Contribution to SDGs Through Introduction of Cogeneration Systems

Ⅰ. Benefits of cogeneration systems

Cogeneration systems generate power and heat on-site. They provide energy / non-energy benefits in terms of economics, environment, disaster prevention, urban development and regional revitalization. Such value can contribute to attain sustainable world and to help private companies, national / local governments and communities to undertake SDGs (Sustainable Development Goals). This paper describes the various benefits of cogeneration and its contribution to SDGs.

■Value provided by cogeneration

No.	Value provided	Description
1	Shift to low-carbon energy utilization  Low-carbon	The heat that is produced through power generation is used on-site, achieving efficient energy use and a shift to low-carbon energy utilization.
2	Introduction of renewable energy  Renewable energy	Cogeneration systems that use renewable energy as well as mixed use of renewable energy heat and cogeneration waste heat help to promote the introduction of renewable energy.
3	Contribution to electrical power grid  Contribution to grid	As cogeneration systems are placed in customer areas, investment in power transmission and distribution networks can be reduced. In addition, the systems can be operated in response to power supply and demand, helping to reduce peak power, decrease investment in system equipment and regulate renewable energy fluctuations.
4	Increased resilience  Resilience	Cogeneration systems, connected with earthquake-resistant medium-pressure gas distribution networks and equipped with power-outage-ready function, help to improve disaster resilience and to increase property values.
5	Contribution to urban development  Urban development	The introduction of cogeneration systems in cities helps to achieve safe, low-carbon urban development and internationally competitive cities.
6	Contribution to regional revitalization  Regional revitalization	The shift to energy resources that are available locally promotes the creation of new industries and jobs, the circulation of financial resources within the region, helps to promote local economic development. In addition, it also helps to create compact cities in regional areas.
7	International cooperation and stronger partnerships  Overseas infrastructure	The resale of LNG, construction of LNG plants and involvement in downstream sectors like construction of cogeneration systems for other Asian countries will help to maintain good international relations.

1 Shift to low-carbon energy utilization

Low-carbon

Combined heat and power supply systems

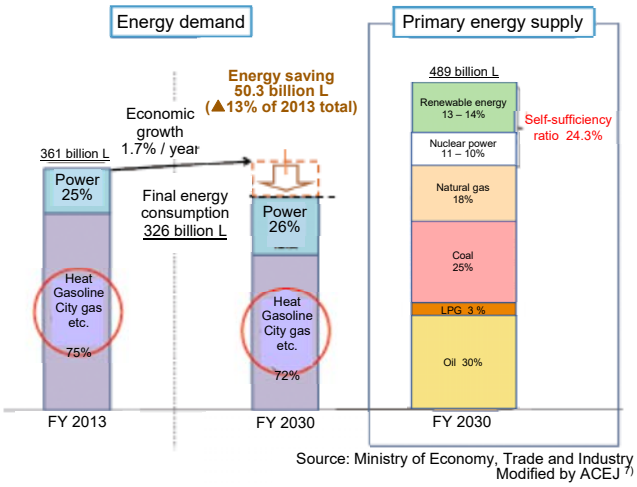
In the shift to low-carbon energy utilization, electrical power use attracts most of the attention. However, heat use currently accounts for approximately 70% of final energy consumption in Japan, and this is expected to be similar in 2030 as well. Accordingly, the shift to low carbon heat is extremely important. Normally, large-scale centralized power plants are constructed far from customer areas, so the heat produced through power generation cannot be transported to customer areas and is simply discarded as waste heat. Conversely, cogeneration systems are placed near customer areas and the heat produced through power generation is used effectively. By increasing energy efficiency, they make a major contribution to the shift to low-carbon energy utilization.

SDGs

Affordable and Clean Energy

Climate Action

Energy demand in Japan and primary energy supply



Source: Ministry of Economy, Trade and Industry
Modified by ACEJ [7]

Cascading energy use

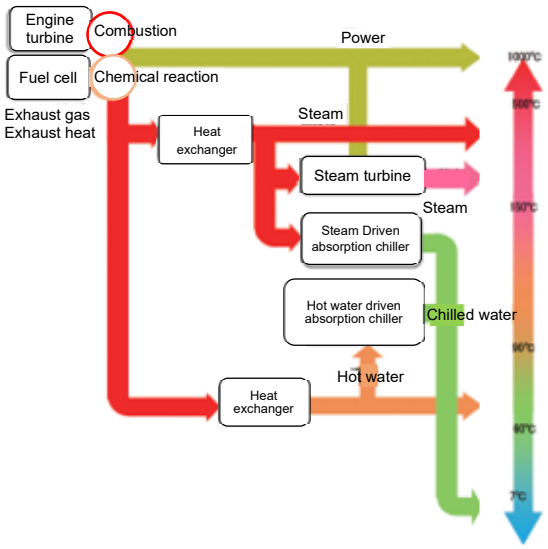
Cogeneration systems employ “cascading heat use” in which the thermal energy derived from fuel combustion is initially converted to motive power that can only be obtained at high temperature levels, and subsequently exhaust gas heat is used step by step with temperature lowering as it goes downstream so that all of the heat is used up. Cogeneration systems can apply to many different heat usages; depending on the temperature level, steam, hot water or chilled water using thermally driven absorption chillers.

SDGs

Affordable and Clean Energy

Climate Action

Cascading use of heat from cogeneration



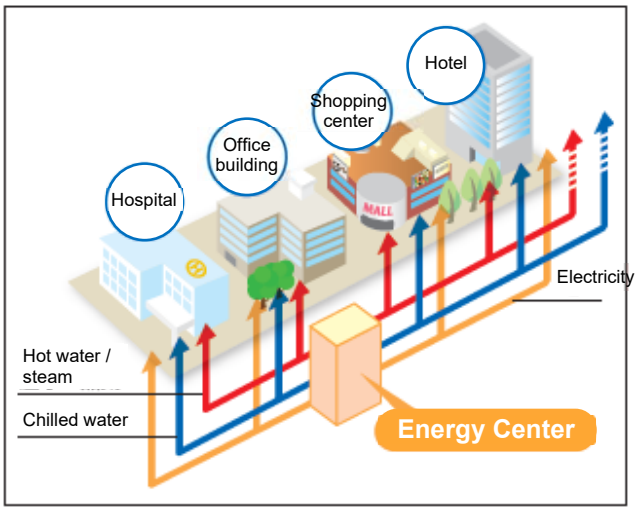
Area-wide energy use

As heat cannot be transported to far-away places, it must be produced where it is consumed. If a cogeneration facility is operated in accordance with the demand for electric power, it is possible that the heat supply from the cogeneration may not match the demand, resulting in heat being discarded. However, connecting buildings with pipes, to supply heat and cool and to achieve area-wide energy use, enables all of the exhaust heat to be utilized effectively and results in regional energy optimization.

SDGs

- Affordable and Clean Energy
- Industry, Innovation and Infrastructure
- Climate Action

Area-wide energy use

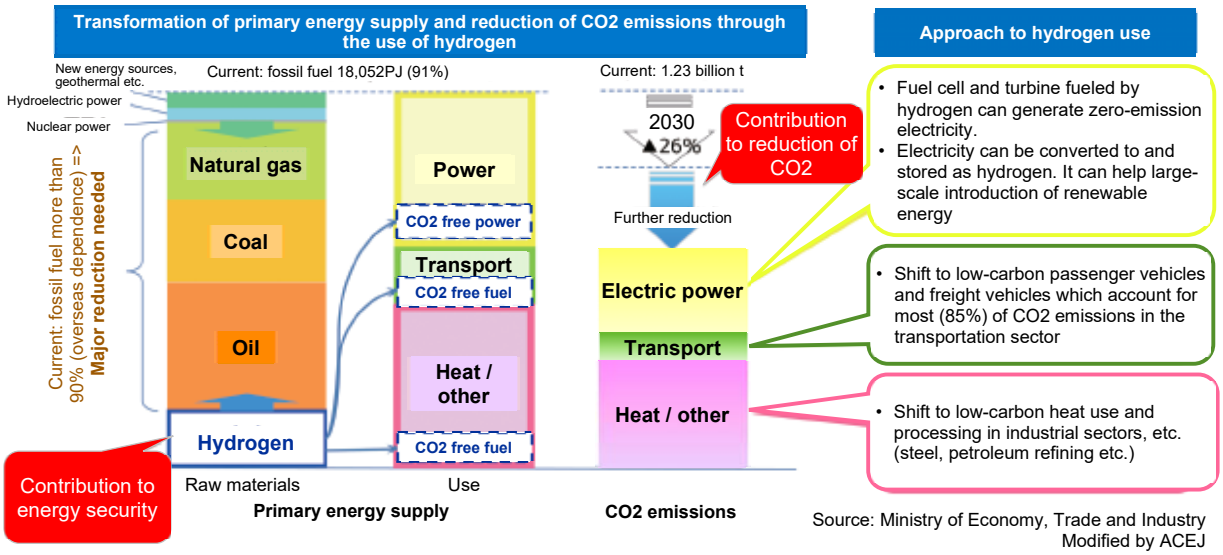


Fuel cells to build hydrogen-based society

Hydrogen is being proposed as one of the next-generation energy sources. Hydrogen-based society ~~use~~ does not merely attain decarbonized society; it also contributes more broadly to energy policy as a whole, as noted below.

- Hydrogen can be manufactured from various energy sources, contributing to energy security.
- Producing or consuming hydrogen to make up for the fluctuations in renewable energies enables generation and storage of electrical power and ensures a stable grid operation.
- Hydrogen can be used not only for generating electricity, but also for providing heat and for transporting energy, so it aids in the shift to decarbonization for all types of energy.
- Fuel cells are highly energy-efficient, helping to reduce energy consumption.

