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STI Roadmap to Achieve the Sustainable Development Goals

The Road to 2050

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THE ENGINEERING ACADEMY OF JAPAN
Science, Technology and Innovation 2050 Committee
(STI2050)

Abstract

The Committee was established in November 2019 with the aim “to determine the necessary technologies for achieving the desired future vision for 2050 based on an assessment the current situation, including an inventory of technologies looking forward to 2050, and to draw a roadmap for science, technology and innovation to materialise these technologies.

As the impacts of COVID-19 became more serious in Japan, discussion on selection of issues changed. The debate was reexamined, and selections were narrowed down to the following three issues.

1) Realisation of smart cities and comfortable and resilient human settlements
2) Realisation of sustainable and equitable access to water, food and energy
3) Realisation of governance based on visualised evidence and tolerance of diverse values

- The report presents measures to enhance mutual understanding and trust among people, society, policy makers, and the scientific community, and to realize an advanced knowledge-based society that can respond flexibly to new events that the world will face in the future.

- Although the energy-food-water relationship has synergies and tradeoffs with each other, the concept of Sufficiency was introduced to present a roadmap for achieving carbon neutrality and Energy Sufficiency in all regions of the world.

- Furthermore, as a vision for the future city, we propose a "Multi-AI Networked city" that successfully utilizes cyber and physical space, pursues well-being with humans at the center, and aims to ensure comfort during normal times and safety and security during outbreaks.

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1. Introduction: Turning to the preface

In 2015, the United Nations General Assembly unanimously agreed on the 2030 Agenda for Sustainable Development (2030 Agenda), and Nippon Keidanren (Japan Business Federation) expressed its resolve to promote ‘Society 5.0’ in order to realise the Sustainable Development Goals (SDGs) set out in this agenda by radically revising its Charter of Corporate Behavior in 2017. In addition, large long-term investors such as pension funds and reinsurance companies are increasingly demanding that companies disclose non-financial information such as proactive practices related to the environment, society and corporate governance. Companies that pursue short-term, self-serving profit are increasingly excluded from long-term investment.

Meanwhile, although human damage from natural disasters has been on a downward trend worldwide over the long term due to infrastructure development through active investment in disaster prevention and improved risk management, economic damage is increasing, and in particular, the negative impacts of climate change caused by anthropogenic global warming are becoming more apparent. The Paris Agreement, which aims to limit the increase in global average temperature to 2°C or lower compared to pre-industrial levels, was adopted by the United Nations Framework Convention on Climate Change in 2015 and went into effect in 2016.

Reports by the Intergovernmental Panel on Climate Change (IPCC) have scientifically shown that greenhouse gas emissions must be brought to zero globally by the second half of the century to achieve the Paris Agreement. Many developed countries have announced their intentions to achieve zero GHG emissions by 2050, i.e. carbon neutrality, and have set ambitious reduction targets as milestones to be achieved by 2030.

In the midst of the COVID-19 pandemic that began in late 2019, with still no clear end in sight, there is an increasingly urgent need for governments, local authorities, businesses, universities and research institutes to engage in initiatives from a long-term view in order to achieve the desired future society. While realising a carbon neutral society is a must, the development and diffusion of information and communication technologies also has an important role to play in transforming the world into the better society without disparities, as Agenda 2030 aims to achieve. The realisation of a desirable future society requires not only a shared vision, but also the technology and institutions to make it a reality.

In 2017, the Engineering Academy of Japan (EAJ) launched a project entitled “The Role of Science, Technology and Innovation in the SDGs” (led by Haruo Takeda) with the aim of ensuring that the Japanese government and its ministries and agencies introduce and implement policy on various strategies to achieve the SDGs related to science, technology and innovation. In 2019, the project recommended the establishment of a “Special Committee for Creation of a Sustainable Society (tentative name)”, an organisation in which EAJ would be centrally involved. In response to this recommendation, the “Committee for Science, Technology and Innovation 2050” (STI2050 Committee) was launched with a new name as a special committee. This Committee was established by the Board of Directors in November 2019, and its volunteer members from both inside and outside EAJ have been engaged in discussions since. At the time of its establishment, the issues listed below were envisioned to be the main topics of debate. The first three points were borrowed from the three steps of the Talanoa Dialogue, which was held after the UNFCCC COP23 in the lead up to COP24 in 2018 to motivate action on climate change.

(1) To ascertain where we stand today: “Where are we?”
(2) To present a vision for the future: “Where do we want to go?”
(3) To discuss concrete proposals for action to achieve these goals: “How do we get there?”
(4) Development of a roadmap for technologies to support social innovation
(5) Creation, recommendation and review of an action plan to realise a sustainable society

The goals of the Committee were to talk about our engineering dreams on what kind of future society could be realised in 2050 and 2100, to review visions for the future proposed both in Japan and abroad to determine an ideal future vision for 2050, or potentially 2100, to identify key or niche technologies that would facilitate the structural transformation of society necessary to realise this vision, to draw a roadmap for social innovation supported by these technologies, and to recommend an action plan for realising a sustainable society looking ahead to the 22nd century. In addition to predicting the future in 2030 and 2040 based on current prospects for technological development, the Committee also looked back at history to draw an ideal future image of what kind of "better world" we want to materialise, taking into consideration the unchanging desires and behaviours of humanity. Then it tried to apply a bird's-eye view approach to think about the technological development that needs to be done now to achieve it.

In the course of these discussions, we came to the obvious consensus that it would be very difficult to look at the entire technology roadmap for 2050, and tried to narrow the discussion down to three main points.

- Technologies to break away from economic systems dependent on fossil fuels
- Technologies that contribute to the elimination of poverty and inequality
- Technologies that contribute to a dramatic improvement in quality of life

Initially, the plan was to intensify discussion on these three technological aspects, identify the key technologies and create a technology roadmap for a better society in 2050. However, in light of the worsening impacts of COVID-19, a majority of members agreed that it would be better to reexamine the plan in its entirety. The Committee then decided to hold a workshop in August 2020 with lectures from external experts. The following topics were newly narrowed down, corresponding to the three groups of this report.

- Realisation of smart cities and comfortable and resilient human settlements
- Realisation of sustainable and equitable access to water, food and energy
- Realisation of governance based on visualised evidence and tolerance of diverse values

Although it was not always easy for committee members to make time for voluntary committee activities, their high sense of purpose and ambition, especially of the main authors of the chapters, has resulted in this unprecedented report. It is the hope of the EAJ STI2050 Committee that this report will contribute in some way to the future development of technology in Japan and around the world, and help to build a better future society. Last but not least, I would like to express my deepest respect and gratitude to the workshop lecturers, to committee members Taro Arikawa, Miho Kamei and Shoko Hirakawa, who served as dedicated coordinators, and to committee member Michiharu Nakamura (former Deputy Chair of EAJ) for giving us this opportunity.

Taikan Oki, Chair, EAJ STI2050 Committee

2. Thoughts on a future society in 2050

2.1. Background

The Club of Rome, founded in 1970, launched a project on the “Predicament of Mankind”. Dr. Dennis L. Meadows, who was the Director of the project, coauthored “The Limits to Growth” in 1972, a commissioned analysis report on the project.[2.1.1)] In the afterword to the Japanese translation of the book, Mr. Yasukawa, then Chairman of the Club of Rome Tokyo Office, described the report’s background in detail.

The Club of Rome's sense of urgency was based on an understanding of the benefits of recent scientific and technological progress alongside the existence of various disharmonies as a hidden by-product of these benefits.

In 1970, the world faced many issues:

1 Escalation of nuclear capability
2 Population growth
3 Widespread environmental pollution
4 Depletion of natural resources
5 Progression of urbanisation
6 Growing social unrest
7 Alienation of the youth
8 Widespread inflation
9 Collapse of traditional values

In particular, the report expressed the fear that the pursuit of wealth did not necessarily lead to the well-being of mankind as a whole.

The report was based on the results of research at MIT on modelling global systems. Fifty years later in 2020, the concerns of that time are increasingly prominent in Japanese society, including the impacts of environmental pollution and increasing urbanisation, as well as regional disparities due to the collapse of traditional values. Moreover, amidst advancing globalisation, creating models of global systems is essential.

While calling for a shift from growth to global equilibrium, the report also speaks to the difficulty of dealing with human values: “As soon as a society recognizes that it cannot maximize everything for everyone, it must begin to make choices.” It then focuses on the trade-offs that arise due to the finite nature of the earth, identifies realistic alternatives, and establishes social goals. The report highlights the importance of defining long-term goals, then setting short-term goals that are compatible with them. Dr. Meadows later pioneered the community of Cobb Hill in a project called Cobb Hill CoHousing[2.1.2)], which aimed to develop a lifestyle that enabled cyclical production and consumption within the community while maintaining interdependence with the outside of the community (local production for local consumption), and to study sustainability and train the next generation of leaders. However, Dr. Meadows died in 2001 before he could witness the completion of the project. Since then, the project has continued, and the web page (http://www.cobbhill.org/) reports on the life in the community.

Further, in 2009, Rockström et al. proposed the “Planetary Boundaries” framework involving the following nine indicators.[2.1.3)]

1 Climate change
2 Biodiversity loss

3 Biogeochemical flow boundary (Nitrogen cycle, Phosphorus cycle)
4 Global freshwater use
5 Change in land use
6 Atmospheric aerosol loading
7 Chemical pollution
8 Ocean acidification
9 Stratospheric ozone depletion

Among these, biodiversity loss and biogeochemical flow boundary have already reached very dangerous levels, while the threats of climate change and land use are increasing. [2.1.4)]

In this context, the 2030 Agenda for Sustainable Development, adopted at the UN Summit in September 2015 as the successor to the Millennium Development Goals (MDGs) of 2001, set forth the Sustainable Development Goals (SDGs) as international goals aimed at realising a sustainable and better world by 2030. Consisting of 17 goals and 169 targets, the SDGs pledge to "leave no one behind" on the planet. [2.1.5)]

In working towards these goals, reports published by IIASA (International Institute for Applied Systems Analysis) in 2018[2.1.6)] and 2019[2.1.7)] are considered to provide a roadmap. The report titled “The World in 2050” (TWI2050) shows the six transformations that would be effective for achieving the 2030 goals. Likewise, Sachs et al. (2019) [2.1.8)] presents six transformations and classifies numerically how each relates to the 17 goals of the SDGs. The six transformations are as follows:

(1) education, gender and inequality;
(2) health, well-being and demography;
(3) energy decarbonisation and sustainable industry;
(4) sustainable food, land, water and oceans;
(5) sustainable cities and communities; and
(6) digital revolution for sustainable development.

These six transformations are considered to be Sustainable Development Pathways (SDPs), and how to realise the transformations is examined based on Shared Socioeconomic Pathways (SSPs) (Riahi et al., 2017) [2.1.9)]. For example, for (1) education, gender and inequality, the impacts of enhanced education levels on demographics are shown. Furthermore, for 6) digital revolution for sustainable development, which is also discussed in particular in the 2019 report, digitalisation in all fields is said to be essential to achieve the SDGs. Moreover, homo sapiens in such a society are referred to as homo digitalis by the German Advisory Council on Global Change (WBGU) [2.1.10)].

In this context, the global spread of COVID-19 in 2020 led IIASA to issue the third TWI2050 report [2.1.11)], the central theme of which was “from efficiency to sufficiency”. This report could be considered a response to Dr. Meadows’ report of 50 years ago. It is an attempt to move away from the pursuit of wealth and economic rationality to realising the well-being of humanity as a whole by focusing on “sufficiency”. We will follow this approach in this report.

2.2. Background and objectives of the Committee

The Committee was established in November 2019 with the aim “to determine the necessary technologies for achieving the desired future vision for 2050 based on an assessment the current situation, including an inventory of technologies looking forward to 2050, and to draw a roadmap for science, technology and innovation to materialise these technologies. Its goals are to review visions for the future proposed both in Japan and abroad to determine an ideal future vision for 2050, or potentially 2100, to identify key or niche technologies that would facilitate the structural transformation of society necessary to realise this vision, to draw a roadmap for social innovation to support these technologies, and to recommend an action plan for realising a sustainable society looking ahead to the 22nd century.

2.3. Topics to be addressed

The committee has met 20 times to develop this roadmap and action plan, with the aim of identifying topics and challenges to be addressed, identifying the necessary technologies to address them, and considering pathways to get there. The committee carried out discussion to narrow down the topics to be addressed to around three.

Following the example of the "Talanoa Dialogue" held in the run-up to the UNFCCC COP24 to motivate action on climate change, the Committee has asked, (a) "Where are we?", and (b) "Where do we want to go?" to ascertain where we stand today and to determine the desired future to aim for (goals). Likewise, it asked (c) "How do we get there?" to discuss concrete proposals for actions to realise this future.

As the impacts of COVID-19 became more serious in Japan, discussion on selection of issues changed. The debate was reexamined, and selections were narrowed down to the following three issues.

(1) Realisation of smart cities and comfortable and resilient human settlements
(2) Realisation of sustainable and equitable access to water, food and energy
(3) Realisation of governance based on visualised evidence and tolerance of diverse values

Lastly, we would like to conclude with a few remarks on how the debate underwent change before and after COVID-19.

The themes of "topics and challenges to be addressed leading up to 2050" and "technologies considered necessary to toward addressing these challenges" were assigned as homework at the third committee meeting and discussed at the fourth committee meeting at the beginning of 2020. At that time, keywords related to "topics and challenges to be addressed leading up to 2050" included:

- World peace
- Decarbonised societies
- 100-year-life societies
- Stable food supply
- Resilient and sustainable societies
- Enhanced QOL
- Financial revolution
- Enhanced level of well-being

It is evident that before the COVID-19 pandemic, the main focus was on how our societies could cope with issues such as climate change, population decline, aging population, work style reform, and natural disasters. On the other hand, once the full-blown pandemic had begun, discussions concentrated on the "realisation of governance based on visualised evidence and tolerance of diverse values", mentioned in (3) above. Also related to responses to climate change, many agreed that the state of governance in our increasing digital societies is an important key to building a sustainable society.

Accordingly, this report begins with a discussion on the realisation of such governance, then addresses the issue of the water-food-energy nexus, and finally describes a vision of the future in which cities realise the well-being of all people, which can easily become a trade-off with the pursuit of wealth. We are pleased to report that part of this report has also been published as a paper in the IATT report [2.3.1)].

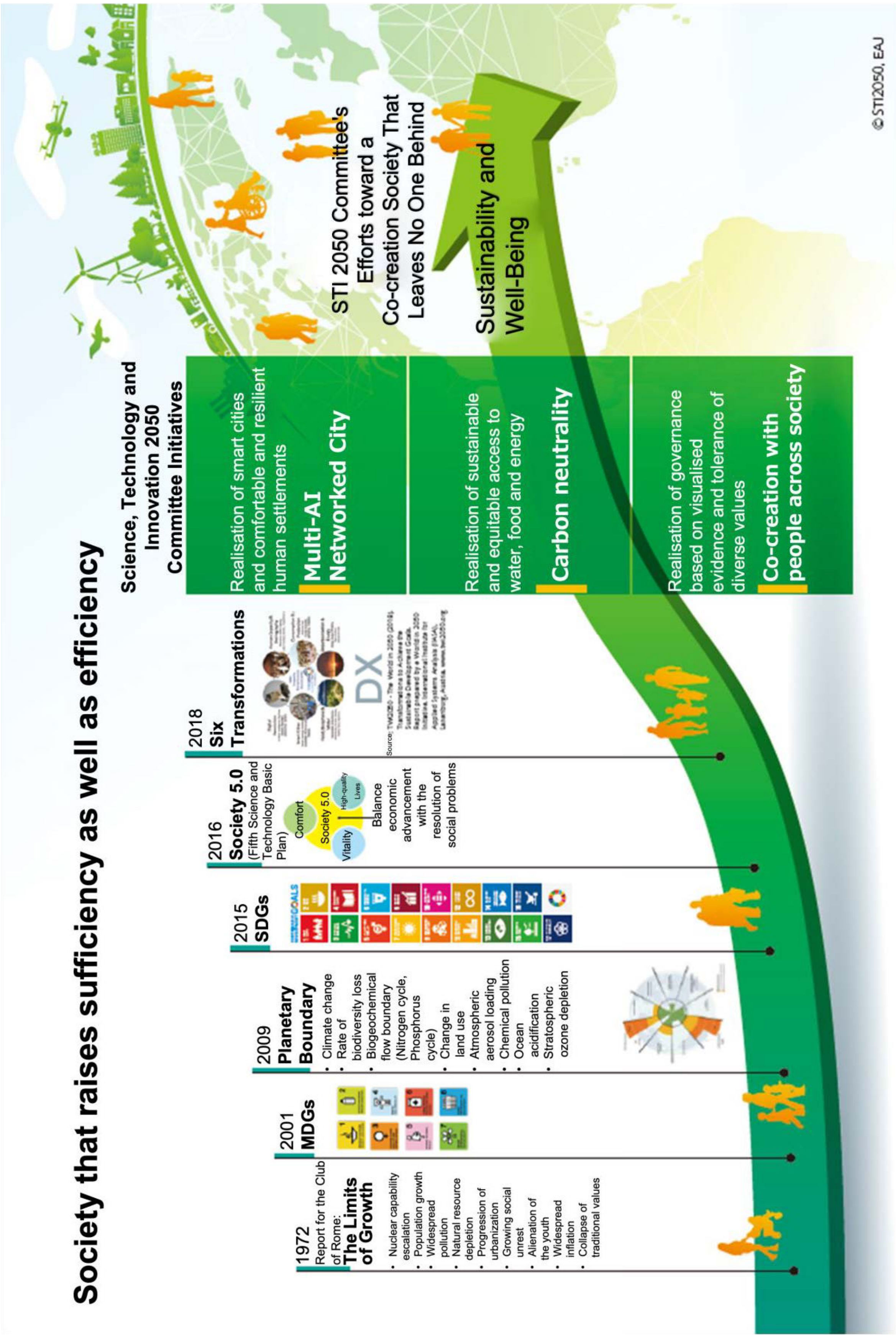

Figure 2.3.1 STI's Positioning of the STI2050 Committee's Efforts Toward a Co-Creation Society that Leaves No One Behind

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3. Roadmap toward realisation of governance based on visualised evidence and tolerance of diverse values

3.1. Introduction: "What does governance look like, and what are we trying to achieve?

3.1.1. Significance of this chapter

The aim of the Committee was to draw up a “science, technology and innovation” roadmap to materialise the technologies required for an ideal future vision for 2050. Specifically, in addition to the two themes of smart cities and comfortable and resilient human settlements, and sustainable and equitable access to water, food and energy, going forward the project will share the common theme of the realisation of governance based on visualised evidence and tolerance of diverse values, which will also incorporate the first two themes.

This theme was handled by Group 3 of the Committee. While working on this topic, we were aware of the fact that when looking ahead to future society and its challenges to draw up a roadmap for the technologies needed to develop society and solve its problems, it was necessary to take a broader view and not merely consider the technologies themselves.

3.1.2. Why visualised evidence and governance are currently a challenge

Science and technology are the product of human intellectual activity. Multiple individuals come together to form a society with each human being an individual component. Accordingly, science and technology are strongly related to the state of the society at the time. The origin of modern science, which is the basis of today's science and technology, occurred in the mid-17th to early 18th century, coinciding with the formation of modern states in Western Europe, the emergence of Western democracy and the Industrial Revolution. Science and technology to date have developed mainly in societies where Western democracy was a common value, and economic development via the Industrial Revolution was remarkable. But what about the societies of today? Although many developed countries profess themselves to be democracies, division has become a serious problem. Meanwhile, authoritarian and despotic countries have emerged, affecting the future of developing countries. Likewise, in the developed world, now that rapid economic growth has become stunted, inequality is widening. In this changing world, people's values are becoming more diverse. What people and societies are demanding is dramatically different from the simplicity of the past, where economic growth brought material wealth. In other words, societies must recognise that people have diverse interpretations of well-being and aim to bring about, not a maximum, but a reasonable level of well-being to as many people as possible.

Science and technology, which are closely related to society, must respond to changes in society and present compelling facts and options for the best available approaches to fulfill the wishes of as many people as possible. Furthermore, this process must be carried out not only with science and technology, but also with the participation of people and society. As the development of science and technology wields significant impacts on society, this process is governance itself, defined as "decision-making among the actors involved in a collective problem that leads to the creation, reinforcement, or reproduction of social norms and institutions" (Wikipedia), in this case as it pertains to science and technology and society. The formation of mechanisms and platforms for stakeholders to participate in this process and take action is essential.

Therefore, this chapter will first briefly review the increasing complexity of society’s changing relationship with science and technology, and then present an example of how today's cutting-edge science and technology, represented by the use of AI, could visualise the situation and grasp the diverse demands and values of people. We will also outline the development of scientific advice, which is an important process in society’s relationship with science and technology, from the perspectives of scientists and engineers, policymakers, scientific academies and legislative bodies, both as it relates to Japan and the situation overseas. COVID-19 is used as a recent example of how science and technology have responded to problems facing the world. Based on this, we will attempt to present a roadmap for better governance of society’s relationship with science and technology.

3.1.3. Science and technology and society in the 20th century

Since the second half of the 20th century, society’s relationship with science and technology has become extremely interrelated and complex. For the first half of the 20th century, the relationship developed along a linear model in which the results of scientific and technological research were utilised by various players in society, i.e. industry and public organisations, as they spread throughout society. However, society’s relationship with science and technology has become more bidirectional as they influence each other. One example is the environmental pollution of the 1970s, which raised the issue not only of the benefits that the products of science and technology bring to society, but also of the negative impacts on society due to side effects generated in production processes. At the same time, while technological progress since the Industrial Revolution had sought to achieve greater productivity and efficiency and to produce higher economic value from the same resources and effort, as societies and standards of living reached a certain level of affluence, perspectives shifted from the pursuit of solely quantitative goals, to also include qualitative ones. In other words, rather than a single criterion based on economic value, society has begun to pursue goals based on a variety of values.

For example, when the global environment became a major issue in the 1990s, developed countries that had already achieved economic development argued for curbing economic development to some extent in order to prevent further destruction of the global environment, whereas developing countries differed in their stance. They felt that responsibility for the destruction of the global environment lay with developed countries, and that because their economies were not sufficiently developed, they should not be deprived of the right to continue.

Developing countries that have recognised the benefits and harmful effects of technology and development are calling for minimising these effects, and values have diversified. In contrast, the benefits of economic development have not reached the majority of the world. This difficult dilemma was incorporated into the term “sustainable development”.

3.1.4. Transformation of society’s relationship with science and technology in the 21st century - the emergence of the SDGs

Sustainable development, and all the complex problems around the world that it involves, has become a more prominent global issue in the 21st century alongside the increasingly interdependent and globalised nature of the world's people, material flows and economies. It is no longer just about the environment. From the point of view of sustainable development, the disparity in development level around the world became an issue, and the Millennium Development Goals were established. These set out eight goals, with a focus on improving the situation of developing countries.

The 8 Millennium Development Goals
1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

In this context, for example, if we look at extreme poverty (living on less than 1.9 USD a day), which is related to basic human rights and can trigger regional conflicts, there has been a significant improvement from 36% of the population in 1990 to 10% in 2015. However, the fact remains that there are still 700 million people facing extreme poverty.

Subsequently in 2015, the Sustainable Development Goals (SDGs) were adopted by the United Nations to build on the achievements of the Millennium Development Goals (MDGs) and to put forth stronger efforts to address unachieved goals, as well as to provide a set of common global goals that are also relevant to developed countries. The SDGs are a set of 17 goals, underpinned by 169 targets. The 17 goals were developed to encompass the proposals of various stakeholders, and the 169 targets are intricately linked to each other. Recognised as a set of goals with complicated benefits and drawbacks that cannot be addressed by simply extending existing approaches, the SDGs call for new innovations. For this reason, high expectations have been placed on science and technology and the new innovations resulting from them (hereafter referred to as science, technology and innovation). This calls not only for the creation of higher economic value, as has been the case in the past, but also for more sophisticated solutions, such as ways of demonstrating synergy and achieving optimisation in the achievement of mutually conflicting goals. For example, the issue of cities can be seen as a compound issue involving poverty, food, industry and the environment. Likewise, it is clear that food, water and energy security are strongly correlated, and that maximising solutions to one issue could have negative impacts on the others. For instance, maximising the supply of food according to people's preferences would consume large amounts of water and energy, upsetting the balance. Science, technology and innovation are called upon to address these conflicting issues by first clearly showing the correlations between them, and then creating alternative methods or new ways of dealing with them.

This is the first time that such high expectations have been put on science, technology and innovation with regards to global issues. On the other hand, although research and development in various fields of science and technology is ongoing, it is not possible to deal with the complex issues mentioned above by confining ourselves to certain fields which can only produce partial solutions. Therefore, science and technology, as well as those involved in them, need to operate from a bird's eye view and carry out initiatives across fields that actively acknowledge the need to "cross borders".

3.1.5. The need for "governance"

The SDGs and science, technology and innovation call for a kind of management that differs from the past. In other words, as implied in the title of this report, after acknowledging diverse values and factoring in society's evaluation of these values, potential solutions should be sought based on data and objective facts. These solutions should then be proposed to society and implemented with a certain level of consensus. This process can be called a new kind of governance.

3.1.5.1. Governance required for science and technology

We begin by discussing the governance that is needed for science and technology as well as those involved in it. As mentioned earlier, many of the challenges we face today are complex and involve multiple perspectives and disciplines, so the pursuit of simple objectives will not lead to solutions to these problems. Firstly, as mentioned at the end of the previous section, those involved in science and technology must have an understanding of these issues. While this may sound obvious, it can be surprisingly difficult. This is because scientists and engineers, compared to those in other fields, generally have a special interest in a certain field or on a certain issue, regarding which they acquire a great deal of knowledge that is translated into scientific and technological results. It is therefore natural that they are more aware of the importance of the issues that they themselves address. Moreover, the fields of science and technology that are more closely related to society, such as various engineering disciplines, are tackling real social issues, and therefore research and development is being carried out from a broader viewpoint. However, we must be more imaginative in asking ourselves if our own research and development are truly set apart from other relevant fields and social issues.

Accordingly, when undertaking projects to tackle various issues, it is advisable to incorporate measures to gain a broader perspective. For instance, when addressing a particular issue, in addition to core stakeholders in the field, parties interested in social issues from other fields, especially those in the humanities and social sciences, as well as experts from NGOs and non-profits, could be invited to participate in the discussions to contribute to a broader view from the project's conceptual stage. To date, the main methods employed have been meetings to seek consensus and public comments at the deciding stage of a conceptual proposal, as well as evaluation from ethical, legal and social perspectives (ELSI) at the final stage of the conceptualisation. However, by seeking more diverse opinions from the conceptual stage, we can better reach solutions that respond to the challenges of today's society.

When carrying out a project and compiling results, it is essential to carefully explain what is known and what must be done for outside the project, particularly those who will be involved in the hands-on work of social implementation, such as policymakers and business people, to gain their understanding.

3.1.5.2. Governance required on the part of society

On the other hand, there are also demands on the part of society, which will enjoy the fruits of the challenges posed by science, technology and innovation. Even if those involved in science and technology formulate a concept based on exchange with a wide range of stakeholders, the way in which their results are materialised in the real world is often left up to others, such as policymakers and business people, not the scientists and engineers.

On the part of society, including policymakers and businesses, there are important issues to be considered when utilising the results of scientific and technological innovation. First of all, it is important to understand without prejudice what is currently understood and what is possible. Specifically, the more serious the situation, the more urgently solutions are sought. Accordingly, it is easy to look to what is easily understood, but disregarding facts and easy judgments should be avoided. This may seem obvious, but in reality, it often happens. When certain figures or facts regarding scientific and technological innovations are presented, practitioners often dismiss them in favour of prioritising other reasons. For example, in the recent collapse of a staircase in an apartment building, the designers had intended to use metal materials, but for some reason wood was used, leading to the accident.

Policymakers and businesses need to pay due respect to the solutions obtained through science, technology and innovation, and when they decide to take a different approach, they need to give full consideration and a clear explanation of the change. Of course, in some cases scientific and technological innovations are not feasible in the real world, and in such cases those involved in science and technology must be included in the discussion.

One example is the triage of the sick in a disaster situation, where the available medical resources have to be ranked in order of priority from a professional perspective.

Today's challenges are more complex than ever, and the science and technology involved is wide-ranging and complicated. The complexity and depth of science, technology and innovation must be borne in mind by policymakers and businesses in society when choosing how they will deal with issues. Moreover, it should be clearly understood that solutions proposed by those in science, technology and innovation are scientific advice only, and that the responsibility for determining solutions lies primarily with the policymakers and businesses.

3.1.5.3. The premises of governance

A prerequisite for realising the governance called for on the part of science, as well as on the part of society, especially policymakers and business practitioners, is a greater understanding and agreement among people and society on the relationship between science and society.

First, people must be interested in the relationship between science and society. We have the opportunity to think about policymaking and business practices during elections and in the choice of products and services, but what about science? For example, science can never be 100%, but many people expect “absolutes” or “perfection”. Various responses based on science, including medical treatment and drugs, are choices between benefits and risks. It is up to the people to understand the nature of science - that it is not magic, but repeated attempts to gain benefits while minimising risks. Of course, careful effort on explanations is presupposed on the part of science.

Secondly, science is only one element, albeit an important one, in policymaking and business operations. To give a simple example from the perspective of the science of COVID-19, the most effective measures called for by infectious disease medicine may be known, but economic activity cannot be completely stopped. Both the state of emergency declarations in Japan and lockdowns in Europe and the US allowed a minimum level of activity, accompanied by some risk, therefore requiring extra time to control the spread of infection.

The above mutually understood relationship between society and science is a precondition for governance.

3.1.6. Governance of science, technology and innovation built upon on push-and-pull tension and mutual respect

In summary, those involved in science and technology must be prepared to use their imagination to understand the various aspects of the challenges facing society, and be willing to work with many others to do so. Meanwhile, policymakers and businesses must take responsibility for making tough decisions, including making choices in conflicting situations based on the understanding that complex issues rarely have simple solutions.

Turning to experience to date, we can reflect on two facts regarding the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant following the Great East Japan Earthquake of 11 March 2011. One is the response of scientists and engineers and the other is the response of business operators.

3.1.6.1. Issues with the response of science and technology professionals

In the face of the nuclear accident and the subsequent spread of radioactivity, a number of researchers, mainly in the field of radiation, appeared in the media and rushed to the side of individual politicians. I would like to believe that many of them did so as an act on goodwill as experts in the field, in order to help people and society who were anxious about the accident and the invisible threat of radiation, wanting to know the facts. However, the problem was that they focused only on the parts of the complex and massive technology of nuclear power that were related to their own expertise, thereby contributing to the confusion by discussing the issue in a way that lacked an overall picture and giving difficult explanations using too many technical terms. In addition, the effects of radiation are imprecise, making it difficult to say with certainty what the effects will be at low doses. It was not possible to make people fully understand this inherently difficult phenomenon, and in some cases the various explanations only increased anxiety.

Public opinion polls at the time showed that a majority of people felt that there had not been enough communication from the science and technology side about the nuclear accident, while many people also called upon experts to express their opinions. Thus there is a gap between the perception of the science and technology side, which felt that it had done the right thing.

This situation can be attributed to a lack of adequate preparation on the part of those involved in science and technology in Japan. When it comes to society's relationship with science and technology, the understanding and support of the public have been important since the 1950s, when science and technology policy began. In 1996, at the time of the formulation of the Science and Technology Basic Plan, public understanding was increasingly promoted. It can be said, however, at the time that science and technology helping society was seen as a given, and this was only asking for the understanding of the people on this matter. In other words, this was an idea that came from the side providing the knowledge, but it did not address the questions and or awareness on problems of people and society, nor attempt to promote science and technology based on fully listening to people's opinions. Even for policymakers and business operators, explanations were focused on benefits and advantages.

In contrast, in 2013 the Science Council of Japan revised the Code of Conduct for Scientists to stipulate the position of scientists when giving scientific advice. The Code of Conduct was established in 2005 to restore public trust in the scientific community following a series of incidents involving research misconduct and misuse of research funds, and was revised following a review in 2011.

We believe that this is the starting point for the governance of those involved in science and technology

3.1.6.2. Challenges for the users of nuclear technology

There is a lot of debate about nuclear power and how it should be treated in order to achieve carbon neutrality in the future. Nuclear power, with a lack of a clear policy pathway for the ultimate disposal of waste, has long been the subject of debate. Here, we examine the question of whether nuclear power, in the wake of a nuclear accident, can be safely controlled as a technology from the perspective of governance.

The accident at TEPCO's Fukushima Daiichi Nuclear Power Plant has led some to argue that nuclear power cannot by controlled by humans. However, the same type of reactor at the Tohoku Electric Power Company's Onagawa Nuclear Power Plant was subjected to similarly severe conditions, but the initial safety equipment functioned and an accident was avoided. Therefore, with proper governance by operators, nuclear power should be considered controllable. However, the Onagawa plant benefited from the fact that it was designed and built to cope with the largest possible earthquakes and tsunamis based on historical facts. Thus, as mentioned earlier, governance over the use of such advanced technology should begin at the conceptual stage.

Science, technology and innovation, which are becoming increasingly sophisticated and complex, entail not only benefits, but also risks. Those utilising the outcomes must be aware of the risks and have the governance to minimise them as they maximise benefits.

3.1.7. The aim of "governance"

It is of utmost importance that those who produce science, technology and innovation, as well as the policymakers and businesses who implement the results in society, be aware of what they are aiming for based on the governance described above.

The SDGs aim to address a range of human-induced global challenges by the year 2030. However, not all of the goals have processes drawn up for reaching complete solutions by 2030, and some have set numerical targets for improvements by 2030. The year 2030 is a transit point, and efforts must be made to look even further ahead.

When we consider the course of humanity within this process, various ideas emerge and greater demands are made on governance. This introduction will conclude in mentioning some of them.

The International Institute for Applied Systems Analysis (IIASA), an international non-governmental public interest group that is looking beyond the SDGs, along with others, has proposed "sufficiency" as a way to achieve sustainable development. In contrast to "efficiency", which has been a requirement of economic development to date, sufficiency is seen as a concept that restricts unlimited desires, aiming to find a balanced state of sufficiency based on at least the fulfillment of basic human needs. It is a concept worthy of further discussion in order to achieve more balanced progress among developed, emerging and developing countries to materialise sustainable development within the limited resources and environment of our planet.

An important aspect of the sufficiency debate is how to achieve well-being for people along the way. Well-being is highly subjective, and many efforts have been made to find a way to measure the level of well-being, but no definitive conclusions have been reached. Nevertheless, people and society would find science, technology and innovation unacceptable if they only caused people and societies to endure and suffer. Governance that takes into account what human well-being is and how to contribute to its realisation is needed. In this respect, the Sixth Science and Technology Basic Plan, approved by the Cabinet in 2021, which clearly states that it aims to develop policies with a view to people's well-being, can be considered an epochal development.

Furthermore, an issue related to the SDGs is that in the pursuit of welfare and well-being for the world and society as a whole, the existence of large disparities can lead to conflict, thereby reducing overall welfare and well-being. Economically speaking, it is difficult for the uneven distribution of wealth to trickle down to all corners of society, and according to the economist Thomas Piketty, inequality tends to increase in capital terms. Addressing growing inequalities is an issue on which consciousness should be raised.

3.2. The roles of visualised evidence, diverse values and well-being

3.2.1. Well-being and QoL

The Constitution of the World Health Organisation (WHO) written at its founding in 1946 states the relationship between health and well-being as follows: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". Moreover, in WHO's WHOQOL-26 (2011) [3.2.1], a further summary of the WHOQOL-100 established in 1996, quality of life (QoL) is defined as "individuals' perceptions of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns", and identifies it as a factor alongside physical health, mental health and social relationships [3.2.2]. Amartya Sen's research on "capability" is also relevant to QoL. He set out requirements for achieving "quality of life", which he considers to be a combination of "doing" and "being", where "capability" is the "freedom" to choose between them [3.2.3].

In 2007, the European Commission (EC), European Parliament, Club of Rome, Organisation for Economic Co-operation and Development (OECD) and WWF organised the "Beyond GDP" international conference, which was followed by a series of national initiatives to develop indicators to measure wealth. In 2008, French President Sarkozy asked Joseph Stiglitz, Amartya Sen and Jean Paul Fitoussi to establish the Commission on the Measurement of Economic Performance and Social Progress (CMEPSP). CMEPSP's report proposed 12 recommendations and the following indicators. Some of the CMEPSP messages are as follows.

"More and more people look at statistics to be better informed or to make decisions. To respond to the growing demand for information, the supply of statistics has also increased considerably, covering new domains and phenomena."

"…the time is ripe for our measurement system to shift emphasis from measuring economic production to measuring people's well-being."

To support these messages, CMEPSP proposed the following measurements of well-being.

a) Material living standards (income, consumption and wealth)
b) Health
c) Education
d) Personal activities including work
e) Political voice and governance
f) Social connections and relationships
g) Environment (present and future conditions)
h) Insecurity, of an economic as well as a physical nature

While a) is a conventional economic indicator, the other items b) through h) correspond to well-being. This concept led to Joseph Stiglitz's statement at a UN Summit in 2015, that the "SDGs are important in setting global norms" and Amartya Sen's assertion that "Democracy is a key to achieving sustainable development" [3.2.4]. These ideas on well-being led to the concept of physical, mental and social well-being, which became the goal of the SDGs adopted by the UN General Assembly in September of the same year. In the view of the authors, when comparing the above-mentioned definition of "well-being" and that of "QoL" referred to in WHOQOL-26, the difference is that well-being sees the individual externally from the viewpoint of economy and society, while QoL is based on individuals' self-perception within the culture and values in which they live. However, for an awareness survey report in the UK entitled "Personal well-being in the UK: April 2019 to March 2020", despite the use of well-being in the title, focus is on self-perception.

3.2.2. QoL development by government

In the United States, President Johnson (1963-1969) stressed the importance of improving the quality of life of the people. Subsequently in the 1968 presidential election, President Nixon remarked, "We need a high standard of living, but we also need a high quality of life...We need a strategy of quality for the 70's to match the strategy of quantity of the past". In 1968, Norman Dalkey of the RAND Corporation attempted to better define quality of life in order to promote concrete improvements in the lives of citizens, proposing the following nine basic elements of an individual’s QoL: health, status, affluence, activity, sociality, freedom, security, novelty and aggression. President Nixon's “high standard of living” corresponds to the a) material living standards (income, consumption and wealth) indicator in the CMEPSP report (2009) mentioned above, and the “high quality of life” corresponds to the b)-h) indicators. Comparing the CMEPSP (2009) b)-h) indicators and Dalkey’s (2009) nine elements, we find that although the subject of CMEPSP’s report is well-being and Dalkey’s paper refers to QoL, they have many similarities.

3.2.3. National well-being

Let us look at the background and objectives of the UK’s advanced efforts to measure well-being. The indicators of the UK’s Statistical Information Service system, which began in the 1970s, have included the Sustainable Development Indicators (SDI) of 1996, which followed 1987’s Our Common Future (Brundtland) and the 1992 Rio Summit, the Voluntary QoL Indicators of 2001, and developing again into the Sustainable Development Indicators (SDIs). The SDIs were then split into SDGs and National Well-being Indicators in 2016, after which the SDIs were retired. The National Well-being Indicators were then replaced by personal and economic well-being in the UK [3.2.5], which is ongoing. The 2019 “Dashboard” of well-being indicators included eight economic indicators such as disposable income and unemployment rate and four personal indicators such as happiness and anxiety about life. The total of 12 indicators are presented with changes over time (Figure 3.2.1).

