rural areas and cities by building natural connections

(connections between the forests, the countryside, the rivers and the sea) and economic con-nections (the flow of human resources and capital). Through this circularity based on the char-acteristics of local resources, new businesses and employment opportunities will emerge. Though not being proposed from the perspective of addressing the high dependency on imported resources (accounting for 57% of Japan's total inputs of natural resources in 2017, see Figure 2-1), by achieving a self-reliant and decentralized society at the regional level, RCES will reduce the reliance on imported resources and materials, particularly fossil fuels such as coal and oil, thus contributing to less dependency on the imports of resources.

Figure 2-2_ Concept of RCES



Source: MOEJ, 2019a.

RCES has been explored by the local governments through various approaches and in differ-ent sectors. An overview of relevant cases for the promotion of RCES is summarized in Figure 2-3. These cases can be categorized into three areas: First is the development and utilization of renewable energy based on the pattern of local production for local consumption and through cross-regional electricity transmission from areas with rich natural endowment in renewable en-ergy resources to the areas with less natural endowment but high energy demand. It is estimat-ed that Japan has a total potential of 1.8 trillion kWh for renewable energy supply, about 1.8 times of the country's total energy demand. One of the cases for the promotion and applica-tion of locally-produced renewable energy is the development of a decarbonized regional transport system. The LRT system in Utsunomiya City, to be introduced as a case study for the promoting of RCES in Section 3, is one such case.

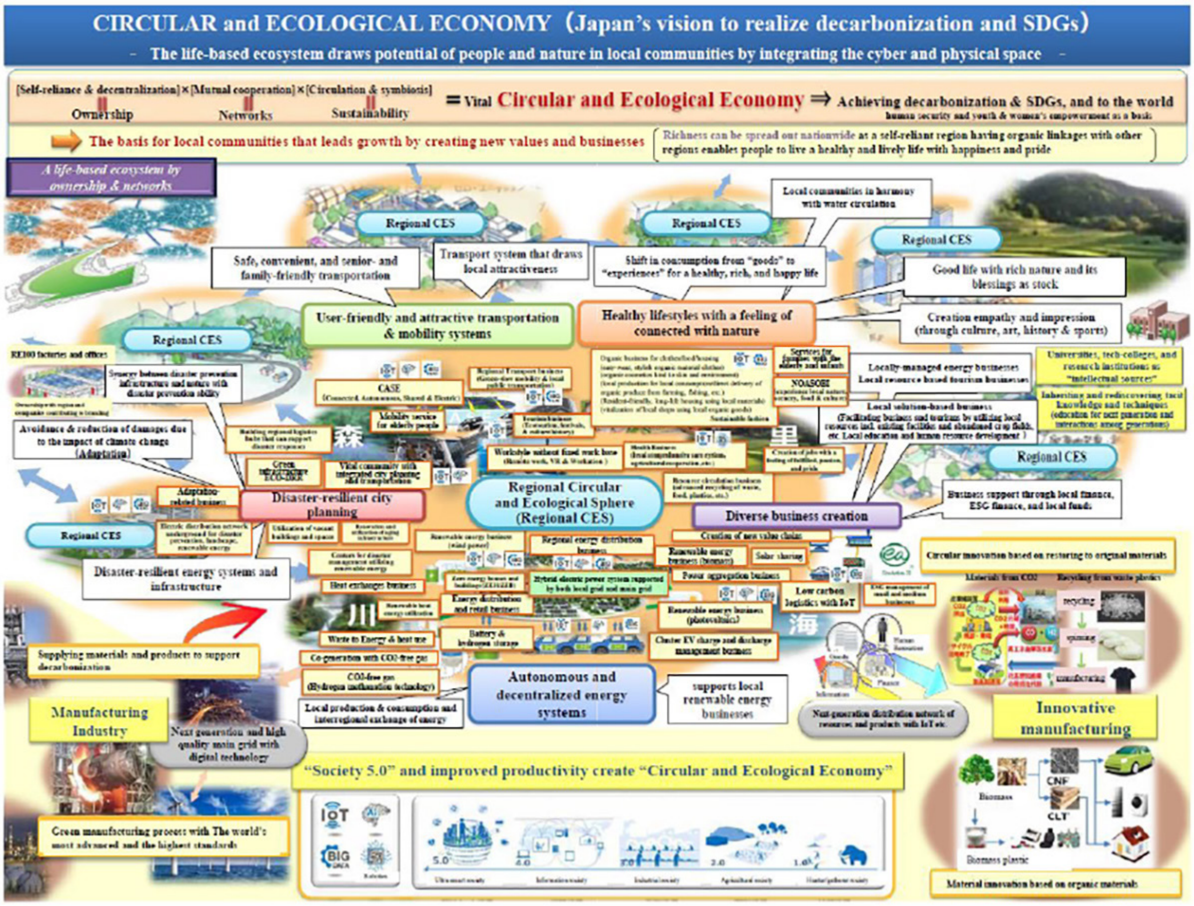
In general, the potential of renewable energy supply is higher in rural areas than in urban areas. On the other hand, as of 2013, more than 90% of the local governments have a deficit in their energy balance with capitals flowing out of the region for purchasing electricity (MOEJ, 2019b). The cross-regional transmission of electricity generated from renewable energy, particularly from the so-called "local areas" to the three "metropolitan areas"[20], is an effective solution to address energy and financial deficits in local areas by using untapped resources. In February 2019, Yokohama City and 12 municipalities in three prefectures in the northeast of Japan, which have abundant renewable energy resources, signed a partnership agreement on renewable en-ergy supply with the aim of achieving a carbon-free society. This collaboration is the largest among similar cases in Japan. Through the supply and utilization of renewable energy and col-laboration between the rural and urban areas and between the three metropolitan areas and lo-cal areas, a new model of RCES will be created to revitalize regional economic development for the benefit of all partner areas.

[20] The three metropolitan areas are the Greater Tokyo Area (including Tokyo and seven prefectures centered withinTokyo, Yokohama City and Kawasaki City, etc.), Chukyo Area (including three prefectures centred within Nagoya City), and Kinki Area (including Osaka City, Kyoto City and four prefectures centred within Osaka City, Kyoto City and Kobe City). Local areas include all areas other than the three metropolitan areas.

Another area is building the recycling systems and the utilization of locally-recyclable resources such as livestock manure, food waste, sewage sludge, plastics and metals, etc. for solving local issues. One example is the production of biogas and hydrogen produced from livestock manure in Shikaoi Town, Hokkaido (MOEJ, 2019b). Shikaoi Town is an area where dairy farming and upland farming are the major agricultural activities. The treatment of large amounts of live-stock manure had been a great burden to individual farmers. Now, livestock manure is collect-ed and processed by a centralized biogas facility which generates methane gas for local ener-gy use. In addition, the generated digestive juice is returned to the farm for circulation. The sur-plus heat generated from the facility is used for greenhouses for mango cultivation, sturgeon breeding, and long-term storage of sweet potatoes, benefitting local economic revitalization. Currently, Shikaoi Town is working on the construction of a low-carbon hydrogen supply chain which produces hydrogen from biogas and supplies heat and electricity with fuel cells.

A third area is the utilization of natural endowments, including rich drinking water, clean air, food and natural resources, and unique cultures built on nature, supported by various ecosys-tem services that are formed by the forests, villages, rivers, sea and their links. One example is the development of organic farming and the production of organic food in Ogawa Town in Saitama Prefecture, for the demand both within the town and in large cities. Ogawa Town is aiming to build an RCES centered around organic farming that starts from Shimosato Farm. Organic food products made in Ogawa Town include local wine produced from organic rice and tofu made from organic soybeans, among others. Local farmers cooperate with each other to exchange technology, information, and joint sales. Collaboration work has expanded beyond the town. OKUTA, a remodeling company in Saitama City, supports Ogawa Town by purchas-ing organic rice from four farmers in a lump sum payment and providing organic rice to the supporting employees with a payroll deduction.

Figure 2-3_ An overview of RCES cases



Source: MOEJ, 2019a.

2. A CASE STUDY OF THE RCES MODEL PROJECT ON THE DEVELOPMENT OF A LOW-CARBON LIGHT-RAIL TRANSIT SYSTEM IN UTSUNOMIYA CITY

In this section, an RCES model project on the development of a decarbonized light-rail transit (LRT) system in Utsunomiya City will be introduced focusing on the role of sustainable mobility and related infrastructure system and services in achieving integrated urban development. The contribution from this project to improveme the use of renewable energy, sustainable resource, and productivity enhancement, revitalization of the local economy, job creation, and building resilience will be analyzed. In addition, their linkages with achieving the SDGs will be elaborat-ed.

2.1 MAJOR CHALLENGES IN UTSUNOMIYA CITY

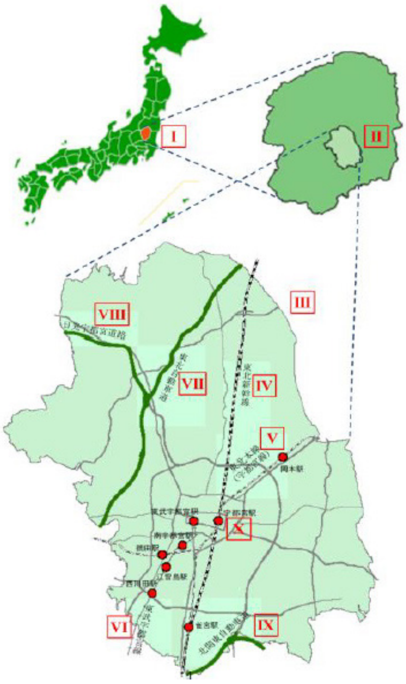
Utsunomiya City is located in the center of Tochigi Prefecture, about 100 km north of Tokyo (see Figure 2-4). The city has an area of 416.85 km2, accounting for about 6.5% of the prefecture's land area. The Tohoku Shinkansen (high-speed railway lines), Japan Railway (JR) Tohoku Line and Tohoku Expressway run through the city from north to south, and the Kita Kanto Expressway runs through the sourth edge of the city from east to west. The population is declining due to the natural and social dynamics, such as low birthrate and aging population, with a peak in 2018 (520,503 persons) and then declining to 519,277 at the end of 2019 (Utsunomiya Smart City Promotion Committee, 2020). According to estimates by the population vision of Utsunomiya City, the population will continue to decline to about 450,000 in 2050 (Utsunomiya City, 2019b). Futhermore, the share of senior people, which was 23% in 2015, will increase to 37% in 2050.