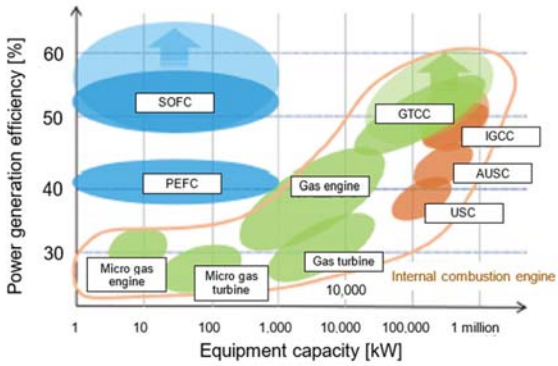
Significance of hydrogen energy use



Source: Ministry of Economy, Trade and Industry
Modified by ACEJ

Fuel cells are a cogeneration system that converts hy
efficiency equivalent to that of a large power plant, yet ha
a distributed power source to enable the use of waste h
equipment costs and lead to the hydrogen-based society

■ **Relationship between generator capacity and efficiency**

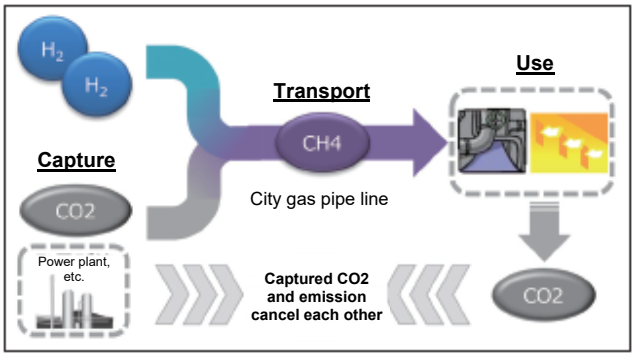


Source: Ministry of Economy, Trade and Industry
Modified by ACEJ

One of the hydrogen utilization methods that is being considered is arising reaction between hydrogen and CO2 to manufacture methane (methanation) for use as city gas or for power generation (PtG: Power to Gas). If the CO2 emitted from factories, etc. is captured and reacted with hydrogen to manufacture methane, the amount of CO2 emitted and captured are equal to each other, and therefore the amount of CO2 will not increase.

Widespread installation of cogeneration systems that u
consumption and aid in the shift to low-carbon society at p

■ **The carbon-neutral methane**



Source: Ministry of Economy, Trade and Industry
Modified by ACEJ

SDGs

- Affordable and Clean Energy
- Industry, Innovation and Infrastructure
- Climate Action

2 Introduction of renewable energy

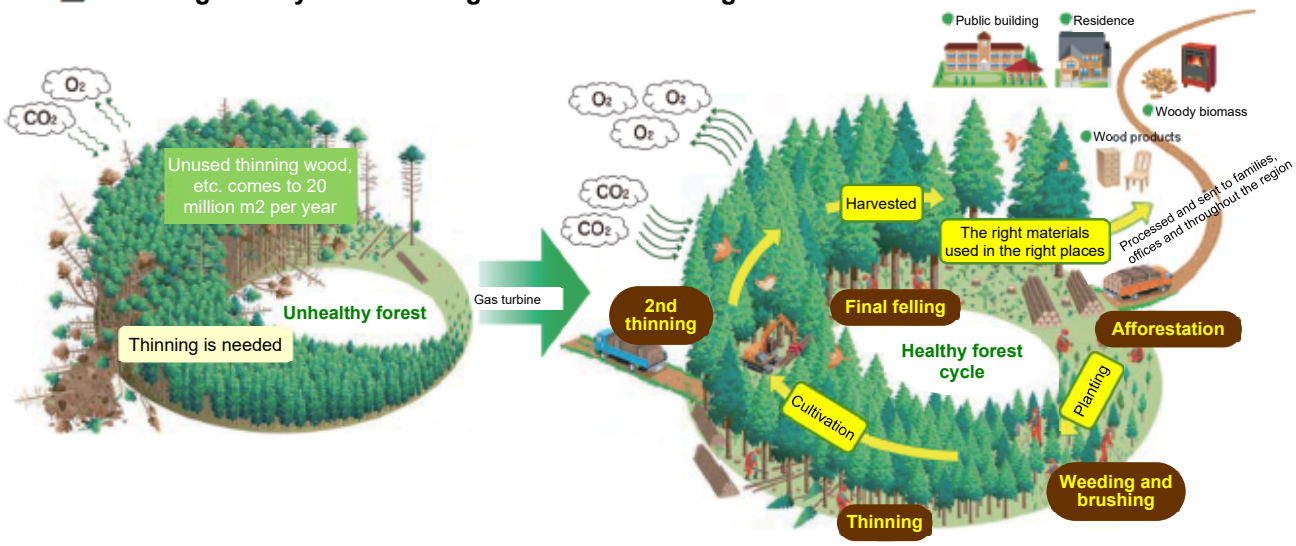
Renewable energy

Biomass use

Cogeneration systems can also use woody biomass, wastes, the digestive gases that are produced by sewage processing and other renewable energy sources as fuel. Using the byproducts and wastes produced at the district will promote local industry, enable sustainable development and help to prevent depopulation in rural areas.

With regard to woody biomass, the use of unused wood from thinning as fuel will promote forest maintenance and sustainable operations, and thereby will also help prevent deforestation and the resulting occurrence of landslides.

Nurturing healthy forests though the use of thinning wood



Source: Ministry of Agriculture, Forestry and Fisheries
Modified by ACEJ

SDGs

- Affordable and Clean Energy
- Responsible Consumption and Production
- Climate Action
- Life on Land

Establishment of a smart energy network

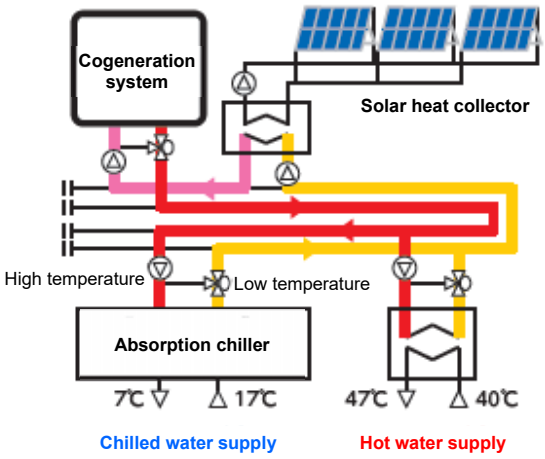
Cascading use of cogeneration waste heat and solar heat makes it possible to use the cogeneration waste heat to regulate fluctuations in the temperature of the heat from heat collectors, helping to ensure the effective use of renewable heat. Moreover, a “smart energy network” that is composed of (1) a cogeneration system at its core, (2) an area-wide network of heat and power produced in that region, (3) local generation and consumption of renewable and heretofore unused sources of energy and (4) energy management by means of information and communication technologies (ICT), will optimize energy use throughout the entire region.

SDGs

Affordable and Clean Energy

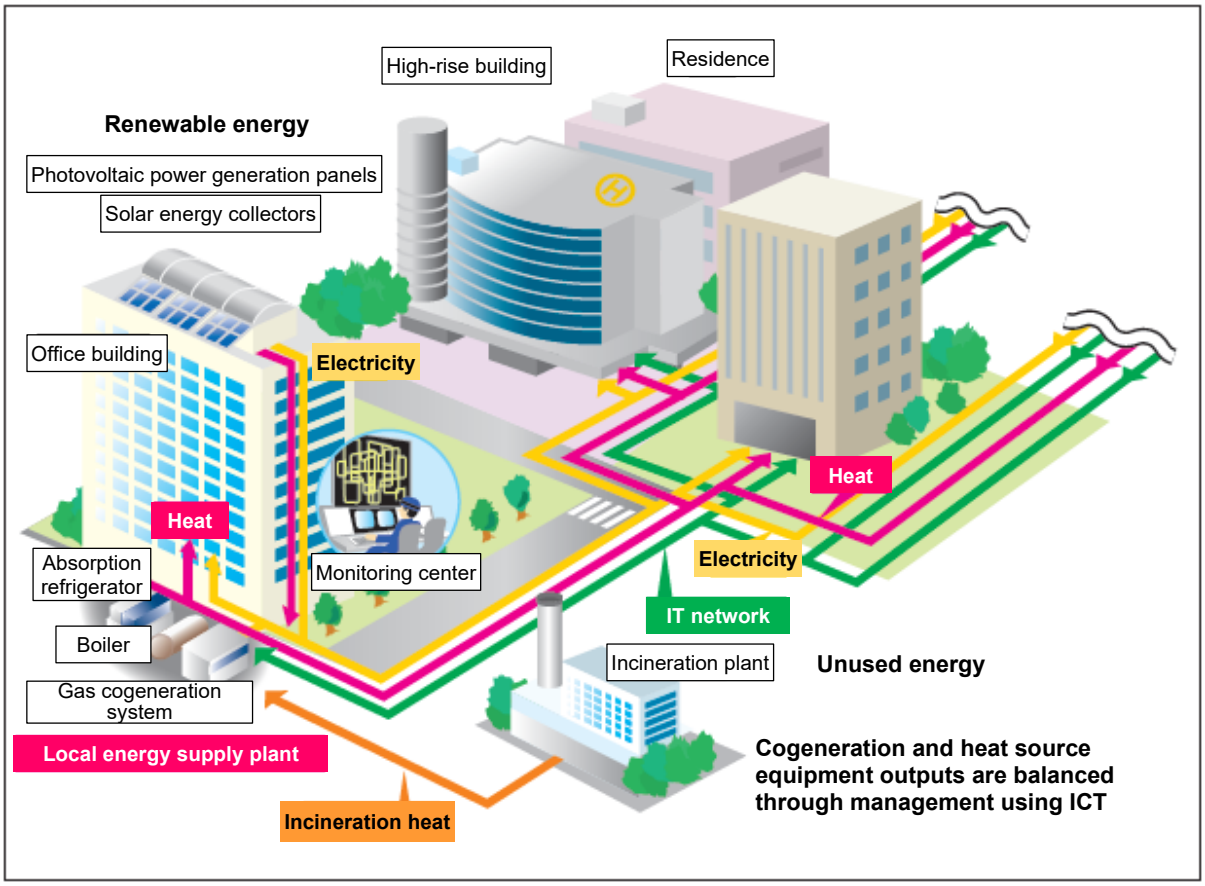
Climate Action

Cascading use of solar heat and cogeneration waste heat



Waste heat from cogeneration is released in the downstream of solar heat in order for cascading use of heat to keep hot water temperature

