New Approach for Environmental Future City Created by ICT: Sustainable City Network

● Michinori Kutami ● Minoru Takeno ● Hiroko Ioka

Various projects for the achievement of a Smart City or an environmental futuristic city are being advanced in Japan and all parts of the world. Recently, organizations have been required to cross-functionally solve different problems in different fields like energy, buildings, traffic, the environment, medical treatment and the industries of agriculture, forestry and fishery. Information and communications technology (ICT) is expected to be an effective tool for monitoring, visualizing, analyzing and optimizing flows of resources, energy, information, persons and goods. Here, we introduce Sustainable City Network as a new approach to solving various problems with ICT and achieve optimization by having cooperation in large areas in and between cities, towns, and villages. In this paper, we describe the results of a study and case studies on environmental fields. In addition, we introduce results of efforts to expand this new approach from environment problems to areas such as traffic/transportation, medical treatment, and agriculture.

1. Introduction

Looking at the world's society, we can see there are many issues such as a population increase, global warming, securing of food and water, conservation of biodiversity and resource depletion.[1),2)] In order to solve these issues, the conventional way of one company taking one action to address one issue does not seem to lead to a fundamental solution. It requires various industry sectors to each bring knowledge and technologies for eliminating fundamental factors causing the issues based on the recognition that they are common social issues. Global-scale problems are recognized as belonging to the individual countries and the problems of the individual countries are in turn recognized as belonging to the places where people live in built-up areas such as cities, towns and villages. The issues of each of these cities, towns and villages then depend on the lifestyles of the people working and living there, how they make goods, how they move and how they consume goods and energy. Without improving the lifestyle of each of these people, the ultimate solution to global-scale issues cannot be found. However, improving the lifestyle of each of these people needs to be coordinated with that of many other people, rather than leaving many diverse lifestyles. The smallest unit allowing implementation of common policies may be a city, town or village. Environmental futuristic cities, Smart Cities, sustainable cities, environmentally conscious cities and smart communities currently under study are based on the concept that this is the most effective unit of study for various discussions.[3)–5)] Fujitsu proposes the "Smart City" concept based on the idea of a Human Centric Intelligent Society and provides related information and communications technology (ICT) solutions.[6),7)]

ICT, which essentially transcends time and distance, is capable of improving process efficiency, reducing resource consumption and offering new values. For that reason, ICT is expected to help solve many issues in Smart Cities as well.

Meanwhile, many Smart City projects currently planned and implemented in Japan and overseas have two characteristics. One is the focus on cities as targets and the other is the focus on the individual fields including power/energy, buildings and traffic. The number of Smart City projects known to be proposed and operated so far is 400 worldwide, including 24 in Japan. However, not many of them have clearly-defined

roles or applications of ICT. In terms of the forms of development, there are 151 urban development projects, 150 smart grid ones for electric power, 120 renewable energy projects and 103 next-generation traffic system ones. In contrast, there are only 27 ICT development projects.[8)]

ICT has the potential to provide future Smart Cities with new solutions, further enhance the effect of the existing Smart City projects and technologies, and effectively link multiple issues and multiple elements of infrastructure (such as energy, traffic/transportation, environment, medical treatment, education, employment and industry) for efficiently solving issues of cities, towns and villages.

This paper presents the potential based on a new perspective called Sustainable City Network. It shows the results of analysis of the fields of the environment and energy and examples of specific solutions. In addition, it further extends the viewpoint to describe examples to deal with a variety of issues such as those in the fields of traffic/transportation, medical treatment and agriculture and future outlook.

2. Sustainable City Network created by ICT

Introducing ICT leads to the solution to problems for a sustainable society and, in terms of the environment, it is intended to solve various environmental problems including the climate change, resource depletion and biodiversity problems as well as the energy problem.

To solve these problems, we need to have a perspective of a multilayered issue solution, in which various issues (of human awareness, management, infrastructure, industrial fields and products/technologies) are seen as multilayered issues and linked together for simultaneous solutions. One characteristic of ICT required here is the effect on various physical "networks" as well as information. At the base is an idea of realizing a solution to complicated issues by seeing flows of resources, energy, movement of persons and goods, environmental and other types of information as arteries and veins and using ICT to visualize and control these flows. It is also important to incorporate into a network not only cities with concentrations of population but also sustainable towns and sustainable villages with consideration to sustainability of the neighboring towns and farming/fishing villages linked with cities. Positioning of relations between multilayered issues and ICT and association of technologies, products, solutions and services of ICT with wide-ranging links are significant. Issues with realization of a Smart City encompass many fields including traffic/transportation, medical treatment, industries, agriculture/forestry/fishery, buildings and households as well as environmental issues. Important issues to be discussed also vary depending on the individual cities, towns and villages.

Sustainable City Network is a concept of giving comprehensive consideration to resources, waste, environmental management, traffic, medical treatment, education, industries and agriculture/forestry/fishery in addition to energy creation/conservation/storage that is intended to solve multilayered and cross-regional issues and overall optimization of a wide area by making use of a network. While issues with realization of a Smart City cover many fields including the environment, traffic/transportation, medical treatment, industries, agriculture/forestry/fishery, buildings and households, the following describes the composition of Sustainable City Network with the focus on the environment and environment-related items.