In the transport sector, the use of automobiles for transportation within the city increased continuously, reaching 69% in 2015, which is higher compared with other cities (Utsunomiya City, 2019b). The rate of using public transportation showed a decreasing trend with a combined rate of using railways and buses at 6%. In addition, even for short trips, such as with a travel time of less than 3 minutes, the rate of using private cars exceeded 50%.

To increase public transportation coverage, Utsunomiya City has been working on the enhancement of public transportation network such as construction of new bus routes and extension of the existing ones and introduction of intra-regional transportation to all 13 suburbs. From 2008 to 2018, public transportation coverage increased from 67% to 90% (Utsunomiya City, 2019b). However, in the urban areas with narrow roads and in some suburbs, the public transportation system has not been fully covered. In addition, connections between different means of public transportation were not convenient. 20.9% of railway users connect their next trips by bicycle and 14.1% by bus. 7.8% of railway users travel by bus and 5.6% by bicycle before making a train connection. Only 0.6% of those who use public transportation use bus-to-bus services to connect their trips (Utsunomiya City, 2019b).

Bus fares are a heavy burden for traveling within the city. For example, traveling from "JR Utsunomiya Station", which is located in the city center to other functional areas in the suburbs, industrial parks, and the sightseeing spots, the maximum bus fare for a one way trip is JPY 800. In addition, 95% of the total travels by bus in the city costs JPY 500/trip which is a heavy burden on users, particularly to senior citizens whose disposable incomes are less than other generations.

Figure 2-4_ Location of Utsunomiya City and major existing transport routes



Source: Utsunomiya City, 2018b.

Note:
- I-Location of Tochigi Prefecture in Japan;
- II-Location of Utsunomiya City in Tochigi Prefecture;
- III-Utsunomiya City;
- IV-Tohoku Shinkansen (high-speed railway lines in Japan);
- V-Japan Railway Tohoku Line (Utsunomiya Line);
- VI-Tobu Utsunomiya Railway Line;
- VII-Tohoku Expressway;
- VIII-Nikko Utsunomiya Road;
- IX-Kita Kanto Expressway;
- X-Utsunomiya Station

(Translated by the author).

In Utsunomiya City, where the capital of Tochigi Prefecture and many companies and schools are located, about 56,000 people commute from neighboring cities and towns to Utsunomiya City for work or education. On the other hand, about 41,000 people travel out of Utsunomiya city to neighboring cities and towns for work or education. Under such circumstances, however, bus utilization for the connections between Utsunomiya City and neighboring cities and towns have decreased due to inconvenience or low services.

Due to the decreasing population and the changes in the demographic structure, it is expected that the overall demand for transportation will decrease, and the transportation for commuting to work and school will decrease, but transportation for other purposes such as going to the hospital and shopping will increase.

In recent years, the number of tourists has gradually increased in Utsunomiya City. The Oya Musume, with a large underground quarry site, is attracting people not only from Japan but also from overseas. In May 2018, the story about the Oya stone culture was recognized as a Japanese heritage, and the number of tourists can be expected to increase in the future. Besides using private cars, more than 60% of tourists travel on foot with very low utilization of public transportation such as buses or taxis.

Total GHG emissions generated from Utsunomiya City was 4,370,000 t-CO2 in 2015, of which the industrial sector, transport sector, commercial sectors and households accounted for 26%, 25%, 24% and 18%, respectively. Emissions from the transport sector, 1,1040,000 t-CO2, reached the highest level in the 1990-2015 period (Utsunomiya City, 2019b). Utsunomiya City has faced the greatest challenge in mitigating emissions from the transport sector.

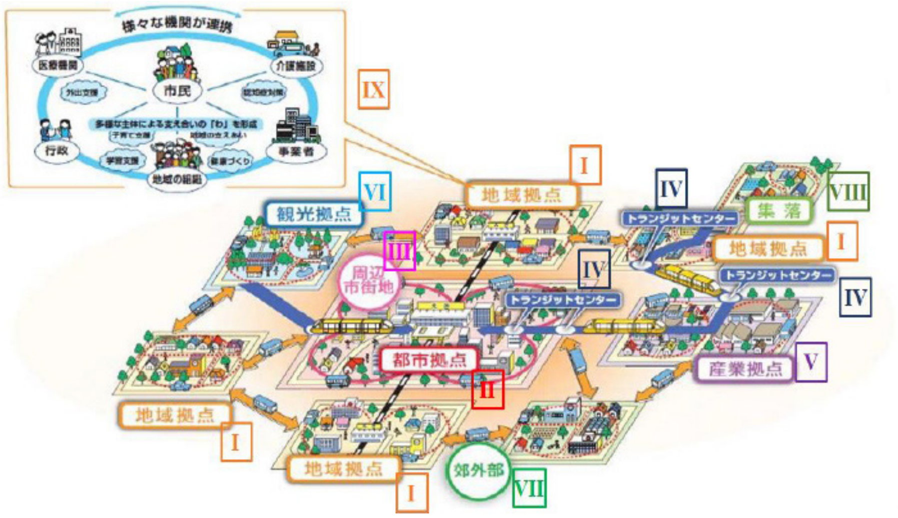
2.2 THE LOW-CARBON LRT PROJECT

As a pioneer city in Japan, Utsunomiya City has been working on the development of a network-type of compact city (NCC) since 2008 to cope with the demographic trends and support long-term sustainable development (Utsunomiya Smart City Promotion Committee, 2020). In the NCC, the central urban area and peri-urban areas, together with other functional areas (residential areas, commercial areas, industrial parks and tourism areas, etc.), will be connected by a comprehensive transportation network to enable convenient mobility by means of public transportation such as LRT and route buses, automobiles and bicycles. The realization of the NCC in Utsunomiya City will support sustainable industrial development and the improvement in the provision of various services including childcare, education, healthcare and well-being, as well as building resilience against disaster risks to make it more attractive for living and doing business (see Figure 2-5).

To support building a network-type of compact city, the Utsunomiya Urban Transportation Strategy (2009-2018) was formulated in September 2009, in which a hierarchical public transportation network including railways, LRTs, buses and regional transportation, etc. were proposed to be linked effectively and efficiently according to their respective roles. To respond to the declining population, the declining birthrate and aging population, and the changing needs for public transportation, together with rapid scientific progress such as autonomous driving technology in recent years, the 2nd Utsunomiya Urban Transportation Strategy (2019-2028) was announced in March 2019.

As a key element for building the NCC, the LRT system will make fundamental changes in the structure of the city and impact people's lifestyles and industrial activities. Construction of the LRT track --the first of its kind in Japan-- is underway and operations were originally scheduled to begin in March 2022 (now postponed to open from March 2023 due largely to the impacts of COVID-19). To be powered by the electricity generated from local renewable energy, the LRT project was selected as one of the demonstration projects by the MOEJ for achieving RCES.

Figure 2-5_ An image of the network-type of compact city of Utsunomiya



Source: Utsunomiya Smart City Promotion Committee, 2020

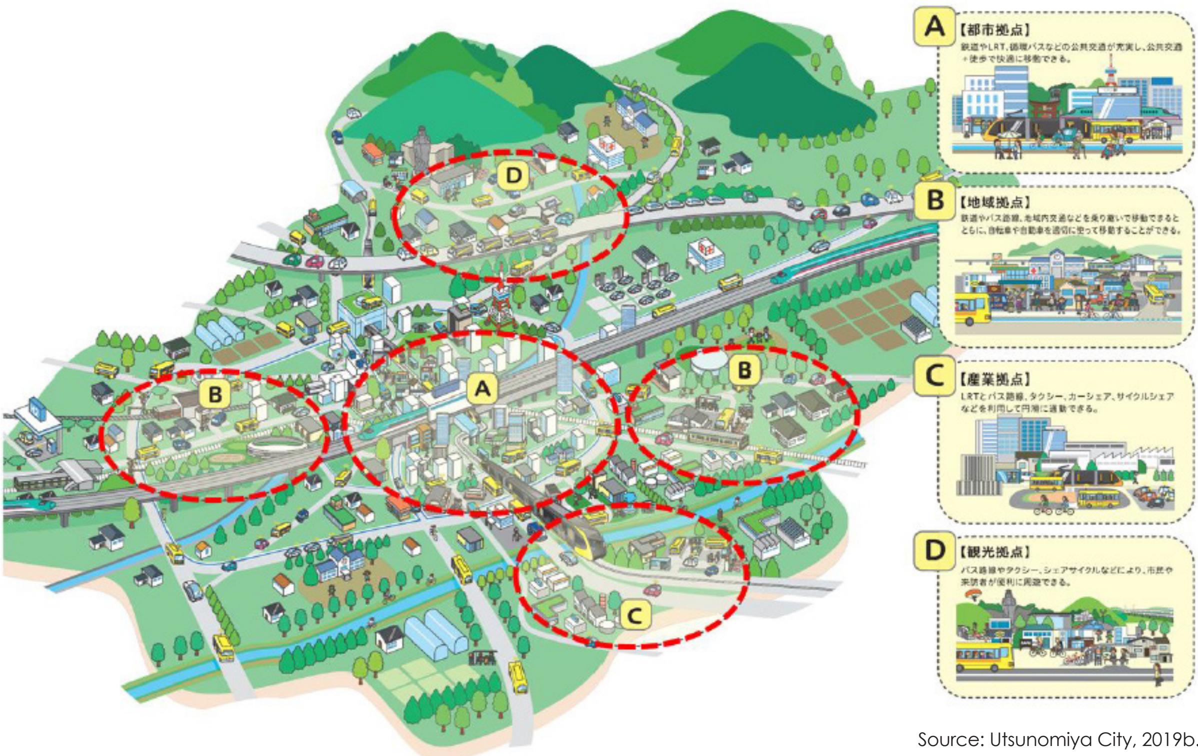
Note:
- I-Residential areas;
- II-Central urban area;
- III- Surrounding roads and streets of the central urban area;
- IV-Transit centres;
- V-Industrial areas;
- VI-Sightseeing spot;
- VII-Peri-urban areas;
- VIII-Villages;
- IX-Various institutions including hospitals, nursing homes, local governmental organizations, and companies, etc.