The “smart energy network” concept



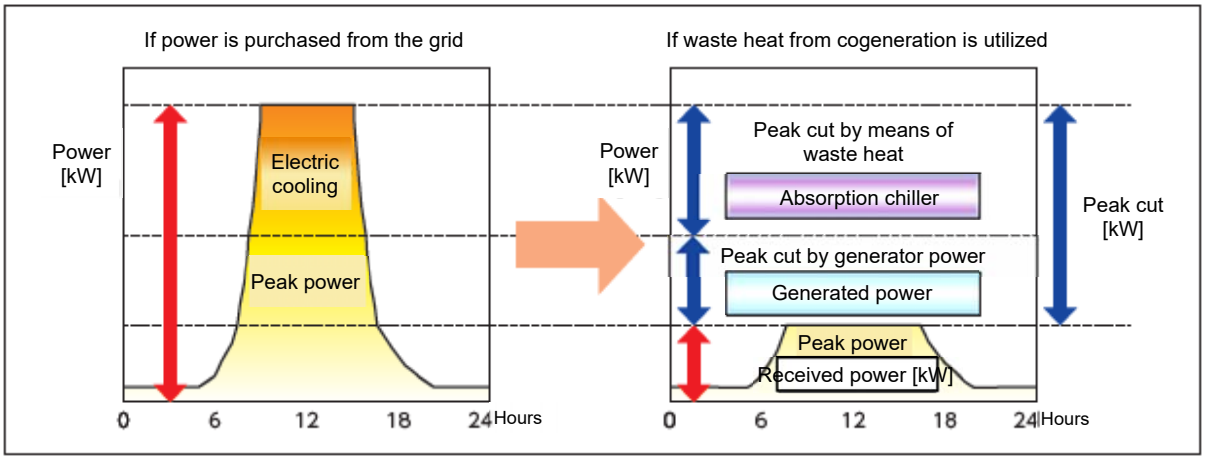
3 Contribution to electrical power grid

Contribution to grid

Cogeneration systems as power sources

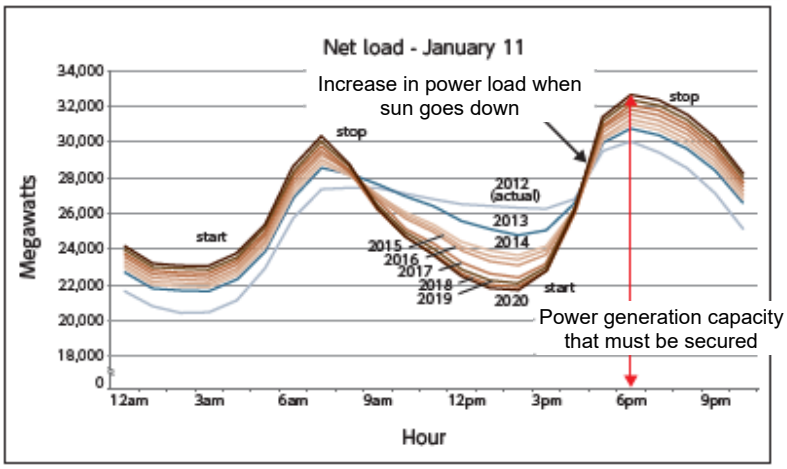
Cogeneration systems have a cumulative installation capacity of approximately 10 million kW, equivalent to 8% of the combined 120 million kW of LNG and oil-fired thermal power that are expected to compensate for domestic output fluctuations, and therefore they constitute a valuable power source. Since they can be built in a short time as compared to large-scale power sources, they are also effective as a means of rapidly supplying power. Moreover, cogeneration systems can be operated at peak times in summer and winter to cut peak demand (load equalization), eliminating excessive investment in electric power equipment and thereby reducing infrastructure construction and costs and providing a stable supply of electrical power. The power peak cut quantity can be increased further by changing from electric heating and cooling systems to air conditioning systems made up primarily of absorption refrigerators and other waste heat use equipment.

■ Load leveling effect of cogeneration



Introducing large quantities of photovoltaic power generation will reduce the daytime power load in summer. Moreover, as there is zero photovoltaic power generation output after dark, the power supplied by thermal power generation or other back-up power sources are still necessary. Moreover, as the photovoltaic power output drops rapidly in response to sudden changes in sunlight as evening approaches, another source that offers excellent control and to track these changes is needed.

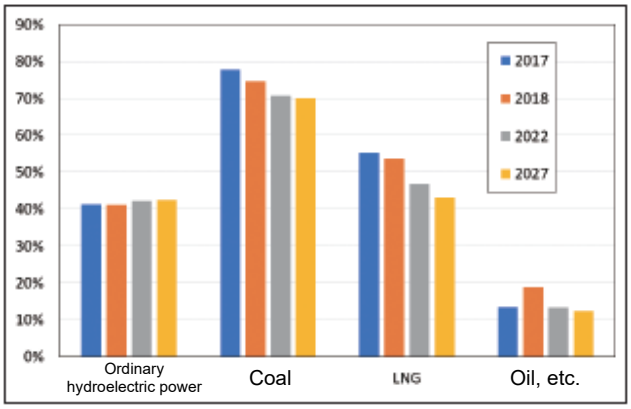
■ Daily power load in the future



Source: California Independent System Operator (CASIO)
Modified by ACEJ

For this reason, thermal power generators will continue playing an important role even when large quantities of renewable energies are introduced. However, the rule to prioritize renewable energy is gradually reducing operating hours of thermal power plants, and reduced profitability means that replacement and new construction of thermal power plants will stop, so there is a concern that in the future it might be impossible for the grid to keep stability and to cope with peak demand.

■ Working rate by power source



Source: OCCTO, modified by ACEJ

Cogeneration systems offer excellent controllability, being able to start up and control power quickly. They can ensure power during peak demand periods, and through participating in an electric power retail market or balancing market, can play a significant role in regulating power to stabilize the grid.

SDGs

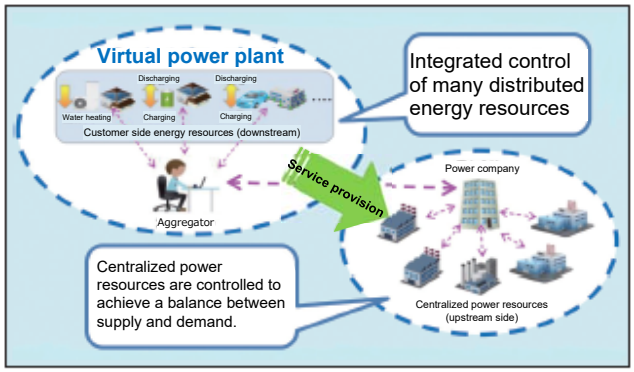
Affordable and Clean Energy

Industry, Innovation and Infrastructure

Coordination with naturally fluctuating power sources

Power systems must always balance supply and demand (this is known as a simultaneous commensurate power supply). However, as variable renewable sources such as wind power and photovoltaic power have constantly fluctuating output, a source of power that can make up for the fluctuations is needed. As noted above, it is difficult to anticipate additional construction of thermal power plants. Instead, advanced energy management technologies are expected to create a single virtual power plant (VPP) by means of integrated control of the power sources distributed on the power grid: (1) cogeneration systems and other distributed power sources (2) storage cells and (3) load adjustment (demand response) on the customer side. This VPP can be used to balance naturally fluctuating outputs, promoting the introduction of variable renewable energy sources.

■ VPP concept



Source: Ministry of Economy, Trade and Industry
Modified by ACEJ

SDGs

Affordable and Clean Energy

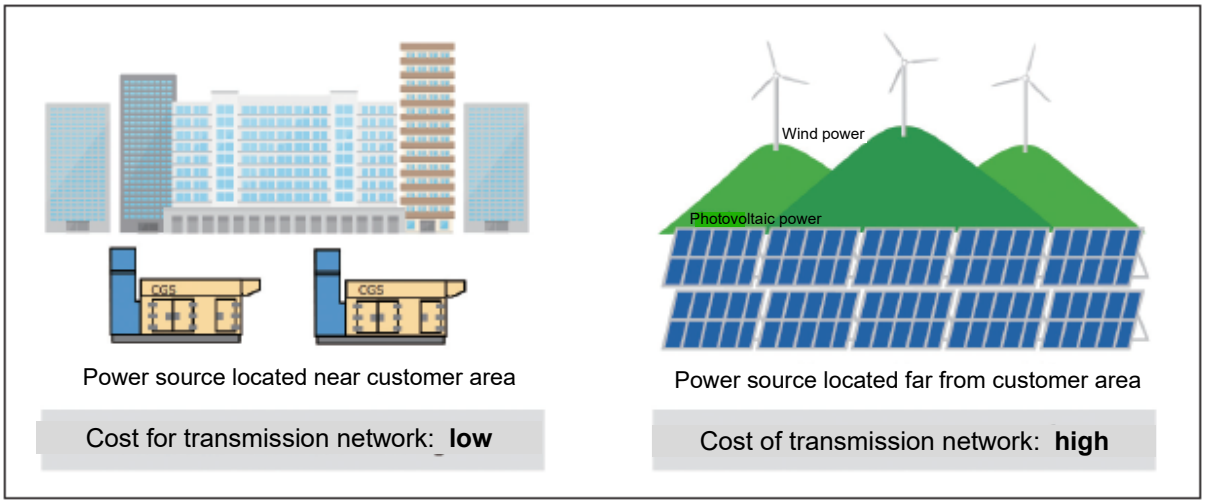
Industry, Innovation and Infrastructure

Improved power flow through installation of distributed power source near customer locations

The introduction of large scaled solar and wind power generators and other renewable energy sources in locations far from customer areas has resulted in increased investment for power transmission networks and increased transmission loss.