Figure 1 shows a concept of how issues of cities, towns or villages are grasped in Sustainable City Network. Issues of a city, town and village and fields related to the issues can be seen in multiple layers as shown there. The figure represents one city (or town or village). Issues with the environment of cities include environmental, resource and energy issues and the individual cities are engaged in their own characteristic activities. Values of cities can be described by environment (environmental quality), society, economy and other factors. Items that support or influence them include human awareness, visualization, management and foundations of livelihood (such as housing, water/food, work, clothing and movement). They are in turn supported by various technologies such as mobile devices and IT equipment used by people and infrastructure such as buildings, traffic/transportation, environment/resources/energy and waste. These elements of activities generate values of the city and, at the same time, have an impact on the global environment in some respect. What is required now is to improve the values of the city and reduce this impact.

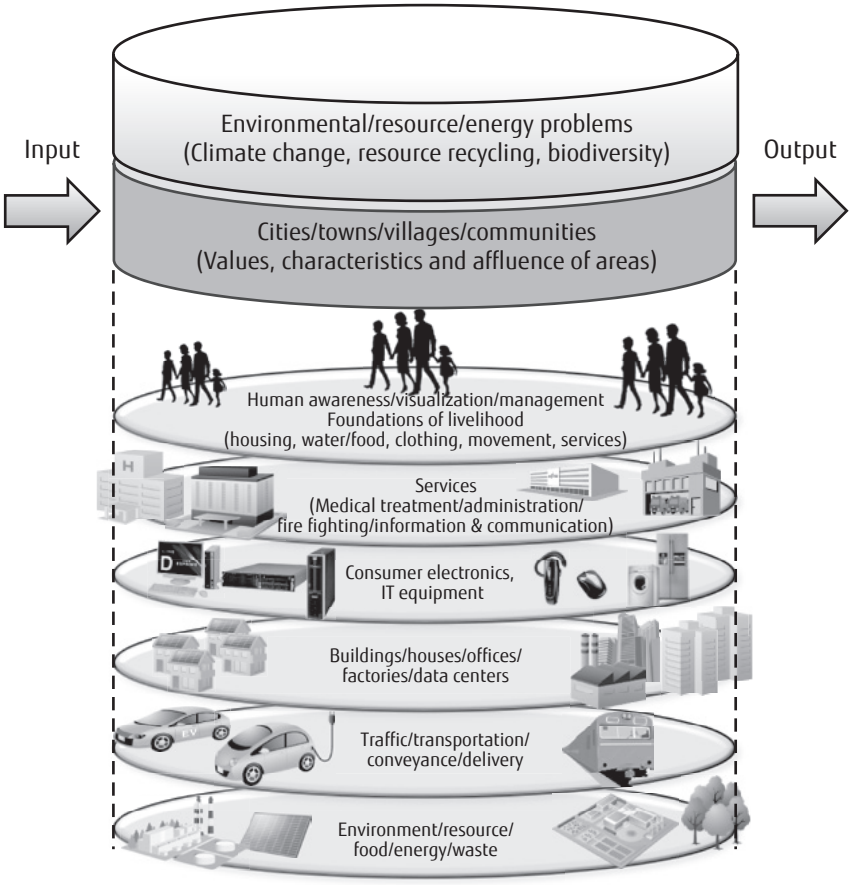


Figure 1
Overview of Smart City configuration in Sustainable City Network.

There are three points in the basic concept of how ICT can contribute to this:

1) Consideration of overall optimization in multiple issues, multiple fields and a wide area
2) Consideration of the balance between materials including resources, goods and waste and flows of materials (arteries and veins)
3) Consideration of things that flow including energy, resources (minerals, rare metals, natural resources, water/food, recycled resources), waste, information, persons and goods

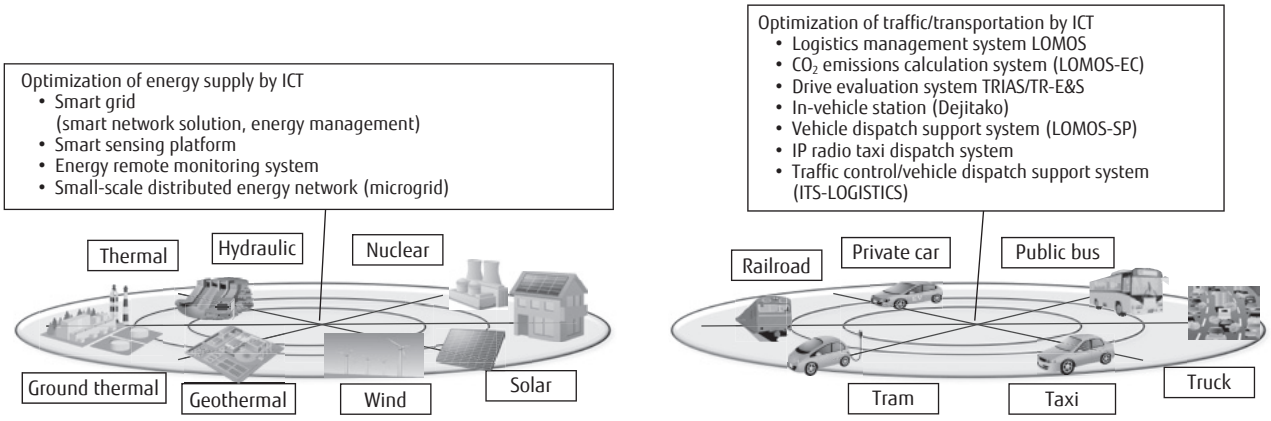
3. Three network levels

In Sustainable City Network created by ICT, it is important to have a network to link the individual issues including climate change, energy problem and biodiversity and the individual fields including construction, traffic, energy, operations, households and industry. Three network levels (Levels 1, 2 and 3) need to be considered here.