(translated by the author).

Complementing the existing public railway transport system across the north-south direction, the LRT will be introduced as the main transport system across the east-west direction, together with improved services, the development of transit centers, enhancement of bus routes, and improvement of local transport systems. Major means of public transportation in different functional areas in the city are presented in Figure 2-6. To contribute to decarbonization and enhancing the adaptive and preventive capacity against disasters, solar power generation and storage batteries will be installed. By using Japan Railway's regional cooperation IC card system, local public transportation will become more convenient.

The LRT will impact the appearance and functions of the city and the lifestyles and behaviour of citizens significantly. To make mobility more comfortable, convenient and efficient, MaaS, i.e. mobility as a service, will be introduced. Currently, searching for routes and paying for the services are conducted separately for each means of transportation such as trains, buses and taxis. In the MaaS society, it is possible to search for routes and make payments for various transportation services in a single application. By providing new services such as data collection and analysis and information dissemination for attracting customers, and promoting renewable energy for a decentralized energy supply, decarbonization and building resilience to disasters, anyone can move without difficulities. For senior citizens, bus fare discounts for encouraging the use of public transportation for connecting trips, separation of the roads for pedestrain and bicycles to aviod bicycle traffic accidents, construction and extension of bus routes connecting to railways, as well as the improvement in smooth connections between route buses and local transportation, etc. will make transportation more accessible, safer and more comfortable.

Figure 2-6_ Appearance of urban transportation in Utsunomiya City in 2050



Source: Utsunomiya City, 2019b.

transportation

A-Central urban area: Public transportation using various means including railways, LRT, circular bus and walking will make mobility more comfortable;

B-Residential areas: Railways connected with route buses and local transportation, as well as automobiles and bicycles will enable mobility;

C-Industrial areas: LRT and route buses, taxis, car-pooling and bicycle-sharing will make commuting smoother;

D-Toursim area: Route buses, taxis and bicycle-sharing, etc. will enable the tourists go around the tourist sites more conveniently.

For sightseeing-type MaaS, ICT-based smart phone applications will help provide services such as route search for transportation, reservation of transportation, payment, and provision of tourism-related information, etc. Tourists can stay and enjoy sightseeing and going around town in a convenient and comfortable way. For achieving smooth connections between various means of transportation, an Utsunomiya version of the MaaS will utilise AI and ICT to help provide comprehensive services such as transportation route search, transportation reservation, payment, and operation schedules, connections, parking areas and availability, and transit centres and their services, etc. Technologies such as AI, IoT and drones will be used to support the activities around people, products and things and all the people can live happily in a smart city supported by a convenient, efficient and low-carbon transport system.

Local energy circulation

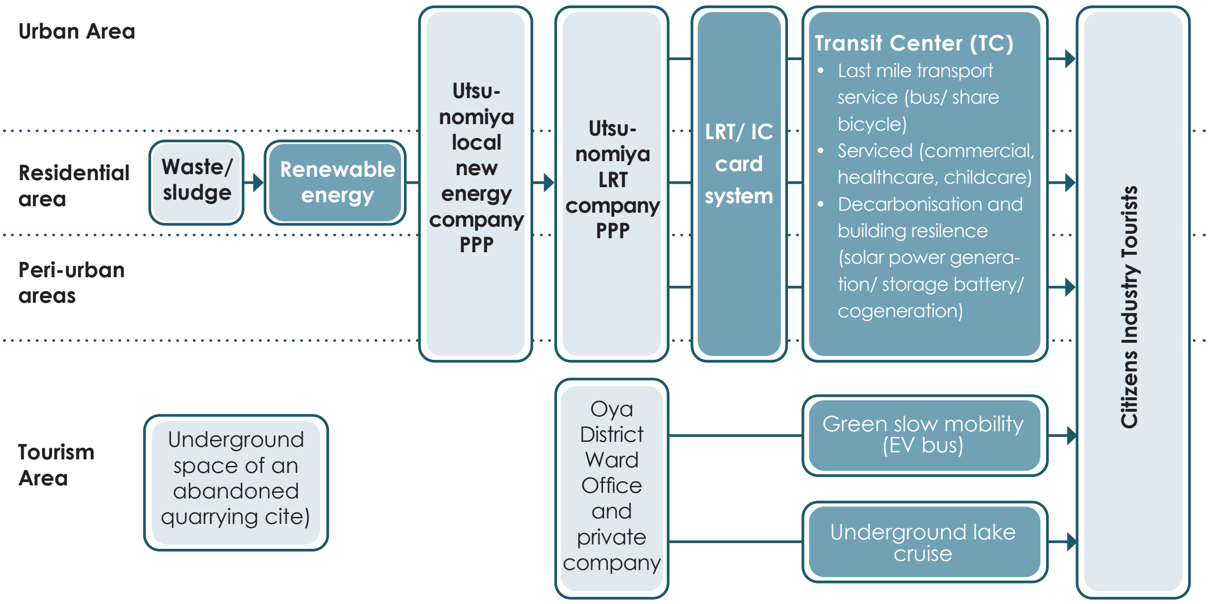
Utsunomiya City is rich in renewable energy resources. The main renewable energy produced in the city include biomass power generation operated by the city and residential solar power generation for their own use. Currently, two facilities, Clean Park Mobara (garbage incineration facility with a capacity of 7,500 kW) and Kawada Water Reclamation Center (sewage treatment facility with a capacity of 840 kW), are operated by the city government for biomass power generation with a total capacity of approximately 8,300 kW (Utsunomiya City, 2019a). In addition, a power generation facility of approximately 3,500 kW will be installed at the new incineration facility, which was constructed for its operation from 2020. Furthermore, the city has been promoting the introduction of residential solar photovoltaic power generation (with a capacity of 40,979 kW) by using the natual endowment of abundant sunshine in winter.

For the promotion of renewable energy and achieving decarbonization, although the amount of renewable energy generated in Utsunomiya city area has been increasing, most of the electricity generated was sold outside of the city. The purpose of promoting renewable energy for decarbonization and local production for local consumption has not been achieved. In addition, there is an increasing need for builidng local resilience through a stable supply from renewable energy to the evacuation centers in the event of a disaster. To address these issues, a local new power company will be established in 2021 to promote the local generation of renewable energy for local consumption and virtual power plants to integrate decentralized energy generated from remote households and factories. Together with solar power generation systems, co-generation systems, electric vehicles and storage batteries, renewable energy will be used by public facilities including public transport (LRT operation, LRT transit centers and Green Slow Mobility, etc.), schools and hospitals and to the evacuation shelters in the event of a disaster (see Figure 2-7).

With the expiration of the Fit-in-Tariff (FIT) system in November, 2019, the local new power company will purchase electricity produced from the existing biomass power generation plants and sell to the LRTs and other public facilities for local consumption. Through local energy circulation, the existing capital outflow due to electricity purchase from outside will be circulated within the city. In addition, at the LRT transit centers, renewable energy will be used and managed with a smart energy management system (Utsunomiya Smart City Promotion Committee, 2020).

In addition, along the LRT route, there is the Kiyohara Industrial Park, the largest inland industrial park in Japan. In the Kiyohara Industrial Park, the country's first large-scale gas co-generation system with a capacity of 30,000 kW was constructed from October, 2016 and started full operation in February, 2020. The Kiyohara Smart Energy Centre provides electricity generated from natural gas through its self-operated transmission line and provides steam and hot water generated from heat waste to seven business establishments located in the industrial park. By utilizing a smart energy management network based on information and communication technologies, the centre has realised local production for local consumption of energy in an efficient way (Hisamitsu Pharmaceutical Co., Ltd., 2020) with 20% energy saving and 20% CO2 emissions reduction expected to be achieved (based on the levels of seven business establishments in 2015).

Figure 2-7_ Achieving RCES through LRT-based sustainable mobility powered by local renewable energy in Utsunomiya City



Source: Compliled and translated by the author based on MOEJ (2019c).

Except for energy circulation, Utsunomiya City, in achieving its future city planning and SDGs, has actively promoted the 3Rs and decarbonization in all industries and sectors, including the transport sector (Utsunomiya City, 2019a). This will help reduce the environmental load in the life cycle of the transport infrastructure.

Using untapped local resources for the revitalisation of the local economy

The Oya area is located in an abandoned quarrying area where huge underground space remains. In 2018, Oya Stone Culture was certified as a Japanese heritage, which helps further promote tourism in this area. An "underground lake cruising" service aiming to serve international tourists will be opened. Located on the west side of JR Utsunomiya Station, the Oya area will be connected by an LRT route. In the tourism area, a Green Slow Mobility zone with EV buses running on public roads at less than 20 km/hour, will be introduced. During the summer vacation in August 2019, an experimental demonstration on. the green slow mobility was implemented for four days from August 10th to 13th (see Figure 2-8). There were 1,353 users in total and 11.7 persons per trip. Based on a questionnaire, for all the questions including joy, comfort, frequency of operation, and easy guidance, more than 50% of the users expressed their satisfacton over the service. About 12% of users mentioned that without the Green Slow Mobility, they would not want to visit the area.

On the other hand, because the journey to the Oya area is overwhelmed by private cars, managing the inbound traffic in this area is a challenging issue. As the area expects to welcome 1.2 million tourists per year, effective traffic management in the Oya area is urgently needed (Utsunomiya Smart City Promotion Committee, 2020).