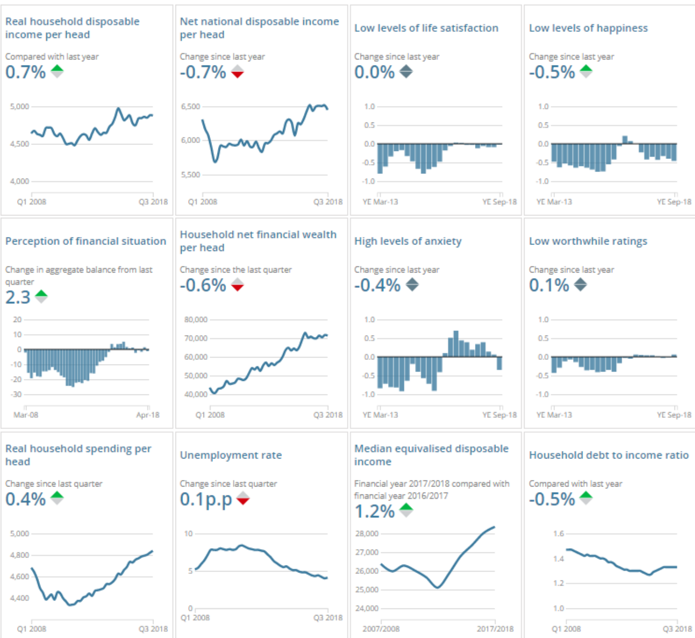

Figure 3.2.1 Personal and economic well-being in the UK: Dashboard as of February 2019 [3.2.6]

For the four personal well-being indicators, as of the end of March 2020, the percentage of people who were happy decreased by 1.1%, and the percentage of people with anxiety increased by 6.5% compared to the same period in 2019, coinciding with the COVID-19 lockdown in the UK. Meanwhile, in a slightly later period from July to September 2020, the average percentage of those who were happy increased by 2.1%, coinciding with the end of the lockdown. These changes are depicted visually by region and city, as well as over time, as shown in Figure 3.2.2. This provides a clear picture of the contrast between the performance of public administration and personal well-being.

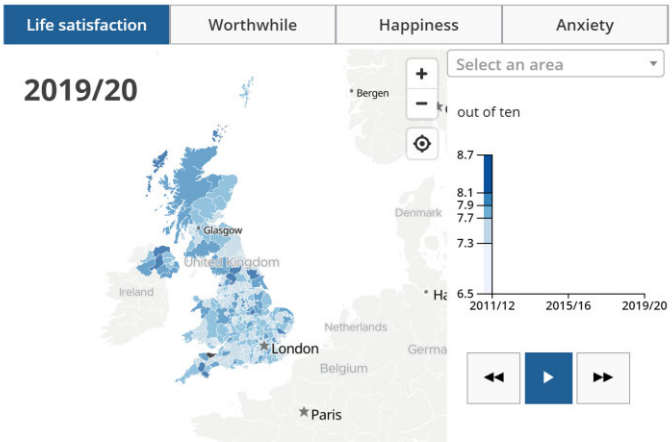

Figure 3.2.2 Personal well-being in the United Kingdom (2019-2020) distribution by region and city [3.2.7)]

3.2.4. Local government initiatives (Bristol, UK)

The City of Bristol has a metropolitan population of 760,000 (2017) and is recognised as one of the best places to live in the UK. In 2001, Bristol became the first city in the UK, ahead of the central government, to launch a QoL survey based on its own local indicators. This system of indicators is intended serve as a source of information to redress inequalities and imbalances in the city as a whole, as well as to monitor the performance of the city's One City Plan and other projects based on it. According to the city's “Quality of Life Survey 2020/21 Priority Indicators: Briefing Report” (Jan 2021), surveys were conducted online and by post in 33,000 households in 34 randomly selected wards (Figure 3.2.3).

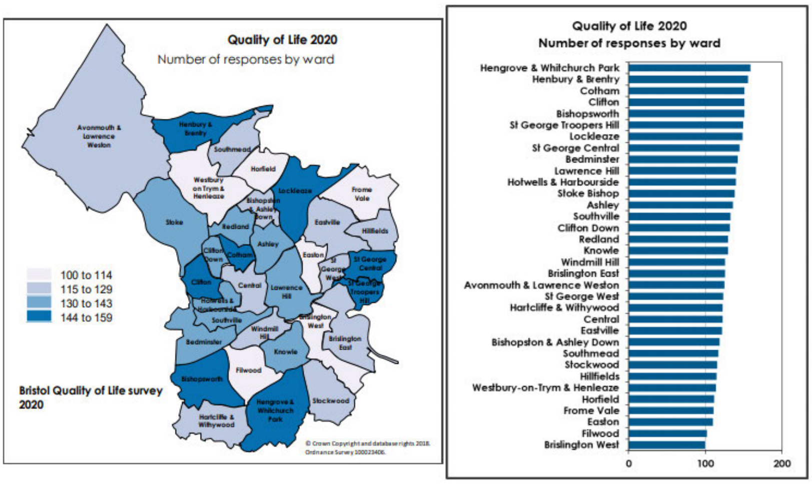

Figure 3.2.3 Local-level QoL survey [3.2.8)]

The survey consisted of 70 questions relating to 200 indicators such as health, lifestyle, community and local services. The system includes an element of push-and-pull tension. If the performance of the municipal government and related bodies is deemed inadequate, the budget of departments in charge is cut. In regard to COVID 19, 4,000 respondents were asked to select the most important of several key words. Top responses included: business, community, family, health, jobs, local, normal, safe, support, social, stay and work (Figure 3.2.4). It is noteworthy that even in difficult times, the municipal authorities and related institutions have a wide range of systems to monitor and support the lives of citizens, which leads to a sense of trust and participation of citizens in the administration, which is at the heart of governance.

Figure 3.2.4 Key words from the COVID19 questionnaire in the Bristol Quality of Life survey 2020/21 [3.2.8)]

3.2.5. Life satisfaction and values in Japan

Various indicators that measure quality of life and well-being include the OECD's Better Life Index (BLI), the Inclusive Wealth Index of the United Nations University (UNU) and the United Nations Environment Programme (UNEP), and the World Happiness of the United Nations Sustainable Development Solutions Network. Japan has also made efforts to incorporate multifaceted assessment in the "Dashboard for Satisfaction and Quality of Life Indicators" of its 2019 Framework Policy. The OECD's Better Life Index, for example, provides quantitative assessments in 11 areas of QoL, ranging from employment and income to safety. For Japan, results show low levels of satisfaction with regard to work stress, housing and sanitation, holidays, sense of health, and civic life and governance (Figure 3.2.5). In terms of values, this means that people see value in measures and policies that improve balance between work and personal life, and at the same time increase their sense of participation in government and society. This is relevant to the multi-AI city described in Chapter 5 of this report, which proposes living spheres that enhance well-being and reduce stress, and which can be realised through automated decision-making systems involving AI and human collaboration. In other words, the realisation of the multi-AI city is compatible to the desire of Japanese people to ameliorate their current complaints and worries, and has the potential to contribute to improved governance both in normal times and during emergencies.

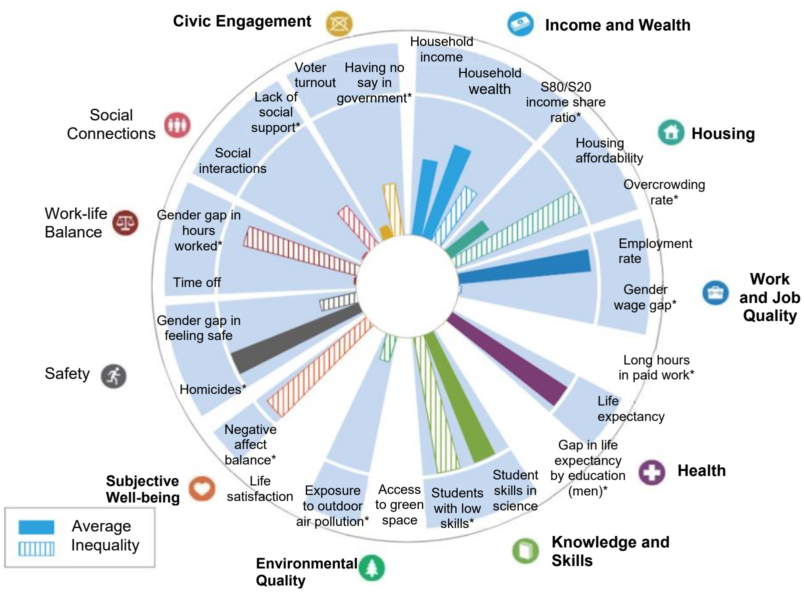

Figure 3.2.5 OECD Library How's Life? 2020: Measuring Well-being, [3.2.9)]

3.2.6. Technology to measure well-being in the age of AI

Methods for directly measuring comfort, one aspect of well-being, are being developed. Figure 3.2.6 shows an example of such a method, which uses AI image recognition technology to estimate walking comfort based on the difference in facial expressions from two videos: the upper one of a lakeside walkway and the lower one of a train station concourse during rush hour. The curve for the lake video (blue) in the middle is higher than the curve of the rush hour video (orange) at the bottom, meaning that we can predict that the walker on the lakeside walkway felt more comfortable when walking (vertical axis: comfort, horizontal axis: time).

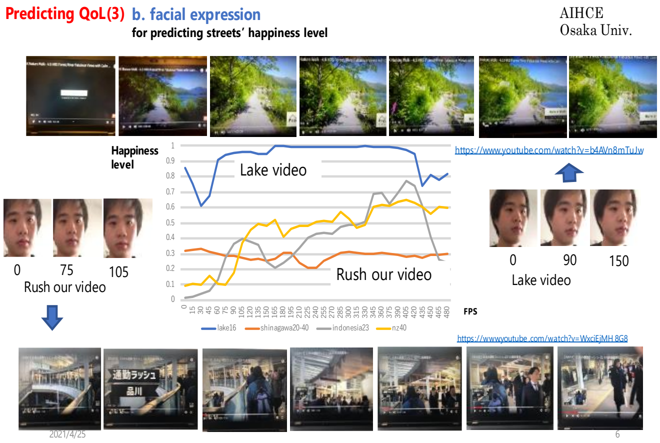

Figure 3.2.6 Estimating spatial comfort by facial expression

Figure 3.2.7 (left) shows a pedestrian's line of sight (target) while walking using eye tracking technology. Figure 3.2.7 (right) shows the count of people, motorbikes and cars in UAV (drone) images using AI image recognition technology. Combining these techniques with comfort analysis of facial expressions, it is possible to measure where and what we see during walking that makes us feel comfortable or uncomfortable.

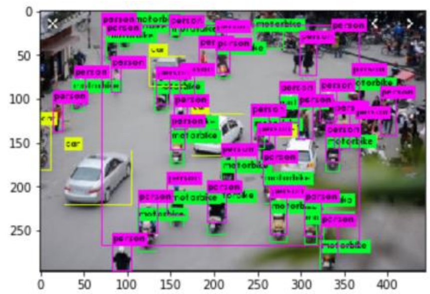

Figure 3.2.7 Pedestrian viewpoint analysis (left) and aerial object identification (right)

In addition, vital data from wearable devices and mobile applications can be used to measure body temperature, blood pressure, physical activity and metabolic rate with regards to personal health. By combining these health data with location data from smartphones and the comfort measurement technology described above, it is possible to monitor changes in people's well-being during different activities in their daily lives. In order to realise sustainable cities, particularly in the context of COVID 19, maintaining well-being while avoiding the risk of infection is essential. The Multi-AI system proposed in Chapter 3 of this report is based on the creation of an open platform to enable evidence-based scientific advice, at the core of which is the use of image recognition technology to measure well-being and visualise it in real time.

3.3. Redesigning scientific advisory systems to respond to the SDGs and the pandemic - the importance of the Science-Policy-Society Interface: from linear models to ecosystems

3.3.1. Redesigning scientific advisory systems driven by the COVID-19 pandemic - from linear models to ecosystems

Scientific advice has been defined as "the provision of expert advice by individual or groups of scientists (including engineers, physicians, and scientists in the humanities and social sciences) that enables governments to make sound policy and decision-making decisions on particular issues" [3.3.1)], but this interpretation is now coming under pressure to be redesigned. In response to the pandemic which began last year, scientific advisory systems established mainly in developed countries were generally dysfunctional. At present, various efforts are being made to overcome the COVID-19 pandemic, according to the political, economic, social and technological realities of each country. Based on this experience and lessons learned, case studies are being collected, analysed and discussed in depth at the United Nations, IIASA, OECD, ISC (International Council for Science and Technology), and International Network for Governmental Scientific Advice (INGSA), to redesign scientific advisory systems aimed at achieving the SDGs and preparing for future pandemics over the mid- and long-term [3.3.2)]. Japan needs to actively participate in these discussions.

3.3.2. The historical evolution of scientific advisory systems and the impacts of the SDGs and COVID-19 pandemic

As a premise for discussion, we would like to briefly summarise the historical evolution of scientific advisory systems as follows.

It was in the 1970s that the theoretical study of scientific advice and the creation and implementation of systems began in earnest. Before that, scientific knowledge was simply used in a variety of policymaking activities because it could lead to better policies by providing neutral and accurate knowledge to be applied to the issues. In the 1970s, this simple arrangement began to fall apart as people began to question whether a clear division could be made between science and policy, and whether science could produce and provide neutral and objective knowledge. Around this time, the field of policy studies began to recognise that there were two main pillars to science and technology policy. These were "policy for science" and "science for policy". This becomes an important framework when considering the objectives of scientific advice. In Japan, this framework was finally written into law with 2020's Basic Act on Science, Technology and Innovation, which is discussed below. The following is an overview of the evolution of the scientific advisory system since the 1970s, divided into three periods.

3.3.2.1. 1970s to 2000: growing recognition of importance and accumulation of examples

During this period, as environmental pollution and pharmaceuticals and food safety became social problems (e.g. "Silent Spring", Minamata disease), systems for risk assessment and risk management began to develop. In the 1980s, global issues such as global warming and infectious diseases became a major focus in international politics. As evidence-based policymaking was increasingly emphasised, risk assessment and risk management systems were developed in Japan, including the Food Safety Commission, the Pharmaceuticals and Medical Devices Agency, and the Earthquake Research Commission.

In 1999, the World Conference on Science, co-organised by UNESCO and the International Council of Scientific Unions (ICSU), adopted the "Declaration on Science and the Use of Scientific Knowledge (Budapest Declaration)". In addition to the traditional "science for knowledge", the global scientific community agreed on "science in society and science for society" as the responsibility of science in the 21st century, confirming the importance of scientific advice. A World Science Forum is still held every two years to review this declaration.

3.3.2.2. 2000 to 2010s: growing institutionalisation of scientific advisory systems and the expansion of international networks

Entering the 21st century, many governments and academies developed principles and methods for scientific advice, as well as other systems such as codes of conduct (see reference). International networks of scientific advisers and organisations have also expanded rapidly.

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(Reference) Universal principles of scientific advice (note: these principles now need to be reviewed) Separation of risk assessment and risk management. Ensuring the quality of scientific knowledge at international standards. Provision of objective evidence. Ensuring independence and transparency on the part of science. Appropriate selection of experts and expert bodies and avoidance of conflicts of interest. Openness of the process. Ensuring the quality and quantity of data. Communication with society. Political decisions should be influenced not only by scientific evidence, but also social, economic and political factors. Understanding of the differences in speed and of both sides and continuous dialogue and trust building.

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Internationally, the Foreign Ministries Science and Technology Advice Network (FMSTAN) and the International Network for Government Science Advice (INGSA) were established; INGSA has held biennial conferences since its launch in 2014 (Auckland, Brussels, Tokyo (2018) and Montreal (2021)) and is the international leader in the review of scientific advisory systems and their dissemination and implementation in countries around the world. In 2018, ICSU (International Council of Scientific Unions, 1931) and ISSC (International Social Science Council, 1952) merged to form the International Science Council (ISC). The ISC aims to promote cross-disciplinary collaboration between the natural and social sciences to ensure the foundation and quality of science in the fast-changing 21st century and to address a range of challenges facing society. This marked a turning point in the 300-year history of modern science, which had seen increasing fragmentation of disciplines and separation of the humanities and sciences. During this period, the OECD compiled reports that formed the basis of current scientific advisory systems, including "Scientific Advice for Policy Making" (2015) [3.3.3)] and "Scientific Advice During Crises" (2018). OECD is actively working on projects related to mobilisation of science during crises and research integrity.

In the aftermath of the Tohoku earthquake, tsunami and Fukushima nuclear accident, distrust of science and technology grew in Japan, and our country's system of scientific advisory was criticised internationally [3.3.4), 3.3.5)]. In response, the Nuclear Regulation Authority was established (2012) and the Science Council of Japan established a new section on "scientific advice" in its "Code of Conduct for Scientists" (2013). In 2015, the Science and Technology Advisor to the Minister for Foreign Affairs and the Advisory Board for the Promotion of Science and Technology Diplomacy were established, becoming key members of the global community on scientific advice and science and technology diplomacy.

3.3.2.3. 2010s to present: SDGs commanding changes in the STI system

In the 2010s, as seen in the UN resolution that adopted the SDGs (2015), socio-economic, as well as science and technology, goals were greatly expanded to encompass not only economic value, but also public and social value such as quality of life, environment, etc. Accordingly, the science and technology policies of countries expanded to become science, technology and innovation policies, shifting to promoting social change. The SDGs have commanded major changes not only in the values aimed for and methods of science and technology, but also in the scientific advisory systems. The COVID-19 pandemic instantaneously accelerated this pace of change. In terms of technology, digital technologies such as AI and big data are expected to support these changes.

In 2020, Japan extensively revised the Basic Act on Science and Technology. The major differences from the previous law (1995) are that the law now includes “innovation” as an objective in addition to “improvement of science and technology”, and that promotion of the humanities and social sciences is clearly stated. As mentioned earlier, the two pillars of science and technology policy, “policy for science” and “science for policy”, which were proposed in the field of policy research in the 1970s, have for the first time been legally defined in Japanese law. The major objectives of the Science, Technology and Innovation Basic Plan (2021-2025), formulated on the basis of this law, include social change, well-being and people’s happiness, values that had never been pursued by conventional science and technology policy. These domestic and international trends call for reform of the governance of science and technology, in particular expansion of the objectives, methods and scope of scientific advice, as well as new methods and knowledge and capacity building of the organisations and people involved.

3.3.2.4. 2020 onwards: The convergence of two international trends in scientific advice - a paradigm shift

The 2015 and 2019 editions of the Global Sustainable Development Report, the quadrennial report released by the UN Scientific Advisory Board that is highly influential in the theory and practice of STI for SDGs activities worldwide, when read in detail from the perspective of scientific advice, reveal that the term “science-policy interface”, one of the foundational concepts of the reports, was changed to “science-policy-society interface” [3.3.6)]. In the 2015 edition, as exhibited in the definition of scientific advice mentioned above, the emphasis is undeniably on providing expert knowledge from the science and technology side to the policymaking side—a linear model. However, following discussion on STI for SDGs roadmaps and the sharing of practical examples over a four-year period, the 2019 edition deliberately added “society”, indicating a deeper recognition that three-way collaboration and the formation of an ecosystem are essential.

The advisory systems for scientific advice and their methods and standards, established since the 1980s led by the providers of scientific knowledge, such as ISC (former ICUS), INGSA, and scientific academies in developed countries, remain active today. On the other hand, since the UN resolution on the SDGs, the UN Scientific Advisory Board, STI Forum for SDGs, and IIASA have played a central role in focusing attention and analysis on the importance of the structure and function of scientific advisory systems from the perspective of addressing social problems. As these two trends converge, discussion is progressing on a paradigm shift and redesign for scientific advisory systems. Some recent developments are described below.

With a view to achieving the SDGs and responding to future pandemics, the UN and IIASA emphasise the diversity of the science-policy-society interface across countries and regions, the development and implementation of roadmaps for sustainable interaction of the three sectors to achieve the goals, and partnerships at multi-levels (global, regional, national, local) that take local values and culture into consideration [3.3.6), 3.3.7)]. In its flagship report "STI Outlook 2021", published in February this year, the OECD, under the broad framework of the importance of establishing science and technology governance to respond to challenges such as COVID-19 and the SDGs [3.3.8)], stressed the need to strengthen scientific advisory systems, to formulate mission-oriented policies [3.3.9)], and to use digital technologies, transdisciplinary research (TDR) [3.3.10)] and foresight strategies as the basis for such governance. Meanwhile, the 4th INGSA Conference will be held in Montreal this autumn under the theme “Build Back Wiser: Knowledge, Policy, and Publics in Dialogue”. In the light of lessons learned from the COVID-19 pandemic, the conference will bring together a diverse range of organisations and people to discuss the structural transformation and redesign of scientific advisory systems, bringing together national and regional experiences, case studies, and proposals for reform with the aim of consolidating the paradigm shift trend. One author of this report is a member of the programme committee, whose prospectus states: “There is no single path for the future of scientific advice. There must be multiple pathways to respond to the diverse contexts and dramatic changes in the relationship between science, policy and civil society” [3.3.11)].

3.3.3. Direction of the redesign of scientific advisory systems to respond to the SDGs and the pandemic

This section will summarise discussion so far into five points and describe the direction of the redesign of scientific advisory systems. We hope that the Engineering Academy of Japan, in collaboration with related organisations both in Japan and overseas, can move forward to create and implement a scientific advisory system for a new era.

3.3.3.1. Building a scientific advisory ecosystem for a new era

The COVID-19 pandemic has exposed the weaknesses of the traditional linear model of scientific advice that bridges politics and science. Utilising lessons learned, we must now create an ecosystem in which diverse stakeholders in society participate in the advisory process. An understanding of the science-policy-society interface is important to do so [3.3.2)]. Approaches for society are often difficult. The scope of societies, their political economies and their cultures are diverse, and national and local authorities must carefully consider feasible interfaces between the three areas according to their respective characteristics and contexts. In addition, the importance of involving citizens in the scientific advisory process has long been pointed out, but has been put off due to difficulties in designing a process [3.3.3)]. These challenges now need to be addressed head on in our responses to the SDGs and pandemics. Figure 3.3.1 shows IIASA's proposal for a local-national-global network for social change using digital technologies such as big data and AI [3.3.7)]. Introducing these digital technologies into the citizen engagement process must be considered.

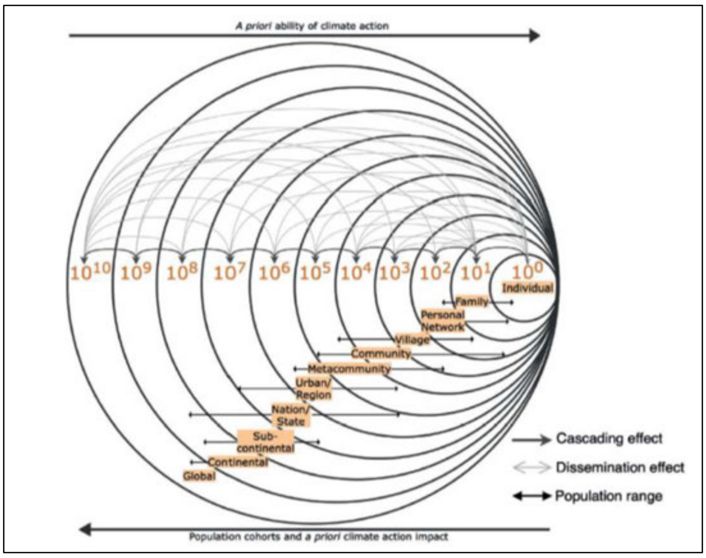

Figure 3.3.1 A networked governance approach for societal transformation[3.3.7)]

3.3.3.2. Setting the agenda and developing a roadmap for scientific advice

As the definition, scope and objectives of scientific advice broaden and become more diverse with recent emphasis on inclusion and resilience, the agenda-setting capacity and implementation processes of advisory bodies are key. In addition to emergency responses, countries and sectors need to work together to develop roadmaps and actionable mid- and long-term strategies for recovery from crises and preparation for future pandemics and disasters [3.3.12)]. In the age of social media, the humanities and social sciences have a key role to play in dialogue among stakeholders with diverse values, trust-building, trade-off analysis of conflicting values, and consensus-building. The diagram below shows the steps in the development, implementation and evaluation of the roadmap developed by the UN IATT, in which the function of scientific advice needs to be explicitly incorporated.

Figure 3.3.2 Six Steps and Core Inputs for Roadmaps, by UN IATT[3.3.12)]

3.3.3.3. Expansion of frameworks for scientific advice and incorporation of new technologies

Scientific advice began within the framework of risk assessment, risk management and risk communication, but this framework has now expanded and diversified at both national and local scales to encompass global issues and initiatives such as smart cities. As seen in the "Local SDGs" efforts, accumulating practical examples and experiences in addressing social issues and scientific advice in local areas with differing conditions, and conducting meta-analysis of these are essential. To this end, it is important to incorporate new methods into the advice process, such as big data, AI and other digital technologies, sensor technologies for social measurement, and foresight approaches. Moreover, transdisciplinary research (integration and collaboration on the knowledge and experience of various disciplines and stakeholders), including the humanities and social sciences, is essential. [3.3.13)]

3.3.3.4. Ensuring the development of human resources for scientific advice and the science-policy-society interface

Securing and developing human resources with the ability and determination to respond to diverse and dynamic scientific advisory activities has become a major global challenge. The UN and ISC have jointly proposed four categories of such personnel [3.3.2)]. They are the "generators", "synthesisers", "brokers" and "communicators" of scientific knowledge. The EU has similarly emphasised the development of a "new type of scientists for policy" [3.3.13)]. To realise these aims, it is essential to enhance the skills and capacities of individual scientists, as well as to establish incentives and career paths, which will lead to the overall reform of the science and technology system.

In addition to the individual's role in scientific advice, organisational capacity building or collective knowledge is also important. The Engineering Academy of Japan is expected to function effectively as a "boundary organisation" [3.3.2)] for scientific advice, with its capacity to easily cross disciplinary, organisational, gender, generational and national boundaries (2).

3.3.3.5. Japan's presence in international collaboration and competition in scientific advice

Recent years have seen a rapid increase in global issues, such as climate change, SDGs, the COVID-19 pandemic and large-scale disasters, and it is essential to establish an international system for coordination that transcends the boundaries of governmental, industrial, academic, and civil sectors. As shown in the figure below, international networks and partnerships in each sector related to the SDGs are rapidly expanding and taking shape, and considerable efforts are needed to maintain and increase Japan's presence (see figure below) [3.3.14)]. Moreover, rebuilding of countries' scientific advisory systems that were crippled by the pandemic involves an element of competition. Japan must work to strengthen its scientific advisory system as soon as possible taking into account lessons learned.

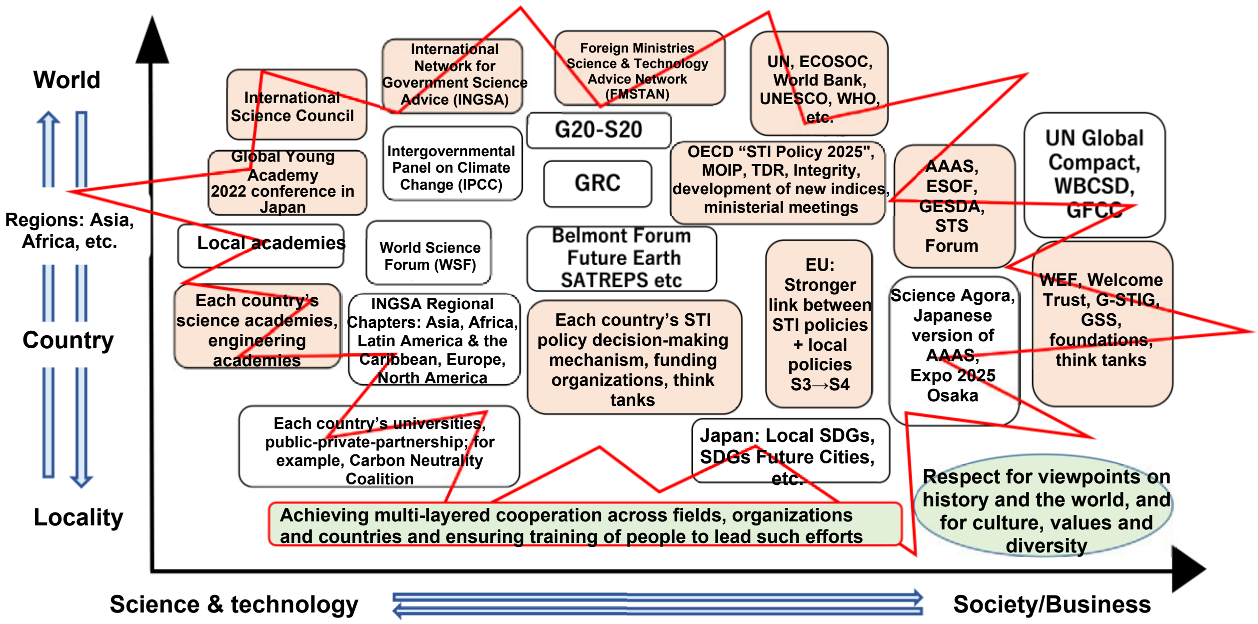

Figure 3.3.3 Deepening partnerships between scientific advisory organizations in response to the SDGs and pandemics [3.3.14)]

3.4. The relationship of legislative bodies to scientific advice, with European academies an indispensable presence

3.4.1. Interesting points on the relationship between academies and legislatures in Europe

When considering scientific advice, it is important not only to advise government, but also to have a relationship with parliament. The political systems in Europe have a long history, and there are many differences between countries, with revolutions and surviving monarchies. There is also a great deal of mutual influence, and as a result there is some commonality in the way that the people themselves think about the political system.

In terms of the relationship between science and politics, the creation of the Office of Technology Assessment (OTA) in the United States had a major impact on Europe. Even after the abolition of OTA, sharing of scientific and technological information with politics and discussion of science and technology in political affairs have developed in various ways in many European countries, with technology assessment (TA) at the core.

In 2017, the Engineering Academy of Japan (EAJ) was commissioned by the National Diet Library to conduct a research study entitled "Policymaking and Science Literacy". As a part of this study, we conducted a survey on the relationship between parliaments and scientific academies. One of the interesting findings was that in the 1950s, the Royal Swedish Academy of Engineering Sciences and the Swedish Parliament jointly established an organisation called the "the Swedish Society of Parliamentarians & Scientists" (Rifo) to freely discuss policy based on science. RIFO frequently organises seminars and tours for parliamentarians and scientists to promote interaction and mutual understanding between them. RIFO has about 500 members, of which about 100 are members of parliament (as of October 2017), which is nearly a third of the total 351 MPs. The Royal Academy of Engineering Sciences organises a major event once a year, which is said to be the largest gathering of MPs in Sweden outside the parliament hall. This regular interaction between MPs and the scientific academy is said to have precipitated Sweden's first agreement on a long-term energy strategy between the eight ruling and opposition parties in 2016, after which the Minister for Energy expressly praised the practice. This is an example of the importance of providing information to parliament, which plays a key role in determining the direction of policy, and of parliament making decisions on the basis of appropriate information, in the operation of government. Recognising the importance of building relationships between legislatures and academies, the EAJ conducted further research into the situation in a number of European countries in 2019. The case of the UK is illustrated in the following diagram.

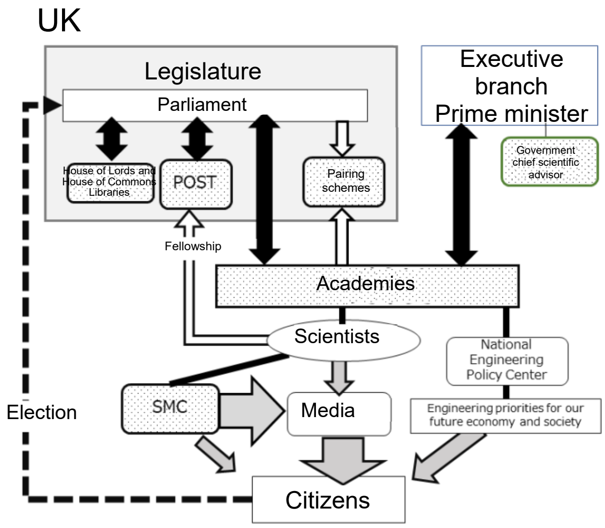

Figure 3.4.1 Flow of scientific advice to Parliament in the UK

The country surveys revealed a number of interesting points.

a) Parliaments and scientists in European countries have a close relationship, not only relationships with individual scientists, but also between parliaments and academies as organisations of scientists.
b) The role of the academy is to propose policy options, which the parliament utilises to debate and decide on policy.
c) Many academies grew out of spontaneous gatherings of scientists that were later approved by kings and other authorities. Accordingly, they are not institutions of government, but independent entities, and it is unlikely that parliaments or

governments would seek to influence the activities of the academies. Furthermore, scientists have played an indispensable role in shaping Western society, and academies are considered to have a respected role in society.

d) To support their activities, the independent academies are provided with funds from parliaments and governments, who then receive recommendations.

e) Some activities to create contact between scientists and parliamentarians are noteworthy. For example, in the United States, the American Association for the Advancement of Science (AAAS) has led the Science and Technology Policy Fellowships programme since 1973, in which every year 30 young scientists spend one year in the Congressional Research Service or under the supervision of a member of Congress, gaining first-hand experience, including drafting legislation and handling petitions. The programme has been ongoing for nearly 50 years, so that in the United States more than 1,000 people on both sides, science and politics, have been trained in two languages (the language of science and the language of politics). Pairing schemes also operate in the UK and the EU, with activities aimed at similar objectives. Yet, Japanese scientists and politicians remain unaware that these steady efforts to connect scientists and politicians have been taking place for many years.

The activities of parliaments and academies in Europe and the United States in sharing scientific and technological information with parliaments and developing human resources for this purpose is depicted in the following diagram.

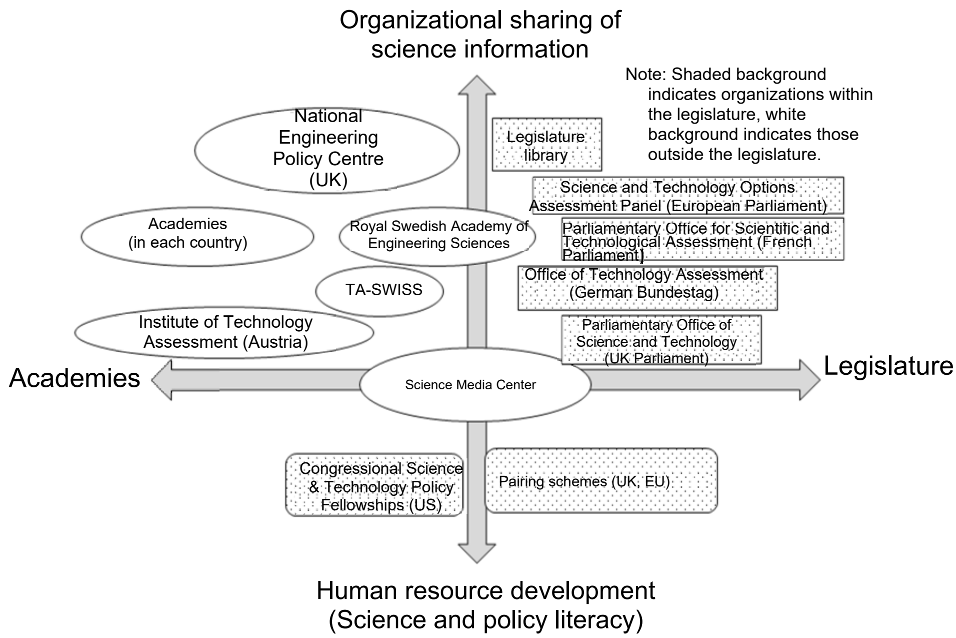

Figure 3.4.2 Provision of scientific information to parliament and human resource development (Europe, USA)

The top half represents science and technology information sharing activities, with examples of organisations carrying out initiatives on the parliamentary side on the right and academy-led initiatives on the left. The bottom half shows examples of activities to improve the policy and political literacy of researchers. Parliamentary libraries are on the right, near the centre line at the top. In the case of Japan, while the National Diet Library fits into this category, there are no other organisations conducting activities that could be represented in this diagram.

3.4.2. The situation in Japan

So what is the situation in Japan? As shown in the diagram below, there is no mechanism in place for academia as an organisational body to advise the legislature.

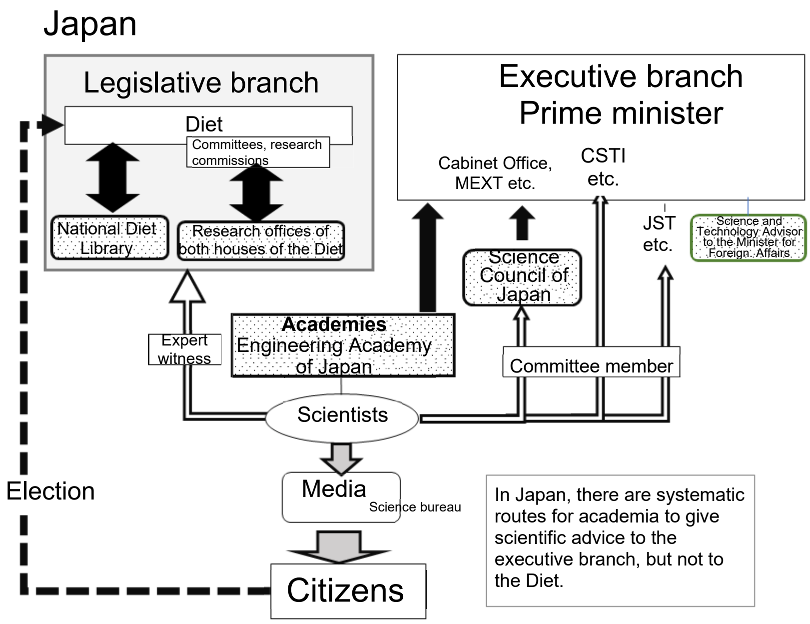

Figure 3.4.3 Flow of parliamentary scientific advice in Japan

The Science Council of Japan, which has been in the news a lot recently, has its mandate defined by the Act on Science Council of Japan, making it legally obliged to submit advice and recommendations to the government. From its outset, it was not assumed to have any relationship with the legislature. The Japan Academy, regarded as the Japanese scientific academy, does not carry out such activities, so in effect, there is no contact point between the legislature and an academy as an organisational body of scientists. Accordingly, it is not possible in Japan for the legislature to debate and make optimal policy decisions utilising multiple options proposed by a scientific academy. As a result, the legislature in our country debates on the basis of information provided by the government. Interestingly, this is rarely perceived as a problem. Yet, this also creates a problem for the scientific community as there is little opportunity to train scientists who can explain what the people are calling for and what can be achieved as policy based on scientific evidence.

These deficiencies came to the fore in Japan in 2020. In early spring, when measures based on the views of infectious disease experts were put into effect in response to COVID-19, there was a debate on whether experts should be allowed to decide policy, exposing the lack of a firm division of roles between experts and policymakers. Later, the opinions of experts in fields other than infectious diseases, such as economics, began to emerge. At the time, political scientist and University of Tokyo Professor Izuru Makihara, sounded an alarm, “When the opinions of both infectious disease experts and other experts emerge, politics waits for and takes advantage of the opinions that are most convenient. This causes frustration on the part of the public at the lack of transparency in the policymaking process, which in turn leads to dissatisfaction and criticism of both experts and government. When this situation worsens, it can lead to the rise of populism.” The refusal to appoint members of the Science Council of Japan in the autumn may have seemed sudden, but both of these problems may be partly due to the absence of a regular channel of communication between scientists and the legislature.