3.1 Level 1: optimization in intra-layer network

Level 1 corresponds to an intra-layer network (network for solving issues within one layer) and represents a network of resources, energy, movement, environmental information, etc. in a layer defined for each issue and each field. This level is intended for optimization to solve issues within one layer. Examples include smartification of energy and traffic. Examples of linking networks within the energy and traffic/transportation layers are shown in **Figure 2**.

To take energy infrastructure as an example, optimum use of multiple types of energy is important and, in this energy network, ICT implements monitoring, visualization, analysis, control and optimization. Regarding energy, offices and factories have introduced energy management systems such as building energy



(a) Linking within energy layer

(b) Linking within traffic/transportation layer

Figure 2
Examples of intra-layer linking network.

management systems (BEMS) and factory energy management systems (FEMS) up to now, and they have helped to reduce the amount of wasted energy. In the same way, home energy management systems (HEMS) have been adopted for reducing wasted energy in households. As these systems become widespread and linking between offices and households and optimum control are provided, overall optimization on the intra-city/town/village level can be achieved. Specific solutions include HEMS, BEMS, smart grid (smart network solution, energy management), smart sensing platform, energy remote monitoring system and small-scale distributed energy network (microgrid).

As specific solutions for linking within the traffic/transportation layer, there are logistics management system, CO_2 emissions calculation system, eco & safety drive evaluation system, in-vehicle station (digital tachograph), vehicle dispatch support system, IP radio taxi dispatch system and traffic control/vehicle dispatch support system.

3.2 Level 2: optimization in inter-layer network

Level 2 relates to an inter-layer network (network across layers of multiple issues and multiple fields) and is aimed at solving multiple issues and achieving optimization as a whole by linking between different layers of issues. **Figure 3** shows an example of a network that links between the "building (factory/household and building) layer," "traffic/transportation layer" and "energy layer." The power supply side uses ICT to achieve an optimized mix of renewable energy and thermal, hydraulic and other conventional types of energy, and the demand side uses ICT to optimize power demand of factories, households and traffic. There are many examples of application such as nighttime power storage of plug-in hybrid and electric vehicles and use of waste from factories for power generation. Specific solutions include a building management system, facilities management system, building total management system, factory electric power dashboard, HEMS/CEMS (Community Energy Management System), hydrogen station centralized management system, electric vehicle charging station, travel eco-point system and location data utilization system by vehicles. Another example of linking between the environment and management layers is an environmental information management system for environmental pollution monitoring of air, rivers and oceans and information disclosure.

3.3 Level 3: optimization in inter-city/town/village network

Level 3 relates to an inter-city network (network across different cities, a city and a region, etc.) and represents a network of resources, energy, movement, environmental information, etc. across cities, regions and municipalities. **Figure 4** shows a composition of

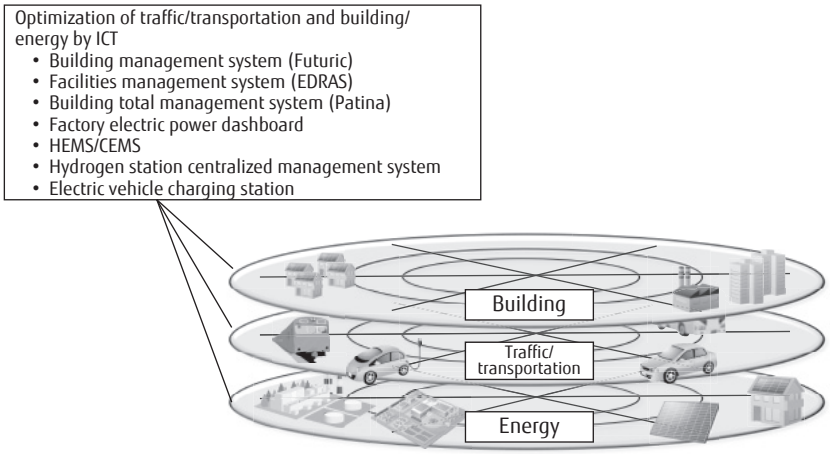


Figure 3
Linking network between building, traffic/transportation and energy layers.