The revitalization of the Oya area depends on the improvement of public transportation, including the LRT system, route buses and bicycle sharing which will create new job opportunities in relevant hospitality and tourism sectors and contribute to the revitalization of the local economy through the value chains.

Figure 2-8_ An experimental demonstration on the green slow mobility zone covering a dis-tance of 700 metres from Oya Park to Oya Museum with automatic driving on 10-13 August 2019.

Source: Utsunomiya Smart City Promotion Committee, 2020

2.3 KEY PERFORMANCE INDICATORS AND LINKAGES WITH SDGS

To solve the issues in urban and community development and contribute to the SDGs, peo-ple's movement is raised as a common concept to integrate the three aspects of sustainable development, i.e. the economy, society and the environment through connection and circula-tion. People's movement, such as consumption, participation in social activities, mobility and education, is the source for economic revitalization which helps to promote various activities, including production and the provision of various services. Connection and circulation will be created along with people's movement, therefore, "movement" is the key word for the contribu-tions to achieving the SDGs in Utsunomiya City. In 2019, Utsunomiya City government devel-oped the Future City Plan for Achieving SDGs in Utsunomiya City, in which priority areas around the key word people's movement and related key performance indicators (KPI) are pro-posed. Tables 2-1 are the KPIs relevant to convenient, comfort and sustainable mobility in terms of its enabling role played to promote renewable energy (Target 7.2) and decarbonization (Target 13.2), sustainable tourism (Target 8.9), sustainable industrial development (Target 9.2), women's employment (Target 10.2), living conditions (Targets 9.1 and 9.2), sustainable infra-structure and public transportation (Targets 9.1 and 11.2), waste generation and reduction (Tar-gets 12.3 and 12.5), public participation in community development (Target 17.7) and access to all-level education (Targets 4.3, 4.7).

Table 2-1_ Economic KPI

SDG targets	Indicators and targets	
8.9	Indicator: Annual number of tourists	
	Present: 2016 14.83 million persons	Target in 2022: 15.50 million persons
9.2	Indicator: GDP	
	Present: 2014 2,719 billion JPY	Target in 2022: 2,956 billion JPY
10.2	Indicator: Female employment rate	
	Present: 2016 60.8%	Target in 2022: 62%

Table 2-2_ Social KPI

SDG targets	Indicators and targets	
9.1	Indicator: Share of population in the central urban area and residential areas	
	Present: 2016 19.4%	Target in 2022: 20.1%
10.2	Indicator: Share of parents who want to raise their children in Utsunomiya City	
	Present: 2016 95.9%	Target in 2022: 98.5%
11.2 **11.3**	Indicator: Public transport night coverage	
	Present: 2017 89.8%	2028: 100%
13.1 **13.3**	Indicator: Percentage of citizens preparing for a crisis such as a disaster	
	Present: 2017 44%	2022: 46%

Table 2-3_ Environmental KPI

SDG targets	Indicators and targets	
7.2 **7.3**	Indicator: Number of households solar PV facilities installed (cumulative)	
	Present: 2016 15,138	2022: 21,000
12.3 **12.5**	Indicator: Non-recyclable waste generation per person per day	
	Present: 2016 781g	2022: 734g
17.17	Indicator: Number of people engaged in “mottainai” campaign	
	Present: 2016 36,896	2022: 43,800

Table 2-4_ Other cross-cutting KPI

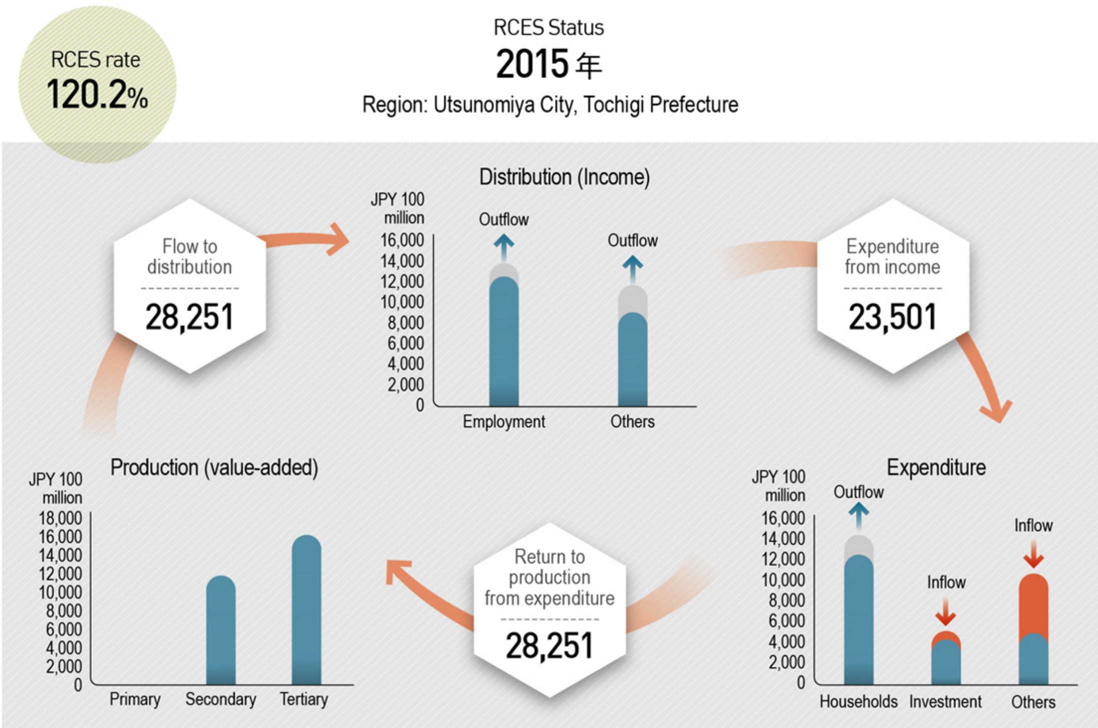
SDG targets	Indicators and targets	
4.3 **4.7**	Indicator: Share of population engaged in education and learning	
	Present: 2016 38.4%	2022: 43.2%
17.17	Indicator: Share of population participating in community development activities	
	-	2022: 25%

2.4 ANALYSIS OF THE ECONOMIC CIRCULARITY

To help analyze the economic circularity of RCES, an online tool, namely Regional Economy Society Analyzing Tool (RESAS), was developed to provide data and relevant analysis on the structure of regional economy and capital flows for about 1,800 administrative units in Japan, including prefectures, cities, towns and villages.

Figure 2-9 shows the level of economic circularity in Utsunomiya City, which is calculated by dividing the total production (value-added) by the total distribution (incomes). A high level indi-cates high economic circularity of the regional economy. The value-added produced in Utsunomiya City was mainly from the secondary and tertiary industries, particularly the tertiary sector. This is due to its high specialization in the sectors of manufacturing, information and communication, public utilities (electricity, gas, heat and water supply) and academic research and technical services. In terms of income, both employment incomes and other incomes (in-cluding property and corporate incomes, allocation taxes, social security benefits and other subsidies, etc.) are shown as a balance in the outflows, indicating that the amount of incomes earned by locals and industries were less than incomes distributed by local industries. This shows the influx of workers living outside of the city. In terms of expenditure, household con-sumption shows a balance in outflows, indicating that the amount of local consumption was less than the total amount of household consumption. On the other hand, investments and ex-ports showed substantial balance in inflows indicating the effects of attracting investments from outside and net exports. At the overall level, the regional economic circulation rate of Utsunomiya City was 120.2% in 2015, greatly more than 100%. This indicates that Utsunomiya City is able to return more to production than its incomes.

Figure 2-9_ RCES economic circularity status of Utsunomiya City in 2015



Note: Translated by the author.

Source: RESAS, https://resas.go.jp/regioncycle/#/map/9/09201/2/2015

2.5 ENABLING POLICIES

LRT is a next generation transport system which is friendly to people and the environment. It can help promote the use of public transportation in urban areas, revitalize the central urban area, reduce environmental impacts from transportation, and ensure convenient mobility for the elderly and those with difficulties in mobility. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) provides relevant financial support to the implementation of LRT projects in Ja-pan.

For the implementation of an LRT project, an LRT Promotion Committee will be set up compris-ing members from private companies, the local government, NOPs and the national govern-ment including the MLIT and the Public Safety Commission. The LRT Promotion Committee will develop a plan for the implementation of the project. The national government provides rele-vant financial support for the implementation of the LRT project based on the plan. The support covers: i) the construction of hard infrastructure including railways, relevant roads, stations, and other relevant space arrangements; ii) improvement of the operation and management systems including speed setting and examination of the route, etc.; iii) improvement of convenience, including the introduction of IC system and the arrangement of connections with other transport systems; iv) relevant activities for the revitalization of the station areas and transit centres; and v) parking areas for automobiles and bicycles and the implementation of experimental opera-tions.

The national government will provide financial support to both the local government and private companies separately for the implementation of relevant activities. The financial support to the local government and the private companies will cover 50% and one third of their respective total costs for the implementation of the LRT project.

3. CONCLUSION

The LRT system will contribute to achieve an RCES in a network-type of compact city in Utsunomiya City through the provision of convenient, comfortable and sustainable mobility infrastructure and related services. The local challenges and solutions with expected results through the development of the LRT system are summarized in Figure 2-10.

i. A couple of good lessons can be learned from this RCES model project.

The development of sustainable infrastructure based on a shared long-term vision or relevant governmental development plans and strategies is a success factor.