3.4.3. Necessary measures

Not necessarily related to the current situation we face, the Engineering Academy of Japan has been looking into the issue of the relationship between legislature and academia since 2017, as mentioned at the beginning of this report. Based on the results of our research, we decided to hold meetings to promote dialogue between members of EAJ and Diet members. The first meeting was held in December 2020 on the topic, “The state of science, technology and innovation in post-COVID times”. Both Diet members and members of EAJ reported that they found taking the time to exchange opinions on a single topic to be meaningful. Accordingly, a second meeting was held in March 2021 on the topic of “Co-creation with young researchers who will be responsible for Japan’s future”, and a third meeting was held in June on the topic of "Co-creation towards an inclusive STEM education and research environment”. The meetings attracted a great deal of interest from the media. More experience needs to be accumulated over many more meetings, and we are not sure exactly how this project will develop in the future, but we will continue to aim to build the relationship between the legislature and academia, which is the missing link in Japan's policymaking system. In order to improve the governance of policymaking in Japan, it is essential not only to point out problems, but also to solve them through action, and the Engineering Academy of Japan will make every effort to do so.

3.5. Issues concerning the relationship between science and society in the era of COVID-19

3.5.1. COVID-19 as a major event commanding a transformation in the relationship between science and society

The novel coronavirus that began spreading in China in late 2019, igniting a major global crisis. Named COVID-19, the virus has yet to be adequately contained 18 months later in mid-2021, due to the emergence of various variants. The impacts of COVID-19 on people and societies around the world has been, as predicted, great.

COVID-19 is urgent issue for people and societies because it has no borders, is faced by all people equally, and its transmission and spread is closely related to lifestyle. In addition, it commands a balance between three essential elements of modern societies (the search for a compromise in a trilemma): the realisation of public health by controlling the spread of the virus, the realisation of economic activities involving physical contact between people, and the guarantee of human rights in society related to freedom of action and protection of privacy. This balance must also respond and flexibly adapt according to time and place.

On the other hand, although coronaviruses have been known for some time, COVID-19 involves many unknowns and differs from previous coronaviruses in many ways, being highly infectious and causing cytokine release syndrome (a severe form of cytokine storm), which leads to disease in the lungs and other organs. Under these circumstances, the academic and scientific communities were confronted with a major challenge that demanded appropriate action both implicitly and explicitly.

The COVID-19 pandemic is an event that continues to have major impacts on people and society. Because it involves many unknowns, science can play a major role in resolving it, and the multifaceted relationship between science and society also comes into play in how it is handled. In this regard, it serves as an example of the governance of science, technology and innovation looking ahead to 2050, and can be viewed as a valuable experience for both science and society. Next, we will consider issues that have emerged regarding the relationship between academia, science and society, with particular regard to policymaking, referring to examples from both Japan and overseas.

3.5.2. Scientific, social and political responses to COVID-19

In the wake of the COVID-19 crisis, the relationship between politics and science has evolved in a number of ways, both nationally and internationally, and has been subject to various recognitions and criticisms. We will look at some examples of how science provides scientific advice for policy decisions, and how politics responds to that advice.

3.5.2.1. The UK Example

The UK has continued to develop its system for scientific advice to government based on experience. In the 1990s, following criticism of the scientific community's response to bovine spongiform encephalopathy (BSE), commonly known as mad cow disease, in which it was claimed that there was no oral transmission of the disease, there was a growing debate about the role of scientists in policy among various stakeholders in the scientific community, including the Government Office for Science led by the Chief Scientific Adviser, and the Royal Society. In 2010, a guidance entitled, "Principles of scientific advice to government" was compiled, establishing guidelines for the roles and responsibilities of scientific advice, independence from politics, transparency and disclosure. Subsequently, the Science Advisory Group for Emergencies (SAGE) was set up under the Chief Scientific Adviser, to bring together scientific advisers from various ministries in times of crisis. Since 2009, SAGE has been effective in responding to infectious diseases such as Ebola and influenza, volcanic ash from Iceland, and flooding. In 2011, following the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant, SAGE was the first to release estimates on the impacts of radiation in the Kanto region based on publicly available information on nuclear fuel and weather forecasts, and to advise British citizens in and around Tokyo that there was no need to evacuate.

The UK's response to COVID-19 has been criticised by the Asahi Shimbun (7 August 2020) as "a response that followed the science but then lagged behind". Within SAGE, scientists apparently advised caution on stringent measures, and as a result relatively modest action was taking leading to some of the most serious devastation in Europe. The Prime Minister, Boris Johnson, has himself expressed regret at this. The UK's highly developed scientific advisory system did not produce the best results in the face of the COVID-19 crisis and its many unknowns. The minutes and documents compiled for each meeting of SAGE, chaired by Sir Patrick Vallance, the Prime Minister's Chief Scientific Adviser, are available on its website. These documents have become an important source information for verification of the UK's scientific advisory system, to learn from past challenging experiences and improve the system for the future, as called for by the Prime Minister.

The UK's cumulative number of infected people is around 4,450,000, with 128,000 deaths (12 May). The UK has been systematically vaccinating its population, with two lockdowns (three in England), and dealing with variants arising from the large scale outbreak. Having developed policy based on experience, the UK now expects to return to normal life in late 2021, with a view to achieving herd immunity through vaccinations.

Of course, the situation will continue to be unpredictable, for example, due to the impact of a variant from India, with which the UK has a close Commonwealth relationship. Nevertheless, the UK's efforts will undoubtedly serve as a substantial reference point for improving scientific advice and responding to potential future unknowns. The UK's COVID-19 measures will be reviewed by an independent panel in spring 2022, likely leading to further progress in establishing the relationship between science, society and policymaking.

3.5.2.2. The Sweden example

Sweden also opted not to adopt lockdowns of its cities, rather took more lenient measures such as social distancing. As a result, its death toll was one of the highest in Europe. Initially, it was said that the country's aim was to achieve herd immunity against COVID-19, but the Swedish government denied this. Stating that any response must not be a short-term fix, but would require a long-term approach that takes into account people's acceptance and social lives, the government claims to have made policy decisions that took into account the opinions of scientists and experts. The state epidemiologist leading the response, Dr. Anders Tegnell, frequently briefs the public. Although infections have been spreading since late 2021, experts and policymakers have been carefully explaining the challenges of the previous response and the changes in policy. As a result, public support for government policy does not appear to be significantly lowered.

This demonstrates the importance of repeated explanations by experts and policymakers over sufficient periods of time.

3.5.2.3. Examples from other countries

On the other hand, there are some leaders in the world who pay little heed to the advice of scientists and experts, or who view taking their advice as problematic. COVID-19 infections have been particularly rampant in countries whose leaders did not take the pandemic seriously.

One of the biggest challenges from the perspective of academia and science is scepticism of science. According to Australian environmental scientist Dana Nuccitelli, scepticism of science begins with “denial”, followed by “blame shifting”, “trivialisation”, “criticism of the cost of measures”, and then “pessimism that it is too late” (Asahi Shimbun). A typical example is scepticism about global warming, and the same phenomenon has occurred for COVID-19.

Scepticism of science in the US is a typical example. In its response to COVID-19, the Trump administration put an exceedingly limited emphasis on science. John Holdren, the Obama administration's Assistant to the President for Science and Technology, claims that while the previous administration understood how important science was to addressing the nation's challenges, the current administration has left expert positions empty and experts have remained silent so as not to offend the leadership. He also points to the relationship with division in society, as people are encouraged to accept the leader's claims as the truth rather than listen to the experts.

But while blind faith in scepticism is a problem, for its opposite, blind faith in science, the problem is that sceptical debate about science should not be renounced. Excessive trust in science is also a problem, and a certain amount of scepticism and debate in society is healthy and leads to the refinement of science. A healthy relationship between society and science is closely related to a mature democracy.

In the United States, Anthony Fauci, director of the National Institute of Allergy and Infectious Diseases, who was at the centre of the Trump administration's fight against infectious diseases and provided scientific advice and statements, was temporarily shunned by the administration for his criticism of its measures. However, when Joe Biden became president-elect after winning the election against Donald Trump, Fauci became Biden's chief medical adviser and became involved in the Biden administration's infectious disease measures. As a scientist, Fauci set the standard for scientific advisers by speaking and acting on scientific evidence and not deferring to policymakers. He is also to be commended for his courage in confronting the “anti-science” trend head-on, even in the face of anonymous threats and public criticism from the Trump administration.

3.5.2.4. The case in Japan

With regard to the Japanese government's response to COVID-19, the Cabinet Office set up the Novel Coronavirus Response Headquarters in January 2020 in cooperation with the Ministry of Health, Labour and Welfare and other ministries, to carry out infection control measures. An expert panel on the novel coronavirus, with more than 30 members, was also convened in February 2020. Most of the members of the expert panel were medical professionals and virologists, whose mission was to provide medical advice. Although the expert panel did its best to analyse the spread of infection and proposing concrete countermeasures, it was criticised for going beyond its advisory role to actually determine measures to be taken by the government. In June 2020, after six months of activity, the panel issued a press release explaining that it was concerned enough about the situation to propose measures, rather than just express views on the administration's proposals as originally requested. However, as the expert panel was not required to keep detailed minutes of its discussions, and politicians claimed that they had taken the view of experts into account in their political decisions, society viewed the experts as deciding everything.

Japan's experience in dealing with infectious diseases has led to a well-established bureaucratic system within the government, which may have prevented a flexible response to COVID-19, which has had a faster and greater impact than infectious diseases to date and involves more unknowns. In this light, the response of experts went beyond "expressing opinions" within this system, to expressing opinions on the need to change the status quo.

The biggest problem lies in the way policymakers handle scientific advice. In the case of COVID-19, politicians always explained that they had "taken the opinions of experts into account" in their political decisions. Yet they do not clearly state their reasons, nor adequately explain what advice they received from experts, which parts of the advice they adopted in their policy decisions, and which parts they did not. The press and media who attend politicians' press conferences rarely ask clear questions on this point, and even when they do, they do not receive clear answers. Many scientists have felt that politicians have used the experts as an excuse to make decisions that differ in their objectives from preventing the spread of the disease, as politicians must also consider stimulating the economy.

Emergency measures were put in place nationwide, or in certain areas, on three occasions as of mid-2021, but when the third round of measures was applied, many experts opposed the initial response plan that the government had asked for from a committee of experts (the Subcommittee on Basic Response Policy of the Expert Committee on Novel Influenza Countermeasures), and the government had to reissue the plan in line with the experts' opinions. As a result, measures were taken that were more effective in preventing the spread of infection, but challenges to the relationship between policymakers and experts became all the more apparent. Experts reportedly communicated with each other the day before the committee meeting to discuss what action was appropriate, but by all rights, discussions should have been recorded at the expert meeting. The question was raised as to whether the government perceived the role of the expert committee to be an endorsement of the government's draft plans. In May, Tetsuya Matsumoto, president of the Japanese Society of Chemotherapy, made the following statement. "We are now in the fourth wave of the pandemic, and the number of seriously ill patients has reached a record high, partly due to the effects of variants. The situation is becoming more serious with each successive outbreak. Some people still want to take a wait-and-see approach with an optimistic outlook, but the reality is that the declaration and lifting of the state of emergency is based on vague grounds that are difficult to understand. I would like to see more respect for the opinions of experts." This statement reveals the doubt in the government's response to the opinions of experts and the facts presented by academia and science.

In contrast to the UK, where there are clear principles guiding scientific advice on transparency, disclosure and accountability for policymaking, Japan’s meager guidelines include the Science Council of Japan’s revision of its Code of Conduct for Scientists in 2013, in which a chapter on “Science in Society” emphasises the importance of dialogue between scientists and society, and describes methods of scientific advice. This revision was made in response to the disparate responses of various scientists on the politics of the nuclear disaster that occurred immediately after the Great East Japan Earthquake in 2011. However, unlike in the UK, there are no provisions that set out the basics of dealing with scientific advice for the government, which is on the side of receiving scientific advice. For example, there are no provisions that establish how government should publicly explain the reasons for their policy decisions, or how evidence for decisions should be indicated, particularly where decisions are inconsistent with scientific advice. Scientific advice is only one basis on which policy decisions are made, and policymakers make decisions based on a wide range of possible considerations. Policymakers need to understand the limitations of science and clearly state the rationale for their decisions. They should take responsibility for their decisions, not rely on scientific advice to justify them.

3.5.3. Key issues in the relationship between science and society uncovered by COVID-19

COVID-19 and its many unknowns have revealed a number of issues in the relationship between science and society.

3.5.3.1. What society needs from science

What exactly do people and societies expect from science in the face of the unknown? Looking at COVID-19 and earlier examples, there are three main points. These are: the provision of information and science-based explanations on various situations; research and development to directly address mitigation and adaptation to various situations; and the provision of scientific evidence-based options for better policy decisions (scientific advice).

a) Provision of information and explanations on COVID-19

In response to an unknown situation, people and societies first seek information and knowledge on what is happening. On the other hand, in many cases, fears and worries about the situation contribute to the appearance of various speculations and false remarks. Historically, there have been false rumours after the Great Kanto Earthquake, the Rumor in Orleans, and more recently, urban legends. However, the recent development of social media has made the rapid spread of questionable information become a problem. In response, science needs to communicate accurate information based on systematic knowledge in an easy-to-understand and rapid manner if it is to stifle this false information in the way that witch hunts were quelled by modern science.

Confusion arose surrounding the nuclear accident that followed the Great East Japan Earthquake when various scientists explained the situation using limited knowledge from their own research fields. Even if the scientists thought they had explained the situation, the explanations did not reach the society. In comparison, for COVID-19, accurate information was delivered to the people and society in Japan. Of course, some false information was spread on social media networks, but it was countered by appropriate explanations from experts.

What is noteworthy in this context is that scientists from various fields, not limited to medicine and other scientific fields directly related to infectious diseases, used their knowledge and experience to examine various aspects of COVID-19 and express many helpful opinions. For example, for predictions on infections and scenarios for containment, in addition to medical scientist Hiroshi Nishiura’s proposal for an “80% reduction in contact”, mathematicians and physicists presented the results of studies into human behaviour and prediction of infection spread. These predictions were generally complementary. Use of the results of scientific research to date transformed lifestyles and society and influenced policy decisions.

While recent information and explanations provided by scientists to society are commendable, it is our hope that going forward efforts will be made to test the system and achieve the even more systematic, accurate and prudent provision of information.

b) Direct responses to COVID-19

Next, people and society expect science and scientists to indicate measures to mitigate and adapt to the crises they face. During a discussion on the Sustainable Development Goals (SDGs) at the United Nations in 2017, the Chair of the Forum on Science, Technology and Innovation, Kenya’s Ambassador to the United Nations, Macharia Kamau, said that society has invested significant resources in scientific activities in the past and that science was now expected to provide possible options today in the face of the common global problems outlined in the SDGs.

The main players in the response to COVID-19 are medical professionals. Those in medicine, particularly in the clinical field, are focused on the treatment and care of patients and the testing and study of infections. In non-clinical medicine, many researchers are working to develop drugs and vaccines for COVID-19. In foundational research fields such as virology, researchers are working to understand the properties of coronaviruses, such as infectivity and mechanisms of transmission. This will serve as basic knowledge to come up with better countermeasures.

Moreover, many scientists and researchers in scientific fields other than medicine are using their knowledge and capabilities to tackle COVID-19, including the examples of mathematical science and physics mentioned above. Professor Shinya Yamanaka of Kyoto University has also proposed using the PCR capabilities of university laboratories to expand opportunities for PCR testing. These initiatives, which initially utilised existing materials or allocated existing research funds, are highly appreciated by society.

It is important to note, however, that in Japan in particular, despite the efforts of various stakeholders, research into COVID-19 and the development of vaccines for it has lagged behind that of Western developed countries. This may be in part due to issues of policy, which will be discussed later.

c) Scientific advice on policies to address COVID-19

How has science responded to policy surrounding COVID-19?

As noted in the UK situation, the governments of many Western countries have scientific advisors, expert panels and advisory mechanisms in place to advise on policy. They also have prescribed basic matters related to advice, requirements for advisers and how policymakers should treat scientific advice. Examples include the UK guidelines and US federal regulations.

Coming back to Japan, our scientific advisory system remains underdeveloped. In 2010, a panel of experts issued a report on scientific advice within the Cabinet Office, but due to a change of administration, the report was never implemented. The only existing provisions on scientific advice are in the “Code of Conduct for Scientists” that was revised by the Science Council of Japan in 2013.

As already mentioned about the relationship between policymakers and experts on COVID-19 in Japan, policymakers did not clearly explain which parts of the policy were based on the opinions of scientific experts and which parts were based on different points of view. In some cases people questioned whether experts were making all the decisions, and in others claimed that expert opinions were not sufficiently respected, showing how convoluted the relationship is. The section on “Scientific Advice to Policy Planners and Decision Makers” in the Science Council of Japan’s “Code of Conduct for Scientists” states:

> “When scientists offer scientific advice to persons who plan or decide on policy, they shall recognize that while scientific knowledge is something to be duly respected in the process of creating policy, it is not the only basis on which policy decisions are made. In the event that a policy decision is made that diverges from the advice of the scientific community, scientists shall request, as necessary, accountability to society from the policy planner and/or decision maker.”

This statement concerns only how scientists should behave, and does not prescribe the behaviour of policymakers. It is also unclear whether this Code of Conduct is widely shared throughout the scientific community.

In order to ensure that the relationship between science and policy facilitates meaningful scientific advice that leads to better policy, it is essential to have a set of rules that can be shared by the scientific community and policymakers.

3.5.3.2. Pursuit of governance that can respond to unknown challenges

When it comes to policymaking, how policymakers (or in short, politics) view their responsibilities is an important point, but the administrative system also presents a problem. For COVID-19, government was involved in infectious disease control, and it had experience with the H1N1 influenza. In this respect, the situation is unlike that of the nuclear accident, where the tacitly accepted safety myth was that no accident would occur. Provision of information and development of related research at least went more smoothly. However, three main problems arose with the administration.

a) Structure of administrative system and flexibility

Governments respond to challenges faced by society by establishing administrative systems. Strong administrative structures are essential for the effective implementation of a range of measures.

In terms of infection control, a robust system based on past experience was in place. However, this robustness may have made it difficult to cope with COVID-19, with its many unknown factors. Japan, which had established vaccines, testing systems and methods to deal with successive global influenza epidemics and had escaped the Ebola, SARS and MERS epidemics, was too busy maintaining its established administrative system to focus a sense of urgency or deal flexibly with a new situation.

While noting that there is a certain incompatibility between a steadfast response to existing infectious diseases and flexible responses to unknown infectious diseases, globalisation and the expansion of global interactions is predicted to pose greater risks, including new infectious diseases. Responses, however difficult, are required.

b) Proposing administrative reforms and monitoring their implementation

The infectious disease administration missed the opportunity to take advantage of the expert report of 2010, which followed the global pandemic of the H1N1 influenza virus in 2009, that did not cause serious damage in Japan. The report looked ahead to necessary preparations in the event of a similar situation in the future and included matters that have been recognised as problems in the response to COVID-19, such as a stronger system for testing for infectious diseases (e.g. crisis management, PCR), stronger border control measures, and a stronger system for vaccine development. In fact, not only were the report’s recommendations not heeded, but the system was weakened by staff cuts at the National Institute of Infectious Diseases and public health centres.

This is an unfortunate precedent. While the reasons that this report was not implemented should be examined, on the other hand, we must continue to expect the government to be proactive when it comes to well-founded proposals for reform. It is also essential that reforms based on proposals are monitored, including ongoing examination of their effectiveness.

c) Science, technology and innovation policy and a scientific community that supports the administration

Although not directly related to measures on infectious disease, the focus of research on trendy issues, which is the result of the tacit agreement between science and technology policy and the scientific community mentioned above, has resulted in a significant lack of ability to respond to unknown events. On the policy side, the emphasis on “choosing and focusing” research has undermined the range of science and influenced the decision-making of the scientific community, creating an atmosphere in which "trendy" research is valued. On the other hand, there are complaints from the scientific community that science and technology policy is overly biased towards "immediately useful" research. Yet, the scientific community has also pushed researchers, especially young researchers, toward "trendy" research, for example by placing excessive value on the citation of papers. In any case, as a result of the tacit agreement between policy direction and the inscrutable will of the scientific community, science has not developed to encompass a sufficient range, resulting in a lack of scientific capacity to deal with unknown events such as the current one. The scientific community should not merely criticise the government, but also make efforts to explain the significance, depth and potential of scientific research to society in an easy-to-understand manner, and to cultivate in scientists an awareness of the position of science in society. We should also make efforts to cultivate in scientists the meaning and perspective of science in society. The will and ideas of people and society will become more and more important for the betterment of government and policy in the future.

Finally, a significant part of scientific research, including in the field of medicine directed at COVID-19, stems from the voluntary actions of scientists, who allocate their resources, time and abilities to their research. Society should not merely thank them for these actions, but should always strive to understand and respect the significance and importance of high quality research across a wide range of fields and the high aspirations of scientists. Likewise, government should take financial measures to reward their efforts by covering the necessary costs.

3.5.3.3. Summary of governance issues seen in the COVID-19 response

COVID-19 has provided valuable opportunities and experience in the acceptance of diverse values, which will become increasingly important in the future, and the consideration of better governance based on this acceptance.

a) Shared awareness on multi-faceted challenges

In the beginning, the response to the spread of COVID-19 was concerned with the relationship between infection control and the economy (dilemma), then became a trilemma as people’s freedom of action also became a factor. The first point of building governance is to foster a shared awareness among the sciences, as well as people and society, on the multi-faceted nature of the issue, which is relevant to different sciences (e.g. infectious disease medicine and economics), and that solutions are best not based on one over another. Science, and especially engineering that addresses practical problems, has the potential to look at the issue from a bird's eye view.

b) Clarification of the scientific perspective

In order for people and society to understand situations and make judgments, and for policymakers to formulate better policies or more accurately indicate the basis of policy decisions, it is essential to accurately indicate the facts and interpretations on which decisions are based. This includes stating what is known and what is not known appropriately at a given point in time, as well as what assumptions are being made in interpretation. Here, the scientific point of view should first be presented with facts and scientific knowledge. Of course, it can be presumed that a final decision would be based on a variety of other grounds. In other words, there is no need to speculate that the scientific viewpoint will be incompatible with other opinions, much less to present only a part of the scientific viewpoint deemed to be in line with the most likely final decision.

It is the responsibility of policymakers to synthesise various views to make policy decisions, and science should recognise that it is inappropriate for science to serve in this role. If science attempts to do so, it would bear an undue responsibility to society for the results.

c) Establishing communication between science and society

Communication between science and society should be primarily focused on how to communicate the significance and nature of science to society.

This should include the inherent uncertainties and certainties of science, as well as the incomplete aspects of current science. It is imperative to indicate what is understood and possible in science at present, what is yet to be achieved, and the benefits and risks that science brings. Conventional science and technology communication developed from the notion of a top-down effort to “enlighten the ignorant”, and activities only touted the enjoyment and benefits of science. We need to clarify the possibilities and limitations of science, including what the intellectual activities of science can do for people and what scientists are aiming to do, and work harder to improve both society's view of science and science's view of society.

In doing so, it goes without saying that a broad perspective on society and high aspirations on the part of scientists are required.

d) Etiquette for scientific advice

It is important that scientists and policymakers share a common understanding of the meaning and handling of scientific advice if science, technology and innovation are to have a strong relationship with society and policy going forward. The UK's establishment of guidelines for scientific advice is an important reference point in this regard. Moreover, a mechanism for creating this shared understanding within society and the scientific community is required.

It is also essential to include a record of the process by which scientific advice is formed, i.e. what facts and data are used and what arguments were made, to ensure that it can be verified later and experience carried forward into the future.

e) Reconfirmation of the main points of science, technology and innovation policy

Science, technology and innovation is expected to play an increasingly important role in the transformation and development of society. At the moment, however, no one can foresee the future. Accordingly, even if individual researchers or research groups are able to narrow down the topics to work on, it is risky for institutions and governments to at some point focus resources on a few options looking to the future. Naturally, society's resources are finite, and their effective allocation is required, especially for public institutions funded by taxes. Moreover, policy that lacks any "choosing and focusing" at all not only makes policy intentions unclear, but also significantly undermines the tone of the research field.

Nevertheless, if we are to seek optimal solutions in the future based on the existence of diverse values in society, excessive "choosing and focusing" would deny diversity and squash possibilities. The scientific community should not simply seek a balance between “choosing and focusing” and maintaining diversity. Rather, it should avoid excessive "choosing and focusing" while indicating the role that diversity has to play in future society and focusing wisdom on bringing about science, technology and innovation policy that is most likely to lead to diverse possibilities in the future.

f) Suggestions for administrative flexibility

As a part of scientific advice, the scientific community should be proactive in describing the mechanisms of science, technology and innovation if it is to play an even greater role in society. Government organisations are by their nature skilled at steadily implementing what has already been decided, so flexible responses are difficult. With this in mind, co-created proposals are ideal.

It is also important for the scientific community to continuously verify the implementation and subsequent effects of specific proposals.

3.6. The ideal future direction of scientific advice and the technology roadmap

In order for science and technology to accurately respond to the problems facing human society in the future, those involved in science and technology must systematically promote policy, research and development, and concrete measures based on facts and data related to said problems, while including the various people and ideas that make up society. In other words, we must try to create a roadmap by listing a wide range of actions that the Engineering Academy of Japan can take to collect and present visualised evidence such as facts and data, build societies that tolerate diverse values, and realise systematic governance based on such evidence.

1. Development of tolerance for diverse values, including responses to global warming and other global issues: Outreach to society and participation in international activities

    a) Spread knowledge in society on the significance of the future aimed for by the SDGs
    Opportunities for public debate at symposiums and dissemination via the web

    b) Activities to realise SDGs and evaluation of processes aimed at achieving them
    Continued deliberations by EAJ members
    Participation in international activities by EAJ and its individual members

2. Fostering a culture of governance
    a) Society and people: Acceptance of the significance of science in co-creation and discovery of diverse opinions in society
    Shared recognition of the multi-faceted nature of issues, need for clarification of scientific perspectives (science that provides evidence), development of communication between science and society

    b) Policymakers: Interaction with those involved in receipt of scientific advice and policymaking, such as politicians and bureaucrats; calls for policy and requests to the government

c) Scientific community: Interaction with EAJ on acceptance of diversity in society and understanding of policy (in cooperation with the Science Council of Japan and science-related non-profit organisations)

3. Systematisation of governance
   a) Develop draft guidelines on governance, especially on the various standpoints, relationships, and responsibilities of the scientists and engineers who give scientific advice and the policymakers who receive it, and encourage the government to enact them.

   b) Verify the scale of the groups subject to governance and the effectiveness of governance (for various policies)

   c) With regard to governance, enhancement of methodologies, especially for scientific advice, and capacity building of those involved

4. Demonstration of science and technology that contributes to assessing the effectiveness of governance
   a) Trial of methods for evaluating the effectiveness of governance through visualisation of evidence and tolerance of diversity.
   Example: An attempt to use AI to engineer a way to measure people's well-being, one of the goals of scientific and technological innovation.

The future vision for the ideal relationship between society, policymaking and science that this draft recommendation puts forth is as follows.

Science and technology hold great potential to solve various societal problems and society has high expectations for them. Yet, when considering any future constructive relationship between society and science and technology, it is important for both society and the scientific community to share the facts about science and technology on three points. First, science has its own inherent uncertainties, and the understanding of nature by science and technology involves probability. Second, current science and technology is still in the process of development, and there are limits to our current understanding. Finally, interpretation may vary from one scientist to another, even based on the same facts and data. If these understandings are shared, expectations for science and technology will not be excessive, and excessive reactions to and fear of published research results will be curbed. Likewise, scientists and engineers will be able to solemnly go about their research, creating an environment in which policymakers make accurate and rational decisions.

The scientific community aims to be a community of scientists and engineers who view science as part of society and who tolerate and understand diverse values. Moreover, it conveys to society the significance of science as a broad and profound human intellectual activity, and based on ongoing research, provides knowledge and information, including explanations and predictions, on various issues facing society, including global-scale issues. Likewise, it offers options for possible scientific and technological measures, and supports better policymaking by providing evidence to be used in decision making on policy.

The aim of the scientific community is to create a society in which people have tolerance for diverse values and utilise intellect as well as emotion to make decisions on various issues supported by the knowledge and information provided by science.

While recognising the diverse values held by people and societies, policymakers should fully respect evidence provided by the scientific community, as well as other grounds, and take personal responsibility for making decisions and clearly explaining the process and rationale for these decisions to the people, society, and the scientific community.

Creating such relationships will strengthen mutual understanding and trust between people, society, policymakers, and the scientific community, and will enable the advancement of a knowledge-based society that can flexibly respond to new events that the world will face in the future. However, the lack of any one of these elements could lead to the estrangement of science from society, a descent into populism, or political stagnation.

Such a knowledge-based society will be one that allows for a variety of challenges and actions to respond to new situations, and supports people and groups that defy conventions. Such efforts, including failures, could also serve as an important reference for developing countries that aim to develop based on scientific and technological innovations.

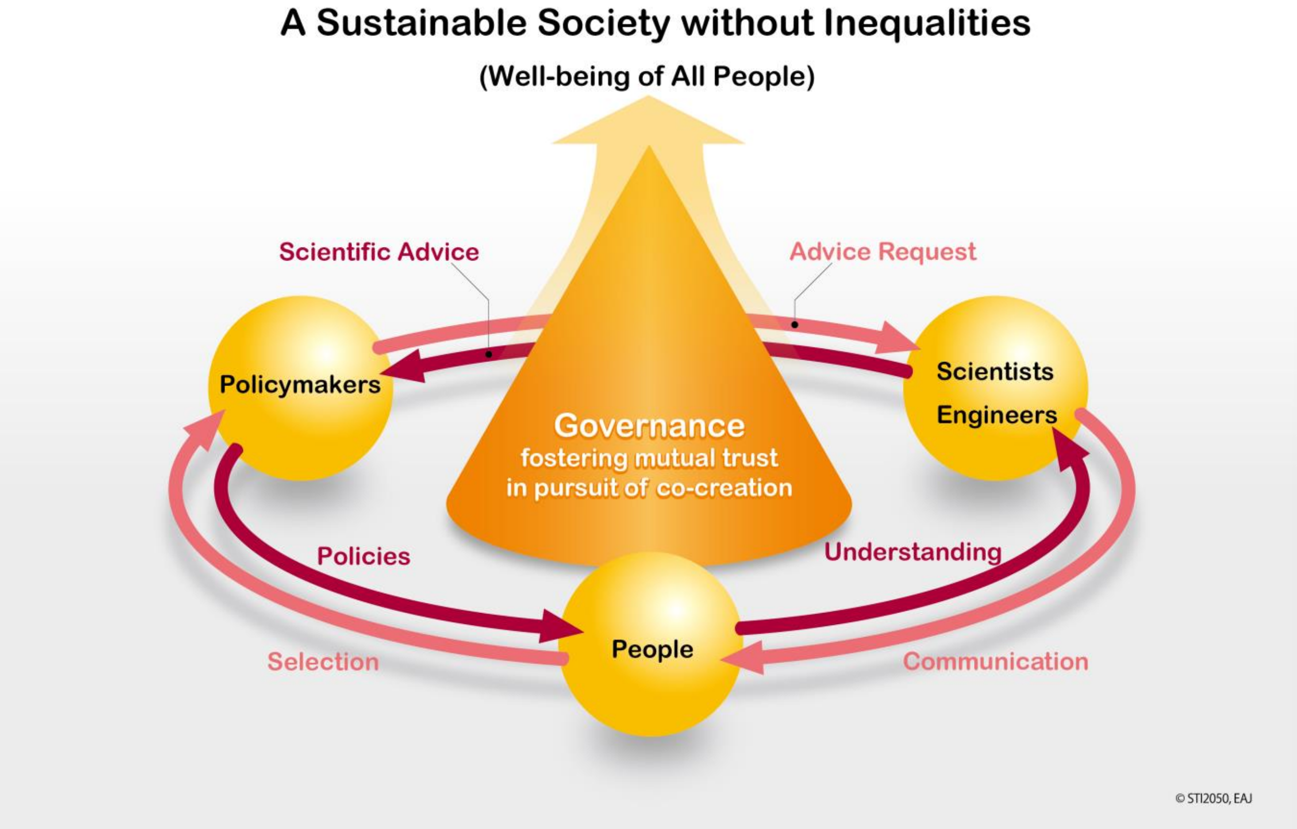

Figure 3.6.1 Vision of expected governance

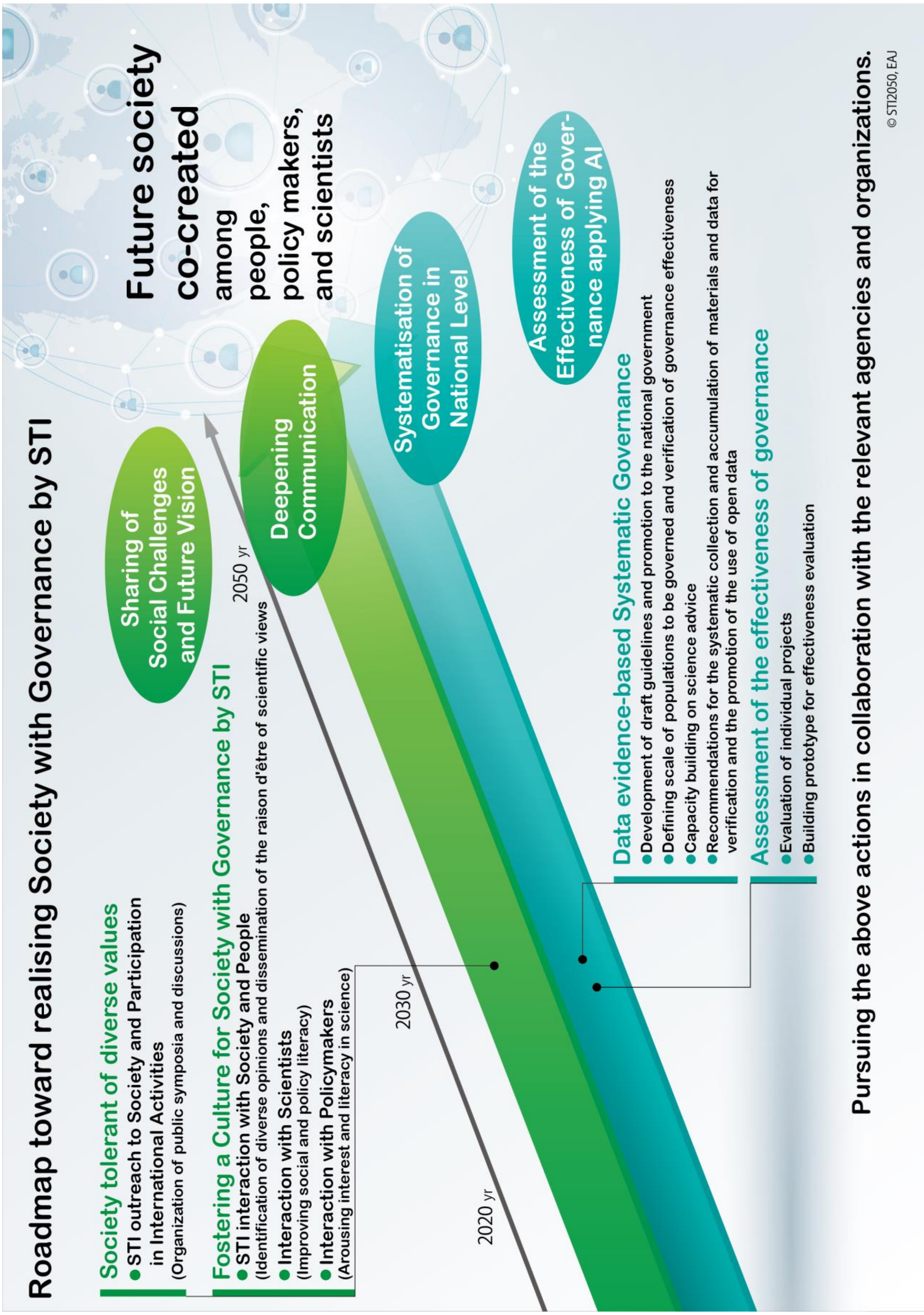

Figure 3.6.2 Roadmap toward realizing the governance by STI

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4. Global Food, Energy, and Water Nexus in 2050: With a focus on energy

In both developed and developing and emerging countries, achieving sufficiency in energy, water and food for people while taking into consideration the balance between sustainability, the global environment and the economy, namely pursuing the global "energy-food-water nexus" toward 2050, is an extremely major challenge for the current generation.

Looking at these three elements individually, first of all, energy requires massive infrastructure to build a supply network. Also, on the demand side, it is not always easy to respond to changes in supply patterns due to varying patterns of energy usage and extremely large numbers of users. Indeed, in recent years, distributed energy systems are becoming more technologically and economically feasible, but when viewed as a whole, they remain a large social and economic system. With regard to food, it is noteworthy that natural conditions (e.g. temperature, precipitation, soil) as well as the food culture of people living in any certain area vary, and that it takes a certain amount of time to improve varieties of food. Water is also highly dependent on natural conditions (e.g. temperature, precipitation, condition of rivers and underground aquifers, etc.), as well as local demand patterns for agriculture and daily life, industrial composition, and the state of pollution. What is even more important are the mutual synergies and trade-offs among these three elements. For example, food production and distribution require inputs of water and energy. The production of drinking water and the purification of waste water also require energy. Moreover, many processes for obtaining energy require the use of water.

In this context, particularly with regard to energy issues, there is an increasingly shared recognition in the world of the need to achieve carbon neutrality by the middle of the century in order to solve global environmental problems while taking into account the balance between society, the global environment and the economy. Energy is representative of issues that need to be approached through engineering to solve complex global environmental problems in a rational manner based on close cooperation among nations. Accordingly, this chapter will focus on the issue of energy and examine the following.

(1) A review of challenges faced by each country and the status of policies and initiatives;

(2) Establishment of the following five principles to achieve global carbon neutrality "not long after 2050" and Energy Sufficiency in all regions of the world "as soon as possible before 2050".

i) The establishment of a forum (tentative name: FICNES) where developed countries and developing and emerging countries can discuss not only energy and environmental policy, but also industrial policy, agricultural and food policy, urban policy, transportation policy and technology policy.
ii) For the poorest and least developed countries in particular, allow for a shift in policy towards carbon neutrality from a long-term perspective, while prioritising the achievement of Energy Sufficiency for the time being.
iii) For developing and emerging countries with large populations (exceeding 100 million in 2050) that are already achieving high economic growth rates, the world should provide support and investment for measures to simultaneously achieve carbon neutrality and Energy Sufficiency.
iv) For infrastructure related to renewable energy and energy storage and transport, taking advantage of regional characteristics and construction of infrastructure among multiple

countries should be discussed at the abovementioned FICNES forum to build international consensus and promote investment.

v) The world should monitor CO2 emissions and sequestration, design and build a framework for the steady development and diffusion of new technologies, ensure the safety of nuclear power, manage transitional fossil fuel resources, elucidate CO2 sequestration mechanisms, and recruit and train outstanding human resources in these areas.

(3) Based on these five principles, specific countries that could be called upon to simultaneously achieve carbon neutrality and Energy Sufficiency were selected based on four criteria, and the nature of cooperation to resolve any issues was examined. (Of these, the seven countries identified as “particularly important target nations for cooperation” were India, Nigeria, Pakistan, Indonesia, Egypt, Philippines, and Vietnam.)

(4) In addition to an examination of the various technology options currently advocated in the three areas of energy supply, energy demand, and energy distribution, critical issues for engineering to create a sustainable society were identified.

(5) Since the readiness of individual technologies remains unclear and we are not at the stage of narrowing down the list, a “Policy Framework Roadmap” was developed which includes four elements: “policy and international cooperation”, “human resources development”, “technology assessment systems” and “investment guidance schemes”. In addition, in order to identify timescales and challenges, a Technology Roadmap was developed as a general framework for technology. Both roadmaps need to be continually updated by the relevant communities, and it is important that they are always discussed as a 'pair'. This is because achieving carbon neutrality and Energy Sufficiency requires both top-down and bottom-up approaches.