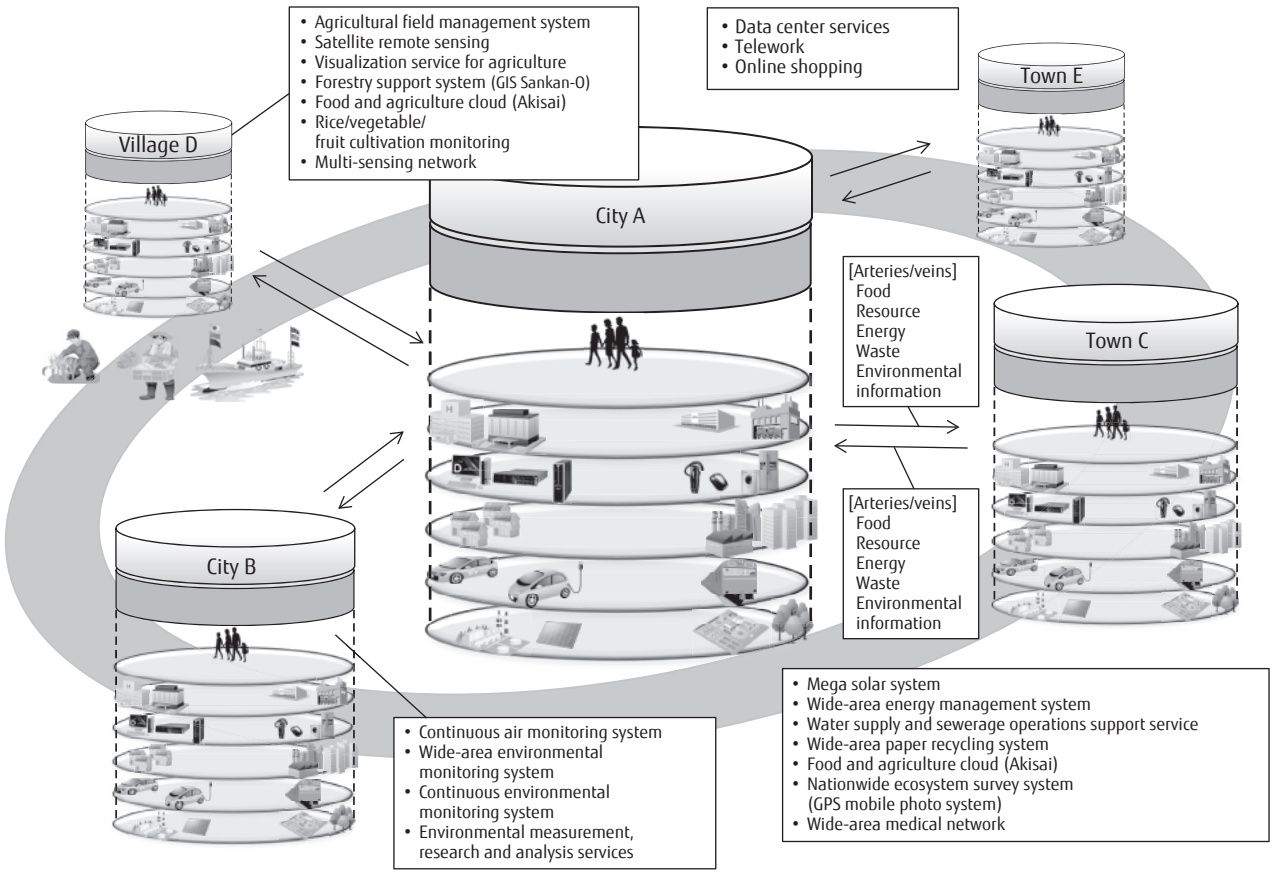


Figure 4
Composition of Sustainable City Network on Level 3.

Sustainable City Network on Level 3. Level 3 is intended to solve issues and achieve overall optimization in view of linking between multiple cities, towns and villages such as between cities, cities and their neighboring towns, cities and farming/fishing villages, or between towns and between villages.

For example, with City A at the center, linking with City B (exchange of resources, energy, waste and environmental information) can be realized by using ICT to achieve overall optimization, rather than just having optimization within the cities. In a network with Town C, which has different values from those of cities, exchange of work and shopping via the Internet in addition to exchange of resources, energy and waste allows the town to reduce the environmental impact caused by moving between City A and Town C and improve the level of employment in Town C. In a network linking City A and Village D, which has agriculture, livestock farming, forestry and fishery as the main industries, ICT can be used to optimize exchange of food resources, forest resources and waste to ensure resources are used without being wasted, reduce environmental impact (such as CO_2 and waste) and conserve biodiversity. In addition, in a network between City A and Town E, which is suitable as a place to establish a data center, etc., companies in Town A can use a data center in Town E, which thus reduces environmental impact (electric power) in a large area. In the entire wide-area network including City/Town/Village A to E, sharing of values of the respective cities/towns/village (such as industries, employment and natural resources) can be achieved in addition to reducing the overall environmental impact and mutual complementarity can be implemented via the network in the event of disaster or emergency for ensuring sustainability of the wide area.

Specific solutions contributing to the construction of a wide-area linking network like this include a mega solar system, wide-area energy management system, water supply and sewerage operations support service, wide-area paper recycling system, food and agriculture cloud, nationwide ecosystem survey system (GPS mobile photo system) and wide-area medical network.

4. Examples of Sustainable City Network

This section presents specific examples of Fujitsu's solution for realizing Sustainable City Network on the respective levels in the fields of environment and energy. In addition, specific cases studied of traffic, medical treatment and agriculture are shown as well.