Development of sustainable infrastructure based on a shared long-term vision or relevant gov-ernmental development plans and strategies is important for successful construction and oper-ation. Infrastructure, depending on its type, has a long life cycle from dozens of years to hun-dreds of years. Development of infrastructure based on a shared long-term vision of the city, the prefecture or the country is important to ensure its operation and functioning, staying in line with the long-term development of the area. The LRT system in Utsunomiya City was proposed and developed based on the long-term vision of building a network-type of compact city in Utsunomiya proposed and promoted by the local government since 2008. This vision was in-cluded in the 6th Comprehensive Plan of Utsunomiya City (2018-2027), in which the appearance of Utsunomiya City in 2050 is provided. Based on the 6th Comprehensive Plan of Utsunomiya City, the 2nd Utsunomiya Urban Transportation Strategy (2019-2028) was adopted in which a long-term vision and the appearance of transportation in 2050 was provided. Dating back to the Utsunomiya Urban Transportation Strategy (2009-2018), the introduction of the LRT system was included as a means for the improvement and enhancement of public transportation.

Linking infrastructure projects with other services/ activities and urban planning to create multi-ple synergies beyond individual construction projects is the key for maintaining economic sus-tainability.

ii. Ensuring economic sustainability of the infrastructure during its life cycle, including operation, mainte-nance and upgrading, is a challenging task.

Linking infrastructure with relevant services or activities, as well as urban planning, to create multiple synergies beyond individual construction projects is important to ensure its long-term economic sustainability. On the one hand, the development of the LRT system in Utsunomiya City is linked with the utilization of local renewable energy produced from municipal solid wastes and waste water sludge. This is compatible with the country's long-term strategy for achieving 80% reduction of GHG emissions by 2050. On the other hand, the planning, construc-tion and operation of the LRT system are connected with the long-term spatial planning which defines the locations and functions of various areas, including the urban central and residential areas, industrial parks and tourism areas, etc. Binding the functions and services of the LRT system with the activities and services of the functioning areas including industrial activities, tourism, education, healthcare and childcare, etc. will enhance the economic sustainability of the infrastructure project. Furthermore, the utilization of advance technologies, such as ICT-based smart solutions for MaaS, will enhance the efficiency, functionality and convenience of the LRT system and associated services, making it a top runner among similar infrastructure projects. In summary, an infrastructure project which generates multiple synergies with other projects or activities and links with urban planning can, in turn, increase its sustainability in the long-run.

iii. **Governmental financial support for nurturing the development of new models and innovations is important to promote pioneer projects.**

For the promotion of RCES and the development of LRT projects, the Japanese government has provided substantial financial support, including various subsidy schemes, to the installa-tion and use of self-reliant and a decentralized renewable energy system, the establishment of local new energy company for the operation and management of renewable energy supply, and the development of new business models (such as a new type of decarbonized transport sys-tem) and the adoption of advanced technologies (such as AI, IOT and ICT-based MaaS, CASE and smart energy management systems, etc.). This is important at the initial stage for the pro-motion of RCES and the scaling up of similar projects.

Figure 2-10_ A summary of the LRT system introduced in Utsunomiya City

1. Local challenges

Environment

Environmental pressures
- Pick-ups by private cars are energy inefficient
- Shuttle buses and their gas emissions are annoying the pedestrians.

Economy

Decline in the urban central area and local industries
- Decreasing in users and providers, the urban central area has declined and services are decentralised;
- Mobility is inconvenient and the outing rate is low.

Deficit of the transporti sector
- Low profit of the transport sector;
- Local government covers the maintenance costs for public transportation;
- Shortage of drivers.

Society

Using private cars due to inconvenient/declining public transportation
- Poor connections and lack of services for the first/last mile;
- Pick-ups by individual cars causing congestions at the station;
- Elderly people who drive private cars have high risk of traffic accidents;
- Elder people who do not drive private cars face difficulties in mobility.

2. Expected results

Green transportation and logistics
- Utilisation of renewable energy;
- Energy-efficient operation andt dispatch.

Creating a vitalised communi-ty
- Increased outing rate and consumption through attractive services and convenient means of transportation leading to the revitalisation of the urban central area ;
- Stimulating the consump-tion by saving more spare time.

Well-developedt transport sector
- Improving the profits of the sector and maintaining profitability;
- Increase in public transport users;
- Realisation of labour-effi-cient management.

Convenient, comfortable and sustainable daily transporta-tion
- Reduced waiting time during connections;
- Door-to-door transportation and sufficient connected transportation linking with various services
- Flexibility in fares and charges in response to the needs.

3. Solutions

A Introduction of electric vehicles
- LRT
- Green Slow Mobility (Small EV buses and electric bicycles, etc.).
- Local generation of renewable energy for local consumption in electric mobility (solar power and waste/sludge to energy)

B Providing incentives
- Introduction of local points

C Creation of new businesses
- Transit centres (various service sprovided at the transportation hubs)

D Automatic operation
- Automatic transportation by automated driving or drone
- Automation of vehicle dispatch and reservation and payment, etc.

E Supply and demand matching
- Car sharing/ ride sharing

F Multi-tasks/ services mobilisation
- Functional areas (network-type of compact acity)

4. Local resources

Natural resource
- Solar power, woods, small hydro, geothermal
- Waste/sludge
- Landscape/Satochi and Satoyama

Material resources
- EVs
- Unused space of vehicles
- Idle vehicles
- Idle facilities
- Commodities

Human resources
- Local residents
- Tourists
- Public transportation (railway, bus)
- Services (bus, taxis, logistics, well-being, tourism)

Note: Modified and translated by the author.

Source: MOEJ, 2019c.

Chapter 03

Transition to Electric Mobility and Renewable Energy in the Republic of Korea

EXECUTIVE SUMMARY

This case study demonstrates how low-carbon transitions in the Korean transporta-tion and energy sectors can be aligned with Circular Economy goals. As such, the case study details how Sustainable Infrastructure can not only contribute to scaling up a Circu-lar Economy and improving resource effi-ciency in the Republic of Korea (ROK), but also make e-mobility and renewable energy sectors more sustainable. Both sectors are expected to drastically change in response to global and national sustainable development agendas, resulting in accelerating pro-duction of electric vehicles (EVs) and vastly increased generation of renewable energy (most notably solar power). Existing policy frameworks and regulations must, therefore, be updated to include and specify manage-ment approaches for new types of 'future wastes', such as used batteries from electric vehicles (EV batteries) and decommissioned solar photovoltaic (PV) panels. Waste man-agement and recycling/reuse approaches for these and other future wastes should be developed early, before waste volumes be-come too large.

As the ROK is already anticipating and responding to these changes and challenges, this case study provides a review of existing Circular Economy frameworks as well as the waste management and recycling policies and infrastructure to be established in the ROK.

As such, this case study report describes the content and context of the most important national policies on a Circular Economy, such as the "Framework Act on Resource Circulation", as well as Korea's COVID-19 recovery package, the "Green New Deal" and the "Digital New Deal". The case study also discusses the environmental challenges in the ROK associated with the increasing amount of used EV batteries and decom-missioned solar PV panels in recent and cur-rent periods before appropriate waste management regulations and infrastructure systems for these wastes are fully comprehen-sive. It also presents the key challenges faced by the ROK in the establishment of Circular Economy-related policy frameworks and of waste recycling systems.

The focus of the case study is on the introduction of the "Future Waste Recycling Sys-tem" in the ROK that will comprise the entire infrastructure system necessary for the collection, sorting, evaluation, and recycling of used EV batteries and decommissioned solar PV panels. The establishment of this "Fu-ture Waste Recycling System" will serve as a key element in scaling up the Circular Economy in the ROK, thereby generating triple benefits for the environment, society, and the economy.

This case study is designed to serve as an example of good practice for consideration by other countries that are aiming to align low-carbon transitions with Circular Economy goals, and seek to scale up a Circular Econ-omy through the development and deployment of Sustainable Infrastructure. These considerations are particularly relevant in the COVID-19 era, as countries around the world spend billions to stimulate their economies, thus presenting an opportunity to increase Sustainable Infrastructure and promote the shift towards Circular Economies.

INTRODUCTION

This case study provides a review of the waste management and recycling policies in the Republic of Korea (ROK), focusing on a new scheme for recycling used electric vehi-cle (EV) batteries and solar photovoltaic (PV) panels, both of which are categorized as e-waste in the context of this case study. The study presents current issues on these top-ics in Korea and discusses the challenges associated with implementing Circular Econ-omy concepts for these technologies. It thereby shows how Sustainable Infrastructure can contribute to scaling up a Circular Econ-omy, and thus support the realization of global as well as Korean sustainable devel-opment agendas.

As the ROK moves towards achieving net-zero carbon emissions by 2050[21], it will be necessary to ramp up renewable electricity generation that will replace coal-fired and, ulti-mately, natural gasfired generation. Coal- and gas-fired power plants currently provide the vast bulk of the ROK generation mix along with nuclear power. At the same time, in order to reach net zero carbon emissions, replacing much of the existing fleet of motor vehicles with electric vehicles is a key goal for the Korean car industry, the fifth largest manufacturing industry of passengers cars worldwide[22] .

The increasing share of renewable energy – in particular solar PV power – and of EVs in the future economy and the ROK's existing and growing strength in both industries means that substantial and increasing vol-umes of used PV panels and EV batteries will be produced each year. In order to mini-mize hazardous waste and adverse effects on the environment and human well-being, used PV panels and EV batteries will need to be reused or recycled appropriately. It is, therefore, essential to establish innovative recycling infrastructure for solar PV panels and of EV batteries and to include the de-velopment of such infrastructure in the ROK's waste management and manufactur-ing policies and practices, thereby not only making the energy and mobility sector truly sustainable, but also reducing demand for new resources and promoting Circular Econ-omy practices.

In the wake of the COVID-19 pandemic, stimulus programs and funds designed to spur economic recovery can be targeted at "green economy" investments for advancing Sustainable Development, particularly those focused on renewable energy and electrifica-tion of motor vehicles. As such, the plans of the ROK for the recycling of PV panels and EV batteries provide a helpful case study on how post-COVID stimulus funds might be targeted to initiatives that promote sustaina-ble infrastructure, focusing on the energy and mobility sectors, while enhancing transi-tions towards a Circular Economy.