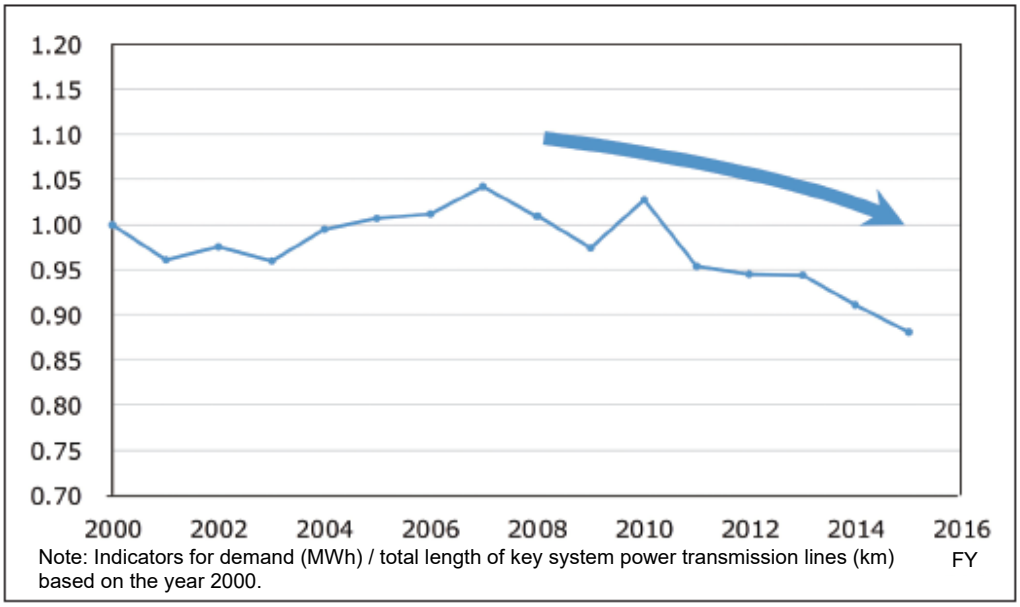
In contrast, cogeneration systems are installed at factories, hospitals, cities and so on where there is a plenty of electricity and heat demand. As the electricity flows inside these areas, cogeneration is expected to help reduce power transmission volume and improve the electrical grid power flow.

■ Distance between customer areas and power plants and cost of constructing transmission networks



Source: Ministry of Economy, Trade and Industry
Modified by ACEJ

■ Use efficiency of power transmission grid



Note: Indicators for demand (MWh) / total length of key system power transmission lines (km) based on the year 2000.

SDGs

Affordable and Clean Energy

Industry, Innovation and Infrastructure

4 Increased resilience

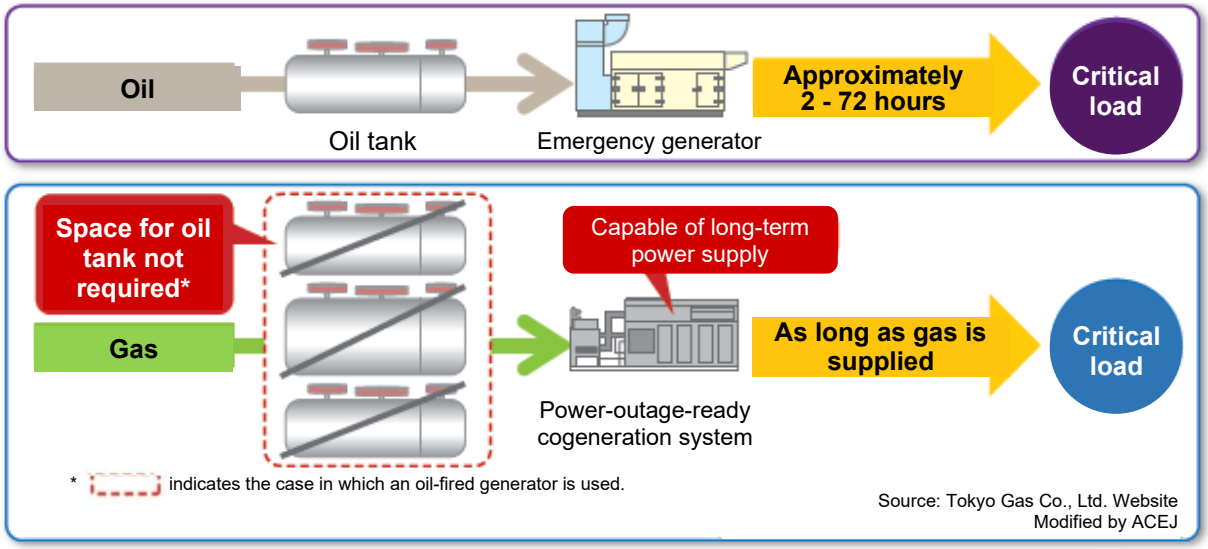
Resilience

Coping with earthquakes and power outages

Promoting the introduction of cogeneration systems will help to increase energy supply resilience (the ability to avoid fatal damage due to a disaster and the flexibility to enable rapid recovery). If natural gas is used as a fuel, the medium-pressure gas pipelines, which are designed to withstand even the fatal disasters that Japan has experienced, like the Great Hanshin-Awaji Earthquake of 1995 and the Great East Japan Disaster and tsunami of 2011, are available, ensuring that the supply of gas will not be cut off. Moreover, adopting power-outage-ready cogeneration equipment will ensure the supply of electrical power to critical loads in the event of a power outage. Furthermore, the system can also ensure supply of heat as well as power, helping to continue factory and hospital, etc. in operation. Use of petroleum or other stockpiled fuel involves issues with assigning a place to store fuel and limited operation time. In contrast, using city gas offers a number of advantages, including the ability to supply fuel continuously and not require a place for storage .

The medium-pressure city gas pipes are made of a material that is strong and flexible enough to withstand the impact of ground deformation during an earthquake, and they do not break even if they are bent by 180° (see figure at left).

Source: Tokyo Gas Co., Ltd. website



Source: Tokyo Gas Co., Ltd. Website
Modified by ACEJ

A cogeneration system, (1) connected with a medium-pressure gas distribution network and (2) designed to operate during grid outages, has the advantages of being earthquake-resistant, being able to supply fuel even during a power outage and not needing space for fuel stockpiling.

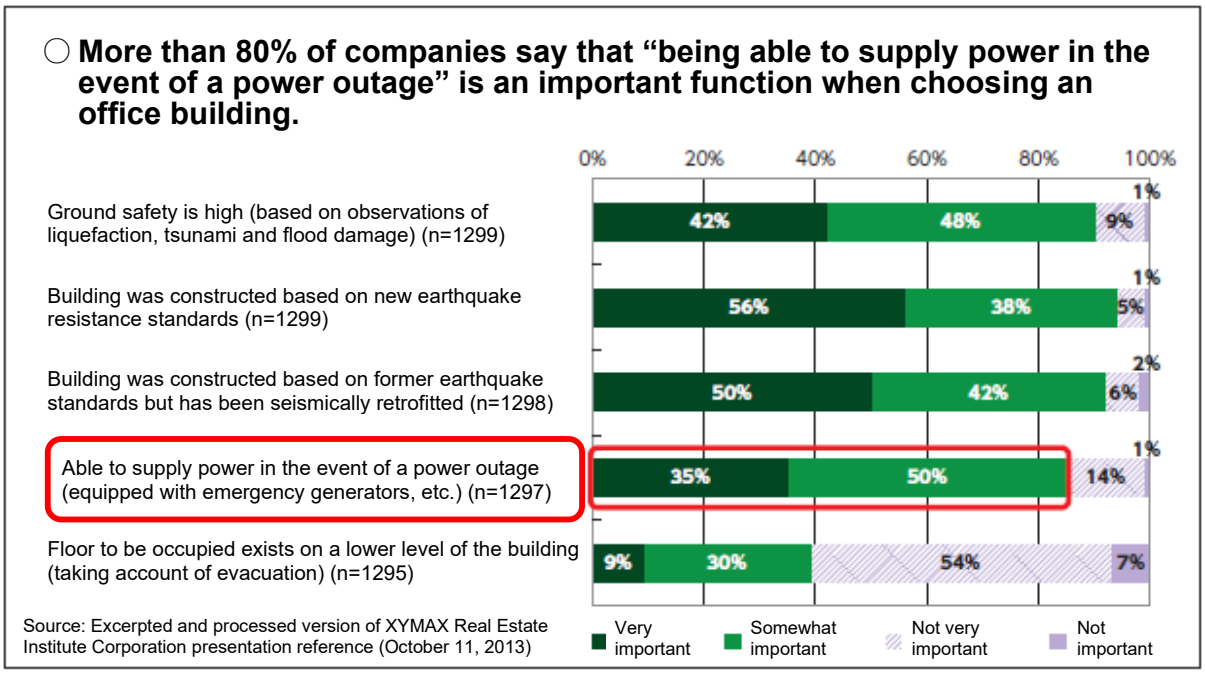
SDGs

Industry, Innovation and Infrastructure

Climate Action

Indirect benefits provided by use of cogeneration for Business Continuity Planning(BCP)

Adoption of cogeneration systems not only provides resiliency to the tenants of the buildings in the event of a disaster, but also provides merits to the owner by raising property values. As shown in the table below, it also provides various non-energy benefits (NEB).