(6) Finally, based on the above, we examine the realisation of the “Energy-Food-Water Nexus”.

4.1. Introduction

According to the latest report published by Working Group I of the Inter-governmental Panel on Climate Change (IPCC) in August this year, an increase in global average temperature of 1.5°C is “likely to occur” between 2021 and 2040 [4.1.1)]. This is about ten years earlier than previous reports have predicted, and shows that global warming has accelerated in recent years. This means that the “1.5°C scenario” agreed upon in the Paris Agreement is going to be more difficult to achieve than previously thought, and there will also likely be greater impacts on energy, food and water security. In light of this information, it will not be easy to achieve overall optimisation of energy, food and water. Moreover, any attempt would require an extremely large investment of funds and time to achieve. Even if we try to make changes today (in 2021), it will take at least 30 years to create a “new world”. Therefore, the question of what the world's energy, food and water nexus should look like in 2050 must be viewed as an urgent issue for engineers to address.

The following is a summary (with a focus on energy) of discussions in the Working Group II of the Science, Technology and Innovation 2050 Committee (STI2050 Committee) established by the Engineering Academy of Japan (EAJ).

4.2. Where to place the target in terms of energy?

The "world" is diverse. That diversity will likely remain, and we do not believe that it is necessarily appropriate or realistic to achieve a uniform society. It is important to have diverse visions of the future that take into account the characteristics of each country and region. Nevertheless, in order to proceed with concrete discussions, it is first necessary to set our targets related to energy.

It goes without saying that the first challenge for energy is global warming (climate change), which is mainly caused by the CO_2 emitted from burning fossil fuels. The European Union, Japan and the United States have already pledged to achieve net zero CO_2 emissions by 2050, and China, currently the largest CO_2 emitter, has also pledged to do so by 2060. According to the Climate Ambition Alliance, more than 120 countries around the world have already committed to carbon neutrality by 2050 [4.2.1)]. However, considering that Annex I countries as defined by the Paris Agreement (mainly developed countries) account for about 40% of emissions, while emissions from "non-Annex I countries" (mainly developing and emerging countries) account for about 60% (of which about half is China) [4.2.2)], and the fact that the latter generally have higher rates of population and economic growth[4.2.3)], it will not be easy to achieve on a global basis. Therefore, we believe that the goal should be to achieve carbon neutrality on a global basis, including both developed countries and developing and emerging countries, not long after 2050. If will not be possible to do this solely based on the actions of the mainly developed countries that are currently committed to carbon neutrality. It will be necessary for these advanced countries to take measures to become carbon negative above and beyond achieving carbon neutrality in their own countries.

On the other hand, the world's energy supply is not equally accessible to all. For example, as shown in Figure 1, even in recent years, roughly 770 million people remain without access to electricity, particularly in sub-Saharan Africa[4.2.4)], and Goal 7 of the SDGs, "Ensure access to affordable, reliable, sustainable and modern energy for all", has not been achieved. Here, we introduce the concept of "Energy Sufficiency" to describe the state of affairs where "everyone has access to a minimum of affordable energy". We also recommend setting a goal of "achieving Energy Sufficiency in all regions of the world as soon as possible before 2050". For those of us living in developed countries, we tend to view Energy Sufficiency as a goal only for developing countries. Yet, the concept of sufficiency also implies "knowing what is enough", i.e. curbing excessive and wasteful consumption and leading cultured lives using the minimum amount of energy necessary. It is therefore necessary to review the current energy consumption in developed countries.

Figure 4.2.1 Global electricity access in % of population (2018)
Source: World Bank (2018) Access to electricity (% of population)

(Note 1) According to an IIASA (International Institute for Applied Systems Analysis) report entitled “Innovations for Sustainability - 3rd Report Prepared by the World in 2050 Initiative", “sufficiency” level is defined as the level at which services (e.g. water, food, healthcare, energy) are provided beyond decent living standards (DLS) [4.2.5)].

(Note 2) It is difficult to make a sweeping definition of sufficiency level because it varies according to differences in individuals, societies and cultures. In general, there are two kinds of social and environmental limits: (1) Pareto efficiency (i.e. one individual’s sufficiency does not deprive others of their sufficiency), and (2) remaining within the planetary boundary of the earth’s resources and environment [4.2.6)].

(Note 3) Although it is not easy to give a detailed description of sufficiency level, the WG2 generally supported the view that the current situation in middle-income countries, specifically provincial cities in Thailand and Malaysia, may correspond to such a condition in terms of both supply stability and price. Both countries have a per capita GDP around 8,000-11,000 USD. Furthermore, China's per capita GDP is also generally at this level, and on average is considered to have achieved Energy Sufficiency. However, as there are large economic disparities between large coastal cities and rural and inland areas of China, it is assumed here that a sufficiency level is roughly the level of the average provincial city in Thailand and Malaysia.

(Note 4) This type of policy cannot be called economically efficient because obviously regarding the marginal cost of reducing CO2 emissions per unit volume: developed countries > emerging countries ≒ middle developed countries > developing countries and poorest countries. In other words, in order to minimise CO2 emissions on a global basis, if we judge on the basis of economic rationality, we should reduce emissions beginning in the places where the marginal cost of emissions reduction is low. In order to solve this dilemma, developed countries need to realise an energy supply and demand structure with “low installation and operating costs and low CO2 emissions” based on new technologies.

(Note 5) According to the World Bank’s "Access to electricity" data, in 2019 there were 29 countries in the world where the population without access to electricity did not reach 50% of the total population in 2019. All but two of these countries (Haiti and North Korea) are in sub-Saharan Africa [4.2.4)]

4.3. Review of policies around the world on achieving carbon neutrality and Energy Sufficiency

4.3.1. Status of CO2 emissions in Japan and around the world and future emission projections (U.S. EIA and IEA)

In 2018, Japan’s CO2 emissions were the fifth largest in the world, as shown in Figure 4.3.1. The world's largest emitters, in descending order, were (1) China (28.2%), (2) United States (14.5%), (3) India (6.6%), and (4) Russia (4.7%). These four countries accounted for more than half of global emissions. While the emissions of other individual countries are less, the four European countries of Germany, UK, Italy and France together account for 5.2% of global emissions. If we are to achieve carbon neutrality globally, it is crucial that these countries become carbon neutral. Meanwhile, India and Russia have not committed to any specific deadlines for becoming carbon neutral. Factors that determine the quantity of emissions include population, scale of economy, industrial structure (e.g. proportion of carbon-intensive industries such as steel and chemicals), energy supply structure, energy consumption efficiency, efficiency of energy trading markets, land area and number of cars, and average temperature. In any case, it should be clear that achieving significant changes in these complex factors in the short-term is problematic.

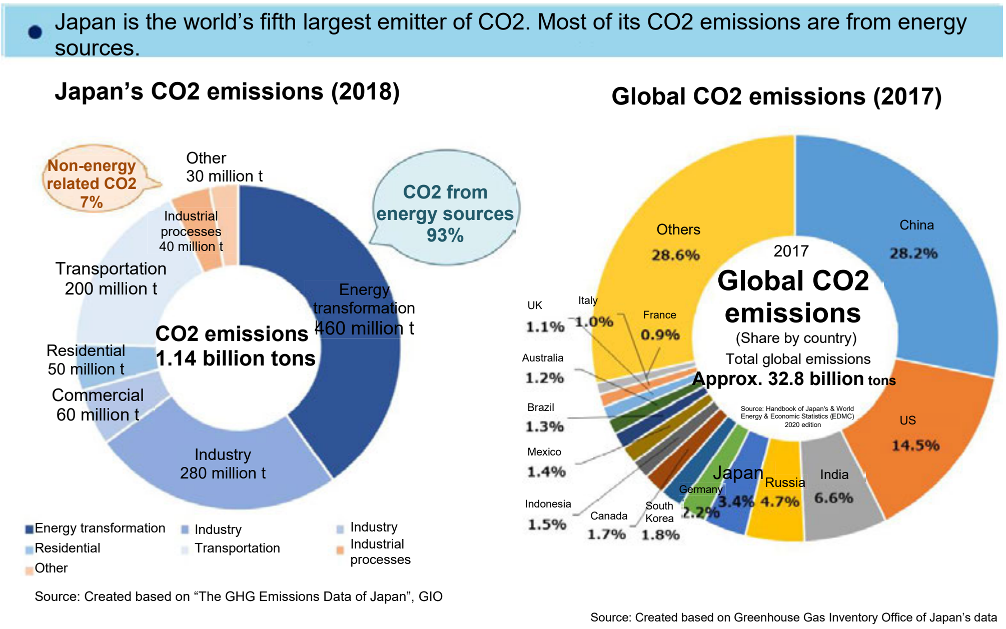

Figure 4.3.1 Breakdown of Japan's CO2 emissions by sector (2018) and global CO2 emissions by country (2017) (Source: Ministry of Economy, Trade and Industry data)

It is also clear from Figure 4.3.1 that, even now, emissions from the Paris Agreement's Annex I countries (mainly developed countries) account for roughly 40% of the world's emissions, while emissions from non-Annex I countries (including China and many so-called developing countries) account for about 60%. Unless exceptional measures are put in place, it is clear that a significant share of GHG emissions in 2050 will come from China (which has declared its intention to be carbon neutral by 2060, but will still be emitting significant amounts in 2050, albeit at reduced levels) and so-called developing/emerging countries.

The "OECD Environmental Outlook to 2050", published by the OECD in autumn 2011 based on analysis prior to the Paris Agreement, estimates that GHG emissions in 2050 will be 81 gigtonnes (CO2 equivalent) [4.3.1)]. As of now, little concrete progress has been made towards carbon neutrality worldwide, so it may be appropriate to consider this figure as a baseline (almost no action) scenario.

According to U.S. Energy Information Administration (EIA) projections shown in Figure 3, global emissions of CO2 from energy sources will increase by 0.6% per year between 2018 and 2050, decreasing by 0.2% per year in OECD countries, and increasing by 1.0% per year non-OECD countries [4.3.2)], which suggests emissions of about 41 gigatonnes in 2050.

In addition, according to "Net Zero by 2050: A Roadmap for the Global Energy Sector" published by the International Energy Agency (IEA) in autumn 2020, if countries implement existing or announced policies (Stated Policies Scenario (STEPS)), global energy-related CO2 emissions will increase from 34 gigatonnes in 2020 to 36 gigatonnes in 2030, and will remain at about the same level until 2050. Furthermore, in the Assumed Pledges Case (APC), where countries are assumed to have fully realised their pledges to achieve carbon neutrality by their commitment dates, emissions in 2030 are predicted to be 30 gigatonnes, falling to 22 gigatonnes in 2050 [4.3.3)].

There are understandably large discrepancies between these figures, as the assumptions underlying the projections differ. In reality, especially in developing countries with large populations growing at high rates, we can expect a demographic bonus in terms of labour supply, an increase in the growth rate due to the synergistic expansion of inputs based on increased investment, an increase in energy consumption due the enhanced consumer purchasing power and changes in industrial structure. The above analyses by U.S. EIA and IEA are premised on technologies that are still under research and development or not yet commercialised, so it is important to keep in mind when planning responses that actual emissions may be even higher. It should be noted that the GDP elasticity of energy consumption during Japan's high growth period (before the first oil shock) was above 1, so the growth in emissions, especially in developing countries, could be even higher.

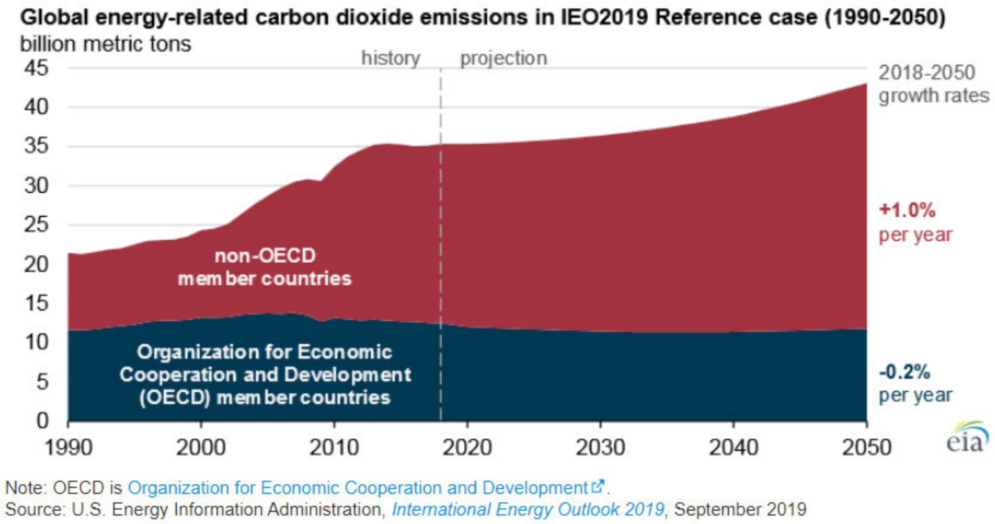

Figure 4.3.2 U.S. EIA projections on energy-related CO2 emissions from 1990 to 2050

Moreover, as a matter of course, continuation of the social structures and technological systems of the past cannot be a precondition of realising the 2°C/1.5°C scenarios aimed for in the Paris Agreement. Figure 4 compares the historical increasing trend in greenhouse gas emissions, projected emissions in 2030 (under the current policy case) and the emissions that must be achieved if the 1.5°C scenario is to be realised [4.3.4]. As can be seen in the graphic, without drastic social and technological change at a level that humanity has never experienced before, this scenario will never unfold.

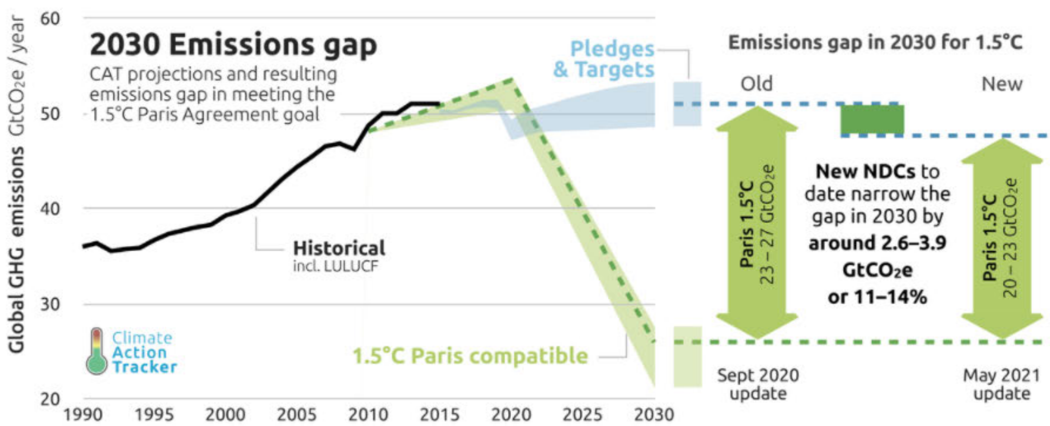

Figure 4.3.3 Difficulty of achieving the 2°C/1.5°C scenarios (Source: Climate Action Tracker)

4.3.2. Status of national initiatives to achieve carbon neutrality (EU, US, Japan, China)

4.3.2.1. EU and European countries

In February 2020, the European Council agreed on an intermediate target of an at least 55% net reduction in greenhouse gas emissions by 2030 compared to 1990 [4.3.5)]. This was a significant increase from the previous target of a 40% reduction [4.3.6)]. However, in the consensus-building process, Central and Eastern European countries such as Poland and Hungary strongly argued that this target was too ambitious, and that the adoption of nuclear power and fossil fuels such as natural gas would be necessary to achieve it (specifically, that these two options would have to be classified as green in the EU taxonomy). Reportedly, the words "technology neutrality" were thus included in the document on the targets. However, the Taxonomy Climate Delegated Act adopted by the European Commission in June 2021 still does not clarify whether natural gas and nuclear power are "economic activities capable of making a substantial contribution to climate change mitigation and adaptation". The Commission has noted that although these activities do not meet the technical criteria of the Taxonomy, they contribute to greenhouse gas reductions, which would be covered by the complementary Delegated Act [4.3.7)]. (More precisely, "natural gas is not included in the Taxonomy at this time because it remains controversial" and "there are no major barriers to including nuclear energy")[4.3.8)]. The share of renewable energies in the EU's total final energy consumption for 2019 was 19.7%[4.3.9)], nearly meeting the 20% target for 2020. The Commission also stated in October 2020 that “key characteristics of the energy market (in particular the high capital intensity, long investment cycles, new market dynamics, coupled with a low rate of return on investment) make it difficult to attract sufficient levels of investment”, recommending further support. The report’s analysis further concludes that “In the ocean energy, renewable hydrogen and wind industry, the EU currently holds a first mover advantage” [4.3.10)].

The situation in individual EU member states varies. France has policy on introducing hydrogen while making the utmost use of the nuclear option, in particular using surplus electricity from nuclear power plants to produce hydrogen by water electrolysis[4.3.11)]. Germany plans to review its EEG surcharge system, which has served as a driving force in the introduction of renewable energies such as solar and wind power. Debate is ongoing on the relationship between the high level of FIT (levy on electricity prices) needed to maintain incentives for investment in renewable energies and the associated maintenance of the availability of existing power sources such as lignite thermal power [4.3.12), 4.3.13)]. In addition, the treatment of lignite, which represents an important part of the domestic energy supply and employment, is likely to be a focal point, particularly going forward as further renewable energy is introduced. Moreover, there are various initiatives ramping up in the industrial sector, such as production, storage and use of hydrogen, fuel cell automobiles, and large-scale HVDC transmission.

The UK's exit from the EU has, in fact, given it a greater level of freedom in global warming measures. In November 2020, Prime Minister Johnson announced the “Ten Point Plan for a Green Industrial Revolution” [4.3.14)]. The plan, among other things, calls for a four-fold increase (40 GW) in offshore wind power by 2030 (40 GW) supported by abundant wind resources off the North Sea, and an expansion of low carbon hydrogen production and testing to allow up blending of hydrogen into the gas distribution grid for all homes from 2023. Other ambitious goals, such as the establishment of four CCUS industrial clusters in the North Sea by 2030, are also laid out. The plan would allow the government to announce a 68% reduction (previously 57%) in CO_2 emissions by 2030 compared to 1990 levels at COP26 in Glasgow in November 2021.

4.3.2.2. United States

After the former President Trump administration's withdrawal from the Paris Agreement, President Biden declared the US' return to the Paris Agreement on the day of his inauguration. The US, following the EU and Japan, also announced that it would achieve net-zero CO2 emissions by 2050 at the latest [4.3.15)]. The Biden administration's policy includes the principle of "environmental justice", which seeks to redress inequalities manifested in climate change and other environmental problems to ensure that the most vulnerable groups in society who suffer from these problems receive a substantial share of the benefits of the policies. To achieve this, the policy plans for a two trillion USD investment in clean energy, and specifically aims to achieve net zero emissions in the power sector by 2035.

On the other hand, the situation in the United States is characterised by very proactive and vigorous actions on the part of non-federal government actors. For example, immediately after former President Trump declared his intention to withdraw from the Paris Agreement in June 2017, former California Governor Jerry Brown and former New York Mayor Mike Bloomberg proposed the formation of "America's Pledge", a network of corporations, local governments, NGOs, universities, and others working together to achieve carbon neutrality [4.3.16)]. Already, nine US states have set goals on becoming carbon neutral by 2050 (or earlier), and 13 states have set goals to achieve 100% renewable energy in their electricity supply. In addition, plans for decarbonisation investments have been announced by a number of large corporations, particularly in the IT sector, and the manufacturing sector is following along.

4.3.2.3. Japan

Former Japan's Prime Minister Suga declared in a speech to the Diet in October 2020 that Japan would "aim to reduce overall greenhouse gas emissions to zero by 2050", i.e. to become carbon neutral in 2050 and achieve a decarbonised society [4.3.17)]. In the Green Growth Strategy [4.3.18)] published by the Japanese government in December 2020, 14 sectors are identified as "key fields". Of these, those related to energy supply include "offshore wind power", "fuel ammonia", "hydrogen" and "nuclear power", and those related to energy consumption in the industrial sector include, "automobiles and batteries", "semiconductors and telecommunications", "shipping", "logistics, people flow and civil engineering infrastructure", "food, agriculture, forestry and fisheries" and "aircraft". Other fields identified are "carbon recycling", "housing and buildings/next generation solar power", "resource circulation" and "lifestyle". Although some questions remain from a technical point of view, such as the fact that geothermal energy is not included, the plan is commendable in that it envisages the bold introduction of new technologies while taking into account continuity with current energy supply and demand. In general, the strategy is aimed at taking measures covering all the bases to find solutions from the long-term perspective based on the best mix of various measures. In this sense, future investment in R&D and promotion of social implementation are extremely important.

In April 2021, at the U.S.-hosted Climate Change Summit, Former Japan's Prime Minister Suga announced [4.3.19)] a new target to reduce greenhouse gas emissions by 46% by 2030 compared to 2013 levels, and to continue to ambitiously aim for a 50% reduction. According to the government's "Basic Policy for Economic and Fiscal Management and Reform 2021" [4.3.20)], in order to achieve this goal, the government will 1) promote policies that contribute to growth with a focus on decarbonisation, 2) ensure that renewable energy is the main source of green power, and 3) promote the use of renewable energy as the main source of electricity. The policy also states that "based on the Green Growth Strategy, Japan will promote research and development and capital investment in priority areas such as offshore wind, hydrogen and storage batteries". The Government of Japan is expected to take measures focusing on the expansion of non-fossil power sources (especially renewable energy) in the electricity sector, and the electrification of the industrial, consumer and transport (non-electricity) sectors with decarbonised electricity, hydrogen, methanation and synthetic fuels, and further energy conservation. This will not be an easy task and will require radical innovations in technology, as well as social and economic institutions.

In addition, according to the government's "Sixth Basic Energy Plan (draft)" [4.3.21)] presented in July 2021, the share of renewable energies in Japan's primary energy supply in FY2030 would have to be around 20%, with the share of renewable energies in terms of the power supply mix around 36-38%. The breakdown is "solar power: around 15%, wind power: around 6%, geothermal power: around 1%, hydroelectric power: around 10%, biomass: around 5%", but the draft states that this breakdown indicates "an outlook for energy supply and demand when various challenges are assumed to be ambitiously overcome", reflecting extremely ambitious figures. In addition, the proportion of nuclear power in the power supply mix in 2030 is stated at around 20-22%, which is quite a large figure considering the current state of operation of nuclear power stations. From this point of view, there are major hurdles in the way of actually realising the Basic Plan.

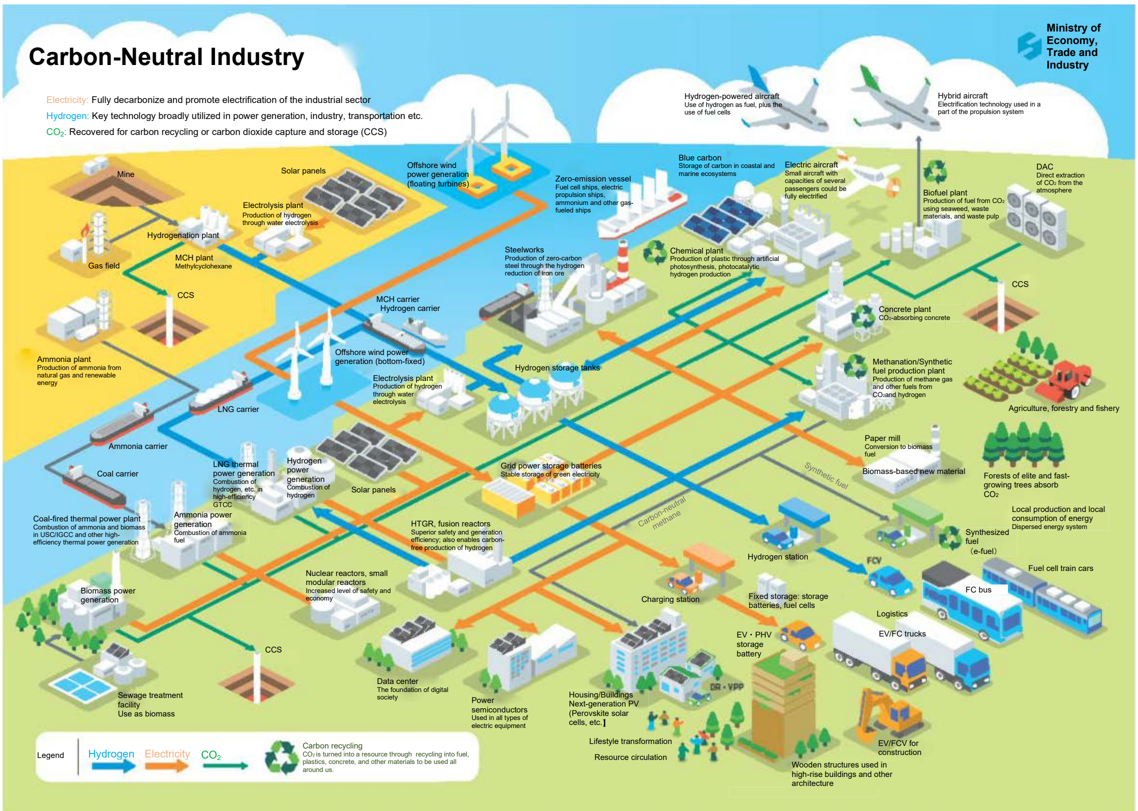

Figure 4.3.4 The Japanese government's image of carbon-neutral industry

4.3.2.4. China

In September 2020, Chinese President Xi Jinping announced at the UN General Assembly that China would "achieve carbon neutrality by 2060" and "peak CO2 emissions by 2030" [4.3.22)]. China is currently the largest emitter of CO2, accounting for roughly 30% of global total CO2 emissions. To date, China has been at the forefront as the leader of developing countries at the Conferences of the Parties to the United Nations Framework Convention on Climate Change (COPs), asserting that developed countries have greater responsibility for global warming, which was caused by massive consumption of fossil fuels and massive emission of CO2 over nearly three centuries since the industrial revolution, and that developing countries that only started to grow in the latter half of the 20th century have the right to use more fossil fuels [4.3.23), 4.3.24)]. Moreover, it has also been argued that China's imports of steel and textiles are the result of China's bearing the burden of manufacturing for the developed world. China's large CO2 emissions are in fact associated with the decline of the manufacturing industry in Japan, Europe and North America, and some analyses have shown that curbing China's emissions would lead to restrictions on the consumption of these goods in importing countries [4.3.25)].

The background to China's major policy shift may be seen in the following points.

1) China accounts for approximately 70% of the global share of the entire value chain of crystalline silicon solar cells (e.g. polycrystalline silicon, wafers, cells, modules) and lithium-ion batteries. It also holds a 50-70% share of the market for materials for lithium-ion batteries (cathode materials, anode materials, electrolytes, separators).

2) In addition to being able to produce and procure at home the mineral resources essential for the production of lithium-ion batteries, such as lithium from Qinghai province and graphite from Heilongjiang province, China has a near monopoly in the world on the production of heavy rare earths (such as Dy) that are added to Nd-Fe-B magnets, which are essential for the production of wind turbine generators and motors for EVs and FCVs.

3) Even though China has a long coastline, it is located on the eastern edge of the continent, which is unfavourable for wind power generation. Nevertheless, it has great potential for offshore wind power. In addition, the political system allows for the implementation of policies with strong incentives to promote the use of hydrogen stations and fuel cell vehicles, which have already started.

Taking into account these industry and economy-related realities, as well as criticisms of domestic air pollution caused by coal consumption and the progression of motorisation, China has taken a "proactive" stance in viewing carbon neutrality as a driving force for further expansion of exports and economic development.

According to the Action Plan[4.3.26)] published by the State Grid Corporation of China in March 2021, the government will promote the development of new energy sources such as offshore wind power and photovoltaic power, the development of hydroelectric power in the southwest region, and the development of nuclear power plants in coastal areas to achieve carbon neutrality. In addition, the government will promote the construction of pumped-storage hydropower plants to enhance the grid's regulation capacity, and LNG power plants to strengthen the peak load regulation super-capacity, as well as the use of energy storage facilities. It will also set out policy on "replacing coal and oil with electricity" in energy-intensive industries.

However, there are still issues to be addressed for China's plans to be realised. For example, China must break away from its dependence on coal (especially in the power sector, where about two-thirds of the power supply mix is coal-fired), which has been an overwhelmingly advantageous energy source from both the perspective of cost and amount of resources that has underpinned China's economic development (even if CO2 is buried underground using CCS). Another issue lies in China's power transmission infrastructure, the so-called "west-to-east" transmission, by which power is generated in sparsely-populated western regions and sent to the densely-populated eastern and coastal regions. Furthermore, it should be noted that the plan presumes that CO2 emissions will continue to increase until 2030, which means that China's share of global CO2 emissions will become even higher. Achieving carbon neutrality in the subsequent 30-year period will involve many difficulties.

4.3.3. the COP26 Conference and the Glasgow Climate Pact
The 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC), held in Glasgow, UK, in October-November 2021, finally concluded with the following final agreements[4.3.27)].

- In response to the frequency of natural disasters in recent years, the committee decided to "resolve to pursue efforts to limit the impact of climate change to 1.5°C," and requested each country to review and, if necessary, strengthen its emission reduction targets by the end of 2022.

- The biggest focus of the resolution was on coal-fired power generation, where India and other countries insisted in the final phase that they would “accelerate efforts towards the phasedown of unabated coal power”.

- In order to promote climate change countermeasures in developing countries, the $100 billion annual financing by developed countries is to be steadily implemented until 2025.

- The Paris Agreement's "leftover" rules for emission reduction trading will also be amended to allow reductions certified under the Kyoto Protocol to be included in the 2030 reduction target.

The final agreement document including the above is called the Glasgow Climate Pact. Besides these government agreements, it is noteworthy that the Glasgow Financial Alliance for Net-Zero (GFANZ) and Zero Emission Vehicle (ZEV) groups, including governments, city/regional governments, automakers, and logistics companies, have announced many commitments on their own measures to deal with the issue.

4.3.4. National efforts to achieve “Energy Sufficiency”
It goes without saying that achieving Energy Sufficiency is a very high priority policy issue in developing countries. Thailand's past policy on electrification[4.3.28)] is cited here as an example of a ‘success story’.

In the early 1970s, the Thai government, with the aim to electrify all villages within 25 years, formulated the National Plan for Accelerating the Electrification of Thai Villages in 1973. The Provincial Electricity Authority (PEA) led the effort and steadily promoted the project with government subsidies and low-interest loans based on monetary policy. In 1972, the electrification rate (population basis) outside the Bangkok metropolitan area was reported to be about 10%; however, by 1981, the national electrification rate (village basis) was 44%, and by 1996, had reached 98%. In other words, nearly all villages were electrified in the 25 year-period as originally targeted. Further, since the 1980s, Japanese companies have actively set up factories in Thailand, and this investment environment is considered to have been a factor in promoting electrification. According to a JETRO survey of Japanese companies with factories overseas[4.3.29)], Thailand was selected least often out of countries in Asia for "underdeveloped infrastructure" related to electricity (Thailand = 5.1%, Vietnam = 22.5%, India = 61.2%, Myanmar = 83.7%), making it clear that a substantial level of industrial electricity supply has been achieved.

In India, for example, per capita electricity consumption was 1,122 kWh (2017), which is less than one-third of China (3,762 kWh), less than 10% of the US (12,988 kWh), about one-seventh of Japan (7,836 kWh), and only one-third when compared to the global average (3,104 kWh). However, the government has to date supplied 80 million households with LPG connections and is currently adding 10 million more. Moreover, the government's budget for 2021 includes plans to expand the city gas distribution network to more than 100 areas over the next three years. In addition, India has the fifth largest proven coal reserves in the world (8.3%), and ranks second globally in production and consumption (9.7% and 12.3% respectively) [4.3.30)]. Accordingly, the continued reliance on consumption of coal, a cheap and domestic resource, is thought to be a necessary option to pursue Energy Sufficiency in this country where many people are still poor. This may become a major point of contention in terms of achieving global carbon neutrality in the future.

In the so-called middle-income countries such as Thailand and Malaysia, where per capita GDP has reached 8,000-11,000 USD, this level of per capita GDP, from a macroeconomic point of view, can be viewed as an approximate level at which Energy Sufficiency is mostly achieved.

It should also be noted that access to electricity implies access to communication networks and information at the same time, and from this point of view, ensuring access to electricity is becoming increasingly important for improving quality of life.

4.4. Global strategic theory (Five Principles)

4.4.1. The five principles

As mentioned above in 4.2, strategies and tactics should be developed based on the following five principles to achieve the two goals of: global carbon neutrality not only in developed countries but also in developing and emerging countries “not long after 2050” and Energy Sufficiency in all regions of the world “as soon as possible before 2050".

[Principle 1] The establishment of a forum (tentative name: Forum for International Carbon Neutrality and Energy Sufficiency (FICNES)) where developed countries and developing and emerging countries can discuss not only energy and environmental policy, but also industrial policy, agricultural and food policy, urban policy, transportation policy and technology policy toward cooperation to globally achieve the second goal in a rational manner. FICNES will naturally take into account existing environmental problems (e.g. water quality, air, noise) aimed at sustainable development, while also taking into account the long-term energy supply security. Specifically, an appropriate approach could involve reorganisation of the IPCC's Working Group III that examines measures to mitigate climate change, reduce GHG emissions and remove GHGs from the atmosphere, or the independent operation of WGIII in close collaboration with the Paris Agreement. This would be extremely important in the context of scientific advice for policymaking, similar to the way in which IPCC is tasked with accumulation of scientific knowledge on the facts and causes of global warming. The forum’s mission would be to coordinate policies globally to achieve an inclusive and sustainable energy supply and demand structure based on scientific knowledge.

[Principle 2] For the poorest and least developed countries in particular, allow for a gradual shift in policy towards carbon neutrality from a long-term perspective, while prioritising the achievement of Energy Sufficiency for the time being.

[Principle 3] For developing and emerging countries with large populations (as a rule of thumb, exceeding 100 million in 2050) that are already achieving high economic growth rates, the world should provide support and investment for measures to simultaneously achieve carbon neutrality and Energy Sufficiency. Moreover, these countries would also be allowed an incremental "time lag", depending on CO_2 emissions and GDP levels. In any case, they should work towards achieving global carbon neutrality not long after 2050.

[Principle 4] With regard to the key points of adopting renewable energies and infrastructure for energy transport and storage, the introduction of solar power, solar thermal power, wind power, geothermal power, biomass, and hydropower should aim for overall optimisation by taking advantage of regional characteristics. Likewise, international consensus building and promotion of investment should be carried out through the above-mentioned FICNES forum when building infrastructure that spans multiple countries (e.g. multilateral power grids, CCS facilities and CO_2 pipelines).

[Principle 5] In order to achieve carbon neutrality, developed countries and developing/ emerging countries should monitor CO_2 emissions and absorption (including by oceans) in each country, design and establish frameworks to facilitate the development and diffusion of various new technologies (incentives for research and development and mechanisms for technology diffusion), ensure the safety of nuclear power, manage trade in fossil resources during transitional periods, elucidate the mechanisms for CO_2 absorption by oceans and forests, and recruit and train outstanding human resources in these fields.

4.4.2. Key countries called upon to achieve carbon neutrality and Energy Sufficiency simultaneously

Specific countries that fall under the third principle above "developing and emerging countries with large populations already achieving high economic growth" and that are called upon to achieve carbon neutrality and Energy Sufficiency simultaneously will be selected based on the following four criteria.

[Criterion 1] Countries with a projected population over 200 million in 2050. Followed by countries that fall between 100 and 200 million and have the potential to become large CO_2 emitters based on economic growth. (Population projections are based on the UN's World Population Prospects 2019 [4.4.1)].)

[Criterion 2] As an approximate value of potential for future economic growth, countries with an average GDP growth rate (in real terms) over the eight-year period from 2012-2019 exceeding 4.6% per year, which is the average for developing and emerging economies during this period. Followed by countries with a growth rate of more than 3.4% per year that are also considered to have the potential for pronounced economic growth in the future. (Note that in 2020, due to COVID-19, many countries have negative economic growth rates, but these were considered outlier values and excluded from calculations.) (The IMF's World Economic Outlook 2020 [4.4.2)] was used for data for economic growth rates.)

[Criterion 3] Countries with current per capita GDP significantly below the levels of Thailand, Malaysia and China (USD 8,000 to 11,000 USD), with a low percentage of population having access to electricity, and where Energy Sufficiency is seen as a major challenge. As mentioned above, there is a particular need in these countries for energy and environmental policies to aim at achieving carbon neutrality and Energy Sufficiency simultaneously. (Per capita GDP data was also taken from the IMF's World Economic Outlook 2020 [4.4.2)]. For data on percentage of population with access to electricity, the World Bank's Access to Electricity [4.2.4)] was used.)

[Criterion 4] Some of the countries targeted in this study currently have agricultureß-based industrial structures that emit little or no CO_2. However, assuming future economic growth and shifts in industrial structure, future emissions are unlikely to remain at low levels. Nevertheless, as current emissions can be used as a basis for forecasting future emissions, priority should naturally be given to countries that have a certain scale of emissions (e.g. 100 million tonnes at present). (The IEA's World Energy Outlook [4.4.3)] was used as the data source for CO_2 emissions.)

Based on these criteria, the relevant countries (excluding OECD countries and Russia, which are considered to be developed countries) are listed below. China has already committed to achieving carbon neutrality by 2060 and is therefore listed below for reference (and comparison) purposes only.

Table 4.4.1 Important target countries for cooperation on simultaneous achievement of carbon neutrality and Energy Sufficiency

Important Countries for Carbon Neutrality and Energy Sufficiency

Country	Population 2050 forecast (million)	Average annual economic growth rate 2012-2019 (%/yr)	GDP per capita 2019 (USD)	% of Population with access to electricity 2019	CO2 (GHGs) emission 2018 (MtCO2)	CO2 emissions global share 2018 (%)
India	1639	6.6%	2172	97.8%	2309	6.90%
(China) (reference)	1402	7.1%	10099	100.0%	9809	29.30%
Nigeria	401	2.8%	2222	55.4%	104	0.30%
Pakistan	338	4.1%	1388	73.9%	194	0.60%
Indonesia	331	5.2%	4164	98.8%	543	1.60%
Ethiopia	205	9.3%	953	48.3%	13	0.04%
DR Congo	194	6.0%	501	19.1%	2	0.01%
Bangladesh	192	7.0%	1906	92.2%	82	0.20%
Egypt	159	4.0%	3047	100.0%	224	0.70%
Philippines	144	6.6%	3294	95.6%	132	0.40%
Tanzania	129	6.6%	1105	37.7%	10	0.03%
Vietnam	110	6.5%	2740	99.4%	226	0.70%
Kenya	92	5.5%	1998	69.7%	16	0.05%

(Note 1) Nigeria's sluggish economic growth, particularly for 2016-2019, can be attributed mainly to low oil prices. (Similar trends can be observed in the Middle East gulf countries, Angola and Venezuela, which are outside the scope of this study.)

(Note 2) Brazil is expected to reach a population of 229 million in 2050, and its per capita GDP in 2019 (8,798 USD) was already higher than Thailand's, with the percentage of the population with access to electricity reaching 99.8% in 2019. Accordingly, it is not included in the above discussion.

(Note 3) Turkey is also expected to reach a population of 97 million in 2050, and its per capita GDP in 2019 (8,958 USD) was also higher than Thailand's. The percentage of the population with access to electricity in 2019 was 100%. As such, it is not included in the above discussion.

(Note 4) The population of Iran is predicted to reach 103 million in 2050. Iran's per capita GDP in 2019 was 5,506 USD, while the percentage of the population with access to electricity was 100% in the same year. Because Iran is a very large oil and gas producing country, it has been excluded from the above discussion.