[21] IISD (2020)

[22] Statista (2020

1. NATIONAL POLICY CONTEXT

This section outlines the ROK's most important policy frameworks concerning resource circular-ity as well as the economic recovery package developed by the Korean government in re-sponse to the COVID-19 crisis, known as the Korean New Deal.

1.1 RESOURCE CIRCULATION POLICY FRAMEWORKS

As the volume of household and industrial waste continues to increase in Korea, the govern-ment is obliged to address the needs by enhancing resource efficiency and reducing the amount of waste generated throughout the product life cycle in order to reduce the amount of waste destined for landfills. The government seeks to realize these reductions in waste volumes through polices, measures, and infrastructure consistent with constructing a Circular Economy.

Against this background, the Korean government enacted the "Framework Act on Resource Circulation" (FARC) in 2016 and enforced it since January 2018. The FARC lays out the policy context for developing a Circular Economy in the ROK and aims "to transform the mass pro-duction-oriented and mass waste-producing economic structure into a sustainable and efficient resource-circulating one at a fundamental level" by streamlining regulations, managing resource-recycling performances, fostering recycling industries and introducing waste disposal fees for incineration and landfill sites (see Figure 1) [23]

Figure 3-1_ Elements of the Framework Act on Resource Circulation

Pursuant to Article 11 of the FARC, the "Basic Plan on Resource Circulation (2018-2027)", here-inafter referred to as the Basic Plan, was established to set mid to long-term Circular Economy goals and strategies, thereby establishing the Circular Economy as one of the key elements to driving Sustainable Development in the ROK. The Basic Plan includes the following policy pri-orities for nearterm implementation: Constructing a resource circulation system throughout the life cycle of materials, from production to consumption, management and recycling; reducing the generation of waste and promoting the recycling of high-quality waste materials; and optimizing community-based waste management through the use of participatory governance.

[23] Korean Environment Institute (2016)

The goals of the Basic Plan are to reduce waste generation rates relative to GDP by 20%, in-crease the rate of materials recycling from 70.3% to 82%, and reduce the fraction of waste materials disposed of in landfills from 9.1% of all solid wastes in 2016 to 3% by 2027 .

After the announcement of the "Comprehensive Measure of Waste Recycling" in 2018, the policy direction in the ROK on topics related to recycling has moved to enhancing a life-cycle based on the circular approach and establishing a resource-efficient Circular Economy. Sup-port for recycling is expanding through increased government R&D to develop improved recycling management and clean production technologies, as well as other government support for the development of recycling infrastructure and recycling markets. It is expected that in addi-tion to supporting the principles of a Circular Economy, there will be positive associated im-pacts in the ROK with regards to making progress on sustainable development goals (SDG), including SDG 12.5 and 12.6 (targeting sustainable consumption and production, or SCP), 9.5 and 9.6 (focusing on sustainable industrialization and fostering innovation), 9.4 (sustainable infrastructure), 11.6 (sustainable cities and communities), 7.2 (clean energy), 11.6 (sustainable cities), 7.2 (renewable energy), and 8.2 and 9.2 (jobs and local businesses).

1.2 THE DIGITAL NEW DEAL AND THE GREEN NEW DEAL

The COVID-19 crisis has dramatically affected the economy of the ROK. In response, the ROK government has introduced an economic stimulus package known as the Korean New Deal that is designed to stimulate the economy, while increasing the resilience of economic agents against the uncertainty of changing economic structures and transforming the country towards a more sustainable, climate-friendly and climate change resilient future. The key elements of the Korean New Deal are the Digital New Deal and the Green New Deal, coupled with a cross-cutting policy to strengthen the employment and social safety net in the ROK.

In the Digital New Deal, the ROK aims to further strengthen its digital capacity, thereby promot-ing innovation, dynamics, and flexibility throughout the economy. The enhanced digitalization will enable further integration of mostly intermittently–available renewables sources of electricity in the grid, and the wider deployment of data and digital technologies will accelerate the transi-tion of the mobility industry towards EVs. Moreover, digital technologies can initiate new pro-cesses in the recycling sector, thereby increasing its efficiency.

Korea's Green New Deal aims to accelerate the transition towards a low-carbon, green economy. To this end, the government plans to build eco-friendly energy infrastructure, renovate public facilities into zero energy buildings and achieve the goals of the ROK's "3020 initiative"[25], namely increasing renewable electricity generation from 6% of the total in 2017 to 20% in 2030. (Chung and Lee 2020; IEA 2020) Building smart grids and "eco-friendly vehicles" are also listed as elements of the Green New Deal. These elements require certain industries to grow rapidly—notably industries associated with producing and, in some cases, installing renewable energy and renewable energy infrastructure, energy storage technologies, and electric and hydrogen vehicles (and the infrastructure to fuel them)—and those industries will need to embrace the goals of a Circular Economy in order to be truly "green".

[24] Korean Environment Institute (2019)

[25] For an overview on the Korean "Renewable Energy 3020 Implementation Plan", please see Korea, Ministry of Trade, Industry and Energy (2017). The 3020 plan targets 20% of energy production will come from renewa-ble sources by the year 2030.

2. SCALING UP THE CIRCULAR ECONOMY IN THE TRANSITION TO ELECTRIC MOBILITY AND RENEWABLE ENERGY

Even though EVs still account for less than 1% of the total vehicles market in the ROK in 2020, the number of total EVs in the ROK has increased more than tenfold over the last four years.

(Korea, Ministry of Land, Infrastructure and Transport 2021) This trend is expected to continue in part because of to the government's strong drive to boost the use of eco-friendly vehicles and the growing public interest in eco-friendly cars. In July 2020, the Ministry of Environment announced that with the government's USD17 billion investment and subsidies, it intends to catalyze an increase in the total number of electric vehicles in the Korean market from the 110,000 units on the road in September 2020 to 1.13 million units in 2025. In addition, the minis-try plans to expand the number of available electric chargers for EVs from approximately 22,000 units deployed in 2020 to 45,000 units in 2025. (Lewis 2020; Shin 2020)

In addition, renewable energy, especially solar power, although a small source of electricity production in the ROK at present, it is set to grow in the long run, with growth supported by government incentives to meet power targets. Renewable electricity generation accounted for nearly 6% of the total 2017 ROK generation portfolio, having risen steadily over the past dec-ade. (Chung and Lee 2020) The government intends to raise the share of renewable energy to 20% of total power generation by 2030 and to at least 30% by 2040 through several govern-ment policies announced in the past few years such as the Korean Green Deal. (International Energy Agency 2020) Solar power generation capacity is also expected to increase from 5.1GW in 2017 to 36.5 GW in 2030. (Chung and Lee 2020)

Increasing production of EVs will result in an increased demand for EV batteries and, ultimately, as EVs become a larger part of the ROK vehicle fleet, more used EV batteries. The produc-tion of EV batteries, however, could bring negative environmental impacts as significant amounts of carbon dioxide and other pollutants are emitted during battery production process-es, and metals like lithium, nickel, and cobalt need to be extracted to produce batteries. The major components in EVs that are significantly different in composition than the components in conventional combustion-engine vehicles are the batteries, which are both larger in size and weight and composed of different materials—for example, based on lithium versus lead—than the batteries in internal combustion-engine vehicles. Greenhouse gases and other emissions are produced when the metals used in batteries are mined and refined, and during the process of making the batteries. The environmental burdens associated with mining of the resources need-ed for EV batteries vary considerably with the type of mining carried out, with the location of resource extraction and with the degree to which mining companies and the authorities that oversee them focus on reducing and managing mining wastes. Mines for some materials in some countries—for example, artisanal cobalt mines in the Democratic Republic of Congo—are reported to produce emission that lead to the presence of soil pollution and toxic surface dust. Apart from the mining itself, when the processing of materials for EV batteries and the manufacturing of EV batteries requires heat and electricity, the sources of these energy forms—ranging from coal-fired boilers and power plants to renewable electricity—determine the amount of GHGs emitted per unit of EV batteries and per EV (US Congressional Research Ser-vice, 2020). Reducing the need for new resource extraction to provide as inputs to the produc-tion process of EV batteries could therefore also limit the environmental burden associated with the full EV battery life cycle. (International Council on Clean Transportation 2018)

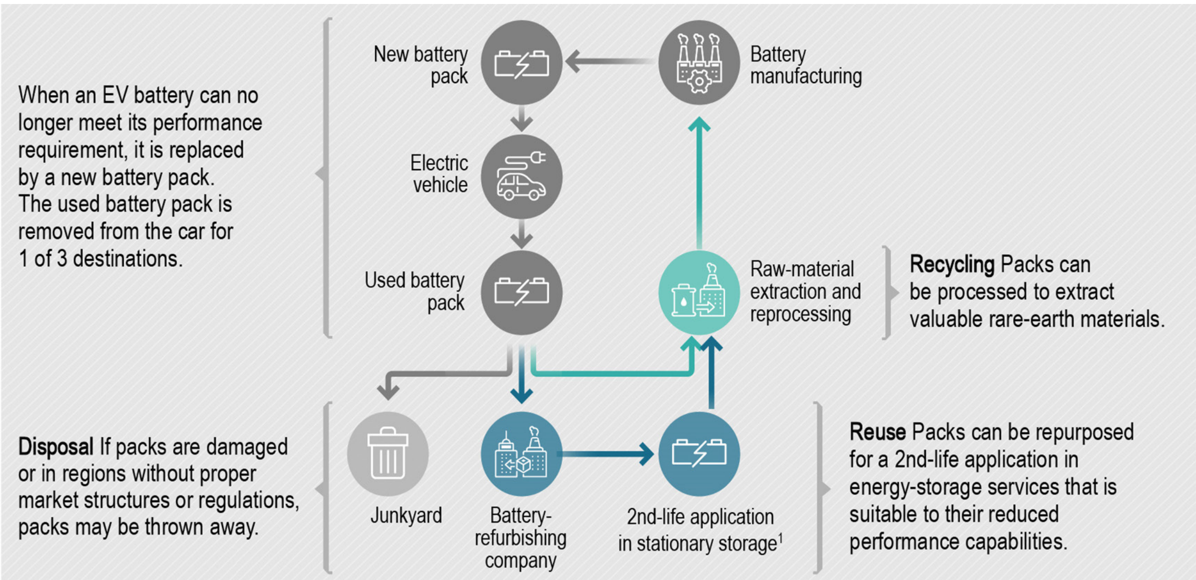
Similarly, the increasing generation of solar power will also lead to a higher demand for PV panels and result in more decommissioned panels. The weight of decommissioned PV panels in the ROK is, in fact, estimated to "increase from 198 tons in 2019 to more than 9,600 in 2023 and even more than 16,000 in 2028".(Ko 2020) Current solar PV panels are mostly glass, but the glass can contain elements such as cadmium, lead, and antimony that make glass recycling difficult, and if the panels are improperly disposed of, have the potential to leak into the envi-ronment.(Shellenberger2018) Moreover, solar modules contain potentially dangerous materials, including silicon tetrachloride. Sulfur hexafluoride, a potent greenhouse gas, is also often used in PV panel manufacturing. (Gies 2010)