4.1 Linking in energy layer in cities

Figure 5 shows an example of a smart grid system that realizes a high-efficiency, low-carbon power grid by using ICT. The energy supply side uses the ICT network to achieve an optimum supply mix of the conventional power from thermal, hydraulic or other ways of generation and renewable energy from solar and wind power generation. The energy demand side makes use of energy management systems such as BEMS and FEMS for optimized energy use in buildings and factories. Individual households can use HEMS, which allows optimization of energy use by consumer electronics and introduction of home solar panels. On the demand side, use of renewable energy and dissemination of plug-in hybrid, electric and fuel cell vehicles

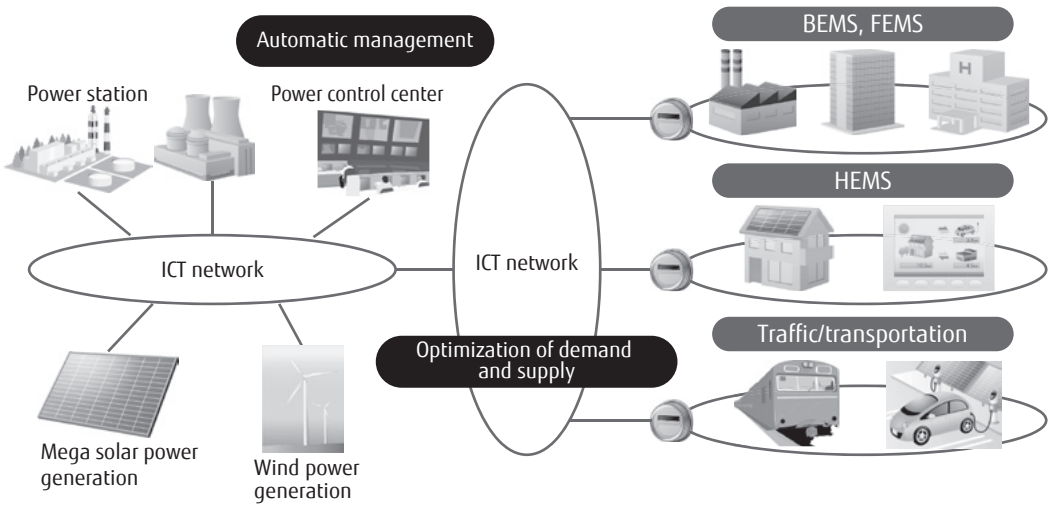


Figure 5
Example of linking in energy layer.

have started in the traffic/transportation field. To optimize the demand and supply sides including these, in the future it will be important to be able to grasp and visualize energy output and real-time demand by means of the ICT network.

4.2 Linking between traffic/transportation, buildings, human awareness and management

Figure 6 shows how a high-value traffic service can be offered by providing drivers with purchase information, road congestion information, construction/engineering works information, weather information, disaster information and traffic information based on FUJITSU Intelligent Society Solution SPATIOWL, a location data utilization system.[9] This system is intended for linking information across multiple fields such as traffic information, construction/road information and drivers' awareness for overall optimization and requirements like this are expected to further increase in the future.

Transportation and delivery systems such as that using trucks with in-vehicle stations (digital tachographs)[10] prompt drivers to be aware of eco-driving by feeding the driving history of individual trucks back to the drivers, which, as a result, is effective in reducing CO_2 emissions. In addition, LOMOS, a movement management system linked with GPS, contributes to improved efficiency of transportation and delivery and leads to CO_2 reduction as a whole. Another example is the travel eco-point system, which makes use of eco-points to link use of public transportation with logistics and shopping by residents for promoting use of public transportation systems such as buses and trams. It is an effective solution that helps to raise people's awareness of the need to make environmental contributions and increase their use of local public transportation by visualizing CO_2 reductions. Furthermore, aggregating CO_2 reductions by affiliation such as company and school and disclosing the result can be helpful to an activity as a campaign of the entire area.

4.3 Linking between environmental monitoring (water, waste, air pollution, etc.), analysis and information disclosure

Figure 7 shows a case study with e-FEINS, an environmental information management system that links environmental monitoring including monitoring of water, waste and air pollution, analysis and information disclosure. The environmental information management system monitors conditions of environmental pollution including that in the air, rivers and oceans 24/7 in multiple locations in a local government, collects and analyzes the results and discloses the information to the citizens and other people.[11] It is used in projects for achieving both development and environmental conservation in multiple industrial complexes and carries expectations as a system that measures, monitors and analyzes performance

Figure 6
Example of linking between traffic/transportation, construction, human awareness and management.