Source: Ministry of Land, Infrastructure, Transport and Tourism, Modified by ACEJ

■ Indirect benefits provided by cogeneration system BCP

Benefit	Main beneficiaries	Detail of Benefit
(1) Avoidance of damage due to power outages	Business owners Building users	• Loss of profit or opportunities due to a power outage are avoided • Supply of heat even during the power outage, so that operation of factories, hospitals, hotels, and etc. are maintained
(2) Increased property values	Land and building owners	• Increase of real estate prices, due to the ability to provide building services that meet BCP needs
(3) Resolution for the people stranded due to transit disruption (4) Securing function as disaster evacuation centers	Local governments Local residents	• Enabling employees to stay in the office for a certain duration for safety • The building being able to function as a disaster evacuation center for local residents

SDGs

Industry, Innovation and Infrastructure

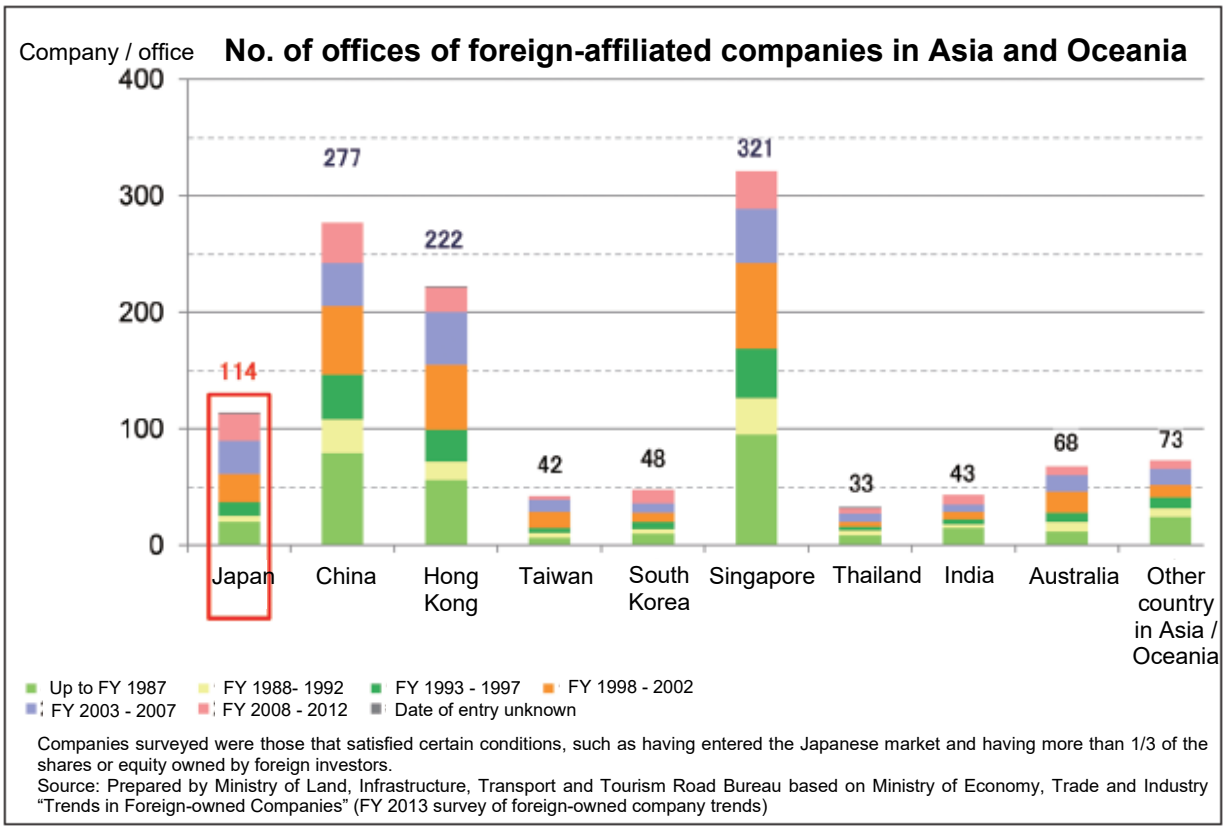
Sustainable Cities and Communities

Climate Action

5 Contribution to urban development

Urban development

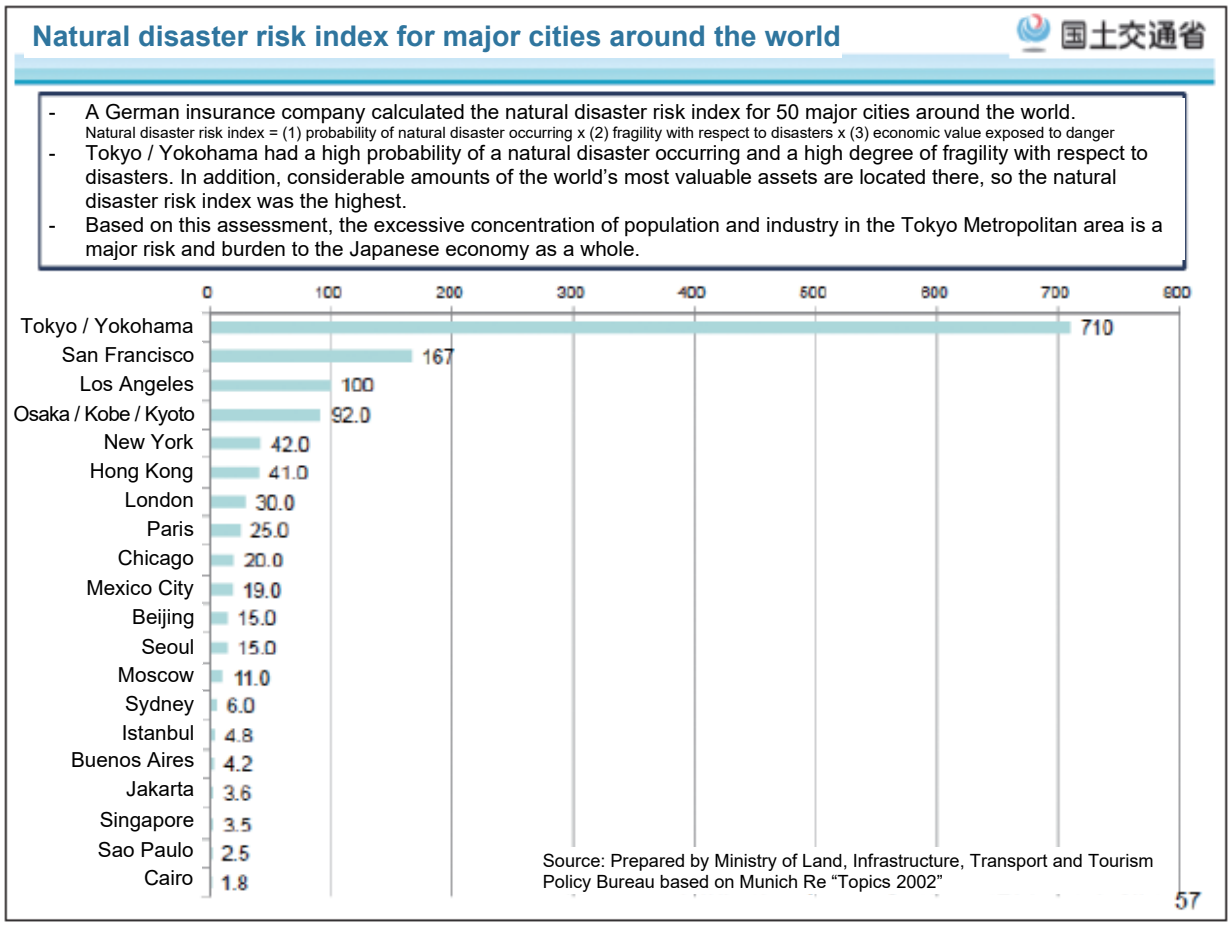
With global economic development and the economic growth and dramatic population increase in other Asian nations, the competition among metropolitan cities to be a hub for people, goods, money and information has become fierce. At the beginning of the 2000s, Japan's GDP accounted for 40% of that of Asia, but this has been cut in half to 20%, and further decline is anticipated as well, putting Japan in a disadvantageous position. In terms of the number of offices of the foreign-based companies, Japan is in a subordinate position compared with Singapore and Hong Kong.