Based on the aforementioned four criteria, the following seven countries can be identified as "particularly important target nations for cooperation" to achieve carbon neutrality and Energy Sufficiency simultaneously from the perspective of Japan: 1) India, 2) Nigeria, 3) Pakistan, 4) Indonesia, 5) Egypt, 6) Philippines, and 7) Vietnam. In addition, the following five countries are designated as "important target nations for cooperation": 8) Ethiopia, 9) Democratic Republic of the Congo, 10) Bangladesh, 11) Tanzania, and 12) Kenya. (However, from the perspective of criteria 3 and 4 above, the Congolese and Tanzanians need to focus more on Energy Sufficiency. In Egypt, Indonesia (especially Java), Philippines (especially Luzon) and Vietnam, where Energy Sufficiency is considered to be at a reasonable level, measures focused more on carbon neutrality are necessary.)

Considering the current CO2 emissions of these countries, India's measures are extremely urgent and important considering that it is the second largest emitter after China among the "non-Annex I" countries of the Paris Agreement, and will have the world's largest population in 2050. Also, India's CO2 emissions (6.9% of the world's total) greatly exceed the countries that follow it in volume of emissions.

4.4.3. Key countries called upon to prioritise Energy Sufficiency

On the other hand, there are some countries where achieving Energy Sufficiency should be the first priority, and it is a major challenge for Japan to promote cooperation with these countries. The following are selection criteria for countries that should be prioritised for cooperation with Japan.

[Criterion 1] As an approximation of Energy Sufficiency, the percentage of population with access to electricity is used, and countries with low levels (generally below 40%) are targeted. (For data on the percentage of population with access to electricity, the World Bank's “Access to Electricity” [4.2.4)] was used.)

[Criterion 2] Countries with a projected population of less than 100 million and more than 30 million (p) in 2050. (For population projections, the UN's World Population Prospects 2019 was used [4.4.1)].

[Criterion 3] Countries with current per capita GDP significantly below the levels of Thailand, Malaysia and China (approximately 8,000 to 11,000 USD). (The IMF's World Economic Outlook 2020 [4.4.2)] was used for per capita GDP data.)

Table 4.4.2 Important target nations for cooperation to prioritise Energy Sufficiency

Country	Percentage of population with access to electricity (%)	Population forecast (2050) (in millions)	Per capita GDP in 2019 (USD)
Benin	40.3	24	1,217
Burkina Faso	18.4	43	718
Burundi	11.1	25	310
Central African Republic	14.3	8	448
Chad	8.4	34	861
Guinea	42.4	26	981
Guinea-Bissau	31	4	785
Liberia	27.6	9	704
Madagascar	26.9	54	464
Malawi	11.2	38	371
Mozambique	29.6	65	484
Niger	18.8	66	405
Rwanda	37.8	23	825
Sierra Leone	22.7	13	547
Somalia	36	35	(N.A)
South Sudan	6.7	20	275
Uganda	41.3	89	770
Zimbabwe	41.1	24	860

Based on these three criteria, Japan should consider the above 18 countries (with a combined projected population of 600 million in 2050) to be appropriate ones with which to cooperate, giving first priority to achieving Energy Sufficiency. All of these countries are located in sub-Saharan Africa, and in addition, almost all of them had a per capita GDP of less than 1,000 USD in 2019. Even if these countries sustained a 5% annual GDP growth rate for 30 years, their economies would be only 4.3 times larger than they are today. In other words, unless these countries achieve a level of economic development that cannot be predicted at present, it is highly unlikely that they will be able to achieve the Energy Sufficiency that Thailand and Malaysia have achieved today, even 30 years from now. In light of this, ensuring Energy Sufficiency, such as the establishment of electric power infrastructure, in these countries is an urgent issue. As it would be considerably difficult for these countries to achieve Energy Sufficiency based on their own autonomous economic development, Japan and other developed countries should get actively involved to contribute to the achievement of Energy Sufficiency.

4.4.4. Cooperation with fossil fuel producing countries

It should be noted that the countries that are currently producers of oil, natural gas and coal and exporters to Japan (e.g. Saudi Arabia, UAE, Kuwait, Iran, Iraq, Brunei, Indonesia, Oman, Qatar, Mongolia) may become suppliers of "blue hydrogen" (or blue ammonia) to Japan in the near future. While many of these countries may be financially well off due to their fossil fuel exports, they could face domestic political instability and the inability to use these fossil fuels, which are a source of foreign currency, for their own economic development if they move too rapidly towards decarbonisation. Therefore, we should promote cooperation with these countries in the development of renewable energies from a long-term perspective, as well as technical cooperation toward the realisation of CCS/CCUS facilities and in the construction of hydrogen and ammonia production and export infrastructure to enable the stable production and export of blue hydrogen and blue ammonia.

4.4.5. Cooperation with countries with CO2 sinks such as large areas of tropical rainforest and large algal breeding areas and coral reefs

Furthermore, considering the extremely high technological, economic and social hurdles that stand in the way of carbon neutrality, it is also extremely important to consider how to conserve and expand the amount of CO2 absorbed by the world's largest CO2 sinks: the Amazon basin, Kalimantan Island and the rainforest jungles of the Congo basin. Meanwhile, research results have shown that the Amazon basin, in particular, has in recent years become more of an emission source than a CO2 sink due to deforestation in some parts[4.4.4)]. Likewise, a rapid shrinkage of forest area due to the expansion of palm oil plantations in Kalimantan has been pointed out. The fact that the products of these forests are exported to the world market also suggests that global economic development is reducing the CO2 sinks in these countries. In the context of conserving the CO2 absorption capacity of these rainforests, it is important to cooperate with countries such as Brazil, Indonesia and Malaysia, as well as with the Congolese people, in the conservation, management and regeneration of these rainforests. It is also important to cooperate with relevant countries in the conservation, management and regeneration of large algal breeding grounds and coral reefs, which are considered to be similarly large CO2 sinks.

4.4.6. Specific examples of response and cooperation measures in these important countries

The following section provides specific courses of action for response and cooperation measures in the "particularly important target nations for cooperation" of India, Nigeria and

Indonesia, for the simultaneous achievement of carbon neutrality and energy sufficiency. These will require further expert examination.

4.4.6.1. India

While it is basically necessary to put in place all measures possible, improved access to electricity and city gas, which the current government is promoting, is of utmost importance with regard to energy sufficiency. In particular, with its large land area and abundant sunlight, India has great solar power potential, and wind power surpasses solar power in the country's current renewable energy supply. In addition, wind power potential is especially great in the south, and development is expected in the future. In terms of local energy, the expansion of the biogas use from food waste from households and commercial establishments and animal manure is also attracting attention (which would also contribute to solving conventional environmental problems). Trials of these various approaches will be important to achieve both carbon neutrality and energy sufficiency.

At the same time, in the realm of energy consumption, challenges include decarbonisation of coal-fired power plants and the heavy chemical industry (e.g. steel, chemicals), the establishment of a mass distribution system using high-speed (electric) railways, the widespread use of energy-saving devices in the consumer sector (in particular LED lighting and air conditioners with inverters), and the widespread use of affordable and compact electric vehicles.

4.4.6.2. Nigeria

In this large oil-producing country, CO2 emissions from the oil production sector are likely to be significant, making it important to first consider the feasibility of adopting CCS/CCUS to control these emissions. As Africa's largest oil-producing country, Nigeria has abundant oil resources, and oil will likely continue to play an important role in its economic development. Meanwhile, the country is well aware of the need to reform its oil-dependent economic structure, and with a very large young population, industrial diversification will be a key focus. Moreover, the development of renewable energies (e.g. solar, wind) is important in terms of energy sufficiency, especially in rural areas. Furthermore, as a large country with an estimated 2050 population of 400 million, challenges for the energy consumption sector include promoting the widespread use of energy-saving devices in the consumer sector (especially LED lighting and air conditioners with inverters) and affordable and compact electric vehicles. Nigeria has traditionally faced racial and religious problems and economic disparities between the south and the north, which have been one of the hurdles to political stability and the introduction of foreign investment, making harmonious development of the country as a whole a top priority.

4.4.6.3. Indonesia

Achieving the widespread use of renewable energies will be a major key. With regard to fossil fuel production, it is important to expand the use and export of natural gas (especially green natural gas with CO2 removed, and the production of green hydrogen). It is also important to figure out how to continue to use coal, a valuable domestic energy source, without emitting CO2 through CCS/CCUS. In terms of mobility, it is again important to promote the use of affordable and compact electric vehicles. Furthermore, CO2 emissions from logging, destruction and fires in forests, as well as from the destruction (fire) and decomposition of peatlands, accounts for an extremely large proportion of the country’s total emissions [4.4.5)]. It has been suggested that significant emission reductions can be achieved in Indonesia by (1) curbing deforestation, (2) preventing peatland fires, (3) improving peatlands, (4) managing forests sustainably, and (5) regenerating degraded forests. In addition, appropriate use of the country's abundant biomass resources (e.g. woody biomass for thermal power generation and jet fuel production) has the potential to reduce CO2 emissions from fossil fuels.

4.5. Technology theory

The following is an examination of various options (alternatives) currently proposed in the four areas of energy supply, energy demand (industrial, transport, consumer), energy distribution and carbon fixation.

4.5.1. How can we change the energy supply structure?

Based on the measures that countries are putting in place and IEA reports, energy supply structures in the future are likely to move in the following direction.

1) Each country will consider reliance on a single energy source unrealistic, and try to create a new best mix by combining multiple options, taking into account the country's location and continuity with the current energy supply structure. With many unknowns in the technology, as well as concerning cost and adaptability, it is dangerous to be "decisive" at this point, and all options need to be addressed.

2) In terms of future options, renewable energy is a serious consideration for all countries. Countries also have a strong recognition of the importance of strengthening electricity transmission and distribution grids and infrastructure for energy storage (e.g. storage batteries, conversion of gaseous hydrogen into organic hydrogen for storage in liquid form) for highly fluctuating energy sources such as solar thermal, photovoltaic and wind power. The focus of renewable energy, particularly over the past two decades, has been on solar PV and onshore wind power, but in recent years expectations for offshore wind power have expanded. In addition, countries share a recognition of the importance of further research and development in storage batteries. It is also likely that, depending on the country, a significant proportion of renewable energy will be operated in a decentralised and independent manner.
   From an engineering point of view, the fundamental problem with renewable energies is that, in principle, their "low energy density" cannot be overcome. In particular, when considering the locations in developing and emerging countries, it is important to consider the following options: for solar photovoltaic and solar thermal, the location should be at a low latitude with a high rate of sunny days; for wind power, the location should be at 30-60° latitude on the west coast of continents with westerly winds; for geothermal power, the location should be in a volcanic country; and for biomass, the location should be in an equatorial region with fast plant growth rate and high precipitation. Thus, it is necessary to focus on and specialise in renewable energies that are suited to the climatic conditions and characteristics of respective regions.

3) As for energy used as a heat source, the use of hydrogen and ammonia, which do not produce CO2 from combustion, has been proposed and research and development is underway. The two main options for hydrogen production are "blue hydrogen", which is produced from fossil fuels such as coal, lignite and natural gas whereby CO2 is buried in the ground using CCS, and "green hydrogen", which is produced by electrolysation of water using electricity generated from renewable energies and nuclear power. For CCS, geological location constraints and cost issues have been identified, and for the latter, efficiency constraints and cost issues have been identified. Moreover, ammonia is attracting attention as it can be transported and stored using existing infrastructure and, unlike hydrogen, can be co-fired with fossil fuels without the need to use energy to extract

hydrogen from organic hydrogen carriers. Furthermore, a method for reacting recovered CO_2 with hydrogen to produce synthetic methane by methanation has been proposed.

4) With regard to nuclear energy, not all countries have positive views on the construction of new nuclear power plants due to related social circumstances. However, research and development on new reactors with improved safety is underway in some countries, and many believe that the role of nuclear energy cannot be ignored at least for a certain portion of power supply. In addition, many countries pursuing carbon neutrality believe that it should not be ruled out as a viable option at this point.

On the basis of the above views, the future global energy supply structure is equivalent to finding a solution that satisfies the following five equations.

(1) Ensuring the required amount of energy supply

$$(E_{sustainable} + E_{storage}) + E_{fossil} + E_{nuclear} > Demand_{peak} * Ks(p)$$

(where Ks is safety factor (margin))

(2) Minimisation and net-zeroing of energy-derived CO_2 (carbon neutrality)

$$CO_{2fossil} \leqq CO_{2ccs/ccus} + CO_{2absorption}$$

(where $CO_{2ccs/ccus}$ is the amount anthropogenic absorption by CCS/CCUS, and $CO_{2absorption}$ is absorption by oceans, forests, coral reefs, etc.)

(3) Equation for maximisation of security for energy supply

$$\int R_{fossil} \cdot D_{fossil}\, dt + \int R_{hyrogen} \cdot D_{hydrogen}\, dt + \int R_{renewable} \cdot D_{renewable}\, dt + \int R_{nuclear} \cdot D_{nuclear}\, dt \leqq L_{GDP}$$

(where R is the supply risk function, D is the disruption damage function, dt is the time integral, and L is the maximum economic loss allowed)

(4) Equation for ensuring sufficiency of energy supply

$$E_{supply}/P_{population} \geqq E_{sufficiency}$$

(where $E_{sufficiency}$ is per capita sufficient energy supply)

(5) Equation for minimisation of social cost for energy supply

$$C_{envir} + C_{security} + C_{infra} + C_{operation} \leqq B$$

(where C_{envir} is environmental cost, $C_{security}$ is the cost of security measures, C_{infra} is the cost of building infrastructure, $C_{operation}$ is the cost of operating infrastructure and B is the total benefit of using the new infrastructure)

4.5.2. How can we change the structure of energy demand?

The most important engineering, social and economic challenges with regard to the structure of global energy demand are considered to be as follows.

a) From an industrial point of view, a major issue is whether or not a new process can be developed that would enable the energy-intensive steel and chemical industries (followed by ceramics, glass, cement, paper and pulp) to significantly curb fossil fuel consumption. Iron ore, which is an oxide of iron, is used as raw material for steel, and carbon (coke) has been used for its reduction because of its superiority as a reducing agent and its heat value. In Japan, a project called "Course 50", a joint effort between NEDO and major blast furnace manufacturers, aims to reduce the proportion of direct reduction of carbon out of three types of reduction reactions (indirect reduction of CO gas (exothermic reaction), indirect reduction of hydrogen gas (endothermic reaction) and direct reduction of carbon (very large endothermic reaction), and thereby reduce CO2 emissions by reducing the heat required for the reduction of iron in the blast furnace as a whole. The project's aim is to reduce CO2 emissions by 30%. In other words, due to the nature of the reaction, it is extremely difficult to completely replace coke with hydrogen (if hydrogen is the only reducing agent, there would be only an endothermic reaction that would lower the temperature in the blast furnace and reduce the efficiency of the reduction process) [4.5.1)]. This suggests that the conditions for the systems and locations of the steel industry may change significantly.

In addition, petroleum products are complementary products. The refining and petrochemical industries produce ethylene and propylene from the lightest naphtha, which is used as a raw material in the manufacture of various plastics, and distill the light to heavy components into gasoline, diesel fuel, jet fuel, kerosene, fuel oil, and coal tar, with each product produced for a specific application. To make the industry carbon neutral in the future, it will be necessary to take into account major changes in the overall material balance of petroleum products and plastics. It should be noted that this will inevitably lead to a global restructuring of the industry as the global supply and demand balance for crude oil, petroleum products and plastics is likely to change significantly. Likewise, the impact of changes in the price structure will also need to be considered. There is also the question of whether it is possible to create social systems that radically reduce the amount of steel and fossil fuel-based plastics used.

In the case of steel, it may be possible to curb the demand for virgin steel and CO2 emissions to a certain extent by using electric furnaces to recycle the steel retained in infrastructure, but global demand for infrastructure is likely to remain strong, particularly in developing and emerging countries, and this may not be enough to curb demand. When it comes to plastics, the question is to what extent it is economically rational to increase the use of bio-based materials. In addition to these innovations in processes, we must of course also consider product innovation, i.e. the development of alternative materials to steel products and plastics. In the case of steel, this presents extremely high hurdles in terms of strength, heat resistance, moldability, cost and availability of raw materials (iron ore). As for plastics, it is also a difficult task to establish scientific and industrial systems for materials that do not use carbon (C) as a starting material. Additionally, we must also address the issue of reducing the power consumption of data centres. While they have not been considered energy intensive industries thus far, their power consumption has increased rapidly in recent years and is expected to continue to increase in the future. It has also been proposed that carbon recycling could be achieved by adopting CCUS in cement and other industries, but there are many issues that need to be addressed, such as cost reduction.

b) Among the means of transport (e.g. cars, aircraft, ships, etc.), particularly for cars, we are moving in the direction of complete conversion to hydrogen or electric power (with a carbon-free power source). It should be noted that the average service life of a car in Japan is about 12-15 years, which means that there are only two renewal cycles before 2050, but other forms of transport are used much longer. Undoubtedly, decarbonisation of the power supply mix is key if electrification is to proceed. In addition, policy involvement is likely essential for the construction of filling infrastructure (especially for hydrogen). Biomass fuels are also seen as an effective option for aircraft and ships, as hydrogen and electrification have elements that are difficult to achieve technologically. In Thailand and Indonesia, plans are already advancing on the construction of power generation infrastructure using biomass-derived fuels and ideas for conversion of jet fuel

4.3.23). Thus, Japan should strengthen cooperation with countries in Southeast Asia where the potential of biomass resources is high and commercial mass cultivation is possible, using the Joint Crediting Mechanism (JCM) to count a certain portion of the CO2 reductions associated with biomass-derived fuels produced and consumed in these countries as Japan's CO2 reductions. Furthermore, from a long-term perspective, it is clear that robots, ICT, and AR (Augmented Reality)/VR (Virtual Reality)/ER (Expanded Reality) will be used in education, employment, commercial facilities, and daily life, as evidenced by the current COVID-19 pandemic, during which remote working has driven advances in terms of both hardware and software. The question of how to build new urban infrastructure based on the premise of minimising physical movement will be key.

c) The promotion of so-called energy conservation, as Japan experienced after the first oil shock, basically requires the assurance that energy is relatively more expensive than energy-using equipment and that energy-efficient equipment is technically feasible and provided at a price affordable enough to allow for diffusion. The question is whether it is possible to build an economic system that allows for this and whether investment can be increased (induced) without compromising the overall performance of the economy. Given the high proportion of electrification in future demand sectors, progress in power semiconductors, batteries and capacitors will be crucial. In developing countries, energy saving in industrial equipment and household appliances is also expected to play an extremely important role.

d) Moves in these directions would, as a matter of course, require sweeping reforms in urban planning, for cities, factories, schools, housing, shops, hospitals and road networks, as well as the corresponding infrastructure for the distribution of water, food, energy and information. We will not discuss this in detail here, but it is considered to be an extremely important factor. However, it is important to note that, particularly in the consumer sector, there will naturally be an increasing number of lifestyle changes. Nevertheless, it will also be imperative to respect indigenous cultures (e.g. food, calendars, etc.) and religions (e.g. various events, etc.). The challenge will be to incorporate this diversity into the infrastructure for energy supply and use of the future.

4.5.3. How should energy policy and energy distribution structures be changed?

In light of discussion in 4.5.1 and 4.5.2, the following points on global energy policy and energy distribution structures may be important.

a) The following principles should be shared internationally and nationally for environmental and energy policies.
   1 To make "minimisation of CO2 emissions" and "achieving energy sufficiency", in terms of both supply and consumption of energy, the objective variables of policy, alongside "ensuring stable supply" and "not restricting economic activity".
   2 In order to achieve carbon neutrality globally “not long after 2050”, each country’s state of progress on carbon neutrality should be assessed by maintaining the current Paris Agreement's system of periodic pledges and expert reviews of the targets set by each signatory nation on reduction and control of emissions. This should be further developed to create a mechanism to promote policy collaboration between countries. (The current Paris Agreement uses a "pledge and review" approach, which should be further developed into a "pledge, review and coordination" approach.)
   3 The creation of a global coordination and cooperation mechanism to achieve energy sufficiency targets, especially in developing/emerging countries. (For instance,

incentives (e.g. priority or preferential treatment in carbon neutral investments in said developing/emerging countries) could be provided to companies or governments that cooperate to improve access to energy for the poor while restricting CO_2 emissions (emission intensity (p)) in developing/emerging countries within certain limits).

4 Even if efforts are made to the maximum extent possible, it will be extremely difficult to achieve the carbon-neutral target. Thus, consideration should be given to ensuring absorption by forests, oceans and coral reefs, and to research and development to enhance the amount of absorption. It is also necessary to devise an international agreement to count the clear improvements achieved in absorption as reductions in CO_2 emissions.

b) With regard to energy distribution systems, the following points may be important.

1 In order for hydrogen and ammonia to become widely-used fuels of the future, a price formation mechanism for hydrogen and ammonia and a mechanism to promote investment in hydrogen and ammonia infrastructure should be established. Also, the form of infrastructure, distribution mechanisms, and price formation mechanisms, as well as the usability of existing infrastructure and necessary renovation costs would differ for blue hydrogen, which is suitable for large-scale production in coal and gas fields and is treated as an internationally traded good, and green hydrogen, which is produced using renewable energy (electricity) and is often treated as a locally-produced and locally-consumed good. As such, it is necessary to create investment promotion measures that are adapted to each of them.

2 The construction of decentralised infrastructure, mainly in areas with low population density and small cities, as well as the construction of distribution infrastructure that spans multiple countries. Specifically, this includes (superconducting) power grids (including storage batteries and pumped-storage power plants), and hydrogen pipelines (mainly liquid organic hydrogen or ammonia, from the viewpoint of transport efficiency, since the density of gas is low). In addition to the development of such hard infrastructure, international trading rules for electricity, hydrogen and ammonia should also be established.

3 Establishment of an international mechanism to accurately and to the utmost in real time ascertain and analyse the “global CO_2 balance” (both emissions and sinks) and to share this information.

4.5.4. "CO_2 fixation"

Even if the various measures mentioned in sections 4.5.1 to 4.5.3 are promoted, achieving carbon neutrality globally “not long after 2050" is an extremely challenging task. CO_2 fixation could therefore be a very important technological challenge. While the preservation, management and regeneration of tropical rainforests and large-scale algal breeding areas and coral reefs is discussed in 4.5., a discussion of CCS/CCUS follows.

At present, the only business model for CCS/CCUS seems to be enhanced oil recovery (EOR) based on re-injection into reservoirs to increase oil sales, so a new business model is essential. If carbon pricing is implemented in some way, there is great potential for new business models to emerge, but at the same time, the system needs to be designed so that carbon pricing does not become a disruptive factor in the global energy market. In addition, the geological location of CCS is a major constraint (large back-slope structure and impermeable caprock are necessary), and therefore, from an international perspective, it is necessary to study the technical issues for the coordinated use of CCS/CCUS facilities in multiple countries, as well as the price formation mechanism and stable trading rules for CO_2 burial and commissioning. It is also considered necessary to establish a CO_2 trading market with a mechanism and stable trading rules. In addition, it will be necessary to establish rules for trading of CCS/CCUS use rights and trading of credits for CO2 burial (this also applies to absorption by tropical rainforests, large algal blooms and coral reefs).

4.5.5. The overall engineering challenge

While individual challenges are presented above, the combination of these elements presents the following critical issues (challenges) for engineering that we will face in the creation of a truly sustainable society.

1) In order to achieve carbon neutrality, it is necessary to create compound infrastructure based on a variety of technologies, taking into account not only energy supply, demand and distribution, but also water, transportation, urban planning, ICT, and waste management. In addition, since the optimal scale for each of these differs, the question of “how to create the optimal solution for social infrastructure that is complex superimposed infrastructure of various types and different sizes and with different time scales in technological development” cannot be answered by the "aggregation of individual optimal solutions" as has been done in the past. Therefore, it is necessary for engineering to take on a leadership role and present pathways to form an appropriate consensus in cooperation with policy authorities, industry and citizens.

2) There is a critical shortage of human resources in Japan's current academic and research institutions that are needed to achieve these goals. It is therefore important to fundamentally strengthen research in these fields at universities and public research institutions, both qualitatively and quantitatively. For example, the establishment of graduate level education and research institutions to study this field could be one way of doing this. For this purpose, and from the perspective of contributing to both Japan and the rest of the world, social institutions should be adjusted so that a large number of outstanding young people, especially from developing/emerging countries, are brought into Japan and can play an active role in the country even after graduation. It may be necessary to teach science and engineering subjects at the university undergraduate level completely in English.

3) In addition, given that the biggest barriers to the social implementation of new technologies in the energy sector are "scaling up" and "cost", it is essential to have a system that allows not only so-called lab-based R&D, but also the expansion of technologies on discontinuous scales - bench scale, pilot scale and real plants. Likewise, it goes without saying that it is essential to have policies to reduce risks. In this regard, input from engineering should be provided.

   (Note) Naturally, the closer we get to the social implementation phase, the more the cost components will vary greatly according to country, location and market conditions. For example, in the case of photovoltaic power, the price of solar cells has fallen significantly in the last 30 years, and related peripheral equipment has also become cheaper in the last decade or so. Thus, the two biggest factors in the spread of the technology in Japan are land prices and the FIT (Feed-in Tariff) purchase price (long-term predictability of the price).

4) In addition, considering that Japan's problem for the past 20 years has been that "the technology exists, but investment has not progressed", it is important to establish a financial mechanism to promote investment in the social implementation of new technologies in these fields in line with the rest of the world. In addition, we must consider

incentives such as the application of FIT to power generation using alternatives to existing fossil fuels, such as green hydrogen, biomass fuels, and synthetic methane from methanation, as a way to induce private investment. Engineering input should also be provided in the design of such a system.

5) Furthermore, the major responsibility of the engineering community is to evaluate the technology readiness and appropriateness for investment without uneven distribution among each specialised field considering the various technological options that have been proposed toward achieving carbon neutrality, with many options still expected to be developed in the future, and to present these to the society both internationally and domestically. In particular, it should be noted that guidance for appropriate future investment will not be possible without clarification of such issues as scalability, the potential for diffusion in terms of cost, other location constraints, the social institutions required for diffusion and the burden on society that this will bring. It will be important for experts to discuss these issues at the aforementioned FICNES and to present certain views.

4.6. Supplementary note: treatment of nuclear energy

The treatment of nuclear energy is controversial both domestically and internationally. The main point of contention is safety. The Engineering Academy of Japan has opted to discuss and mention nuclear energy in this report according to the following policy.

[Policy 1] It is a fact that nuclear power is an energy source with extremely low CO_2 emissions throughout its value chain. Apart from the pros and cons, it is appropriate for the Engineering Academy of Japan to engage neutrally in discussion from the perspective of presenting options for the future from the standpoint of engineers.

[Policy 2] In particular, measures proposed by national governments and institutions such as the IEA towards achieving carbon neutrality are dependent on the development of various technologies that have not yet been implemented in society on a sufficient scale and at an economically acceptable level, such as the use of hydrogen as a fuel, the use of CCS/CCUS technology for the treatment and use of CO_2, and the use of high-performance batteries to expand the capacity of the power grid. As such, it is not appropriate to narrow down the options.

[Policy 3] In addition, we are not in a position to simply promote the resumption of operation of existing nuclear power plants or the construction of new nuclear power plants based on the current state of nuclear technology. In order to operate nuclear power safely (especially in a country like Japan, where the risk of natural disasters such as earthquakes and tsunamis is high), new technologies that have not yet materialised are necessary, as is the development of technologies for the disposal of spent nuclear fuel and decommissioning (These technologies will be necessary even if nuclear power is not used in the future.). The development and commercialisation of these technologies will require measures to promote them on a national scale.

[Policy 4] The choice of nuclear energy as an option for future energy supply should also be a decision for future generations of citizens and policymakers to make in the context of international cooperation.

4.7. "Policy Framework Roadmap" and "Technology Roadmap"

Two types of roadmaps will be prepared for 1) achieving carbon neutrality on a global basis, including both developed countries and developing and emerging countries, "not long after 2050", and 2) energy sufficiency in all regions of the world "as soon as possible before 2050", according to the following policies. First, since the readiness of individual technologies is not yet clear, as mentioned above, we are not yet at the stage of narrowing down technology options. Therefore, a "Policy Framework Roadmap" including four elements, namely "Policy and International Cooperation", "Human Resources Development", "Technology Assessment Systems" and "Investment Guidance Schemes", will be developed. In addition, the "Technology Roadmap" will be developed to indicate the timescales and the broad direction of the issues.

4.7.1. "Policy Framework Roadmap"

The four elements to be incorporated in the Policy Framework Roadmap are as follows.

1) Firstly, in terms of policy and international cooperation, the aforementioned Forum for International Carbon Neutrality and Energy Sufficiency (FICNES) needs to be established by the early 2020s to discuss not only energy and environmental policies, but also industrial, agricultural, food, urban, transportation and technological policies. At the same time, it is necessary for Japan to begin policy dialogue and implementation of cooperation and investment inducement measures with the "particularly important target nations for cooperation" (India, Nigeria, Pakistan, Indonesia, Egypt, Philippines and Vietnam), and the "important target nations for cooperation" (Ethiopia, Democratic Republic of Congo, Bangladesh, Tanzania and Kenya) from the perspective of pursuing simultaneous realisation of carbon neutrality and energy sufficiency.
2) Secondly, in terms of human resource development, current human resource development measures, such as the ABE Initiative, should be fundamentally strengthened, and about 30,000 human resources in science and technology innovation should be welcomed from developing countries and emerging countries every year. Support must be provided for their research activities at graduate schools and national research and development institutes, as well as for any subsequent entrepreneurial and social activities. Naturally, it is also necessary to strengthen support for young Japanese researchers and entrepreneurs in a broad range of fields concerned with carbon neutrality. To facilitate the stable development of such human resources, the establishment of education and research at the postgraduate level, the creation of funds by the public and private sectors, and the development of residential facilities around the country are also important issues.
3) Thirdly, in terms of a system for evaluating technology, a forum for evaluating technology readiness should be formed within FICNES. Within this forum, the maturity of various technologies for achieving carbon neutrality would be assessed based on data from papers, patents, press releases, etc., and this information would be disseminated and shared with the world. This forum would be significant for attracting private investment on an appropriate scale and in an appropriate direction. The forum should also be launched at the same time as the establishment of FICNES in the early 2020s.
4) Fourthly, with regard to an investment inducement scheme, alongside the above-mentioned system for evaluating technology, a mechanism should be established to share information on availability of various public and private funds and information on the marginal cost of CO_2 emission reduction by each technology. In this case, it is likely that information would be focused only on pre-competitive stages due to the relationship with anti-trust laws. But, it should be recognised that in some cases it may be necessary to consider including international treaties and legislative measures within each country.

These are summarised in the roadmap shown in Figure 4.7.1.

Year	2021-2030	2031-2040	2041-2050	2051 + beyond
Carbon Neutrality	2030 **China Emission Peak**		2050 **EU/JPN/US Net Zero Carbon**	2060 **China/Russia Net Zero Carbon** 2070 **India Net Zero Carbon**
Energy Sufficiency	2030 **SDG #7 Target Yr**		- Realize genuine energy sufficiency for all	
Policy + International Cooperation	- Establish FICNES* for comprehensive policy planning	- Implement policies based on advices from FICNES - Strengthen coop for developing/emerging countries	- Strengthen coop for developing/emerging countries, especially for LLDC	
Human Resource Development	- Establish a new graduate school for young scientists and engineers worldwide	- Encourage young scientists and engineers to work for global C/N and E/S (by mobilizing funds)		- Expand network of partners to work for further penetration of new tech paradigm
Technology Evaluation System	- Establish tech expert team in FICNES - Issue "Annual Tech Readiness Report"	- Establish optimization methodology for dynamically-changing multilateral infrastructures	- Disseminate the optimization method globally	
Investment Promotion Scheme	- Establish financial expert team in FICNES - Issue "Annual Investment Appropriateness Report"	- Establish new investment promotion mechanism - Make use of the new mechanism	- Disseminate the new mechanism for scale-up of investment	

*FICNES: Forum for International Carbon Neutrality and Energy Sufficiency (Tentative)

Figure 4.7.1 Global Carbon Neutral/Energy Sufficiency "Policy Framework Roadmap"

4.7.2. "Technology Roadmap”

The "Technology Roadmap" that can be presented at this time is shown in Figure 4.7.2, organised into the four areas of "energy supply", "energy consumption", "energy distribution", and "CO2 fixation". Essentially, the technology roadmap should be created considering the current level of technology and future trends, matching the technologies that will likely be needed at certain points to achieve certain targets and the R&D elements that will be required to bring the technology from its current level to the future. From this point of view, what is shown in Figure 4.7.2 is still an insufficient technology roadmap. It will be necessary to periodically update this roadmap to be realistic and achieve carbon neutrality and energy efficiency, through the aforementioned FICNES forum and by bringing together the wisdom of those involved in industry, academia and government. In addition, it should be noted that the Policy Framework Roadmap and Technology Roadmap should always be discussed as a "pair" going forward.

The International Technology Roadmap for Semiconductors (ITRS) can be referred to as an example of how to clarify priority areas for investment of human and financial resources. It will be important to identify (1) areas expected to be feasible if left up to the market, (2) areas expected to be feasible based on joint initiatives between companies and research institutes and private funding, and (3) areas that require large-scale investments and a major framework for cooperation by governments and international organisations.

(Note) In the ITRS, the required specifications of semiconductor technology (mainly the technical issues associated with the miniaturisation of Si-CMOS semiconductors) at the time of formulation and up to 15 years later were clearly indicated. They were divided by color, with white (no colour) = "a manufacturable solution exists that is being optimised", yellow = "a manufacturable solution is known", and "red" = "there are no known manufacturable solutions”. The "red" was called the "red brick wall" to attract the interest of leading researchers at universities, as well as to attract government funding.

It should be pointed out that both "top-down" and "bottom-up" approaches are crucial to the issues of carbon neutrality and energy sufficiency. Setting big "top-down" goals and principles are indeed indispensable to achieving carbon neutrality, which entails major social reforms. However, if the concrete methods, such as technology and investment, required to realise the big goals and principles are unrealistic, then there is a risk that sceptical forces will try to render them ineffectual. From the point of view of engineers, a two-way approach is essential, keeping in mind the major goals and principles, while at the same time promoting a "bottom-up" discussion on how to move the world towards them while confirming that they are indeed realistic.

Year		2021-2030	2031-2040	2041-2050	2051+beyond
Global Carbon Emission Reduction	Developed	Decrease	Further decrease	**Net Zero 2050**	**Negative emission**
	China	**Peak-out 2030**	Decrease	Further decrease	**Net Zero 2060**
	India				**Net Zero 2070**
	Developing/Emerging				
Energy Supply	Renewable Energies + Grid + Storage	Concurrent cycle of R&D/Scale-up & Cost-reduction/Deployment with incentives/Fully-commercialized deployment (Developed countries ~ Middle Income countries ~ Lower Income countries)			
	Fuel Conversion to H2/NH3				
	Nuclear	R&D for safer reactor	R&D + Demonstration	Deployment (p)	Further Deployment (p)
Energy Demand	Alternatives for Carbon-intensive Process	R&D	Scale-up & Cost-reduction + Deployment by early adopter	Continued Scale-up/Cost-redc + Deployment by followers	Continued dissemination
	Mobility	R&D + Deployment	Continued R&D + Enhanced deployment	Continued replacement of old technologies	Continued dissemination
	Energy Conservation				
	City & Social Infrastructures	R&D + Design + Demonstration		Reconstruction of city	Continued reconstruction
Energy Distribution and Trade	Electricity Distribution	Concurrent cycle of R&D/Scale-up & Cost-reduction/Deployment with incentives/Fully-commercialized deployment			
	Fuel Distribution				
	Networking Distribution Infrastructures	R&D + Design + Demonstration	Regional Deployment	Trans-national Deployment	Trans-continental Deployment
Carbon Fixation	CCS & CCUS	R&D + Location Survey	Scale-up & Cost-reduction + Deployment	Large scale deployment	Continued deployment
	Forestation and Coral/ algae Absorption				

Figure 4.7.2 Global Carbon Neutral/Energy Sufficiency " Technology Roadmap "

4.8. Towards realisation of a "Energy = Food = Water" NEXUS

The relationships between energy, food and water have synergies and trade-offs, making it essential to add in the elements of economy & industry and environment to consider all five elements together. Accordingly, the following diagram has been set up as a model for consideration. For all five elements, there are ten different relationships existing between elements, as shown below.

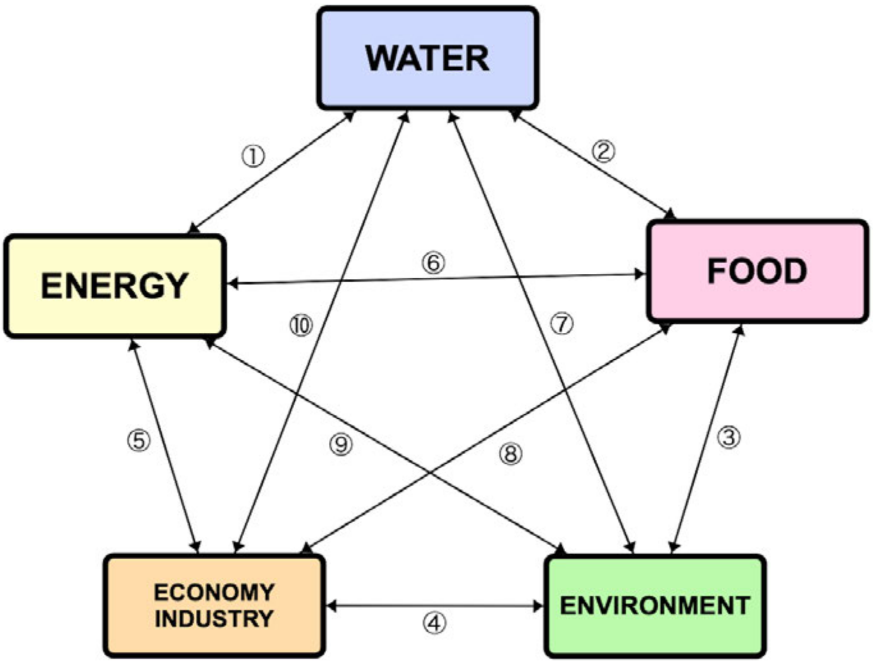

Figure 4.8.1 Pentagonal relationship diagram including ‘Economy & Industry’ and ‘Environment’ in addition to ‘Energy’, ‘Food’, ‘Water’

Representative examples of the ten relationships shown in the above diagram are as follows.

1) Thermal power generation requires water (steam) to drive turbines, and desalination and transport also require energy.
2) A large amount of water is required for grain cultivation, making trade in agricultural products indirectly equivalent to trade in water.
3) Environmental protection of farmland is necessary for food supply, and the unplanned cultivation of agricultural land and excessive use of agricultural chemicals leads to environmental degradation.
4) The risk of environmental pollution increases with economic development, but the primacy of environmental protection retards economic activity.
5) A stable energy supply promotes economic activity, but economic development further increases the demand for energy.
6) Energy is needed to grow and transport food, while biofuel crops lead to energy production.
7) A good environment allows for a continuous and stable supply of water, but a good environment can also be maintained by the proper treatment of waste water.
8) A stable food supply promotes economic activity, and economic development amplifies the demand for and distribution amount of food.
9) Burning of fossil fuels leads to global warming, while environmental pollution makes it socially difficult to secure underground resources.

10) Plentiful industrial water promotes economic development, but economic development increases the demand for and distribution amount of water.

It will also be necessary to develop numerical models for quantitative analysis of the synergies and trade-offs between elements in the future. As a starting point, snapshot evaluations of the current situation for each of the five elements are shown in Figure 4.8.2 and Figure 4.8.3. Figure 4.8.2 was created to assess the sufficiency of energy, water, food, economy & industry and environment for individuals, while Figure 4.8.3 was created to assess them on a national basis. Naturally, the more balanced the pentagon is and the larger its area, the more desirable the situation is for both the individual and the country. Going forward, the dynamic situations of these elements must be analysed to further optimise them. The static assessments for water and food that have emerged from the study so far are as follows.