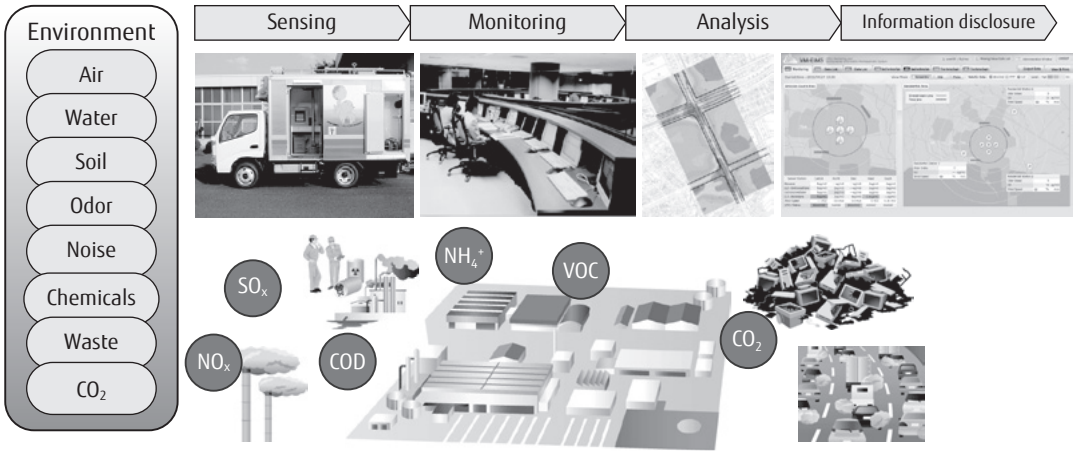


Figure 7
Linking between environmental monitoring (water, waste, air pollution, etc.) and analysis/information disclosure.

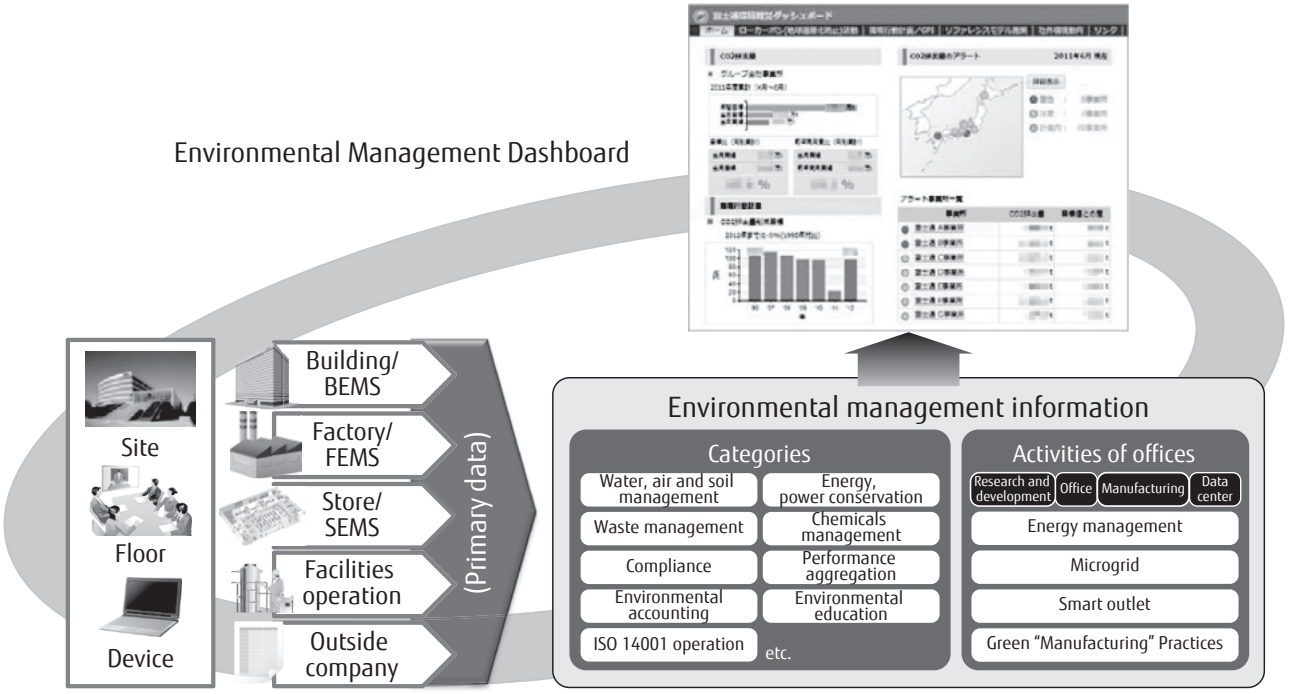


Figure 8
Linking between environmental information and management.

data such as that on the air, water, soil, noise, odor, chemicals, waste and CO_2 emissions and discloses the information.

4.4 Linking between environmental information and management

Figure 8 shows a case study with the Environmental Management Dashboard, which is capable of linking between visualization of environmental information and management.[12] By introducing this solution, environmental performance information including that on energy, water, air, soil and waste can be linked with environmental management (human awareness, management) in a wide area. It is also possible to visualize environmental information of globally distributed bases, buildings,

factories, stores, facilities and data centers. This system allows people to manage water/air/soil, manage waste, manage energy, and aggregate performance and conduct analysis by linking with sensors and monitoring. It is also capable of feeding information back to activities of multiple offices to realize optimization as a whole.

From the perspective of disposal and reuse of used materials generated from offices, one case example of waste management is the paper recycling system implemented by the Fujitsu Group.[13] Used materials from offices, which were separately collected and processed by the respective offices, are efficiently collected by the eleven districts nationwide by linking between companies. The recycling process is also efficiently carried out within the districts, which reduces the environmental impact in the districts. In addition, linking between the respective districts leads to efficient paper recycling on a nationwide scale. To this end, information collection and management by ICT is essential.