The ROK, like many other economies in the early stages of the transition towards a lower-carbon future, lacks capacity, technology, infrastructure, and markets for waste management and recycling of new types of waste from the e-mobility sector and the renewable energy sec-tor, such as used EV batteries and decommissioned PV panels. For example, since 2018 in the ROK, EV batteries that had been produced by manufacturers receiving governmental subsidies are required to be returned to local governments after decommissioning where they will be stored. An effective and profitable recycling system is still missing as of 2020. (Auto Recycling World 2020; Kim 2020b) Furthermore, even in 2020, decommissioned solar PV panels from the ROK were still being exported to developing countries, incinerated, or buried underground. (Kim 2020a)

2.1 POSSIBLE SOLUTIONS AND GAPS IN ALIGNING LOW-CARBON TRANSITIONS WITH CIRCULAR ECONOMY

On-board rechargeable batteries – the lead-acid and, increasingly, lithium-ion batteries that are currently used in electric vehicles have typical lifetimes of a decade or less, but are often re-moved from EVs even sooner. Used batteries, however, could retain up to 80% of their original capacity. (Pyper 2020) There is, therefore, great potential to refurbish and reuse these batteries either for their original purpose as EV batteries or for other purposes, depending on the residu-al life or state of health of the battery. These reused or repurposed batteries are often referred to as "second-life batteries". The greatest environmental benefit of second-life EV batteries oc-curs when they are refurbished and reused as batteries in EVs, effectively reducing the need to produce new EV batteries. Figure 3-2 provides an illustration of possible EV battery life cy-cles. (McKinsey & Company 2019) The effect of refurbishing and reusing batteries is significant in that second-life EV batteries can reduce CO2 equivalent emissions substantially– at a rate estimated at about 48.8 kg of CO2eper kWh of battery capacity. (Korea Energy Economics Insti-tute 2018) The second use of EV batteries is therefore necessary to help solve environmental issues associated with EV production and EV waste management, and should be supported by government policy.

Figure 3-2_ Illustrative EV battery life cycle



Source: McKinsey & Company, 2020

Solar modules are typically composed of 76% glass, 10% polymer, 8% aluminum, 5% silicon and 1% other metals including copper and silver. (Kim 2020a) A substantial portion of these materials can be recovered (see Figure 3-3), and can then be reused as input materials for other manufacturing processes, reducing both the risk for improper and environmentally damaging disposal of used solar PV panels and the need for new resources in the manufacturing process of new solar PV panels and other goods. (Greenmatch 2020)

Figure 3-3_ Illustrative recycling processes of used solar PV panels

Source: Greenmatch, 2020.

As outlined above, there exist several possibilities for recycling and reusing EV batteries and solar PV panels. Therefore, the overarching policy challenge for the ROK is how to establish waste management regulations and infrastructure that can facilitate recycling market develop-ment and deployment of advanced technologies in the e-mobility and renewable energy sec-tors.

Some additional related key challenges include:

- **Institutional arrangements:** Handling of used EV batteries and decommissioned PV panels has not been fully incorporated into existing resource circulation policy frameworks for long in the ROK, resulting in insufficient institutional support for the recycling of these materials compared with conventional sources of waste.
- **Technology and capacity:** Technology is a challenge for all waste and recycling management. Recycling EV batteries and PV panels requires more specialized knowledge than for recycling of many other types of materials, and specific technologies to handle and process them, as well as to handle the intermediate materials produced by recycling processes. In addition, life-cycle resource management capacities must be developed in order to implement Circular Economy policies.
- **Collection:** Used EV batteries and decommissioned PV panel waste collection systems are currently inadequate in the ROK. There is a need to develop public collection systems in part-nerships with the players in the private sector, including users of EVs and PVs, recyclers, and EV/PV producers.
- **Immature markets:** Without supporting infrastructure and institutional arrangements, the cost of recycling EV bat-teries and PV panels will be high in comparison with the costs of managing conventional waste resources. This high cost will be a barrier to recycling market growth, particularly in the early stage of market development when EV and PV producers must be induced to incorporate re-cycled materials into their production processes.

2.2 "FUTURE WASTE RECYCLING SYSTEM"

The ROK's efforts in systematic e-waste management began in the early 1990s with the intro-duction of a Producer Recycling System that placed the responsibility of recycling on produc-ers. In 2003, the "Extended Producer Responsibility" (EPR) system replaced the previous Pro-ducer Recycling system, setting mandatory goals for recycling and penalized producers who failed to follow through on their responsibilities.

In 2018, recognizing the growing need to assure the safe and effective recycling of a broad range of e-waste, including those that are featured in ongoing transitions to a greener Korean economy (such as used EV batteries and decommissioned solar panels) the Ministry of Envi-ronment announced revisions to the "subordinate regulations to the Act on the Resource Circu-lation of Electrical and Electronic Equipment and Vehicles and the Waste Control Act". This policy responded specifically to the need to update regulations in order to establish a system for recycling the expected increasing volumes of used batteries from EVs and decommis-sioned solar panels. The key elements of the announced revisions include (Korea, Ministry of Environment 2018) expanding the extended producer responsibility (EPR) regulations to an ad-ditional 23 products including decommissioned solar panels starting in 2023 (Kim 2020a); and

preparing methods and criteria for the recycling of future waste, especially for used electric car batteries and decommissioned solar panels that require proper treatment and handling in the course of recovery and recycling because they contain hazardous substances.

Moreover, the Ministry of the Environment announced plans to establish a new system for col-lecting EV batteries and solar panels in "Future Waste Resource Collection Centers", which are e-waste treatment facilities specializing in either used EV batteries or PV panels. (Korea, Minis-try of Environment 2018) The role of the Collection Centers goes far beyond the simple collec-tion of e-waste from either EVs or PV panels. It aims to establish basic infrastructure services and institutional arrangements that can facilitate the e-waste management market in Korea via the following key approaches:

Modification of regulations

- Preparing an oversight system that regulates methods and criteria for the recycling of used EV batteries and decommissioned PV panels.
- Introducing extended manufacturer responsibility as to collection and recycling of decommis-sioned PV panels by modifying the subordinate regulations in the Resource Circulation Act of 2018.
- Developing methods and criteria for the recycling of decommissioned PV panels and used EV batteries that contain hazardous substances requiring proper treatment.

Collection

- The "Future Waste Resources Collection Centers" will be set up by the government before the recycling of waste resources becomes active within the private sector in order to make sure that collection infrastructure is in place when large volumes of used EV batteries and decom-missioned solar PV panels require management.
- Waste produced before these regional collection centers are commissioned are collected and stored in temporary warehouses (in facilities owned by the Korea Environment Corporation) thus preventing their improper disposal in landfills.
- The Collection Centers responsible for the collection of used EV batteries will be tasked with recovering the used batteries, performing primary inspections, storing them safely, and deliver-ing them to recycling businesses when demand for used batteries arises. As of 2020, there are four collection centers under construction (one near Seoul, one in the Chungcheong Province, one in South Gyeongsang Province and one in the Jeolla region) that will be responsible for the collection of used EV batteries. The construction of these centers is expected to be completed in 2021. (Kim 2020b)
- Decommissioned PV panels disposed of as municipal waste will be collected and managed by the local government, whereas the responsibility for delivery of waste panels produced by businesses (such as power generators) lies with the owners of the solar PV generation, who must deliver decommissioned solar panels to the relevant PV panel collection centers. The main reason for this division is that solar PV panels in municipal wastes constitute a diffusing resource that must first be separated from other wastes. On the other hand, panels from de-commissioned power plants constitute a concentrated source of decommissioned panels that is more efficiently managed by the power plant owner, who in any case would need to transport the decommissioned panels when the power plant is disassembled, or when the panels are re-placed.

Recycling

- The Collection Centers will be tasked with encouraging the application of private sector-driven recycling technologies that meet the needs of manufacturers for recycled material inputs to new solar panels and batteries, and building relevant infrastructure for recycling. Through a combi-nation of experimenting with new methods and collecting data on the effectiveness of recycling processes under the updated legislation, the Collection Centers will be tasked with promoting the development of decommissioned PV panel recycling technologies and cultivating the growth of expert recycling companies by implementing demonstration EPR projects in joint ventures with PV panel manufacturers and importers.
- Collection Centers will be tasked with encouraging manufacturers to share costs incurred in the recovery, evaluation, and recycling of used batteries by applying EPR to the automobiles sec-tor, thus activating private recycling markets for used EV batteries. Moreover, in order to over-come the lack of recycling infrastructure, the government is currently building recycling facili-ties.
- As of 2020, three recycling centers of EV batteries are being planned or are in operation. The construction of the recycling center on Jeju Island was completed in 2020, and the centers in Pohang (North Gyeongsang Province) and Naju (South Jeolla Province) are expected to be completed in 2021 or later.