First for water, according to Oki and Kanae (2006), on a macro level, a sufficient supply of water is available, even after taking into account population growth and economic development in the 21st century. However, based on Oki’s (2012) assertions that available fresh water resources are unevenly distributed in space and time, and that water infrastructure is not in place to transport water over long distances from water-rich to poor areas or to store water during relatively abundant seasons for use during dry seasons, there will be countries without sufficient water according to region and seasons. The world's population grew by five billion people from about 2.5 billion in the 70 years between the mid-20th century (1950) and the present, and it will grow at most by another four billion people over the next 80 years to reach the predicted population size of about nine to eleven billion by the end of the century. Thus, the macro increase in water demand will be "slower" than in the past. The water challenge, then, is not so much a quantitative issue, rather is contingent on whether investments can be made to facilitate the development, maintenance and operation of regional water storage and conveyance infrastructure (which could be a challenge not only for developing countries but also for more mature and developed countries with declining populations). On the qualitative side, it comes down to whether it is possible to improve social systems to provide water that is safe from the perspectives of sanitation and environment.

In terms of food, FAO estimated that in 2019, 690 million people around the world (about 8.9% of the world's population) would be undernourished due to conflicts and increased droughts and floods caused by climate change, as well as the negative impacts of economic downturn on the poor. In Africa, about 250 million people, or 19.1% of the population, are estimated to be in a state of starvation. FAO predicted in 2012 that the number of undernourished people averaging less than 2,000 kcal per day would be completely eliminated by 2030, as low-income countries were expected to experience rapid economic development. Meanwhile, concerns have grown over impacts on agricultural production of worsening regional conflicts and increasing natural disasters due to climate change. A report published by FAO in 2020 predicted that more than 800 million people will still be undernourished in 2030. Thus, when looking at food supply, it is not always possible to talk only about the quantitative aspects from a macro perspective, as there are significant impacts due to economies at the local level, agricultural land, climate and natural environment, and the adaptability of technology. Moreover, on the demand side, in addition to cultural traditions rooted in the region, it is necessary to take into account changes related to food culture, such as changes in lifestyles, health maintenance and the promotion of environmentally friendly diets.

The following is an example of the interrelationship between water and food. According to Oki et al. (2017), it is estimated that about 70% of the world's water intake and about 90% of water consumption is for agricultural use. Because the unit cost of water is low, rather than transporting water for agricultural production, production takes place where water is available and agricultural products are transported in highly active “virtual water trade”. Water is used in large quantities to grow cereals, and cereals are used in large quantities to produce meat. Meat production is also environmentally damaging in other ways, which is why the European EAT-Lancet Commission has called for a halving of meat and sugar consumption and a doubling of vegetable, fruit, nut and legume consumption in a bid to reform sustainable food production and healthy diets.

In this case, if the water consumption for meat production (in the form of cereal production) could be reduced from the point of view of sustainability, the water availability in the said area would increase. On the other hand, the decline in the meat production industry would require an alternative industry to ensure the income of the people. In the simplest case, land could be reallocated from cereal and meat production to the cultivation of vegetables, fruit, nuts and legumes, but in practice a number of factors would need to be considered.

Figure 4.8.2 and Figure 4.8.3 show the pentagonal relationships for individual and national assessments, based on currently available data. Roughly speaking, the closer the individual ratings are to a large equilateral pentagon, the more balanced and abundant the situation. Further research is needed on elaboration of the index and the assessment approach.

Pentagonal presentation of NEXUS (Individual profile)

Factor	Indicator	Unit	Source	Final source	Details
ENERGY	Total energy supply (TES)/population	TES per capita	IEA2018		Total energy supply (TES) is the total amount of primary energy supplied, and it indicates how much primary energy is supplied for economic and living activities within a country. Total energy supply= (primary energy produced) + (primary energy imported)- (primary energy exported)- (international maritime bunkers)- (international aviation bunkers) ± (stock changes)
WATER	Total renewable water resources per capita	m³/year per capita	Global Note	FAO	Total renewable water resources=internal water resources+external water resources ・Internal water resources: Surface water and groundwater generated within a country through rain ・External water resources: Part of a country's renewable water resources that has been generated in a given year in upstream countries (surface water and groundwater)
FOOD	Average daily dietary energy consumption per capita	kcal	Honkawa Data Tribune	FAO	Daily food supply per capita in terms of calories. Global average: 2,790 kcal; Average for developing nations: 2,120 kcal; Average for industrialized countries: 3,430 kcal
ECONOMY	Real GDP per capita	US$	Global Note	IMF2019	Gross Domestic Product (GDP): Measure of a country's wealth and living standards
ENVIRONMENT	Environmental Performance Index (EPI)	pts	Global Note	YCELP	The Environmental Performance Index (EPI) is an environmental index developed through joint research between Yale University and Columbia University. In addition to the quality of each country's environment, it reflects their environmental improvement efforts, environmental policy implementation outcomes and other factors. Assessments are made from the perspectives of environmental health and ecosystem vitality on a scale of 0 to 100 points to determine the index. (Factors considered: Environmental health; air quality; water resource management; biodiversity; agriculture, forestry and fisheries; climate change, etc.)

Figure 4.8.2 Pentagonal relationship diagrams by country on individual sufficiency of 'Energy', 'Food', 'Water', 'Economy & Industry' and 'Environment'

Pentagonal presentation of NEXUS (Country profile)

Factor	Indicator	Unit	Source	Final source	説明
ENERGY	Overall energy self-sufficiency	%	IEA2018		Overall energy self-sufficiency is the percentage of the primary energy required for a country's living and economic activities that can be met by domestic energy production in a given year. It tends to be higher for countries rich in natural resources and lower if they are poor in natural resources, even for industrialized countries. Overall energy self-sufficiency (%) =energy produced domestically/primary energy supplied x 100
WATER	Total renewable water resources	km³/year	Global note	FAO	Total renewable water resources=internal water resources + external water resources ・Internal water resources: Surface water and groundwater generated within a country through rain ・External water resources: Part of a country's renewable water resources that has been generated in upstream countries (surface water and groundwater)
FOOD	Grain self-sufficiency rate	%	Ministry of Agriculture, Forestry and Fisheries, 2020	FAO	Self-sufficiency of all grains including animal feed. The weight-based percentage of the domestic consumption of grains (rice, wheat, barley, naked barley, corn, etc. including that for animal feed) that is met by domestic production. This indicator is the most widely used around the world.
ECONOMY	Real GDP/per capita	US$	Global Note	IMF2019	Gross Domestic Product (GDP) per capita ：measure of a country's wealth and living standards
ENVIRONMENT	Environmental Performance Index (EPI)	pts	Global Note	YCELP	The Environmental Performance Index (EPI) is an environmental index developed through joint research between Yale University and Columbia University. In addition to the quality of each country's environment, it reflects their environmental improvement efforts, environmental policy implementation outcomes and other factors. Assessments are made from the perspectives of environmental health and ecosystem vitality on a scale of 0 to 100 points to determine the index. (Factors considered: Environmental health; air quality; water resource management; biodiversity; agriculture, forestry, and fisheries; climate change, etc.)

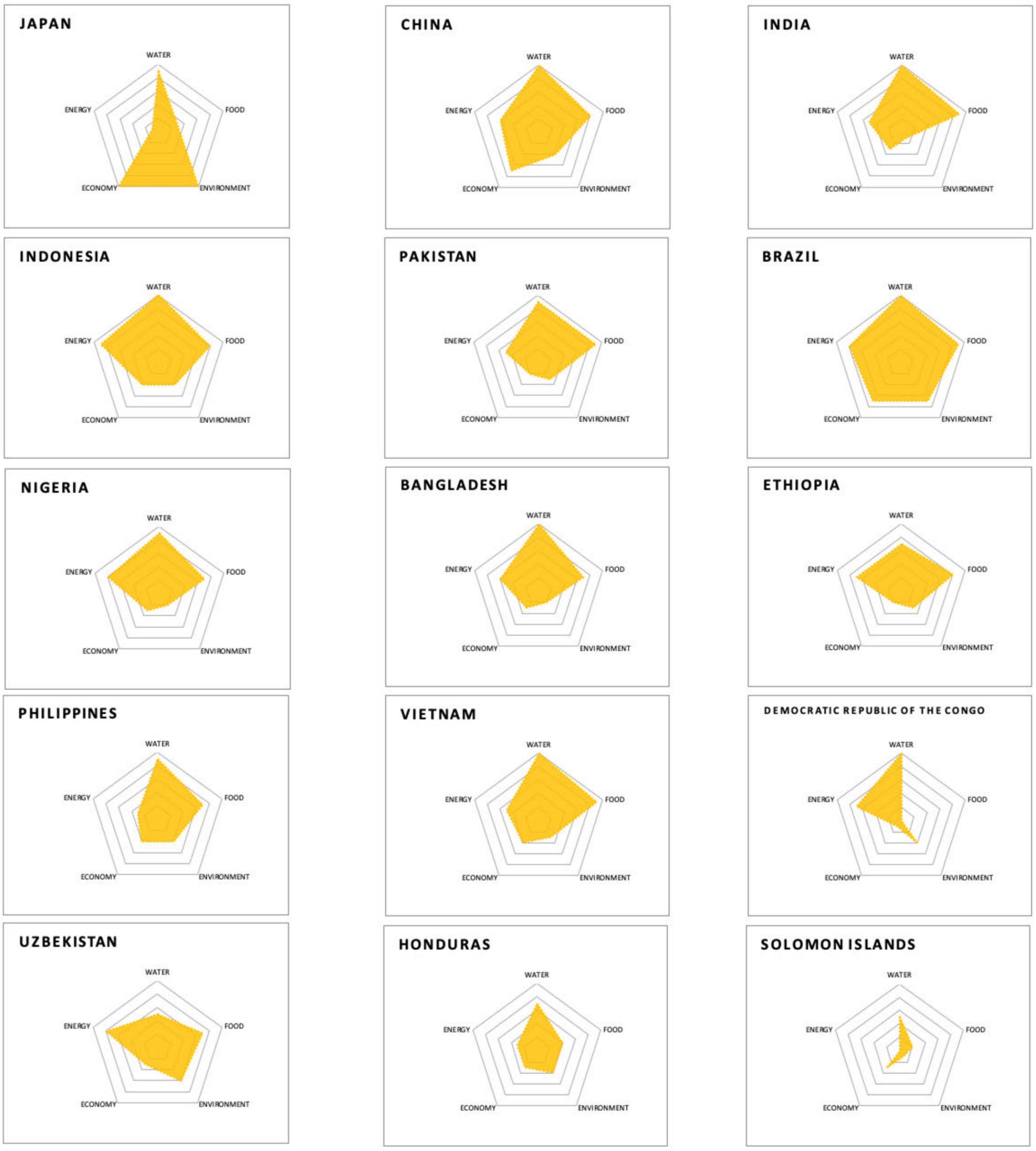

Figure 4.8.3 Pentagonal relationship diagrams of country-based sufficiency of 'Energy', 'Food', 'Water', 'Economy & Industry' and 'Environment'

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[4.5.1] NEDO website, “Development of Environmental Technology for Steelmaking Process”, (https://www.nedo.go.jp/english/activities/activities_ZZJP_100050.html)

5. Smart cities for comfortable and resilient human settlements

5.1. Introduction: Cities are key to achieving well-being through STI

Our solar system came into being 4.6 billion years ago, and life on Earth began 3.8 billion years ago. Later, photosynthesis by cyanobacterium spread throughout the shallow seas on the Earth's surface brought oxygen to the atmosphere, and about 500 million years ago, during the Cambrian period, a diverse range of species (mostly Animalia) emerged. The Earth enjoyed the high energy and low entropy photons from the hot solar surface, emitting low energy and high entropy photons into the cold universe. Organisms have survived in the form of separate heat engines linked to this larger heat engine. Evolution led to mammals, and eventually to humans, who came into being five to seven million years ago. Human history spans an extremely short period of time, just 0.001% of the total history of life. However, the present human species reigns supreme over all species on the planet in terms of total weight, dominates a tremendous number of domestic animals, and has forced the diversity of the natural world into an abnormal situation. At the same time, human activity is concentrated in cities, and human artefacts are destroying not only urban areas but also natural ecosystems such as rainforests and boreal forests. This is considered to be the main cause of global warming and pandemics.

The urbanisation rate was 13% in 1900 (urban population of 220 million), then 29% in 1950 (732 million). It exceeded 50% in 2007, and is expected to reach 60% (4.9 billion) by 2030 (WUP2018). Therefore, the future planning of the cities where populations are concentrated is key to preserving the entire global ecosystem for the foreseeable future. For example, a myriad of organisms symbiotically coexist in the topsoil of countries like Japan that are located in temperate zones, but the mechanisms are not yet fully understood. How to deal with the unresolved aspects of science will also be a critical issue for the future of science.

Design and planning of optimal cities with the limited scientific and technological resources of humankind is both a realistic and unavoidable challenge.

<Note 1> STI: Science, Technology and Innovation
In Japan, the term STI was used in the Fourth Science and Technology Basic Policy (2011) as an abbreviation for Science, Technology and Innovation; the OECD has a Directorate of Science, Technology and Innovation, and the term has been used frequently since the 2000s.

<Note 2> Well-being
Well-being refers to "sustainable, multifaceted happiness". Happiness, on the other hand, generally refers to “single, short-lived, momentary happiness”. The Japanese word for happiness may include both meanings, but traditionally, when used in the fields of medicine, health and welfare, it usually refers to well-being. The right to the pursuit of happiness, enshrined in the Japanese Constitution, comes from the French Revolution and the US Declaration of Independence (Life, Liberty and the Pursuit of Happiness), and is still much debated.

5.1.1. Human Security and Well-Being

When the Cold War’s wall between East and West collapsed in 1989, the concept of common security led to the concept of "human security". 1991 saw the establishment of the Common Security Forum (CSF) <Note 3>, which contributed to the 1993 Oslo Accords (a settlement between Palestine and Israel). Then in the 2000s, Japan participated in the CSF as an activity of the United Nations. Meanwhile, welfare states, which advanced particularly in Northern Europe in the 1980s, ensured medical care and security for the aged, but at the same time the need for purpose in life emerged.

Security and safety alone do not necessarily equate to happiness. When the goal of well-being is juxtaposed with security, we get the phrase "human security and well-being", an expression now used frequently by the Engineering Academy of Japan (EAJ). This phrase better encapsulates the concept of a better life, rather than mere happiness [5.1.1)].

<Note 3> The Common Security Forum (CSF) is a coalition of about ten organisations, including FAFO (Norway), led by the Centre for History and Economics (Director: E. Rothschild) at the University of Cambridge in the UK. Its UN-related activities since 2000 have been led by Emma Rothschild, Amartya Sen, Sadako Ogata and others.

5.1.2. Why are cities the key to well-being through STI?

More than half the weight of the atmosphere is within six kilometres of the Earth's surface and is oxygenated by living organisms. Thus, the Earth's biosphere is like a thin film attached to the Earth's surface. Within this thin film, the only way to make the whole ecosystem sustainable is to make changes to the human way of life that is currently hindering the diversification of life as a whole. Science, technology and innovation pointed in the right direction and based on ethics are inevitably required to preserve the global biosphere, where diversity is vital based on equal human rights.

In addition, by maximising the efficiency of human lifestyles concentrated in certain areas through urbanisation, from the perspective of energy and entropy <Note 4>, the upper limit of the number of people who can live equally (environmental carrying capacity) is determined. As energy is also equivalent to the mass of matter, energy is needed to reduce entropy. The control of entropy also involves information. This implies that ecosystems, encompassing humanity, should be understood as a world of interwoven matter and information. Particularly in today's world of increasing material limitations, STI should be utilised with a focus on information. The numerous sprouts of innovation can grow to substantially contribute to well-being if they are rooted in ethics.

<Note 4> The first and second laws of thermodynamics. Energy is consumed when information is erased.

5.1.3. The new urban structure

We are entering an era in which we must closely examine the multilayered structure of material and information in urban planning for the future. The transformation of physical space, with its long history and the constraints of the surrounding environment as seen in actual cities and towns, is subject to many limitations. On the other hand, as part of the rapid development of DX <Note 5>, there is a new trend towards the development of cities with an added layer of information space on top of the real city. In this sense, the "Multi-AI Networked City" described in 5.2 of this report (Figures 5.2.5 and 5.2.6) is a realistic proposal [5.1.2)]. Many concepts have been discussed in the history of city planning <Note 6>, but the idea by Mr. Sugiyama of this committee offers a new perspective on harmonising human artifacts and nature in the context of advanced information technology <Note 7>.

<Note 5> DX (Digital Transformation) generally refers the way in which physical space and information space have become overlapping and structured entities in multi-dimensional space due to the rapid development of digital devices and systems (ITC/OT,

AI, IoT, etc.). Stolterman et al., *Information Technology and the Good Life* (2004). In Information Systems Research, pp 687-692.)

<Note 6> Garden Cities (E. Howard), Ville radieuse (Le Corbusier), Metabolism City (Kisho Kurokawa) and others.

<Note 7> AI (Artificial Intelligence) is a concept that originated with Alan Turing and emerged at a conference at Dartmouth College in 1956. The concepts of digital and analogue are important to note when dealing with “information”. As in ancient atomic theory and the Chinese classic Book of Changes, digital and analogue are ways of seeing things from microscopic and macroscopic perspectives. From a microscopic point of view, the human being is a digital system whose nervous system, which transmits and controls information, is based on the threshold of inter-neuron communication. When we see things as particles, the so-called “bit” is the elemental unit, but when we see things as waves, essential differences appear as qubits.

5.1.4. What should people living in cities pass on from generation to generation?

If both civilisation and culture are not passed on from generation to generation, the highest level of empathy (Sympathy at the top of the empathy hierarchy), which is essential for the organisation and maintenance of society, cannot be handed down. Civilisation is passed on through language and skills, but without high-level empathy, which our culture depends on, human society can neither be formed or maintained.

Here, the issue of the "language" (symbols) acquired by modern human species gives rise to a profoundly important challenge. The human brain, like that of other animals, has evolved around physicality. Whether or not the hierarchical structure of the language of modern humans existed in Neanderthals (who died out tens of thousands of years ago) is now being studied from genetic analysis of bone marrow fossils.

Language has brought a high degree of sociality to modern humans, but its power is also giving rise to many of the challenges of our time. This is because language has given modern humans the ability to think about the future. In other words, it has not just given us the simple future, but also the intentional future. Language has also created an afterlife. Civilisation has prospered due to language, but the importance of culture that is not easily expressed through language has emerged, particularly in recent times. Culture must be passed on from generation to generation. This includes, for example, the arts, a category which cannot be easily expressed in language, and which is difficult to pass on through intellectual education alone. This is one of the challenges of the new type of city.

5.1.5. How will pandemics change cities and the people who live in them?

The mechanisms of zoonotic diseases are closely linked to natural ecosystems. The novel coronavirus SARS-CoV-2 is likely to have been transmitted from bat species to humans. The same is true for SARS. The Ebola virus was also transmitted from the faeces of a species of bat to non-human primates, and then to humans. Likewise, the topsoil of tundra, which is now melting, is alive with tremendous numbers of viruses and bacteria. There are also countless microorganisms living in a state of equilibrium in tropical and temperate topsoils. It is a must that we realise that the equilibrium of the natural world, which science does not yet fully understand, is falling apart. With the proximity of human and wildlife populations and the increasing frequency of cross-border movements, zoonotic diseases are likely to increase. In the context of the development of civilisations, pandemics can be an opportunity to restore human humility and a strong sense of empathy. As seen in the SDGs, it is important to remember the essence of human existence and to look at the trunk, not the branches.

There is an urgent need to create cities that are resilient to new pandemics, including COVID-19. In order to prevent and quell infection explosions, measures are needed in the context of the relations between "freedom and constraint" that guarantee a better quality of life (human security and well-being).

For subclinical infections, including COVID-19, visualisation of infections is crucial. As shown in Figure 5.1.1, sewage is structurally suitable for quantitative monitoring of virus distribution in a fractal structure from individual elements of houses and facilities to the whole city <Note 8>. It could be a scientific indicator to determine lockdowns, and is likely to be necessary for urban design in the future.

<Note 8> In the case of COVID-19, for example, the SARS-CoV-2 virus is eliminated in the faeces of infected people from an early stage of infection (not directly linked to infectious capacity). Thus, the virus and its fragments attached to the surface of sewer-solids sediment following initial treatment can be used to test sewage and ascertain the state of infections, thereby visualising affected areas and enabling efficient PCR testing of the residents [5.1.3), 5.1.4)].

5.1.6. The ethics of cities

The most important aspect of cities is the coexistence of the self and others. The importance of ethics emerges from the need to be considerate of others in order to maintain a sustainable society. The highly informatised and optimised city will require a comprehensive approach to becoming an "ethical city", which is likely to increasingly be an issue going forward.

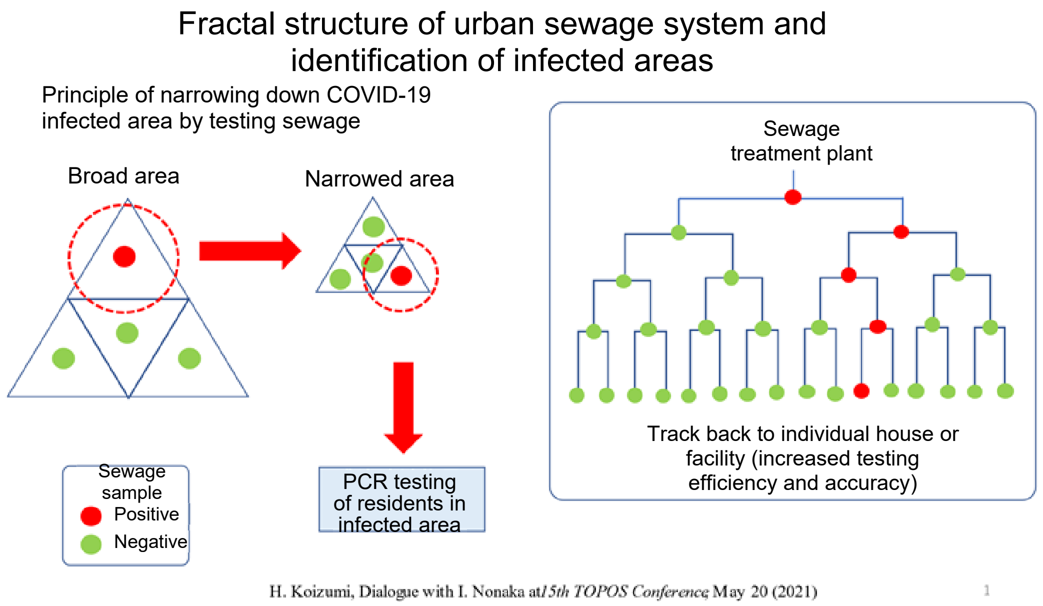


Figure 5.1.1 Fractal structure for PCR testing of sewage

5.2. A “new local” based on multi-AI in a “new normal” era

5.2.1. Human security and well-being in urban areas

The United Nations Development Programme (1994) [5.2.1)] notes that the actors threatening human security have shifted from catastrophic threats such as war to everyday insecurities such as work, income, health, environment and crime, also pointing out that these are no longer limited to individuals, regions or nations, but have become global.

The Independent Commission on Human Security, chaired by Sadako Ogata and Amartya Sen, also noted that human security is a public good, and that nation states and the international community need to work together to protect and assist people in vulnerable situations. Furthermore, in 2012, UN Resolution A/RES/66/290 [5.2.2)] defined human security as “the right of people to live in freedom and dignity, free from poverty and despair”. In this context, the outbreak of COVID-19 in 2019 has posed a threat to human security.

Widespread and prolonged lockdowns were implemented in cities around the world, and according to the UN, this was the first time since 1998 that poverty increased on a global scale. The New Urban Agenda (NUA) 2020 shows that living in cities contributes to economic prosperity, environmental protection and social equality [5.2.3)]. Therefore, we must urgently consider how cities can develop sustainably in the face of infectious diseases, in order to ensure human security and well-being.

The idea of Koizumi (2015), that it is important in cities not only to ensure human security but also to consider the well-being of residents, is shown in Figure 5.2.1. Meanwhile, we have learnt from our experience with COVID-19 to date that prolonged lockdowns have the potential to adversely affect health, both physically and mentally. Based on these ideas, this report proposes a new type of city that allows for sustainable economic development while ensuring comfort in normal times and decent living standards (DLS) <Note 2> during outbreaks.

<Note 1> On 26 February 2015, Mr. Hideaki Koizumi, a member of this committee, gave a lecture at the Japan Economic Research Institute entitled, "Urban Design Concepts Going Forward in the Creation of Living Spheres and Neuroscience". He presented an urban design concept to achieve human well-being, in which cities pursue optimisation of interwoven material and information to create a future in which people grow up healthy, grow old healthy, and experience the joy of living.

<Note 2> In order to ensure well-being, DLS requires both the right to receive necessary goods and services and the opportunity to fulfil one's potential. The former refers to primary goods such as public services, the surrounding environment, food, clothing and housing (Rawls 1971) and basic goods (Reinert 2011), while the latter refers to the capability approach of Nussbaum 2000 and Sen 1987.

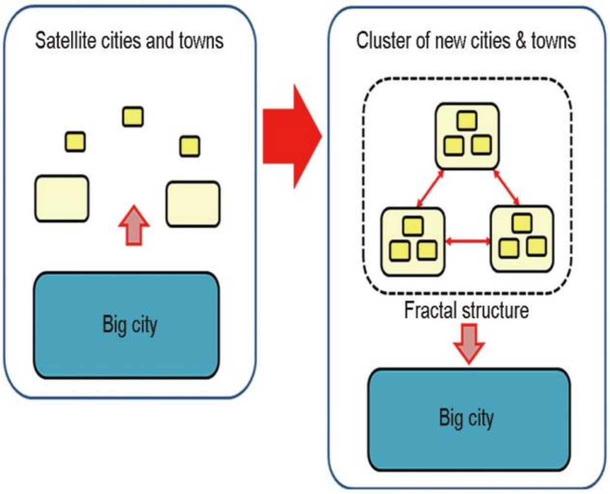


Figure 5.2.1 Fractal cities that prioritise humans <Note 1>

5.2.2. Urban challenges for the 21st century

Urbanisation is a global trend, with Japan's urbanisation rate reaching 92% in 2020. As our society faces a super-ageing population, a situation we have never experienced before, we take a look back in time 100 years to find hints about where Japan's cities should be heading.

In the latter half of the 20th century, many new towns were built in the suburbs of large cities in developed countries. These were modeled on Ebenezer Howard's vision of garden cities of early 20th century England. This was part of a social movement to help those who had suffered from the poor living conditions of inner city London since the Industrial Revolution, and partly to combat the cholera epidemic of the 19th century in Europe [5.2.4)]. Letchworth, one of the garden cities, had a population of 30,000 in the town centre in an area of 405 hectares, and 2,000 people on agricultural land over an area of 2,025 hectares. The city took into account the proximity of work and housing, and even supply of food. Howard's vision, shown in Figure 5.2.2 <Note 1>, was for a network of cities, including Letchworth, to be linked by rail to form a city sphere. However, the scheme was abandoned after two world wars and only two cities, and was only realised in the two cities of Letchworth and Welwyn. Even after 100 years, they are still beautiful towns today.

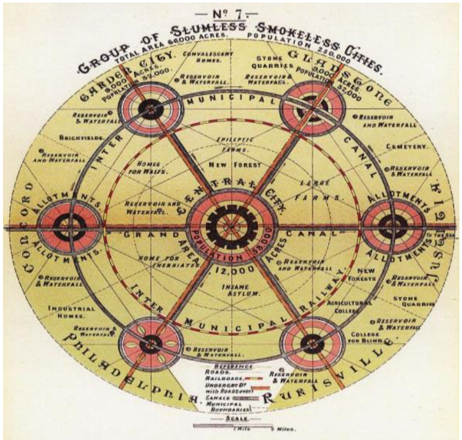


Figure 5.2.2 Ebenezer Howard’s Garden Cities

In 1944, after World War II, the Greater London Plan was formulated, followed by the construction of several new towns around London. Unlike civil society’s vision for garden cities, the government's suburban new towns were actually bedroom communities designed to reduce overcrowding in central London.

Since the high economic growth period of the 1970s in Japan, a number of bedroom towns have been developed in urban commuting areas, including the Senri New Town, Tama New Town and Kozoji New Town. As motorisation progressed in the Tokyo metropolitan area, new towns and small and medium-sized housing areas were developed, sprawling out into the suburbs, encroaching on farmland and forest land, as shown in Figure 5.2.3 <Note 2>.

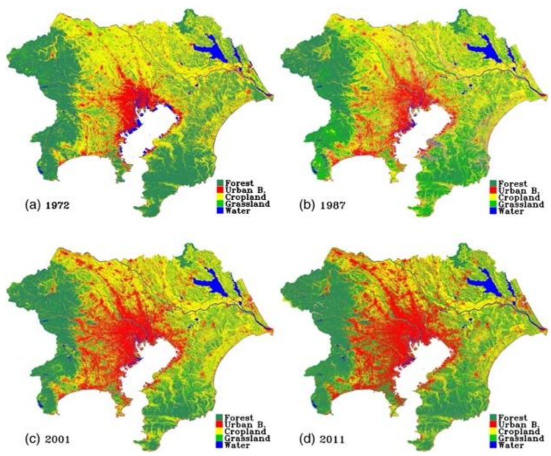


Figure 5.2.3 Expansion of Tokyo metropolitan area to suburbs

As a result, even today, the Tokyo metropolitan area (including the metropolitan area and three prefectures) retains the world's largest population of 36.61 million (2019). The average commuting time is 80 minutes one-way, roughly double the 38 minutes of Paris, 40 minutes of New York, and 43 minutes of London [5.2.5)].

While the cause of Japan's low productivity may not be entirely due to long commutes, it is also true that the country's productivity per worker is the lowest of the G7 industrialised nations [5.2.6)]. A 2017 study by UK-based insurance company, Vitality Health, Cambridge University and the RAND Europe research institute also showed that groups who spend longer hours commuting have higher rates of depression, financial worries and work-related stress [5.2.7)]. In addition, the rapid influx of people into Japan's metropolitan areas during the country's rapid economic growth led to the development of towns in places unsuitable for housing that are vulnerable to earthquakes and flooding. In cases where these areas were created by clusters of wooden houses, areas vulnerable to fire were also formed.

Teleworking has spread rapidly during the COVID-19 pandemic, creating an opportune time to make changes in lifestyles formerly premised on retreat from vulnerable city centres and long-distance commutes. To do this, we need to shift direction to move away from the unipolar concentration of the 20th century to a multipolar, decentralised city suitable for the 21st century.

<Note 1> This diagram was taken from E. Howard's book Garden Cities of Tomorrow, in which he proposes cities uniting the advantages of cities (e.g. opportunities, entertainment, high wages) with those of rural areas (e.g. scenic beauty, fresh air, low rents).

<Note 2> In uncontrolled sprawl, small pieces of farmland on the outskirts of cities are often converted into urban areas. These are generally not connected to transport infrastructure, so residents usually end up leading lifestyles dependent on privately-owned automobiles.

5.2.3. Role of the “Multi-AI Networked City”

The "Multi-AI Networked City" aims to ensure sustainable human security and bring about the well-being of inhabitants. This will require responses on carbon neutrality, NEXUS (energy, food, water) and outbreaks (natural disasters and infectious diseases) in the context of an ageing and declining population. With sustainability and resilience as key words, the following is an explanation of how this city would respond to these challenges.

With regard to the low carbonisation of cities, the Ministry of the Environment's "Towards Carbon Neutrality in 2050" provides one direction [5.2.8)]. This is also linked to the Ministry of Economy, Trade and Industry's "Green Growth Strategy Through Achieving Carbon Neutrality in 2050" [5.2.9)]. According to these plans, Japan's total CO2 emissions in 2018 were 1.14 billion t-co2, of which the urban sector (commercial, households and transport) accounted for 27% (310 million t-co2), as shown in Figure 5.2.4. This includes 110 million t-co2 in the consumer sector (60 million t-co2 for commercial and 50 million t-co2 for households) and 200 million t-co2 in the transportation sector.

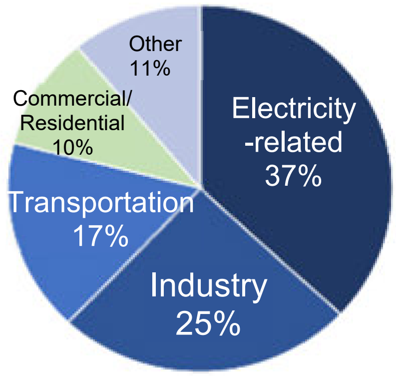


Figure 5.2.4 Japan's CO2 emissions by sector

First, we present our estimates for this reduction of 110 million t-co2 in the consumer sector. According to the Ministry of the Environment's Statistical Survey on CO2 Emissions from the Household Sector (Household CO2 Statistics) [5.2.10)], the annual emissions (total of electricity, gas and kerosene) per house hold are 2.72 t-co2. If we assume, for the sake of simplicity, that the energy consumption of all 27 million house holds in the country is supplied by installation of solar energy on roofs, we get a reduction of 6% (2.72 t*27 million dwellings = 73 million t-co2). We now turn our attention to the 200 million tonnes from transportation. If we assume for the sake of simplicity that all private cars are replaced by renewable energy EVs, taking into account that the proportion of electric cars is increasing worldwide and that about half of the transportation sector's current emissions come from private cars, this would result in a reduction of 8.5%, about half of the transportation sector (100 million t-co2). Thus, adding the 6% for the consumer sector and 8.5% for the transportation sector, we estimate a reduction of 14.5%, about half of the 27% of the urban sector (310 million t-co2).

These estimates show that in order to achieve a 46% reduction in 2030, ahead of carbon neutrality in 2050, urban sector CO2 emissions will need to switch to local renewable energy systems, at least in the household sector, and to switch from fossil fuel vehicles to EVs in the transportation sector. This means the systems for both supply and consumption must be changed simultaneously <Note 3>.

While the proposed "Multi-AI Networked City" aims to be an energy autonomous city, to achieve carbon neutrality by 2050 it will be necessary to further improve the environmental performance of the city as a whole, including making buildings more low-carbon. Assessment systems such as CASBEE (Comprehensive Assessment System for Built Environment Efficiency) and LEED (Leadership in Energy and Environmental Design) are in operation in Japan as tools for assessing the environmental performance of buildings [5.2.11)].

With regard to the "resilience" of cities, the Cabinet Office established the 2018 Guidelines for Assessment of Vulnerability[5.2.12)]. These guidelines list 12 core urban functions (government, police, fire dept., housing, insurance, healthcare, energy, finance, etc.) to be maintained to cope with natural disasters, and five cross-cutting areas (risk communication, human resource development, public-private partnerships, measures on deterioration, and research and development) to link the 12 functions.

The approach of the above guidelines—to avoid the collapse of the entire city by objectively assessing its vulnerability—is consistent with the design concept of the "Multi-AI Networked City", which is a network of multiple living spheres equipped with a minimum of core urban functions.

Furthermore, in terms of long-term urban resilience, the spongification of city areas due to population decline has led to the withdrawal of transportation and lifeline networks. In response, the Ministry of Land, Infrastructure, Transport and Tourism is currently working on the re-consolidation of urban areas under the Location Optimization Act, which is discussed in Section 5.2.6.

<Note 3> Economic recovery from the novel coronavirus (COVID-19) pandemic emphasises sustainable and decarbonised green recovery, recognising that environmental measures are a source of economic growth.

5.2.4. Positioning and objectives of the "Multi-AI Networked City"

With regard to the informatisation of cities and smart cities, the Cabinet Office's "Integrated Innovation Strategy 2019" designates smart cities as the precursor to realisation of a "Society 5.0". In other words, Society 5.0[5.2.14)], which is a further development of Industry 4.0[5.2.13)], an example of IoT and AI, aims for a sustainable society where challenges related to regions and districts are solved and realised together with stakeholders using ICT. Society 5.0 refers to the potential for people-to-people, people-to-thing, and thing-to thing connections in cyber and physical spaces, noting that these connections will change the relationship between cities and people, and between AI and people. Specifically, it points out that various knowledge and information from physical space will be accumulated and visualised in cyberspace, creating the potential for new lifestyles, communities and technologies to emerge.

In response, the Cabinet Office, Ministry of Internal Affairs and Communications, Ministry of Economy, Trade and Industry, and Ministry of Land, Infrastructure, Transport and Tourism established the "Smart City Public-Private Partnership Platform", whose members include companies, universities and research institutes, local governments, and relevant ministries and agencies, in order to accelerate smart city initiatives through public-private partnerships [5.2.15)]. In addition, as smart city-related projects, the Office for the Promotion of Regional Revitalization under the Cabinet Office is promoting the "Future Technology Social Implementation Projects", the Ministry of Internal Affairs and Communications' Information and Communications Bureau is promoting the "Smart City Promotion Project for Facilitating Data Linkage". Likewise, the Ministry of Economy, Trade and Industry's Manufacturing Industries Bureau is promoting the "Project for Creating and Promoting New MaaS in Regions”, and the Ministry of Land, Infrastructure, Transport and Tourism's City Bureau is promoting the "MLIT Smart City Model Project". These projects are overseen by the Office for Science, Technology and Innovation Promotion of the Cabinet Office.

The basic function of the proposed "Multi-AI Networked City" is to accurately ascertain the city’s situation during normal times and during outbreaks, and to visualise this situation using AI to provide information to stakeholders (e.g. citizens, businesses, government) in an easily understandable way. We believe that, as a result, each stakeholder would share in the vision and measures for the whole society, and that their actions would be guided to be autonomous, and empathetic.

In the long term, 21st century cities should not only prepare for sudden disasters such as outbreaks of infectious diseases, which are expected to recur in the future, but also ensure a stable supply of food, water and energy, and achieve a high level of decarbonisation, leading to the human security and well-being that is needed for people in the future. This is precisely the goal of the “Multi-AI Network Cities”. In this sense, the “Multi-AI Networked City” shares the direction of Society 5.0, which aims to create a sustainable society together with stakeholders by using ICT to solve problems related to regions and districts. The “Multi-AI Networked City” can be positioned as one of the proposals for cities in Society 5.0.

5.2.5. The “Multi-AI Networked City”: “New local” city spheres in a “new normal” era

Figure 5.2.5 shows the image of a “Multi-AI Networked City”, which forms “new local city spheres” in a “new normal” era. In this figure, the six circles in the centre are physical living spheres with a population of 10,000 to 30,000. These living spheres are networked together to form a new local city sphere that is prepared for outbreaks even in normal times.

The upper part of the diagram is cyberspace, where various layers of information are overlaid, and in the uppermost part of cyberspace, the information is visualised by AI. The cyberspace in this diagram shows a situation in which medical care and supplies are brought in from outside when the central living spheres are in lockdown. The bottom part of the diagram depicts the local infrastructure, which shows the future transition from the current wide-area network to a local infrastructure with a high degree of independence for each living sphere.

The scale of a living sphere (population, area), shown on the right in Figure 5.2.5, is a fundamental factor related to sustainability in a lockdown. In this proposal, we assume that the population of one living sphere is between 10,000 and 30,000. The rationale for this is, firstly, that the Interim Report on the “Long-Term Outlook of Japan's National Land” [5.2.16)] points out that the probability of an urban area of 17,500 people being able to maintain life service industries such as medical care and welfare under a declining population is 50%, and that this is the limit for population. Secondly, calculations assumed a walkable urban area with a two-kilometre diameter and a population density of 50-100 people per hectare, making the population approximately 15,000-30,000. Accordingly, the population size of the city sphere unit is therefore assumed to be approximately 100,000-180,000 (15,000-30,000 person living spheres)*(6 living spheres).