Companies surveyed were those that satisfied certain conditions, such as having entered the Japanese market and having more than 1/3 of the shares or equity owned by foreign investors.
Source: Prepared by Ministry of Land, Infrastructure, Transport and Tourism Road Bureau based on Ministry of Economy, Trade and Industry "Trends in Foreign-owned Companies" (FY 2013 survey of foreign-owned company trends)

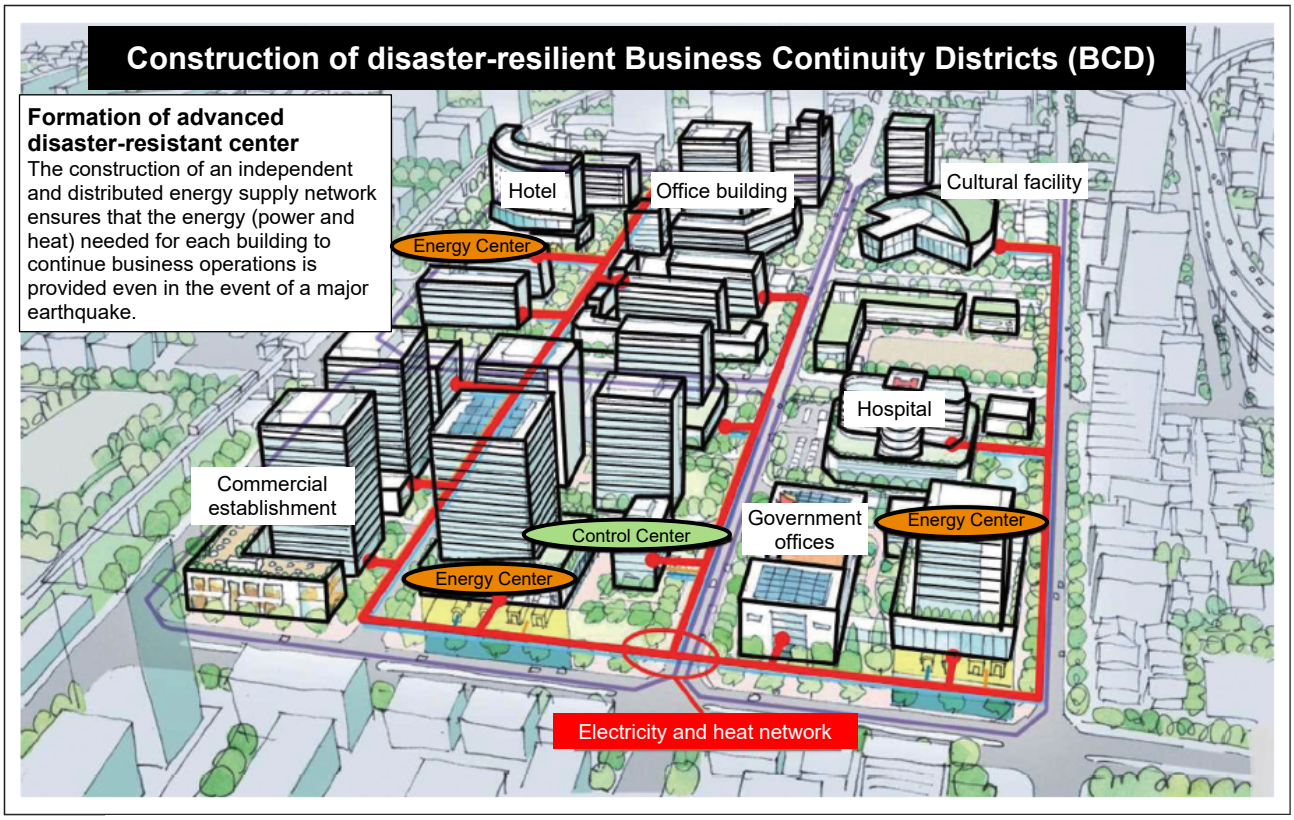
Source: Ministry of Land, Infrastructure, Transport and Tourism, Modified by ACEJ

Moreover, one of the major issues facing Japanese cities is the fact that Japan is a country that frequently experiences natural disasters. Foreign insurance companies assess the risk of the Tokyo and Yokohama area as extremely high from the standpoint of fragility, potential for natural disasters to occur, scale of assets and so on.



Source: Ministry of Land, Infrastructure, Transport and Tourism
Modified by ACEJ

In order for major cities in Japan to be selected as business hub by foreign companies as well, locations where urban functions are centralized must function as Business Continuity Districts (BCD) in which business can be continued even in the event of a disaster. In addition, they must also offer energy independence and redundancy. Cogeneration systems that are provided with earthquake-resistant medium-pressure gas distribution networks and power-outage-ready equipment can contribute to the resilience of the building where they are installed. In addition, constructing a "smart energy network" that supplies power and heat to the surrounding region via independent transmission lines and heat conduits, etc. would improve the disaster resilience of the entire region, and would also help the shift to low-carbon-energy society and increase the value as a competitive city.



Source: Ministry of Land, Infrastructure, Transport and Tourism, Modified by ACEJ

SDGs

7	Affordable and Clean Energy	8	Decent Work and Economic Growth	9	Industry, Innovation and Infrastructure	11	Sustainable Cities and Communities
13	Climate Action	17	Partnerships				

6 Regional revitalization

Regional revitalization

Currently depopulation and aging are progressing rapidly in Japan, and the resulting decrease in consumption, economy and labor force are expected to place a tremendous burden on the Japanese economy and society. In rural areas in particular, there are concerns that these problems, along with the excessive concentration of population and industry in the Tokyo Metropolitan area, will make it difficult to maintain local communities. In order to resolve them, the importance of regional revitalization — which will ensure stable job creation in regional areas, create a flow of people into rural areas and help the younger generation achieve its hope of marriage, childbirth and childrearing — is highlighted. In September 2014, the government established a Headquarters for Overcoming Population Decline and Vitalizing Local Economy in the Cabinet Office to promote activities aimed at regional revitalization.

The introduction of distributed energy infrastructure and local energy businesses that make use of this infrastructure are expected to create a new industry that enables local communities to utilize their distinctive attributes and to develop independently. Use of the region's resources and production and supply of energy within the area will ensure economic virtuous cycles, efficient energy use and energy security, and is also expected to stimulate local manufacturing and create jobs.

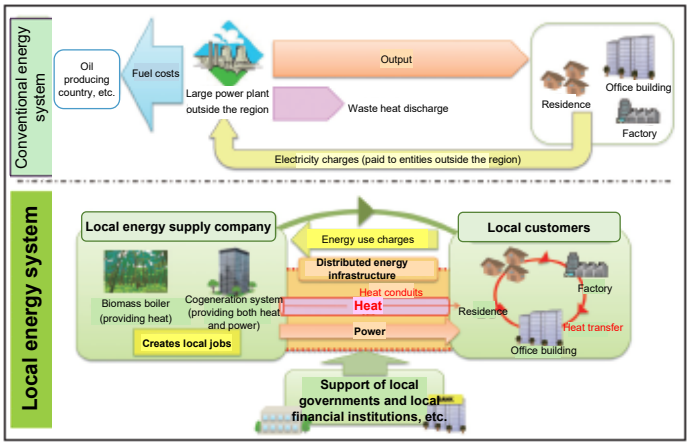
■ Significance of introducing regional energy

Item	Significance of introduction
Economic virtuous cycles in the region	• Use of resources or industrial byproducts (thinning wood, cow manure, waste heat etc.) that are available locally will expand the value chain and produce new revenue from local industry • Local production and local consumption of energy will circulate funds within the region. • Energy-related local job creation and increased tax revenues can be anticipated.
Efficient energy use	• Efficient use of electricity and heat energy will reduce energy costs and improve the profitability of local industries. • New energy-related industries and services will be created (town management, support for energy-saving operations, remote monitoring watch-over services etc.).
Energy security	• Securing energy sources in the region will establish a disaster-resilient energy system and secure energy at regional centers.

SDGs

- Affordable and Clean Energy
- Decent Work and Economic Growth
- Industry, Innovation and Infrastructure
- Sustainable Cities and Communities
- Climate Action

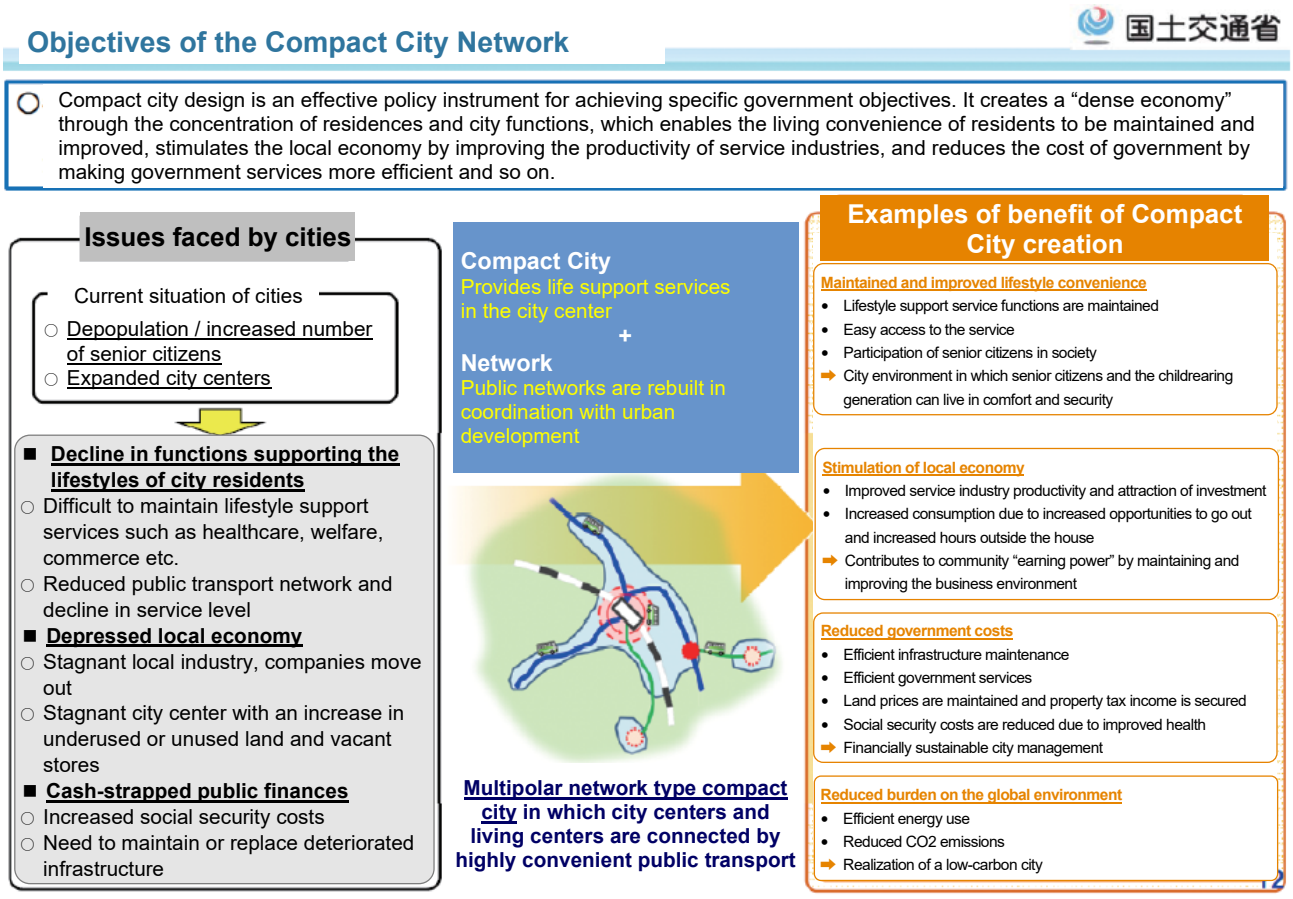
■ Regional energy system and flow of funds within the region