Due to profitability issues, only one privately-run solar PV recycling facility (capable of pro-cessing 3,600 tons per year) operating as of early 2021, with another privately run recycling center (capacity of 2,500 tons per year) plans to start operating in 2022. In order to meet the required PV panel recycling capacity in the future, the government is also currently building an-other facility that will be able to recycle 3,600 tons of decommissioned solar PV panels a year. This new facility is located in Jincheon County and will be in operation in 2021. (Kim 2020a; Lin-nenkoper 2020). “The operation will break down the panels into its component parts of frames, junction boxes, back sheets and glass to recover silver, silicon, copper, glass and tin”, leaving no by-products other than the recovered materials, which are routed to the manufacturers or to the materials markets. (Linnenkoper 2020)

2.3 EXPECTED OUTCOMES AND BENEFITS

The revisions to ROK e-waste management regulations described above embrace the principles of resource circularity and aim to develop a system that safely manages the recycling of de-commissioned solar panels and used electric car batteries in an environmentally-friendly man-ner. The establishment of the regional collection centers provides an integrated infrastructure system for e-waste collection, storage, and assessment of these e-waste materials and will en-courage recycling which will be enabled by newly built recycling facilities. Thus, the ROK is cre-ating infrastructure that is required for the changing transportation and energy sector to be-come truly sustainable.

The goal of the new regulations is that the changes in e-waste management in general, and in management of solar PV panels and EV batteries in particular, will reduce the environmental burden and associated health risks to the local population, facilitate the development and prof-itable operation of recycling businesses, and induce the implementation of Circular Economy concepts in the PV and EV industries.

This new scheme also aims to deliver further benefits. For example, the new system aims to eliminate the disposal of used EV batteries in landfills. Another objective of the new regulations is to encourage the collection of used PV panels from the operators (generation owners) direct-ly, which should lead to very high recycling rates of all materials used in PV panels. In addition, the revised legislation is expected to contribute towards the development of a high-value-added future recycle and reuse industry by promoting the manufacture of energy storage sys-tems (ESS) using batteries no longer suitable for EV use but often with sufficient (up to 80 percent) capacity left to be useful for bulk power storage. (Auto Recycling World 2020) When batteries are recycled, the recovery of precious metals from waste electric vehicle batteries is likely to be profitable.

The new regulations and the establishment of the Future Waste Resource Collection Centers will, therefore, not only provide environmental and social benefits, but also economic benefits in terms of new employment and income opportunities in new industries and/or public infra-structure.

The ROK's Future Waste Recycling System demonstrates various aspects of good practice for the development and deployment of sustainable infrastructure (see table 1).

Table 3-1_ Demonstrated Aspects of Sustainable Infrastructure

International Good Practice Principles for Sustainable Infrastructure [26]	ROK Future Waste Recycling System (FWRS)
1. **Strategic Planning.** Infrastructure development decisions should be based on strategic planning that is aligned with global sustainable development agendas and supported by enabling policies, regulations and institutions that facilitate coordination across departments and both national and sub-national levels of government and public administration.	ROK is reshaping its resource circulation policy framework with the participation of the Ministry of Environment and the Ministry of Trade, Industry and Energy and in line with the global sustainable development agen-das. FWRS is also aligned with national reg-ulations and the ROK's COVID-19 response and a fiscal stimulus package, the Green New Deal.
2. **Responsive, resilient, and flexible service provision**. Infrastructure planning and development should be based on a good understanding of infrastructure service needs and informed by the diverse solutions available to meet those needs. […]	The FWRS will be established in response to the increasing production of EVs and en-hanced generation of solar power and the resulting need to establish an integrated re-covering and recycling system for used EV batteries and decommissioned solar PV panels.
4. Avoiding environmental impacts and investing in nature. Adverse environmental impacts from infrastructure should be minimized […]	The FWRS will be introduced in order to avoid the environmental impacts of the transportation and energy sectors resulting from used EV batteries and decommis-sioned solar PV panels.
5. Resource efficiency and circularity. Circularity and the use of sustainable technologies and construction materials should be planned and designed into infrastructure systems to minimize their footprints and reduce emissions, waste, and other pollutants.	FWRS will enhance the circularity of the e-mobility and renewable energy sectors and increase resource efficiency through ena-bling recycling and reusing. It will thereby decrease resource extraction and the asso-ciated adverse effects on biodiversity and ecosystems.
7. Enhancing economic benefits. Infrastructure should create employment, support local businesses, and build amenities that benefit communities, thereby maximizing and safeguarding its economic benefits.	"Future Waste Resource Collection Centers" will create new jobs and business opportuni-ties within local economies. The resulting establishment of recycling markets will lead to further employment and business oppor-tunities.
9. Transparent, inclusive, and participatory decision-making. Infrastructure development should be underpinned by transparent planning, information-sharing and decision-making processes that facilitate meaningful, inclusive, and participatory stakeholder consultation, and in the case of indigenous peoples, their free, prior, and informed consent. […]	FWRS will be developed by amending laws and national plans including the participation of local governments in the policymaking process.

[26] United Nations Environment Programme (2021)

3. CONCLUSION

This case study demonstrates how low carbon transitions in the transportation and energy sec-tors can be aligned with Circular Economy goals. Moreover, it details how the development and deployment of sustainable infrastructure, in the form of "Future Waste Recycling Systems", not only helps to scale up a Circular Economy and improve resource efficiency, but also helps to make the e-mobility and renewable energy sectors more sustainable.

By planning to extend Circular Economy regulations and policy frameworks and developing the integrated "Future Waste Recycling System", the ROK is working to anticipate and respond to the changes and challenges induced by low-carbon transitions in the transportation and energy sectors, namely the upcoming dramatic increases in volumes of used EV batteries and de-commissioned solar PV panels. This effort to plan for the management of future waste streams underlines the need for integrated strategic infrastructure planning, which is also required to understand and consolidate all of the implications of environmentally-beneficial regulations and policy frameworks, such as the ROK's Green New Deal or net-zero target, and to avoid unin-tended consequences of such regulations including, in this case, the potential environmental harm of improper disposal of EV batteries or decommissioned solar PV panels.

Well-designed policies and infrastructure can help to scale up the Circular Economy and hence benefit the environment, while at the same time generating significant benefits for the people and the economy. To realize these benefits, Circular Economy policies need to be main-streamed into economic policies, particularly those relating to infrastructure since infrastructure is the backbone of economic and social systems.

This case study further outlines the main challenges that countries may face when incorporating Circular Economy principles in the e-mobility and renewable energy sectors. First, strong insti-tutional frameworks need to be established, strengthened, and continuously evaluated to in-corporate new lessons learned from the establishment, deployment, and operation of new re-gional waste management infrastructure. Expanding EPR, as planned in the ROK, can be one step in the right direction. Second, the recycling of e-waste, and particularly that of used EV batteries and decommissioned solar PV panels whose volumes will continue to rapidly increase globally in the upcoming decades, is technically more complex than the recycling of, for ex-ample, municipal solid waste. In many cases, private recyclers currently operating in the con-ventional e-waste recycling markets are not skilled enough to manage new types of e-waste from EVs and PVs efficiently and effectively and technological barriers exist as well. Continu-ous efforts and investment must therefore be directed towards capacity building and technolo-gy research and development. Third, future waste collection centers need to be built. Due to the low profitability of collection centers, this effort to build such centers may, in many cases, need to be led by governments, as demonstrated in the ROK. And last, economic barriers such as immature recycling markets for EV batteries and solar PV panels must be addressed in or-der to decrease the costs of refurbishment and recycling of these new wastes and to increase the economic benefits for local economies, including new employment and income.

The COVID-19 pandemic has had a major impact on social and economic systems around the world, changing both consumption and production patterns, and influencing the direction of technology development. On the other hand, the pandemic has also presented an opportunity for countries around the world to reshape their economies and industries and make them more sustainable. Going forward, COVID-19 economic recovery packages need to ensure a green recovery by fostering sustainable infrastructure, such as the integrated waste recovery and re-cycling system in the ROK, thereby mainstreaming circularity, reducing requirements for re-source extraction and promoting green and inclusive growth.

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การพัฒนาต่อยอด

รายงานฉบับนี้ได้รวบรวมกรณีศึกษาไว้จากประเทศจีน ญี่ปุ่น และสาธารณรัฐเกาหลีเกี่ยวกับโครงสร้างพื้นฐานอันยั่งยืนจากภาคส่วนและระดับต่าง ๆ อีกทั้งยังแสดงให้เห็นถึงความตั้งใจในการปฏิรูประบบเศรษฐกิจขั้นสูงในภูมิภาคไปสู่เศรษฐกิจหมุนเวียน หลักปฏิบัติที่ดีและบทเรียนที่ได้รับเหล่านั้นถือเป็นการขยายและเร่งการดำเนินการที่ผู้วางนโยบายและผู้มีส่วนได้เสียที่เกี่ยวข้องอื่น ๆ จากระบบเศรษฐกิจต่าง ๆในการเปลี่ยนผ่านสามารถจัดทำขึ้นได้

มีการคาดหวังให้ประเทศกำลังพัฒนาต่าง ๆ โดยเฉพาะอย่างยิ่งประเทศในภูมิภาคเอเชียตะวันออกเฉียงใต้ลงทุนในโครงสร้างพื้นฐานให้มากขึ้นเพื่อกระตุ้นเศรษฐกิจ สร้างงาน สร้างการเติบโตที่มั่นคง และฟื้นฟูประเทศจากวิกฤตโรคโควิด-19 นอกจากนี้การเกิดความยั่งยืนและการหมุนเวียนในโครงสร้างพื้นฐานเป็นสิ่งจำเป็นต่อการหลีกเลี่ยงผลกระทบเชิงลบที่อาจตามมา ช่วยสร้างความเข้มแข็งให้แก่ประเทศต่อวิกฤตโลกในอนาคต สร้างความเป็นอยู่ที่ดีให้แก่มนุษย์ และยังเป็นไปตามวาระการพัฒนาที่ยั่งยืน ค.ศ. 2030 และความตกลงปารีสอีกด้วย