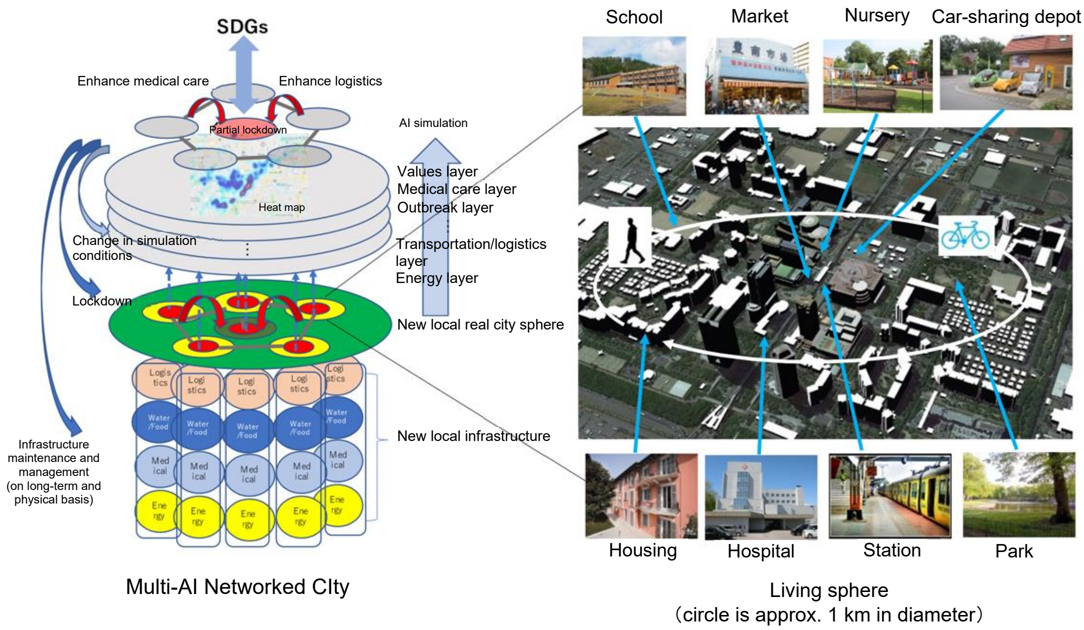


Figure 5.2.5 The Multi-AI Networked City (left) and image of a 15,000-30,000 person living sphere (right)

Using “The 15-minute city: How close is Chicago?” [5.2.17)] as an example of the facilities needed for living spheres, those needed for a 15-minute city in Chicago are: 1. grocery stores, 2. parks, 3. libraries, 4. elementary and middle schools, 5. hospitals and urgent care facilities,

6. pharmacies, and 7. public railway stations. These are largely consistent with the image of the living spheres inFigure 5.2.5 on the right.

In this way, a "Multi-AI Networked City" is able to sustain a comfortable lifestyle using these urban facilities during normal times, while at the same time is able to continuously provide the necessary human resources, supplies and sharing of information, even when the living sphere units are locked down during an outbreak. This requires the AI deployed in the living spheres to monitor both the spread of infections and the well-being of the people living in the area in real time. The decision to initiate or terminate lockdowns would ultimately be determined and controlled by humans at the individual living sphere level, based on information provided by AI and its analysis and predictions.

Figure 5.2.6 shows a comparison of infection rates of a unipolar concentrated city and a multipolar decentralised city patterned under the same conditions (infection rate of 0.05). For the unipolar concentrated city in the upper row (N=20, L=18), 13 out of 20 living spheres are infected at time T=20, while in the multipolar decentralised city in the lower row (N=20, L=20), infections spread to only 4 of 20 living spheres for the same time. The same trend is observed at T=40. These patterns of transmission suggest that the spread of infection takes more time in a multipolar decentralised city, making its structure more suited to partial lockdowns. However, from a different perspective, this means that the speed of face-to-face information transmission in the multipolar decentralised city is inferior to that in the unipolar concentrated city. For this reason, the "Multi-AI Networked City" can compensate for this weakness in multipolar decentralised cities by using AI networks.

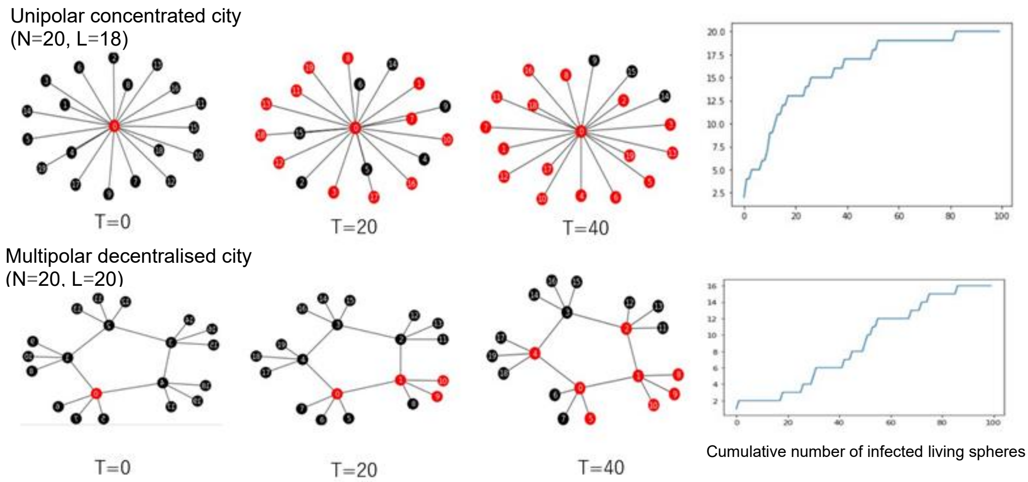


Figure 5.2.6 Infection patterns in unipolar concentrated city (top row) and multipolar decentralised city (bottom row)

Regarding the actual characteristics of outbreaks of COVID-19 infections, Yoneoka et al. [5.2.18] conducted a questionnaire in Tokyo from March to April 2020 using the LINE app, and plotted the postal code areas of respondents with symptoms of both a) body temperature over 37.5°C and b) breathlessness or rapid breathing, shown in Figure 5.2.7. The results show that although there were some problems with the questionnaire, such as a bias in the age range of respondents, it is possible to obtain real-time information on the status of infections over a wide and detailed area.

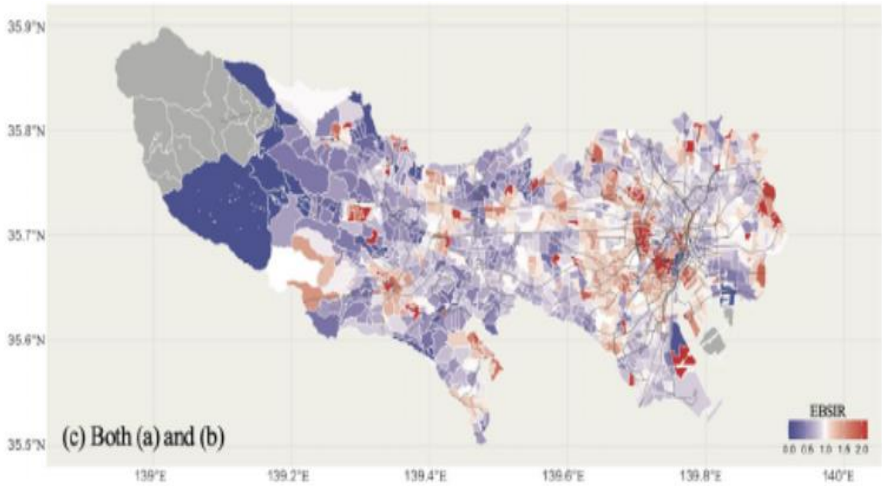


Figure 5.2.7 Infection survey by LINE questionnaire

Figure 5.2.8 also shows the risk map of pre-vaccine COVID-19 infections in Tel Aviv in March 2020, prepared by an Israeli company [5.2.19]. This map shows the risk of infection for building units, based on a survey of the travel routes of infected people. It shows that in the city centre (6 km long and 10 km wide), infections tend to spread in clusters rather than at an average speed. The "Multi-AI Networked City" control system for partial lockdowns by living spheres would be suitable for such clustered infection patterns.

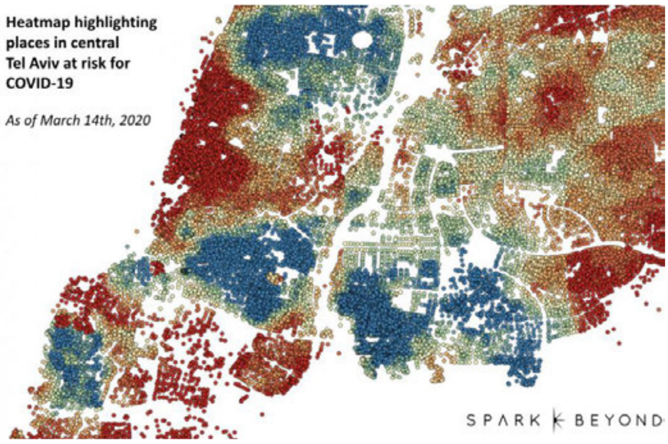


Figure 5.2.8 Infection risk in Tel Aviv city centre (6 km long by 10 km wide)

Of course, a simple comparison cannot be made between the Tokyo metropolitan area (population of 36.61 million in one metropolitan area and three prefectures) and Tel Aviv (metropolitan population of 2.6 million) due to differing numbers of commuters and travel distances. Yet, publicly available infection heat maps for several cities in the US show that infections in urban areas spread in clusters, similar to Tel Aviv [5.2.20].

Particularly in situations such as the COVID-19 pandemic, where virus variants are emerging one after another, it is assumed that we will have to rely on lockdowns for the time being, as it will take time for new vaccines to be introduced into treatment. In this case, measures to quickly identify the source of an outbreak and contain it as early as possible would be effective in an urban structure where infection is easier to control.

5.2.6. Ageing population and population decline over the long-term

Next, we will discuss how Multi-AI Networked Cities should prepare for the long-term challenges of an ageing and declining population.

According to the Interim Report on "Long-Term Perspective of Japan's National Land" [5.2.21] by the Planning Promotion Committee of the National Land Council, Japan's total population peaked at 128.08 million in 2008, and will decline to roughly 100 million by 2050, about the same level as 1970. By age group, between 2015 and 2050, the working-age population in Japan will decrease by 24.53 million, while the elderly population will increase by 4.54 million, with the ageing rate rising from about 27% to about 38%.

Although the data precedes COVID-19, the total population of the three major metropolitan areas of Tokyo, Osaka, and Nagoya will decrease from approximately 60 million in 2015 to 50 million in 2050, while the population of all other areas will decrease from approximately 67 million in 2015 to 50 million in 2050. The Overview (edition1) of the Grand Design 2050 predicts the following more detailed picture of the situation in 2050 [5.2.22].

(1) Rapid population decline, declining birth rate and ageing population
- The population of Japan in 2050 will decrease to about 97 million.
- The population of about 60% of regions will decrease to less than half, and one-third of regions will become uninhabited.
- An elderly population of around 40%, which no other country has ever experienced.

(2) Progression of globalisation
- Intensifying competition between countries and cities.
- The geopolitical positioning will change greatly due to Eurasian dynamism.
- The opening of the Arctic Ocean route and the re-expansion of the Panama Canal.

(3) Impending major disasters and ageing infrastructure
- The impending occurrence of an earthquake directly beneath the Tokyo metropolitan area and a major earthquake in the Nankai Trough (70% probability of occurrence within 30 years).
- Climate change will lead to more severe disasters.
- More pronounced deterioration of infrastructure that was intensively developed during period of rapid economic growth.

(4) Food, water and energy constraints and global environmental problems
- Expanding demands in food and energy, due to increasing population, the production and consumption will be a global challenge.
- Imminent global warming and biodiversity crises.

(5) Dramatic advances in ICT and technological innovation
- A rapid increase in computers and their processing power will be necessary.
- The widespread use of big data will spur the fusion of knowledge space and real space.

The Spatial Reorganisation and Prosperity Creation Project [5.2.23] is being advance to respond to the so-called spongification of urban areas, where unused land is randomly generated in the context of the situation described in (1) above, shown in Figure 5.2.9. Here, we show an example of land use based on this project, where land use for EV sharing and urban agriculture is added. This example proposes the conversion of vacant land caused by spongification into bases for automated EVs (with solar power generation on the roofs) and urban agriculture, which are expected to increase in the future. This is designed to compensate for the weaknesses of the Location Normalization Plan, which requires more than 20 years to reorganise urban areas, in order to maintain the functioning of urban areas by using vacant land without delay, rather than leaving it empty during a project.

Reference：Toshi no sponjika taisaku (teimiriyo tochi kenri settei to sokushin keikaku/ritchi yudo sokushin shisetu kyotei) katsuyo sutadishu [Addressing urban spongification (plan for promoting the establishment of rights, etc. to underused or unused land; Agreements to promote establishment of facilities], partially altered.

Figure 5.2.9 Conversion of spongified urban areas into urban agriculture, processing and sale produce, and MaaS bases

In response to population decline and spongification, MONET Technologies, a company funded by Toyota Motor Corporation and Softbank, announced that it is working with government and private retailers such as supermarkets to launch "Autono-MaaS", an automated shuttle service combined with Maas (Mobility as a Service), in 2021. This is a parcel pick-up, delivery and shop pick-up and drop-off service that will support the creation of communities where people can continue to live, as well as shopping for the child-rearing generation and the elderly. A demonstration project has started in Saijo City, Hiroshima Prefecture.

Delta and Idemitsu Kosan have also announced that they will open an experimental Delta EV Charging Station in August 2021 to roll out a new combined service model for EV charging called Park&Charge. During the 30-minute EV recharge at the station, stations will be developed to provide a variety of urban services such as shopping, banking and gyms in the future. Running parallel with this, Idemitsu Kosan is developing an ultra-compact EV (around 1.5 million JPY) capable of speeds of up to 60 km/h, which is due to go on sale in 2022.

These initiatives are examples of how the private sector is leading the way in using vacant land as a resource for mobility and energy in response to the Grand Design 2050, which predicts that the population of around 60% of regions in the country will fall to less than half, and that one-third of these areas will be uninhabited.

5.2.7. Developing and realising the Multi-AI Networked City

The land use map of the Netherlands shown on the right in Figure 5.2.10[5.2.24)] can serve as a reference for the "Multi-AI Networked City” of 2050. Meanwhile, the leftmost figure shows a 2010 land use map for the Tokyo metropolitan area (1 metropolitan area and 7 prefectures)[5.2.25)]. Comparing the two maps, we can see that in the Dutch land use map, urban areas are dispersed and mixed with farmland and green spaces, while in the Tokyo metropolitan area, urban areas and farmland are separated and urban functions are concentrated in one place.

While the Netherlands’ national land planning was carried out before AI networks and the digital revolution, the question of why the Netherlands chose a multipolar decentralised approach and Japanese cities did not, perhaps due to differing priorities of cities at the time for economic efficiency, comfort and disaster resilience, is one that should be examined further.

The map in the centre of the figure shows population changes in the Tokyo metropolitan area for 2010 and 2050. Yellow indicates areas where the population will decline by less than 50%, while light green indicates areas where the population will decline by more than 50%. This shows that population growth is limited to the very small red areas.

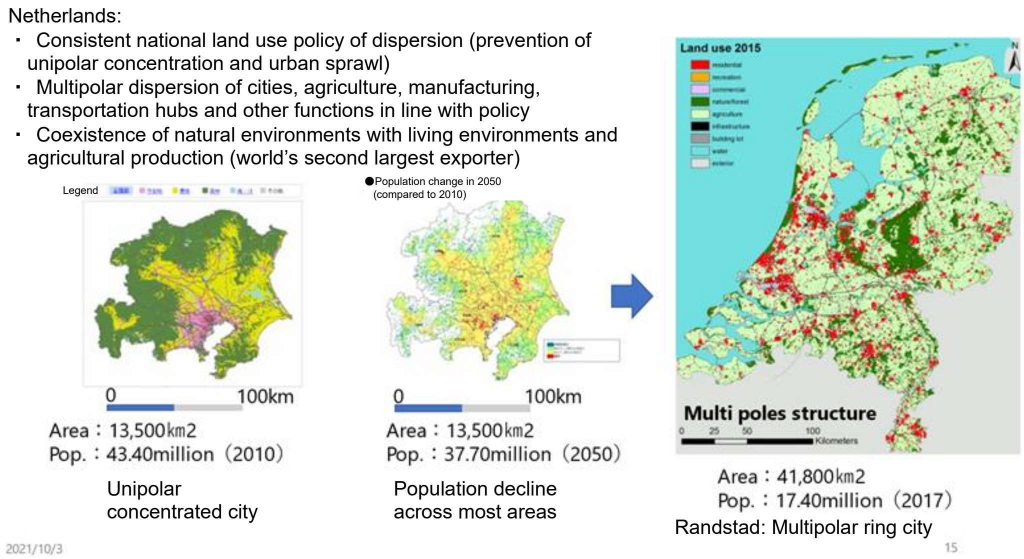


Figure 5.2.10 Comparison of land use in Tokyo metropolitan area (1 metropolitan area and 7 prefectures) and the Netherlands

On this subject, Ito et al. state in the MLIT Policy Research Vol. 160 that "urban spongification" is becoming increasingly apparent in urban areas, and that unused resources such as vacant land, vacant houses, vacant shops and vacant public facilities is increasing. They also argue that if necessary functions for communities (e.g. shopping, spaces for interaction and living, childcare, recreation, etc.), could be added as a complement to these vacant spaces, the quality of life of local residents could be maintained and improved [5.2.26].

With regard to the review of these living spheres, Carlos Moreno of the Sorbonne presented a 15-minute city concept for Paris in 2020. Figure 5.2.11 on the left depicts the concept as it was presented again in 2021 [5.2.27]. The concept of the 15-minute city has commonalities with Howard's garden city and Jacobs's vision of a city rich in diversity while maintaining density, which she presented in her book "The Death and Life of Great American Cities". In addition, the 15-minute city of Paris adds to these the notion that the city should be enjoyable, comfortable, safe and socially acceptable. A similar concept, albeit in different language, is the hedonistic sustainability proposed by the architect Bjarke Ingels, which like the "Multi-AI Networked City", is based on the concept of well-being in living areas.

So, are there any suitable areas where the "Multi-AI Networked City" could be realised first?

Figure 5.2.11 on the right shows the population and area (2016) of municipalities in the Tokyo metropolitan area (1 metropolitan area, 3 prefectures). The figure shows that the downtown area of the Tokyo metropolitan area is represented by the Chiyoda and Chuo wards, which have night-time populations of 50,000-200,000 and areas around 10 km^2 with a large daytime population inflow (circular area). Outside of this circle is mixed business and residential zones made up of Shinjuku, Setagaya, Nerima, and Koto wards, with night-time populations of 200,000-1,000,000 and areas of 20-60 km^2. It is noteworthy that the outer suburbs, 20-40 km from the city centre (C-shaped dotted line), have many commuter cities with areas of 10-30 km^2 and night-time populations of 100,000-200,000.

The “Multi-AI Networked City” assumes six living spheres as a single unit with a population of 100,000 to 180,000. Looking at the Tokyo metropolitan area with the borders of prefectures removed, the populations and areas of each municipality in the suburban zone within a 20-40 km radius of the city centre are close in scale to the “Multi-AI Networked City”. This suggests that there may be areas within a 20-40 km radius of the city centre that are suitable for the multipolar decentralised model described in number 5) in the summary below, where cities are initially multipolarised by multiple cyber living spheres and eventually form physical, independent and autonomous living spheres. However, this is only a one-sided view, and the consideration or assessment of specific candidate sites is outside of the scope of this report.

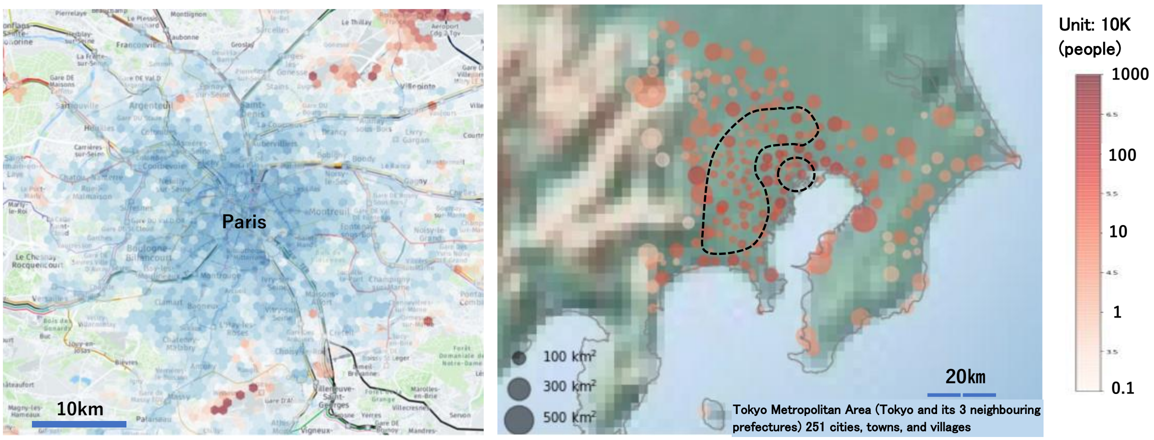


Figure 5.2.11 Image of the Paris 15-minute city (left) and the population and area of municipalities in the Tokyo metropolitan area (right)

5.2.8. Summary

1) We propose a "Multi-AI Networked City", where the pursuit of well-being is centred on human beings, with the aim of ensuring comfort in normal times and safety and security during outbreaks.

2) The “Multi-AI Networked City” would consist of autonomous and independent decentralised living spheres that do not destroy current urban structures, and would prevent the collapse of the entire city under any circumstances, while at the same time guaranteeing human security and well-being.

3) The “Multi-AI Networked City” would involve a MAWSS (Multi-AI Well-being Survey System), which would allow people and AI to cooperate in the autonomous management of the city with a variety of data moving freely between networked living areas.

4) The “Multi-AI Networked City” would be a cyber-physical city to ensure resilience to the challenges Japan faces, including the declining and ageing population, impending mega-disasters, global climate change, unstable supplies of water, food and energy, and outbreaks of infectious disease.

5) The “Multi-AI Networked City” would differ from conventional urban planning in that it encompasses a process whereby the city is initially multipolarised by multiple cyber living spheres, but ultimately forms physical, independent and autonomous living spheres.

6) To realise the “Multi-AI Networked City”, it is necessary to continuously communicate the concept of this city to society in order to garner social acceptance and consensus, based on the recognition that a city is a place of shared purpose and cultural inheritance across generations from the perspective of STI (science, technology and innovation).

5.3. MAWSS (Multi-AI Well-being Survey System)

5.3.1. Proposal for multi-scale and multi-layer living spheres/city spheres

Repeated natural disasters and the spread of infectious diseases such as COVID-19 have transformed our way of life. We are at a crossroads where we must think about a society that can live with these occurrences, rather than treating them as transient phenomena. In order to live with them, we must consider the appropriate isolation of living spheres, as well as sharing and cooperation between these isolated living spheres. The scope of the isolated living spheres (size, criteria for determining the boundaries) has been discussed in previous sections. In order to constitute a living sphere, it is necessary to have all the infrastructure necessary for daily life within the living sphere. In order for this infrastructure to work sustainably over a mid- to long-term time scale, it will be important to have not only indicators for economic activity, but also strategies to recover well-being (nearly = Humanity) and to implement them in society.

First, we will consider the appropriate isolation of living spheres. The less restrictive the living sphere, the closer activity is to normal, and the less comfort is compromised. The multi-scaling of technologies is one solution. When living areas are isolated during natural disasters or infectious disease pandemics, the size of the area isolated can be changed in a multi-scale manner by grouping together multiple smaller living spheres according to the level of emergency and adapting to the situation.

In addition, infrastructure can be divided into four main categories: (1) supply of water, food, etc. (plus sewage treatment), (2) energy supply, (3) social services such as healthcare and public administration, and (4) social production activities such as industry and education. Each infrastructure element has a different number of people and a different population density, and therefore a different optimal size, and it would be unreasonable to force all infrastructure activities to be separated into one living sphere. In normal time, living spheres would approach an equilibrium between supply and demand, and therefore tend to be adjusted to a certain extent to a scope and density appropriate for the population. Even if we take into account the possibility of isolation due to natural disasters or infectious disease pandemics, it is natural to maintain the normal area of each infrastructure element to some extent. On the other hand, social conditions and administrative decisions/measures (hereinafter referred to as administrative measures) interact with each other in a way that affects the other. Administrative measures change when influenced by the social situation, and conversely the effects of administrative measures change the social situation. As each of these systems is non-linear and involves mutual interaction, the two monolithic (i.e. considered as one) systems form a complex system. For simulations and calculations for complex systems, as proposed in [5.3.1)], a system in which the social situation and the administrative measures are implemented as separate layers and interact with each other is considered to work more efficiently than a single bulky system. The design of multi-layer living spheres is one way of achieving this goal.

One solution to realising a society oriented towards well-being and a society that is resilient to natural disasters and pandemics is the implementation of multi-layer and multi-scale society isolation, in which living spheres with differing scopes of infrastructure are multi-scaled and multi-layered, and ascertainment of the social situation and administrative measures are separately layered on top of each layer.

5.3.2. What is MAWSS and what can it do?

Multi-layered and multi-scaled living spheres are one possible solution to maintain and improve people's quality of life while becoming resilient to natural disasters and infectious disease pandemics. However, the potential remains for the social implementation of such a solution to lead to increased complexity of the optimisation process, increased workload and increased complexity in operations. These factors must be taken into account in the number of layers of infrastructure and the multi-phased implementation of the scale of living spheres. To do so, systems operating in each living sphere, in many cases computer systems or, in the future, AI systems, could be utilised as one possible remedy.

An AI network connecting the AI in charge of monitoring each living sphere, or AI network as a whole (AI nexus, AI consisting of AIs), is formed to coordinate information and decisions (as information). The Multi-AI Well-being Survey System (MAWSS) is defined as an AI network that converts living spheres into multi-layers and multi-scales, taking into account the interaction of social conditions and administrative measures.

The Well-being Survey is a multidimensional survey and overview of information and knowledge to estimate the comfort zone of society. Its aim is to create a society that regains its humanity, not just its economic rationality, and AI can help to implement this response in society. The AI is an AI system to help us regain humanity in our society and our lives, and is not meant to simulate humanity. The world would not be managed by a single bulky AI server. Rather, a group of AI servers in charge of a group of layers of appropriate size and with appropriate granularity, would share information with each other to form a consensus. This is ideal from the points of view of construction, management and updating of information systems. One of the reasons why this decentralised AI network is suitable for implementation is that spheres that are close to each other in terms of content (concepts, contents) have a lot in common and thus need to share a lot of information, while spheres that are far from each other need only share summaries, or a small amounts of information. For an accurate understanding of the individual, we need detailed information on a wide range of individuals. However, each individual interacts with other individuals in the world, and the amount of information that needs to be shared depends on the distance between the spheres. We cannot know the whole if we limit ourselves to the thoughts of the individual, but we must know the individual in order to know the whole. The average value indicated by the law of large numbers is not necessarily the best, but in order to know the distribution, including outliers, we can be aware that the whole is a set of individuals and that the combination of information is powerful.

On the other hand, we must be aware of what information should be connected and what information should not. Information, when combined, can render an individual exposed. From the perspective of protecting personal data, information that is better not connected will in some cases not be connected, and even when information is available (and can be connected), it should not be obtained unethically. Information should not be used without consensus to force changes in behaviour that citizens will not accept. AI systems, with their powerful information gathering and analytic capabilities, also present challenges and concerns in their operation.

As with other technologies such as nuclear power, chemicals, medicines, vehicles and other mechanical systems, mobile phones, the internet, concerns about abuse or misuse are inevitable. Appropriate use must be made a prerequisite, and social ethics, operational guidelines and regulatory legislation are needed to ensure this. However, even if social ethics and regulation are required, we should not dismiss these technologies as unnecessary or dangerous, given the history of human development based on the active introduction of such STIs in the past. On the contrary, we should put in place measures for proper operation and actively implement these technologies in society.

5.3.3. Is MAWSS feasible? Examples of implementation

When considering the feasibility of digital twinning of physical and existing systems, which in this case refers to living spheres and people's activities in them, i.e. a complex system like MAWSS, the key is whether or not the targeted system can be seen as a field and formed as whole. In this context, key operations are the sharing of multi-property and multi-aspect information between AIs, and decisions on measures that take into account a variety of values.

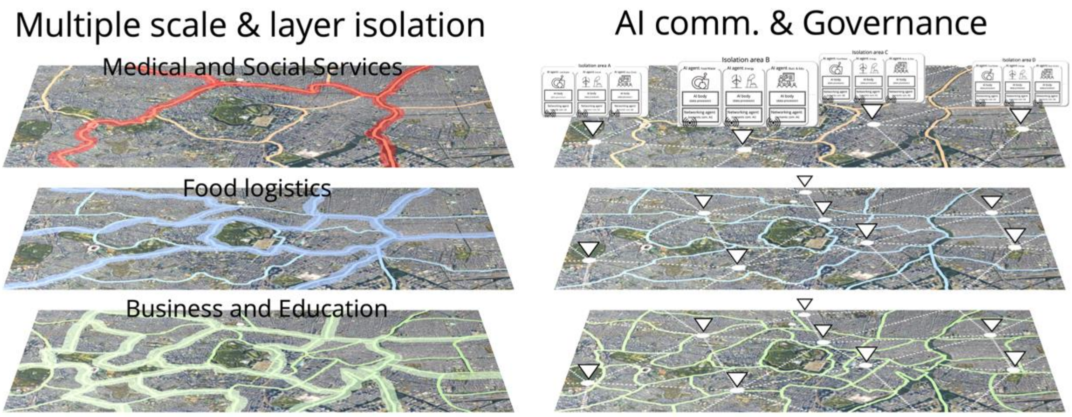
For the former, the multimodal AI network being researched by Tokyo Medical and Dental University as a medical AI system can be utilised as one form of implementation. It consists of a number of AI clusters, and in addition to functioning to communicate and process data between the AIs, additional AI agents for networking are included internally. The networking AI agents communicate autonomously with each other, compute data paths and network to form a kind of AI nexus. In addition to distinguishing data format (i.e. whether the data is processable or not), they also determine the meaning of data (i.e. whether the data should be processed or not), and configure the network accurately and efficiently according to the required processing. The latter decisions on measures should take into account multiple perspectives and diverse values, and are not easy to do with existing AI. Values change according to social position, and the best measures will differ according to the location and scale being considered, e.g. differences in geographical coverage (domestic or global), differences in temporal coverage (local or global), tense, and whether they are past-oriented (maintaining the status quo, optimisation at present) or future-oriented. We have to look at spatial and temporal changes, and take into account the passage of time (chronically), and respond to different values, without making a single value judgment.

Most of the existing AI, especially (deep) neural networks, are machines that pattern frequent data distributions and obtain the probability of simultaneous occurrence. They are inductive reasoning machines that follow the most successful experiences. As such, they cannot be creative about the future. However, AI can look through vast amounts of information, summarise the important information (based on past experience), and present a set of evaluations of various value indicators converted to mathematical formulas to help make holistic and informed decisions. In addition, multimodal AI networks use deductive reasoning to self organise. By creating multistage networks to propagate processing, clusters of AIs handle tasks that are simple one by one, but cumbersome in their complexity when layered into stages.

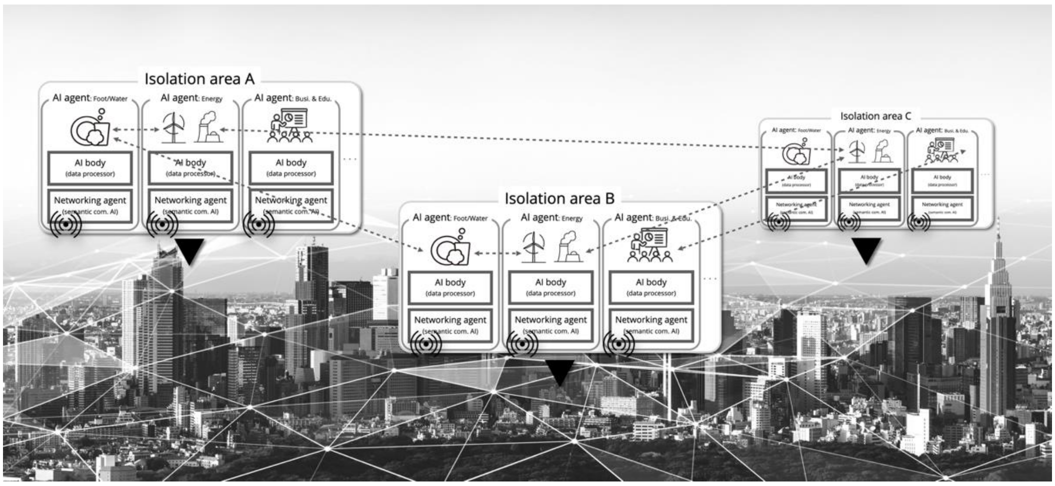
Natural disasters and infectious disease pandemics have in a flash transformed not only the distance and scope of human connections, but also the balance between the cyber and physical. As more and more information is digitalised and digitally linked, people can choose to coexist with AI, letting it take over the simple but not insignificant information tasks and their linkages, to shape a better future. Furthermore, as values continue to diversify, it is also worth considering the use of AI that can summarise and report on the status of various social, environmental and economic values (as is the case in foreign countries where AI with multiple personality traits, such as positive/negative thinking, work together to trade stocks).

5.3.4. Summary

As one of the prescriptions for the realisation of a society and a way of life that can cope with natural disasters and the spread of infectious diseases such as COVID-19, and that restores humanity and achieves well-being in addition to economic rationality, we have proposed multi-layer and multi-scale living spheres and city spheres. These would be supported by a multimodal AI network, and opinions were stated on the linkage of various layers in each sphere and the linkage between spheres. In addition, since administrative measures must be judged on a multi-aspect, multi-scale and multi-standpoint basis, it is extremely difficult for AI alone to make the best judgments. However, we reported that AI has the capacity to report on the current situation in these conditions and present a list of evaluation values based on diverse value criteria. We believe that this is not the only option, nor can it be guaranteed to be the best, but it is one form that people can accept, and we have given it as an example.



(a) multi-scale & multi-layer isolation and support based on multi-AI network simulation



(b) Linking of AI clusters deployed by region and aspect

Figure 5.3.1 Example of multimodal AI network implementation

5.4. Technology roadmap to realise the “Multi-AI Networked City”

5.4.1. What is the goal of the “Multi-AI Networked City”?

As noted in section 5.1, the world's urbanisation rate exceeded 50% of the population in 2007, and by 2018, about 55% of the world's 7.6 billion inhabitants was concentrated in cities[5.4.1)], with this figure expected to reach 60% by 2030 (WUP 2018). This rapid urbanisation has been driven mainly by the increasing efficiency and sophistication of economic activities. It has likewise been supported by extensive urban infrastructure for mobility, lifelines, energy and information, which has been made possible by the integration of systems and innovative technologies that emerge from time to time.

On the other hand, looking 30 years ahead to 2050, cities should aim not only to be economically efficient, but also to have low environmental impact, such as carbon neutrality, and to have functions that keep them convenient, comfortable and safe. Furthermore, with the recent increase in pandemics and disasters associated with global climate change, cities need to be resilient in order to cope. These requirements are reflected in the "Multi-AI

Networked City", with its ultimate aim of ensuring a high level of human security and well-being.

The "Multi-AI Networked City" is made up of a network of living spheres, and at the centre of the network in virtual space is the Multi-AI Well-being Survey System (MAWSS). MAWSS is an AI network that connects that various urban infrastructure and living spheres via data.

For actual operation of the city, the solutions indicated by MAWSS may not always be the best for individual living spheres. This is because, as elaborated on in section 5.3, the MAWSS considers not only the well-being of individual living spheres, but also the harmony of the city as a whole. In addition, the system is connected to multiple infrastructure networks via data. For this reason, the technology roadmap shown in Figure 5.4.1 includes not only the technological feasibility of reaching the end goal, but also the processes of consensus building in society and dissemination of the technology based on measuring well-being and reflecting those results on the actions of each stakeholder.

5.4.2. Technologies to support the "Multi-AI Networked City" and a society accepting them

In Figure 5.4.1, the horizontal axis is the time, showing four images of the city that change along this time axis. Furthermore, technologies are on the vertical direction, with each technology field represented by a single bold arrow, arranged in the following order.

The top row is the basic technology of AI (black), and following rows are the four technology fields (blue), with the MAWSS (black) that integrates the information of each technology field. Below these are not technology fields, but are to assess well-being (green) that ensures societal acceptance, with the education and culture axis (green), which provides the criteria for value judgments, on the bottom row. These bold arrows are connected including redundancy via data to the MAWSS (black), which is at the core of the "Multi-AI Networked City".

Each technology element required for the realisation of this city is placed in the middle of each bold arrow, and the year (red two-digits) in which it is expected to be implemented in society is indicated at the end of each technology element.

These technology elements were selected from the "Eleventh Science and Technology Foresight 2019 Synthesis Report (hereinafter referred to as the S&T Foresight)" [5.4.2)]. In the S&T Foresight, 702 science and technology topics (i.e. technology elements) were identified, divided into the following a) - g), with the timing of technological realisation and social realisation described for each technology element. Furthermore, the forecast period was roughly the 30-year period leading up to 2050, and the target year of realisation was set at 2040.

a) Health, medical and life sciences
b) Agriculture, forestry and fisheries, food, biotechnology
c) Environment, resources, energy
d) ICT, analytics, services
e) Materials, devices, processing
f) Cities, architectural, civil engineering, transportation
g) Space, oceans, Earth, scientific basis

In the following text, items (1) to (8) correspond to the bold arrows (technology fields) in Figure 5.4.1. After selecting relevant technology elements from the above 702 science and technology topics, they were assigned to each bold arrow (technology field). These technology elements are also underlined in the text below. Most of the selected technologies are predicted to be implemented in society by 2040, which is one of the bases for the target year of the "Multi-AI Networked City" being set at 2050.

(1) Development of high-efficiency, high-performance AI

In order to realise the “Multi-AI Networked City”, the basis of all AI technologies is the speed of information processing and the connections between systems, which is based on the development of peripheral computer hardware and software.

On the hardware side, improving data verification speed and reducing power consumption are problems, but the S&T Foresight predicts the development of (28) a computer with 100 times the power performance (2029) <Note 1>. Meanwhile, in terms of software, further development of image analysis technology and human-AI interfaces for text translation, parts of which are already being used today, is expected. As the amount of information to be handled is expected to be enormous, technological innovation that integrates hardware and software is essential.

In addition, (53) a comprehensive elucidation of brain functions (e.g. emotions, memory) (2041) is expected to facilitate the progress of the AI networks themselves, even though this directly relates only to understanding of the human brain. At present, AI collaborative networks are still in the phase of being designed manually, but futuristically, we can expect the emergence of technologies that allow AIs to form networks autonomously with each other. These technological developments are predicted to bring about highly functional AI that curbs power consumption and emits less CO2, AI that can self-control for abnormalities, and AI that can work together autonomously to identify processes and tasks.

<Note 1> The first number (28) is the S&T topic number of the S&T Foresight, and the number at the end of the line (2029) is the year in which it is expected to be implemented in society.

(2) Urban housing and mobility comfort

As shown in Figure 5.2.5, the “Multi-AI Networked City” is a network of multiple living spheres with populations of 10,000 to 30,000, forming a city sphere unit with a population between 100,000 and 180,000. In normal times, this city sphere unit would function to ensure the smooth operation of information, human flows and logistics in the living spheres, and thus the efficiency of economic, cultural and social activities. On the other hand, in the event of an outbreak, the living spheres must be sustainable enough to be separated as necessary and still ensure Decent Living Standards (DLS) on their own for a certain period of time.