Source: Ministry of Internal Affairs and Communications
Modified by ACEJ

Compact city model

Population decrease is also affecting core cities in regional areas. As city centers expand due to the creation of suburbs, it is becoming difficult to maintain lifestyle support services for residents in dispersed areas. In this situation, in order to achieve sustainable cities and societies in limited resources, efforts at “compact city” redevelopment aimed at making communities more compact and linked with transportation networks (“compact city + network”) are underway in various locations. From an energy perspective, centralizing city functions will also centralize the demand for energy, and it is appropriate to use cogeneration systems that supplies multiple buildings with power and heat, enabling the creation of secure, low-carbon cities.



Source: Ministry of Land, Infrastructure, Transport and Tourism, Modified by ACEJ

SDGs

Affordable and Clean Energy

Decent Work and Economic Growth

Industry, Innovation and Infrastructure

Sustainable Cities and Communities

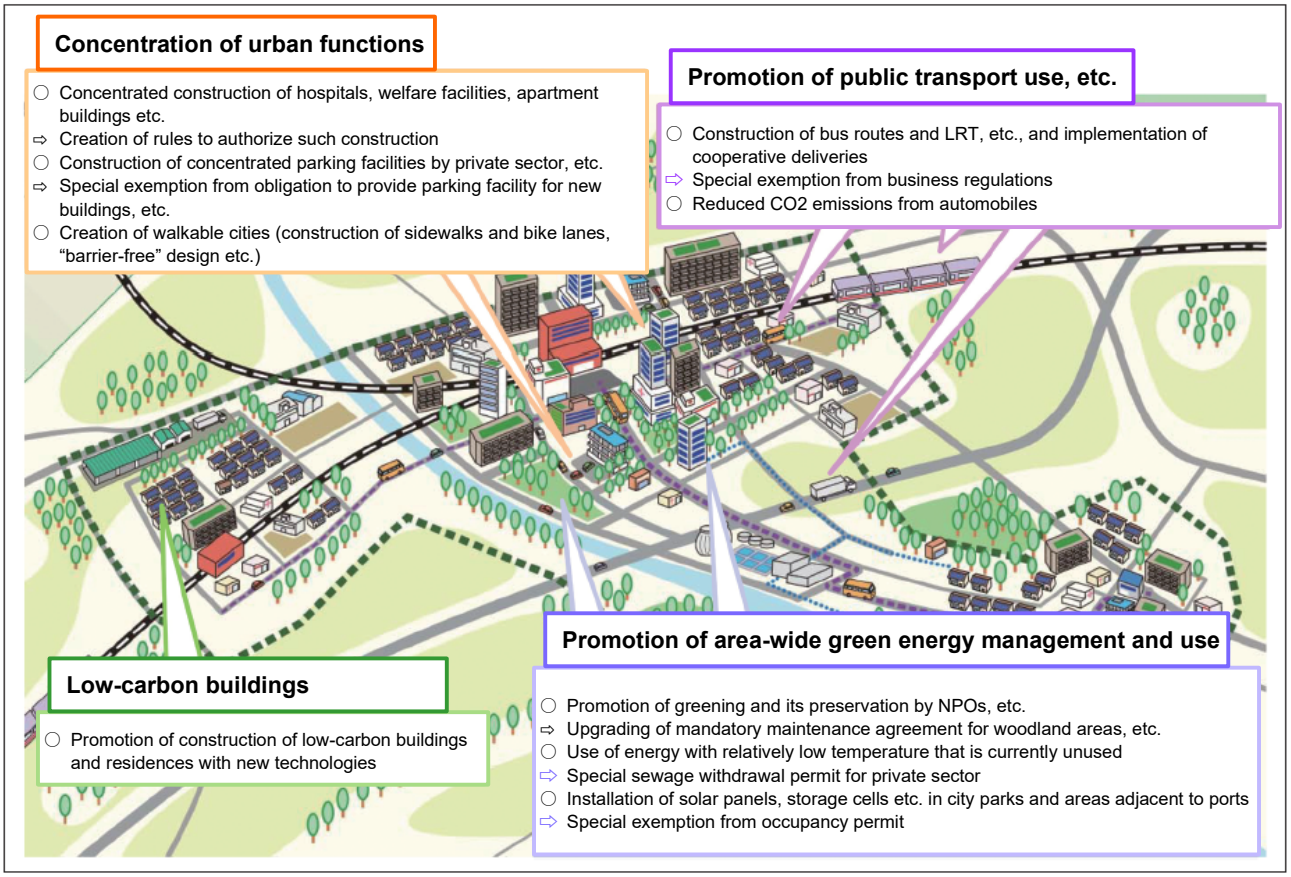
Climate Action

Role of local governments

The creation of compact cities and the introduction of regional energy systems that contribute to regional revitalization will involve many companies and citizens, so there will be a need to promote public, public-private and local community partnerships. Local governments are also expected to formulate and execute urban development plans, taking account of the followings:

- Need for cooperation between customers, local companies and companies that supply renewable energy
- Need for consensus-forming between local companies and local residents on business plans
- Need to coordinate the timing of the construction of infrastructure (heat conduits and a power transmission and distribution network) with urban development and regional redevelopment
- Need for participation in projects in some cases to secure funds and credit due to the enormous investment required

■ Ideal low-carbon urban development plan formulated by local governments



Source: Ministry of Land, Infrastructure, Transport and Tourism
Modified by ACEJ

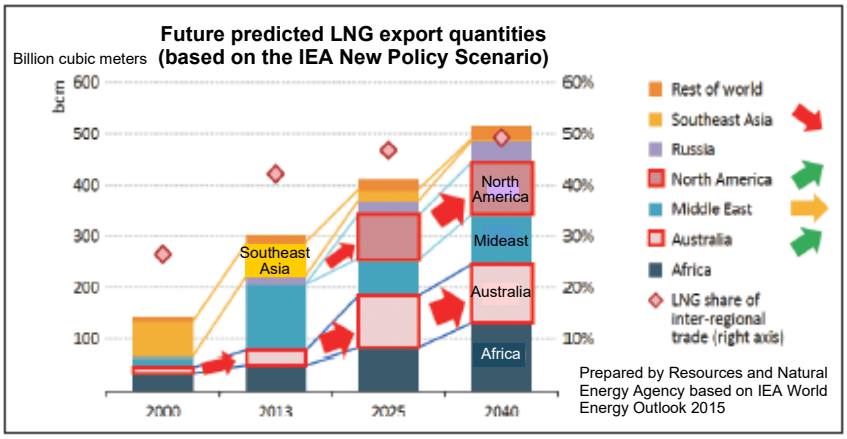
SDGs

17 Partnerships

7 International cooperation through energy

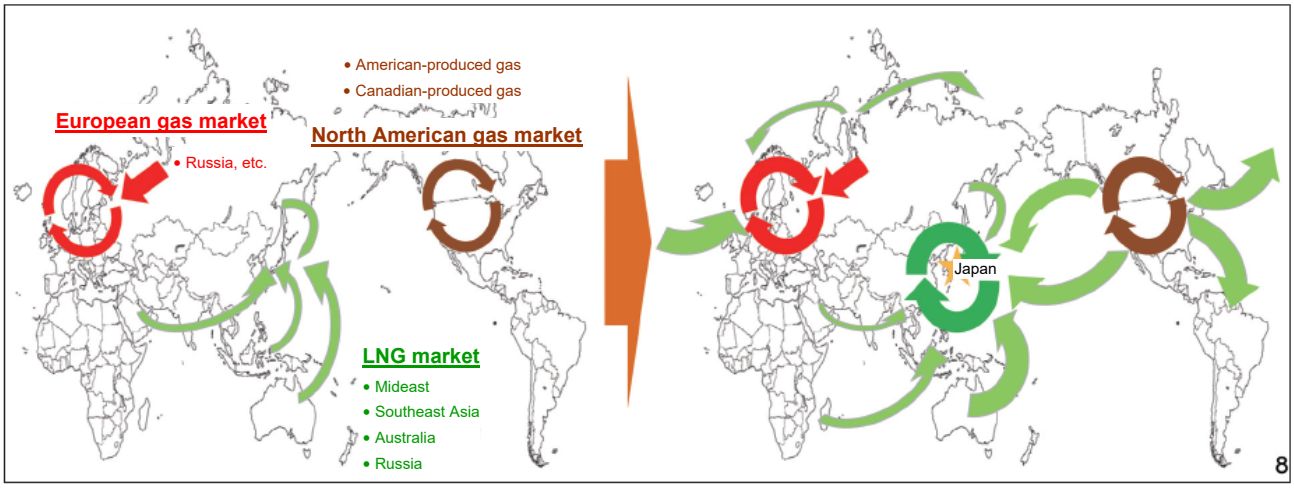
Overseas infrastructure

There is expected to be major growth in energy demand in Southeast Asia, and in the future countries there are expected to become energy importers. At the same time, the United States has become an energy exporter as a result of increased shale gas production, and it is expected to become one of the world's top exporting countries. In this situation, Japan can be a hub for LNG transactions (a center that attracts transactions and where price formation and announcement occur). Also, Japan has the accumulated technological knowledge and expertise as a pioneer LNG user. For Japan, involvement in trading and transporting LNG business, like LNG utilization in Asia and distribution of American-produced LNG in Asia will build good relationships around the world. In addition, not only the construction of LNG production plant in upstream sectors but also involvement in downstream business including the introduction of cogeneration systems are expected to bring further economic development in Japan, as well as contributing to economy and environment in other Asian nations.