4.5 Linking in wide-area network in medical treatment field

Figure 9 is a case study with HumanBridge EHR, a wide-area medical network in the field of medical treatment.[14] The intra-hospital network, which uses FUJITSU healthcare solution HOPE EGMAIN-NX to integrate health information in the respective hospital, is essential for improving the efficiency of medical examinations and reducing environmental impact.[15] Regarding the electronic medical record system, an example trial calculation has shown that its introduction to a 300-bed hospital may contribute to a CO_2 reduction of approximately 30%. By further deploying this intra-hospital electronic medical record solution in the area to build a core network that links clinics, nursing homes and rehabilitation facilities in the area with the core hospital at the center, information sharing, efficiency improvement and even reduction of environmental impact in a wide area can be achieved. In the future, development of a wide-area medical network is anticipated in which a hub-shaped wide-area network is used to link multiple core hospitals that connect the intra-hospital electronic medical record network with the area network.

4.6 Linking between cities, towns and villages in agriculture and fishery

Figure 10 shows an example of a wide-area network that connects cities, towns and villages with

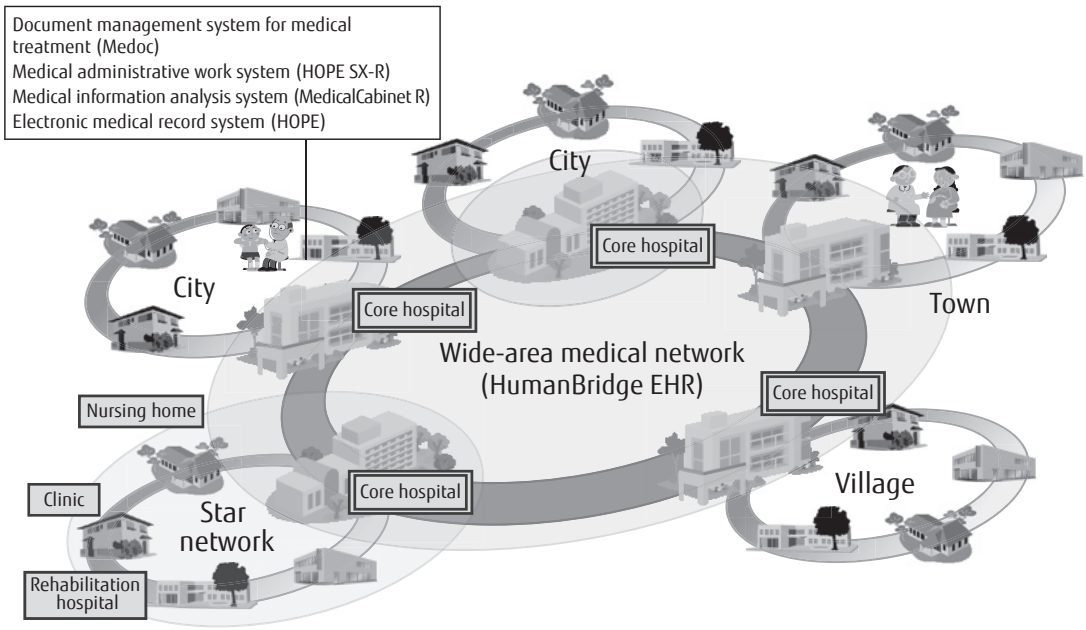


Figure 9
Wide-area medical network between cities, towns and villages.

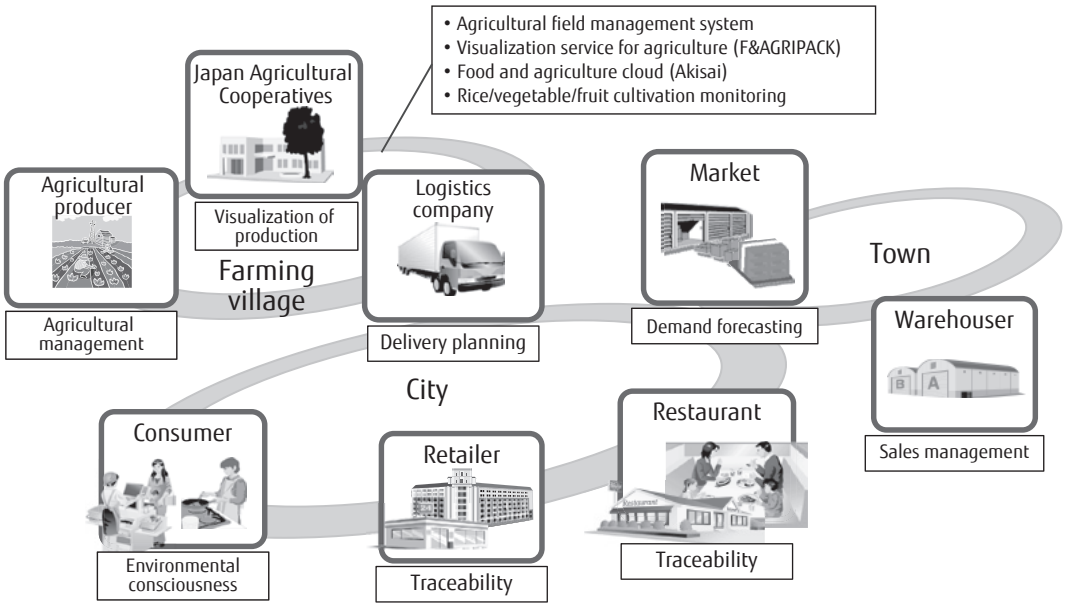


Figure 10
Wide-area agricultural network between cities, towns and villages.

agriculture. The introduction of the agricultural field management system, the F&AGRIPACK visualization service for agriculture and the Akisai food and agriculture cloud allows agricultural producers and consumers to share information by visualizing management and production, and then agricultural producers, Japan Agricultural Cooperatives (JA), logistics companies and markets are linked together by visualizing customer, logistics and production information.[16)–18)] In addition, warehousers, restaurants, retailers and consumers are linked by means of traceability and ICT is used for overall optimization. This makes visible various types of information that were previously unseen and they cover producers, logistics, retailers and consumers, and this can bring optimization including consumers' feeling of security and reduced prices as well as improvement of efficiency of production and logistics. Optimum production/logistics and consumption of agricultural and marine products are required for achieving both an affluent life and reduced environmental impact and sustainable use of food and wood resources that humans are getting from natural ecosystems is hoped for.

5. Future outlook

When applying to the actual cities, towns and villages the concept of Sustainable City Network composed of linking networks of Levels 1, 2 and 3 described above, the first thing to do is to clarify the real issues of the respective cities, towns and villages. What is necessary is an approach based on sufficient analysis of the issues of the respective cities, towns and villages with the residents and local governments, or the central players, at the core. These issues may include population decrease, waste problems, CO_2 reduction, energy supply, utilization of renewable energy, promotion of employment, revitalization of agriculture, depopulation, declining birthrate combined with aging population, environmental contamination and ecosystem destruction. It is easy to imagine that these problems cannot be solved by a single city, town or village alone.

This paper has presented three basic levels in the concept of Sustainable City Network. Study of environmental futuristic cities and Smart Cities started with the study of Level 1 and Level 2 has just begun to be discussed from various viewpoints. This Level 2, specifically use of ICT for linking, monitoring, visualization, analysis, optimization and optimum control across different issues and fields is the most important for the efficient introduction of ICT systems and efficient construction of a common platform. From a medium- to

long-term viewpoint, however, the study of Level 3 is even more important in terms of what future images are created by the respective cities, towns and villages themselves. In order for respective cities to create their future ideal as well as solve issues at hand, what is necessary is to clarify the links with other cities, towns and villages they are related to and positioning of their own characteristics and values are required. Linking and positioning with reference to the entire area based on the characteristics such as the locations, nature, industries and histories of the respective cities, towns and villages are required. ICT has made it possible to collect a wide variety of information, and have real-time visualization together with multifaceted analysis, complicated linked control, high-speed information processing, familiar human interfaces and global information sharing more than before. It is believed to become a major driver to realize a design of the ideal of each city, town and village and Sustainable City Network in the present to the future. The role of Japan in the world should be discussed on an extension of the realization of this ideal.

6. Conclusion

This paper has described Sustainable City Network as a concept relating to how future cities, towns and villages should be. As specific examples, it has also presented solutions that address complicated issues in the fields of the environment and energy and mentioned examples in the fields of traffic, medical treatment and agriculture. The perspective is intended for total optimization by having a comprehensive discussion on multiple issues and fields relevant to cities in order to get more out of the results of past studies of Smart Cities with the focus on one issue such as energy, traffic and buildings. In addition, in view of different characteristics (values) of different cities and environmental impact generated, we have shown that it is important to consider a linking network between multiple cities and a linking network between cities and provincial towns or farming/fishing/forestry villages that have different characteristics from those of cities. For monitoring, visualizing, analyzing and optimizing flows of resources, energy, information, persons and goods in these networks, ICT is a significant tool. It can provide the monitoring and sensing technologies in visualization, the simulation and mining technologies for analysis, various automatic control technologies for control and technologies for optimization. In particular, in order to monitor various types of information in a wide range for linking, the cloud,[19] big data[20] and high-speed information processing technologies are essential. Furthermore, for discussing the priority and effect of these measures realized by ICT, it is necessary to develop a method of quantitatively evaluating the reduction of environmental impact and improvement of values achieved by introducing ICT.[21]

A single relevant company can consider and contribute to Sustainable City Network. However, to accomplish the original purpose, linking between different industries such as traffic/transportation, energy, resource, building, logistics and medical treatment is necessary in addition to linking between industry, government and academia, between the national and local governments and within the ICT industry. Up to now, themes of environmental futuristic cities, Smart Cities, smart communities, environmentally conscious cities and sustainable cities have been discussed in various fields. From now on, further linking between different industries and between cities and regions based on the concept of Sustainable City Network presented here is required. The Fujitsu Group intends to make full use of ICT in order to help realize a more sustainable society that combines improved values and affluence of cities, towns and villages and reduced environmental impact, and to promote global environmental conservation.[22]

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Michinori Kutami
Fujitsu Ltd.
Dr. Kutami is currently engaged in technology studies and strategy planning mainly for green ICT and Smart Cities.

Hiroko Ioka
Fujitsu Ltd.
Ms. Ioka is currently engaged in promotion of green solutions business.

Minoru Takeno
Fujitsu Ltd.
Mr. Takeno is currently supervising environmental management of Fujitsu Group.