In the future, Southeast Asia LNG imports are expected to exceed exports due to increased energy demand. Meanwhile, due to shale glass drilling, the United States is expected to become one of the world's leading LNG exporters.

Source: Ministry of Economy, Trade and Industry, Modified by ACEJ



Source: Ministry of Economy, Trade and Industry
Modified by ACEJ

American-produced LNG is also exported to Asian nations where demand is increasing. Japan can play a major role as an LNG hub for transactions and price formation.

Source: LNG Producer-Consumer Conference 2017
Modified by ACEJ

Based on a proposal by Japan, an "LNG Producer-Consumer Conference" was established where representatives from LNG producing countries and consuming countries can gather and exchange views regarding market development.
At the 2017 LNG Producer-Consumer Conference, Minister of Economy, Trade and Industry Seko announced that Japan would prepare JPY 10 billion in financing by the public and private sector for the start-up of demand in other Asian countries, and would train 500 persons in the next five years.

TOKYO GAS

Major activities in Malaysia

Establishment of Gas Malaysia Berhad
Gas company was established on the Malay Peninsula in 1992 jointly with state-owned enterprise Petroliam Nasional Berhad and other companies. Has constructed approximately 2,000 km of conduits and provides 3.6 billion m3 per year of gas (approximately 40,000 contracts) to primarily industrial customers.

Establishment of GMEA (energy service company)
Gas Malaysia Energy Advance Sdn Bhd was established in May 2014 with joint capital investment from Gas Malaysia to provide energy services to industrial customers in Malaysia. The company introduced a 32 MW cogeneration system at Toray Industries Malaysia, its first customer.

Gas Malaysia Berhad supply area


Area governor


Industrial boiler


GMEA founding

Source: Ministry of Economy, Trade and Industry
Modified by ACEJ

Energy companies in Japan that have up to now imported LNG from Southeast Asian countries will make use of their natural gas utilization technologies and energy saving technologies cultivated in Japan to expand into the natural gas downstream sectors in countries in which future demand is anticipated.

SDGs

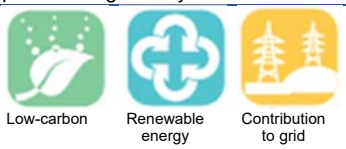
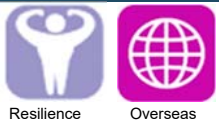
- Affordable and Clean Energy
- Decent Work and Economic Growth
- Industry, Innovation and Infrastructure
- Sustainable Cities and Communities
- Climate Action
- Partnerships

Ⅱ. Goals and Targets that Cogeneration Systems can Help to Achieve

Cogeneration systems can help to achieve SDGs through the aforementioned value. The following examples show the main goals and targets that cogeneration systems can help to achieve. (Note that these are general examples only; goals and targets must be selected based on the individual cases.)

■Goals and Targets that Cogeneration Systems can Help to Achieve

SDG		Value contributed by cogeneration system value
Goal	Target	
 Affordable and Clean Energy	7.1 By 2030, ensure universal access to affordable, reliable and modern energy services.	 Contribution to grid / Urban development / Regional revitalization / Overseas infrastructure Construction of energy supply systems that (1) help to stabilize the power grid and (2) are earthquake-resistant and power-outage-ready
	7.2 By 2030, increase substantially the share of renewable energy in the global energy mix.	 Renewable energy Use of cogeneration systems (1) that are fueled by renewable energy sources, or (2) to control fluctuation of variable renewable energy sources
	7.3 By 2030, double the global rate of improvement in energy efficiency	 Low-carbon / Renewable energy Reduced energy consumption through cogeneration systems (1) operated with high efficiency, and/or (2) fueled by renewable energy
	7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing states and landlocked developing countries, in accordance with their respective programs of support.	 Overseas infrastructure Creation of international relationships through construction of overseas energy infrastructure
 Decent Work and Economic Growth	8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labor-intensive sectors.	 Urban development / Overseas infrastructure Increased property values through construction of environmentally conscious and disaster resilient buildings, which also attract high-value added industries
	8.3 Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services.	 Urban development / Regional revitalization Vitalization of local economies through creation of local energy industries

SDG		Value contributed by cogeneration system value
Goal	Target	
Industry, Innovation and Infrastructure	9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.	 Construction of energy supply systems that (1) help to stabilize the power grid and (2) are earthquake-resistant and power-outage-ready
	9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.	 Reduced energy consumption through cogeneration systems (1) operated with high efficiency and/or (2) fueled by renewable energy
	9.a Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing states.	 Construction of overseas energy infrastructure
Sustainable Cities and Communities	11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	 Development of low-carbon, safe (1) urban cities and (2) compact cities
	11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030*, holistic disaster risk management at all levels.	 Construction of energy supply systems that (1) help to stabilize the power grid and (2) are earthquake-resistant and power-outage-ready
Responsible Consumption and Production	12.2 By 2030, achieve the sustainable management and efficient use of natural resources.	 Use of cogeneration systems that use renewable energy as fuel
	12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.	 Use of cogeneration systems that use wastes as fuel
Climate Action	13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.	

SDG		Value contributed by cogeneration system value
Goal	Target	
		e Establishment of energy supply systems that are earthquake-resistant and power-outage-ready
13 CLIMATE ACTION Climate Action	13.2 Integrate climate change measures into national policies, strategies and planning.	 Low-carbon Renewable energy Urban development Regional revitalization Overseas infrastructure Reduced energy consumption through cogeneration systems (1) operated with high efficiency and/or (2) fueled by renewable energy
15 LIFE ON LAND Life on Land	15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.	 Renewable energy Regional revitalization Use of cogeneration systems that use forestry byproducts as fuel
17 PARTNERSHIPS FOR THE GOALS Partnerships	17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships.	 Urban development Regional revitalization Overseas infrastructure Contribution to vitalization of local economy and the shift to low-carbon society, strengthening communication and relationship among various groups, such as local governments, companies, voluntary organizations and citizens

* Activities that should be conducted to prevent disasters, adopted at the UN World Conference on Disaster Reduction (held in Sendai in March 2015). Includes understanding disaster risks, strengthening governance, investment to reduce risks, activities for recovery and reconstruction etc.

To summarize the content presented up to now, below is the table shown in “ Ⅰ . Benefits of cogeneration systems ” with the corresponding SDGs added.

■ Comparison of value provided by cogeneration and SDGs

No.	Value provided	Description	SDGs
1	**Shift to low-carbon energy sources**  Low-carbon	The heat that is produced through power generation is used on-site, achieving efficient energy use and a shift to low-carbon-energy society.	 Affordable and Clean Energy  Industry, Innovation and Infrastructure  Climate Action
2	**Introduction of renewable energy**  Renewable energy	Cogeneration systems that use renewable energy as well as mixed use of renewable energy heat and cogeneration waste heat promotes the introduction of renewable energy.	 Affordable and Clean Energy  Responsible Consumption and Production  Climate Action  Life on Land
3	**Contribution to electrical power grid**  Contribution to grid	As cogeneration systems are placed in customer areas, investment in power transmission and distribution networks can be reduced. In addition, the systems can be operated in response to power supply and demand, helping to reduce peak power, decrease investment in system equipment and regulate renewable energy fluctuations.	 Affordable and Clean Energy  Industry, Innovation and Infrastructure
4	**Increased resilience**  Resilience	Cogeneration systems, connected with earthquake-resistant medium-pressure gas distribution networks and equipped with power-outage-ready functions, help to improve disaster resilience and to increase property values.	 Industry, Innovation and Infrastructure  Sustainable Cities and Communities  Climate Action

No.	Value provided	Description	SDGs
5	**Contribution to urban development**  Urban development	The introduction of cogeneration systems in cities helps to achieve safe, low-carbon urban development and internationally competitive cities.	 Affordable and Clean Energy  Decent Work and Economic Growth  Industry, Innovation and Infrastructure  Sustainable Cities and Communities  Climate Action  Partnerships
6	**Contribution to regional revitalization**  Regional revitalization	The shift to energy resources that are available locally promotes the creation of new industries and jobs, the circulation of financial resources within the region, helps to promote local economic development. In addition, it also helps to create compact cities in regional areas.	 Affordable and Clean Energy  Decent Work and Economic Growth  Industry, Innovation and Infrastructure  Sustainable Cities and Communities  Climate Action  Life on Land  Partnerships
7	**International cooperation and stronger partnerships**  Overseas infrastructure	The resale of LNG, construction of LNG plants and involvement in downstream sectors like construction of cogeneration systems for other South Asian countries will help to maintain good international relations.	 Affordable and Clean Energy  Decent Work and Economic Growth  Industry, Innovation and Infrastructure  Sustainable Cities and Communities  Climate Action  Partnerships