As technologies necessary for these independent and autonomous living spheres, the S&T Foresight cites (545) the realisation of self-sustaining infrastructure independent of broader infrastructure (2030). Likewise, to address the spongification of urban areas due to population decline, it cites (550) technologies for the maintenance and management of under- and un-utilised land generated by population decline (2031). The living spheres of the "Multi-AI Networked City" aim to implement independent and autonomous infrastructure in order to improve the resilience and DLS of the city. It makes sense to use under- or un-utilised land to solve this problem, as each living sphere would have the capacity to function independently for a certain period of time, allowing for the scope of lockdowns to be flexibly adjusted (Figure 5.5.6).

The S&T Foresight also identifies (93) automated driving and drone operation technologies for public transport and logistics (2031) and (568) level-5 automated driving technology (2034) as key enablers of a low-carbon shift in mobility. These mobility technologies are predicted to evolve to manage of short trips within living spheres, in addition to travel between city sphere units and between living spheres. Futuristically, they will shift to CASE (Connected, Autonomous, Shared, Electric), where AI and automated driving are integrated. The current living spheres of the "Multi-AI Networked City" are aimed to be areas for walking. However, even if we assume that the initial speed of automated driving will be 30km/h or less, if the above-mentioned CASE is realised for a much larger living sphere than is suitable for walking, some of the current public transport services could possibly be replaced by CASE services. On the other hand, there are many issues that need to be resolved before automated driving at level 5 can be widely adopted, including not only the technology but also the structure of roads, the establishment of legal and insurance systems, and the formation of a social consensus on accident risk.

(3) Infrastructure and stable supply of food and energy

In terms of food production, S&T Foresight predicts that (273) technology to predict the regional and product-specific impacts of climate change on food production (2032) and (98) agricultural AI, IoT and robotics (2031) will be ready for social implementation in the first half of 2030s. The introduction of AI into agriculture is expected to lead to a parallel increase in the automation of distinctive agricultural products on small farmlands in city suburbs and on comparatively large farmlands in rural areas, resulting in the diversification of items produced and enhanced production efficiency.

However, the Japan Ecological Footprint Report[5.4.3)] points out that Japan's low bioproductivity imposes environmental burdens on other countries, and at the same time, Japan's food self-sufficiency rate is remarkably low among developed countries, posing problems for food security. In addition, Johan Rockström of the Potsdam Institute for Climate Impact Research has proposed a "planetary boundary"[5.4.4)] for the Earth’s system, and points out that biodiversity and the global cycle of phosphorus and nitrogen are beyond the realm of uncertainty. This implies the need for technologies that improve the efficiency of food production, while at the same time limiting the associated increase in environmental impacts. Further widespread adoption will require a mechanism that allows for the viability of renewable energy businesses as a whole. In this respect, the current guidebook on renewable energies produced for businesses by the Agency for Natural Resources and Energy of the Ministry of the Environment is very easy to understand, but it does not indicate what the bottlenecks and risks may be for businesses.

In general, it is difficult at present to meet 100% of demand at normal times in densely populated urban centres with renewable energies, but rather they can be positioned as a backup to avoid sudden energy shortages during outbreaks. For normal times, it will be necessary to build a diverse and flexible system of coordination, including lending between multiple city spheres and living spheres, utilisation of hydrogen energy storage, and carbon offsets for the country as a whole. The question is who will bear the cost of the functioning of the system in both normal times and in the event of outbreaks.

This is true not only for energy, but also for city water supply. During outbreaks, natural conditions, such as the use of rainwater and rivers, must be considered, and at the same social consensus must be built in normal times on the cyclical reuse of water.

In conclusion, the infrastructure of the "Multi-AI Networked City" will move towards independent and autonomous decentralised infrastructure in the future, including renewable energy projects. However, there are huge wide-area infrastructure networks in the cities of today, and we expect that these wide-area networks and MAWSS (AI), described in more detail below, will maintain a loose relationship through data exchange in virtual space for the time being.

(4) Environmental and disaster forecasting and evacuation management

To reiterate somewhat, for a "Multi-AI Networked City" to be sufficiently resilient in the event of an outbreak, independent and autonomous urban activities need to be possible at the living sphere level during normal times.

According to the S&T Foresight, the construction of this system would require (546) high precision disaster hazard maps for specific areas (2029). At the same time, however, it will be a challenge to ensure that updates can be carried out in a timely manner to keep pace with rapid changes in weather associated with global warming. The report of Working Group I in the IPCC Sixth Assessment Report (AR6) [5.4.5)], released in August 2021, states that if temperatures were to rise by 2°C, the frequency of high temperatures would increase by a factor of 5.6, and the incidence of heavy rainfall would increase by a factor of 1.7, compared with the once-in-a-decade rate from statistics for the 1850-1900 period. This means that the design conditions for (212) design methods for self-sustaining urban spheres (2038), would need to be updated based on the latest projections.

In the event of a widespread outbreak, the first challenge would be to ensure Decent Living Standards (DLS), and the next would be to sustain people's well-being. However, in the event of a severe disaster, these measures may become impossible. In large cities, it may be necessary to evacuate hundreds of thousands of people across multiple cities.

To respond, the S&T Foresight indicates technologies such as (523) AI integration for energy saving and evacuation in housing and mobility (2030) and (563) mobility management technology for emergencies (2031).

The transition from normal time to contingency operations would require the use of AI for pre-event prediction and post-event information gathering, as well as associated countermeasures. In advance of an event, MAWSS (AI) would indicate the scale of the assumed disaster and the population that can be guaranteed DLS in each living sphere. However, after a disaster occurs, it would be necessary to indicate in real time the movement and evacuation of people from areas that differ from those assumed in advance.

(5) Infectious diseases, lifestyles and health monitoring

For infectious diseases, we need to build a system that takes advantage of our experience with COVID-19 thus far. First of all, technology is needed to detect the presence of infected people in living spheres. In Japan, monitoring of infectious diseases by analysis of sewage was implemented in 2021 (see section 5.1.5., Note 8). Furthermore, the S&T Foresight predicts the implementation of (62) ultra-lightweight sensors for rapid detection and determination of infections and infectivity of a particular infectious disease (2031).

In a “Multi-AI Networked City”, living spheres would be temporarily quarantined by means of a living sphere lockdown in response to the spread of an infectious disease. In parallel, DLS would be ensured within living spheres based on self-sustaining operation. With regard to the effectiveness of partial lockdowns, the simulations in Figure 5.2.6 show that the spread of infection in decentralised cities is slower than in unipolar concentrated cities, and also that their structure makes it easier to carry out lockdowns.

(6) Measurements in the pursuit of well-being

For the “Multi-AI Networked City”, we are looking at the types of urban functions and their arrangement in order to maximise the level of people's well-being. The key to this will be (60) technology for measurement, analysis and assessment of emotions such as pleasure, displeasure, likes and dislikes (2031).

It is important to note that a social consensus is needed to acquire and analyse data that contains personal emotions. This will require both confidence in the procedures used to achieve this consensus and confidence in the technology used to protect the information. As such, decisions need to be made by both companies and individuals concerning the treatment of information, including what information should be open or closed, what information to keep in AI, and what information to keep only in human hands. In this regard, there must be (81) a social consensus on the relationship between humans and AI (2035). Going forward, mechanisms for collaboration between data while protecting privacy are expected to be at the core of the data driven society.

Furthermore, in the "Multi-AI Networked City", which is envisioned for post-2050, we would like to point out the possibility of using (53) a comprehensive elucidation of brain functions, such as consciousness, sociality, creativity, etc., (mentioned above in (1) for the year 2041) to predict human judgments and actions that are influenced by latent and explicit memories and emotions, and to connect this to the arrangement of physical urban functions.

(7) MAWSS (AI)

MAWSS (AI) stands for Multi-AI Well-being Survey System. The basic role of MAWSS is to record and integrate the various information of the “Multi-AI Networked City” in multi-layered memory. In other words, MAWSS is "loosely" connected to the operators in the technology fields (2) to (6) above via data, and its role would be to coordinate the well-being of each living sphere and city sphere unit as a whole, while maximising the capabilities of technology fields and giving feedback on compromises to the living spheres.

Technologies for this loose connection to MAWSS (AI) include (532) open data on cities, and the creation of platforms that can be owned and collaboratively used by various stakeholders (2029), (534) infrastructure monitoring, prediction and control technology based on seamless coupling of physical and cyber space (2030), and (13) AI-based control of real-world systems (2030). We predict that the social implementation of these technologies as systems will further accelerate the development of MAWSS.

(8) Shaping well-being through education and culture

The aims of a "Multi-AI Networked City" will be influenced by the values of its time. Throughout the COVID-19 pandemic, although we have been able to stop the spread of infections to some extent by refraining from economic activities, the widespread and repeated declaration of states of emergency has imposed on us a considerable economic and psychological cost.

In Figure 5.4.1, the reason why (8), "Shaping well-being through education and culture", is placed at the bottom is that education and culture are fundamental in influencing the criteria we use for judgments that determine the direction of technology and system development. These criteria are based on the values of the moment, and these values are in part universal and in part changeable according to environment.

The unipolar concentrated cities of the present were built in the 20th century mainly aimed at increasing labour productivity. One of the reasons for the widespread nature of the repeated emergency declarations is that the wide range of routes through which infections can travel in a unipolar concentrated city cannot be ascertained. The problem is that the structure of the city has not changed, even though our current value systems demand well-being based on a multipolar decentralised city with an emphasis on living spheres.

Such a gap between values and real space can also occur between the present and 2050. In this sense, we think it necessary to share among the parties concerned a more accurate “goal image” for 2050 from the point of view of the present. Two episodes are laid out in Figure 5.4.2. However, as Figure 5.4.1 and Figure 5.4.2 are themselves subject to future changes in the environment, they will need to be periodically reviewed.

5.4.3. Scenarios for realisation

We believe that (212) Design methods for self-sustaining and autonomous city spheres based on smart use of materials and energy (2038) in S&T Foresight, will contribute to the diffusion of the “Multi-AI Networked City”. This is because the establishment of design methods will lead to further recognition in society of the roadmap and common use of the design procedures. The commonalisation of these procedures will reduce risks in the development of related technologies and systems, which will lead to their diffusion.

The physical realisation of this city is assumed to take place after 2050, but the transition to this city will be preceded by a virtual "Multi-AI Networked City", where only the information systems are networked, while retaining current infrastructure networks and other city frameworks.

In other words, as the four images at the top of the roadmap show, we anticipate that cities will gradually become multipolar by first establishing multiple living spheres with virtual functions within unipolar concentrated cities. As a first candidate for the establishment of living spheres, Figure 5.2.11 shows a map of the residential population and area of municipalities in the Tokyo metropolitan area. This has already been discussed in more detail in section 5.2.7 on the development and realisation of Multi-AI networked metropolitan areas. To reiterate, Figure 5.2.11 shows that the population of one unit of a “Multi-AI Networked City” (100,000-180,000 people) and the many small cities in the suburban zone (C-shaped area) 20-40 km from central Tokyo are similar in population and area scale. Of course, while population size and area alone do not make a “Multi-AI Networked City” highly feasible, the fact that areas exist with administrative districts physically matched in size is a clue to the question of where to start.

In conclusion, the goal of this proposal is the formation of a virtual "Multi-AI Networked City" by 2050, in which the bold arrows (1) to (7) shown in Figure 5.4.1 and MAWSS are loosely linked via data. The subsequent transition to a real or physical urban structure (living sphere units) is also an issue related to the framework of the area's infrastructure, and should be pursued on a regional, district, or living sphere basis, planning for the timing of upgrades.

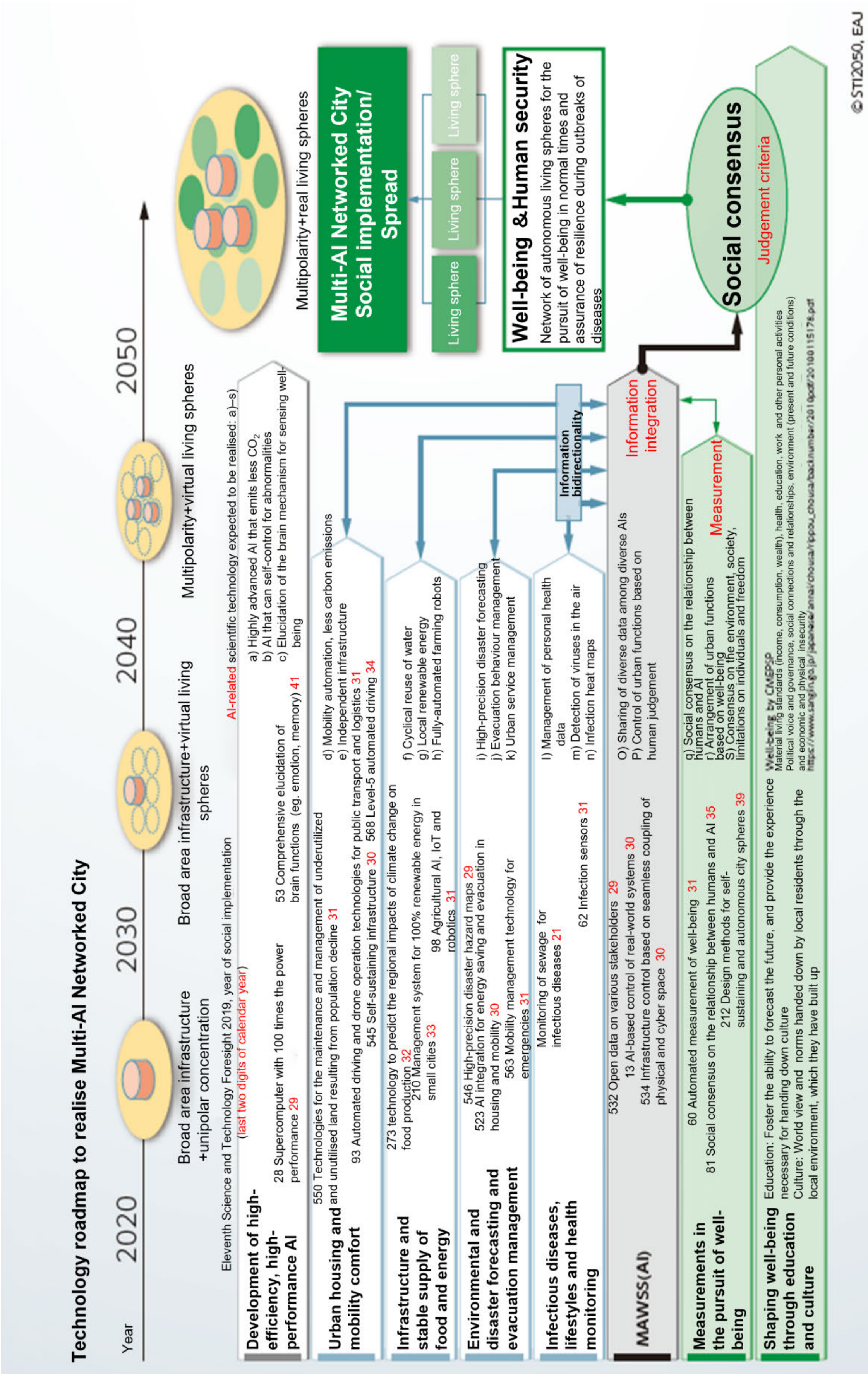


Figure 5.4.1 Technology roadmap to realise Multi-AI Networked City

Episode 1

One day in 2050, Mrs. A, 40-year-old living in the city centre, left her house to go to the office where she works, which is also in the city centre and is 10 minutes away on foot. Her daughter, whose high school is located within their 2–3 km radius[1] living sphere, she left the house with her. Mrs. A works at the office two days and at home two days in a week. On their way, the two talked about how AI and humans can share information, the extent to which AI can make decisions on genetic modification or warfare[2], and the roles of culture and art in education essential for humans. Mrs. A and her husband, also aged 40, are discussing moving to the suburbs because the condominium building, they live in is nearing the end of its structural lifespan. What motivated them to choose moving to the suburbs is that highly detailed hazard maps and information related to energy and other infrastructure are disclosed through the socially open database (532-29) in easy-to-understand formats. Specifically, they came to realize that by combining a home independent of broader infrastructure in terms of energy and water with level-5 automated driving, they will be able to achieve a more sustainable lifestyle by living in the suburbs rather than in the city centre. And even though the spread of remote work means that seats will be available on trains during commute, they are planning to choose where to move taking into account urban planning policies and future residential population distributions.

Around noon that day, the COVID-50 pandemic hit, and Mrs. A's living sphere was locked down because vaccines were still in the process of being manufactured. The market where Mrs. A planned to shop on her way home was outside the virtual boundary of her living sphere, but she can cross the boundary since she has a wearable infection sensor. Today, however, because AI recommended a different market based on the infection heat map, Mrs. A followed the recommendation. Each life sphere has its own virtual boundary, but it changes slightly every day as flexibly defined by AI, taking the state of infections and convenience of daily living into consideration. At night, Mrs. A checked the results of her health and well-being measurements for the past week and enjoyed a conversation with AI, which initiated the talk by asking her questions on her awareness and sociality, before going to bed.

Notes:

1. Many cities looking to the post-pandemic era consider life spheres to be areas coverable mainly on foot. For example, Paris sets life spheres as the range within 15 minutes on foot, and Melbourne sets it at within 20 minutes on foot, equivalent to an area within a 2–3 km radius.
   Although there are generational difference in waking speed and the effect of climate on the distance that can be covered on foot, but in many cases, average waking speed is set at 4 km/h and the length of one trip on foot to be between 15 to 20 minutes.
2. Eleventh Science and Technology Foresight 2019 (Science and technology reference number)- (year of social realisation [last two digits of the calendar year])

Episode 2

Mr. B, 70 years of age, had moved from the city centre to a house located 10 km away from a train station in the suburbs several years ago when he retired from work. One day in 2050, after having a breakfast of home-grown vegetables, Mr. B checked his health, the percentage of electricity remaining on his home battery, the amount of water stored in his tank, and other matters while he waited for the automated car he reserved the previous night to come pick him up. Based on the results of checking, he decided to sell electricity from his home battery and water from his reservoir to the local power company and water utility. The automated car then arrived, but because Mr. B sold electricity and charged the car, he ended up leaving his house about 30 minutes later than intended. He had planned to check on the growth of his vegetables in the field today, but in fact had made a mistake entering information into the farming robot; at the field, the farming robot had already finished harvesting the vegetables. Hurriedly, Mr. B changed the automated car's scheduled route in order to go sell the vegetables at the market.

While he was taking his vegetables to the market, however, a pandemic-induced lockdown of his living sphere was announced. In a lockdown, he would be stopped by AI from going to the market, which is located outside the established virtual boundary, without his wearable infection sensor, so he hurried back home to get it. While at home, a forecast of flood in three weeks' time was issued, so Mr. B had to reserve a means of evacuation on the mobility management system, which took some time. In the end, he decided to go sell his vegetables tomorrow. At night, AI, which had sensed Mr. B's activities during the day, advised that he take a day off tomorrow in consideration of his health. This reminded Mr. B that he had forgotten to enter his plan to go sell his vegetables tomorrow, and so he hastily made a reservation for an automated car to take him to the market, and AI agreed to the change of plans.

Figure 5.4.2 Two Future Stories

5.5. Technology transfer to emerging countries based on the "Multi-AI Networked City"

5.5.1. Social sharing of data in developing countries (DCs)

As for technology transfer to developing countries (DCs), policy is explained in METI's "Final Summary" [5.5.2)]. What is characteristic of this summary is that it points out the effectiveness of the so-called co-creation model in the digital field, based on which data held by business entities is made public as socially shared goods, so that economic benefits can be mutually enjoyed.

On the other hand, in a “Multi-AI Networked City”, the prospect of recurring urban outbreaks such as COVID or natural disasters, creates the need to put certain limits during outbreaks on the well-being that people enjoy in normal times. For example, it is impossible to ignore the fact that making data a social common good in normal times poses the problem of conflict with laws protecting companies and individuals. If a social consensus can be reached in DCs on this point, then it would be possible during an outbreak to accurately assess damage through the smooth circulation of data. As shown in Figure 5.4.1, an approach through the bi-directionality of information between MAWSS and other technology fields would be established.

5.5.2. Urban issues in developing countries (DCs)

UN News[5.5.3)] forecasts a world population of 9.7 billion in 2050. Growth in Asia and Africa is expected to be particularly striking, with urban populations in Asia and Africa predicted to double in 2050 compared to 2015 (Figure 5.5.1 centre).

So what are the unique urban challenges of DCs? The first is that urban areas are rapidly expanding due to a combination of population influx from rural areas and natural growth, as urban areas are sprawling into the suburbs. In this respect, DCs differs from developed countries, where urban growth has ceased and some areas are shrinking or experiencing spongification.

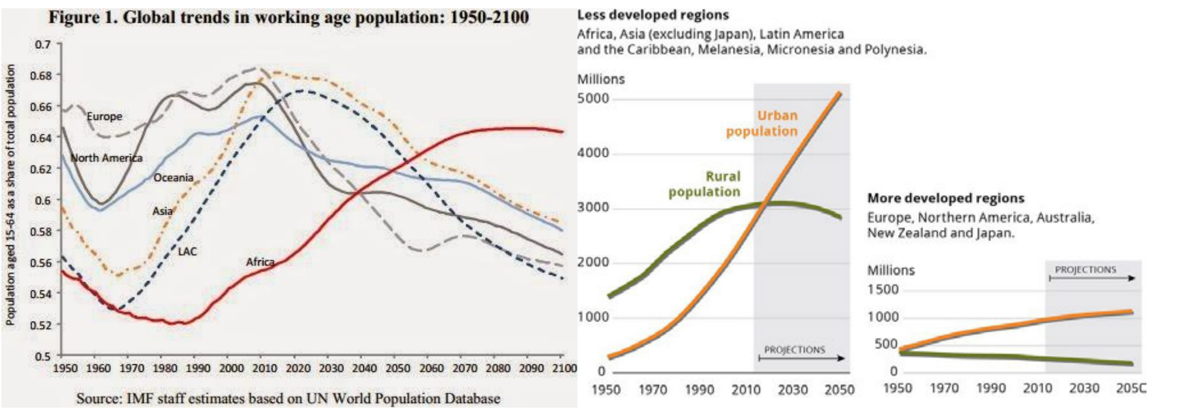
Secondly, insufficient public transport, such as railways, means that, aside from walking, people have to rely on bicycles, motorbikes, buses and private cars to get around, resulting in chronic traffic congestion. Although traffic congestion also occurs in developed countries, the difference is that in developed countries there are alternatives to private cars, as inter-city and intra-city railways were developed before motorisation.

Thirdly, much of the housing development is illegal or informal, causing unplanned suburban sprawl. For example, as shown in Figure 5.5.2, 70% of Africa's urban population is said to live in informal settlements.

Fourthly, areas of urban sprawl are often located in terrains that are vulnerable to disasters.

2. Assess current situation

Issues of African Cities



Rapid increment of working generation in Africa

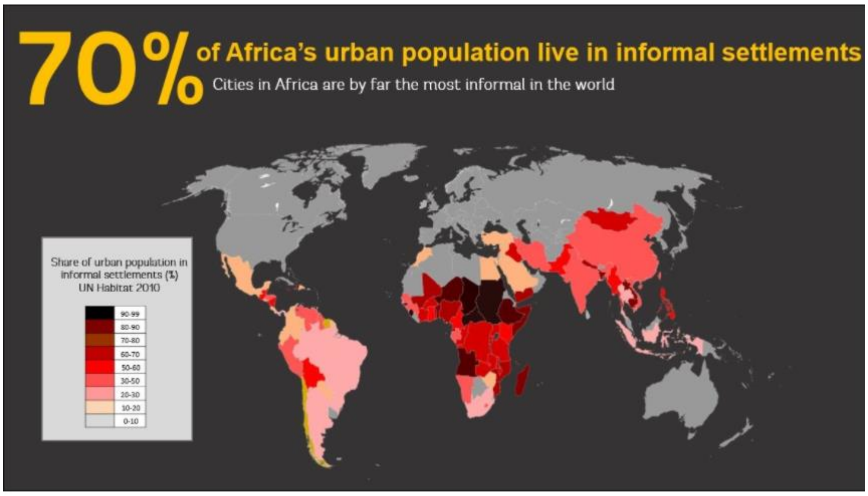
Rapid increment of urban population in Africa/As

http://www.economicsinpictures.com/2014/08/trends-in-global-working-age.html

http://www.eea.europa.eu/soer-2015/global/urban-wc

2021/4/29 21

Figure 5.5.1 Predictions for population trends up to 2050 in developed and emerging countries



Source: UN Habitat, World Bank

Figure 5.5.2 70% of Africa's urban population in informal settlements

To summarise these four challenges, in general, cities in DCs are experiencing ongoing uncontrolled suburban sprawl to accommodate rapid population growth, which has led to the expansion of slums and chronic traffic congestion. The result is a vicious cycle of economic loss due to inefficient movement of people and goods, as well as the occurrence of air pollution, noise and unnecessary CO2 emissions.

It is generally recognised that slums are breeding grounds for disasters, pandemics and anti-social organisations. However, slums, like traffic congestion, are a phenomenon resulting from poverty in rural areas and the rapid influx of people into urban areas, and are not the real cause of these urban problems.

Figure 5.5.3 shows the distribution of urban areas in Kabul, the capital of Afghanistan. The sprawl is shown in the mostly light green informal suburban areas. Accordingly, to solve these urban problems, it is necessary to improve the quality of life in rural areas and to simultaneously put into place land registration systems in urban areas.

In this regard, we will discuss how technological progress is changing rural life and its impact on land registration systems. Figure 5.5.4 shows the results of automated calculation of the area of residential land, roads and greenery (trees) using image recognition technology based on video taken from a drone. The use of AI, such as this image recognition technology, is making it possible to capture, in real time, rapid changes in land use in areas of sprawl and illegal construction in slums, which was previously difficult to do. It is hoped that this new technology will lead to a reduction in informal settlements

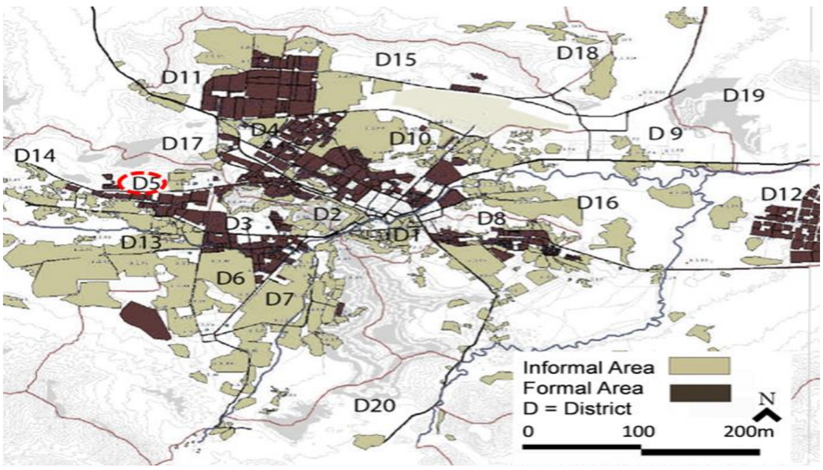


Figure 5.5.3 Informal settlements as suburban sprawl (Kabul, Afghanistan)

Figure 5.5.4 Classification of roads, residential land and green space from images

5.5.3. Rundown of issues and introduction of new technologies

In order to improve well-being in rural areas and to establish land registration systems for urban areas, issues can be divided into two categories: 1) long-term and wide-area issues, and 2) short-term and local issues. For the former, long-term and wide-area improvement, it is effective to proceed with the following five items simultaneously, focusing on a wide-area Multi-AI network (Figure 5.5.7, left). These are a) creating urban visions; b) inheritance of local culture; c) enhancement of rural well-being; d) coexistence of cities and agriculture; and e) concrete responses to outbreaks.

For the latter, short term and local issues, it would be effective to work simultaneously on the following five issues, focusing on living sphere AI networks. These are a) land registration systems; b) durable housing; c) water and sanitation infrastructure; d) promotion of renewable energies; and e) diffusion of compact urban EVs (Figure 5.5.7, right).

With regard to the creation of urban visions, which is the overall key, Japan has a "municipal master plan" system, which requires the establishment of a future vision for the city and the clarification of development policies for each district corresponding to the issues of the whole region. Below, the preparation of this type of urban vision (i.e. master plan) is described as PUD (Planning and Urban Design).

Why is the development of PUD (i.e. master plans) stagnating in DCs? One of the reasons is the lack of human resources due to complete reliance on technology and funds from developed countries to prepare PUD. However, even if the human resources were available, the unique challenges facing DCs would make it difficult to keep up with the rapid influx of people into the city centres, and to obtain and update statistical data due to the fact that many settlements are illegal or informal.

STI is a suitable solution to these problems. For example, with the recent proliferation of smartphones in DCs, it is becoming easier to estimate population and travel routes based on location information obtained from call detail records (CDRs). In addition, satellites, drone aerial photography and related image recognition technologies are making it possible to determine the number of housing units, quantify land use, and detect illegal construction at an early stage. Thus, the "DC-type Multi-AI Networked City" has the potential to improve the acquisition and updating of statistical data through the acquisition and image recognition of data based on the development of various devices and aerospace technology.

Figure 5.5.5 shows an example of an agricultural model in DCs. This model was proposed for a rural area around Kigali, the capital of Rwanda, which is not yet equipped with a wide area electricity network. The core technologies in this model are solar PV, water pumping and irrigation, microgeneration, micro-transmission and agricultural technologies and related systems.

For rural communities in this agricultural model, the increase in cultivated area due to irrigation leads to an increase in income, which in turn enables the purchase of electricity from local power companies. In other words, this agricultural model aims not simply to promote the diffusion of electricity, but also to increase overall self-sufficiency in energy, food and water, to create new jobs related to agriculture and energy, and to realise create self-sustaining and autonomous living spheres.

In the World Bank report “Harvesting Prosperity: Technology and Productivity Growth in Agriculture”, it is argued that stronger investment in creating and ensuring the uptake of new knowledge will lead to a dramatic enhancement of agricultural productivity and hence agricultural incomes.

However, in relation to agriculture today, the UN’s Sustainable Development in the 21st century (SD21) [5.5.4)] points out that more than half of our food comes from three cereal crops - rice, maize and wheat - and that the spread of an infectious disease in any one of these crops could seriously damage the world's food supply. In the Netherlands, a leading agricultural country, the Green Port policy has focused on the integration of primary production, secondary processing and tertiary marketing of crops into a six-tier industry, with the aim of selling the products at high prices in a timely manner. At present, focus has shifted to how to increase production with fewer inputs (e.g. labor, energy, water, fertiliser).

We feel that the implementation of AI farming technology should be accelerated in the suburbs of DCs to increase the production of a variety of crops with fewer inputs through automation and information technology, rather than relying on growing a single crop.

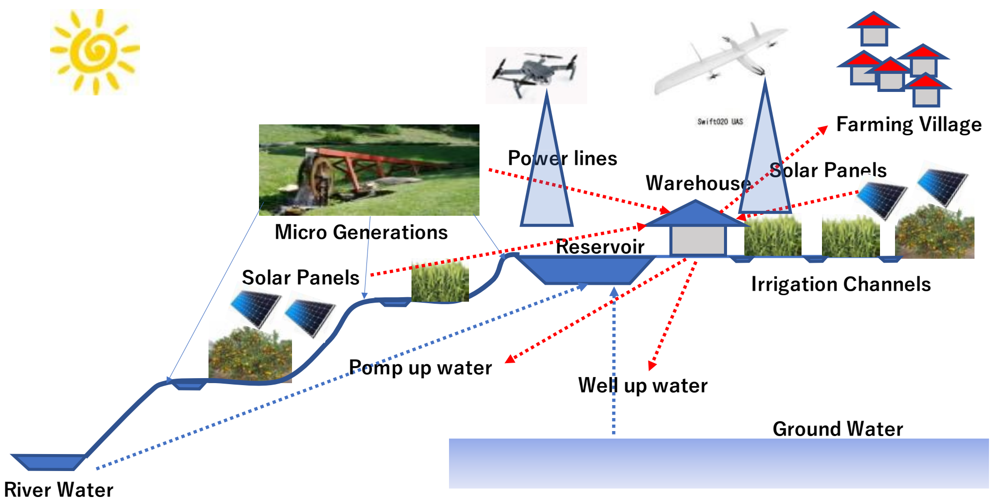


Fig 1 Irrigation System supported by Microgrid

Figure 5.5.5 Pump and irrigation microgrid power system

5.5.4. New technologies that transform cities and agriculture

To date, transportation policy in DCs has generally been to introduce subways and Bus Rapid Transit (BRT) in city centres, and to develop the areas around stations as high-density urban areas based on Transit Oriented Development (TOD) <Note 1>.

Under these circumstances, the practical application of automated driving is now within sight for 2050. Users will be able to travel seamlessly from their point of origin to their destination by Small Smart Vehicles (SSVs) for urban use through MaaS (Mobility as a Service). We expect to break away from the conventional pattern of developing underground areas around subway (or BRT) stations by TOD, and to shift to living spheres with centres based on walking and SSVs, and to on-demand public transport with MaaS and SSVs in the suburbs.

As for the renewable energies that will support the decentralised transportation infrastructure network of MaaS and SSVs, the International Energy Agency (IEA) estimates that solar power could provide a quarter of the world's electricity by 2050, providing a tailwind for low-carbon "Autono-MaaS". In Japan, the “PV2030+” roadmap published in 2009 by the New Energy and Industrial Technology Development Organization (NEDO), predicts solar power generation costs of 7 JPY/kWh in 2030, below current retail electricity prices. In DCs, there will be a shift from the construction of large-scale power stations and power grids to solar power generation on a city block basis in city centres and on a door-to-door basis in suburbs. It is expected that the above-mentioned SSVs will also become a popular method of contactless charging with green electricity while parked.

In terms of water supply, the Organisation for Economic Co-operation and Development (OECD) predicts that by 2050 about 40 percent of the world's population will face severe water shortages, mainly in the context of population growth in emerging and developing countries[5.5.5)]. In areas where there is currently no water service, drinking and domestic water are obtained directly from rivers, lakes, rainwater and groundwater. In these areas, there is a potential for shifting to local systems using a "membrane treatment method" instead of constructing a network of public water supply to cover a large area. Direct Potable Reuse (DPR) has also been in the spotlight recently. In other words, drinking water is produced and distributed at sewage treatment plants. In the United States, there are ongoing discussions on technology development and public acceptance to promote DPR. For the time being, use can be promoted as a backup in case of outbreaks, but use in normal times will depend on social consensus.

Judging from the above-mentioned trends related to transportation, energy and water looking ahead to 2050, we expect that cities in DCs will shift towards a city type that is highly compatible to agriculture, as shown in the (agricultural land + urban land) integration model in Figure 5.5.6, where the dispersal of urban areas is covered by SSV mobility, with independent and autonomous infrastructure. The integrated management of cities and agriculture using AI would be the "Multi-AI Networked City" in DCs.

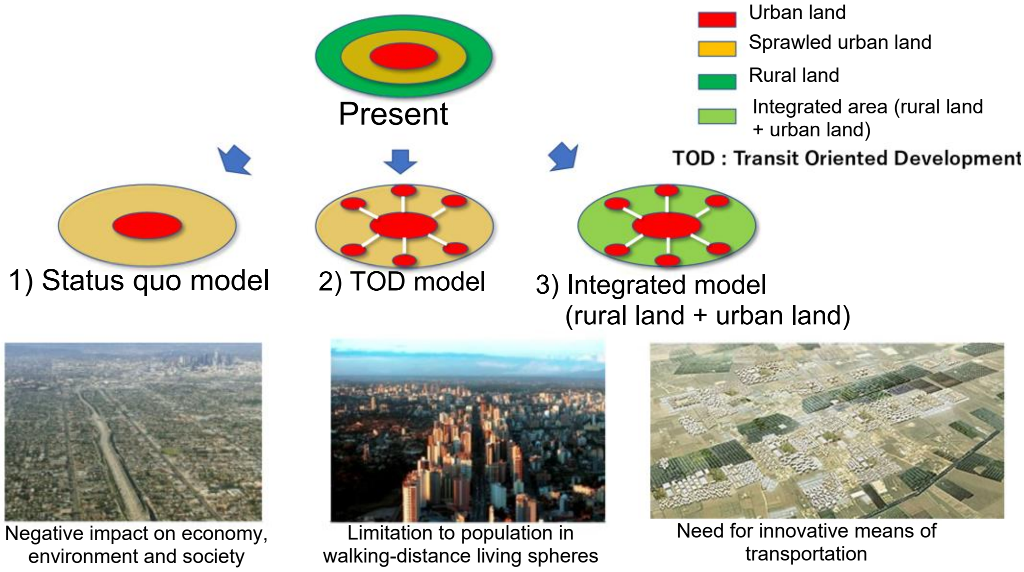


Figure 5.5.6 Multi-AI Networked City: (rural land + urban land) Integration

<Note 1> TOD (Transit Oriented Development) refers to a way of development that focuses on transit (i.e. the movement of people) aimed at converting automobile-dependent cities into rail-oriented cities, such as the systematic development of residential areas around suburban stations, while placing emphasis on commercial facilities around stations in the city centre.

5.5.5. Summary

In DCs, the pace of urban change is exceeding the pace of necessary social reforms. The greater part of populations face problems with water, sanitation, waste water, healthcare and schools, and in some countries, population censuses have not been conducted during the past 15-20 years.

Correspondingly, Figure 5.5.7 provides a graphic representation of technology transfer to emerging countries through the “Multi-AI Networked City”. The diagram on the left shows long-term and wide-ranging issues that are more suited to top-down action by central governments. The diagram on the right shows short-term, local issues, which are more suited to bottom-up approaches by local governments and businesses.

Regarding the diagram on the left, first of all, we need an urban vision (PUD) that includes a system for upgrading, and this urban vision should include a roadmap to improve the well-being of rural areas by planning agricultural land and urban areas in an integrated manner. With regard to the diagram on the right, we believe land registration systems urgently need to be improved in order to ascertain the current situation and to reduce illegal settlements, and next that diffusion of SSVs is important. This is because the land registration system is the basis for the creation of the urban vision (PUD), while the SSVs will help to improve the well-being of farmers through the sale of agricultural products and at the same time be effective in transporting goods to cities during outbreaks.

In Figure 5.5.7, issues specific to DCs are colored blue, and issues common to developed countries are colored green. The green issues are necessary elements in the transition from unipolar concentrated cities to multipolar decentralised cities, even in developed countries. It is hoped that DCs will be the first to introduce these elements, providing the momentum for developed countries to also move towards multipolar decentralised and self-reliant cities.

Rather than copying the "Multi-AI Networked City" of developed countries, necessary technologies should be transferred to DCs, taking into account local cultures and lifestyles. Specifically, we propose that the "DC-type Multi-AI Networked City", which connects the two pentagons shown in Figure 5.5.7, should be socially implemented ahead of developed countries. And finally, Figure 5.5.8 shows that the horizontal axis is time and the vertical axis is well-being, while the third axis is STI. Innovation (STI). This figure shows how emerging country cities skip the growth path of developed country cities due to the social implementation of the leading 'DC-type multi-AI network city model' in emerging countries. Note that both emerging and developed countries share the same goal of improving wellbeing through 'multi-polarisation + real living areas'.

We have learned through our work on global issues such as global warming, energy, refugees, and food that consumption of large amounts of resources and energy and improved well-being in developed countries alone is problematic. We must remember the spirit of the SDGs, that "No one will be left behind" and "Endeavor to reach the furthest behind first". The STI of the 21st century must be “Think globally, Act globally”.

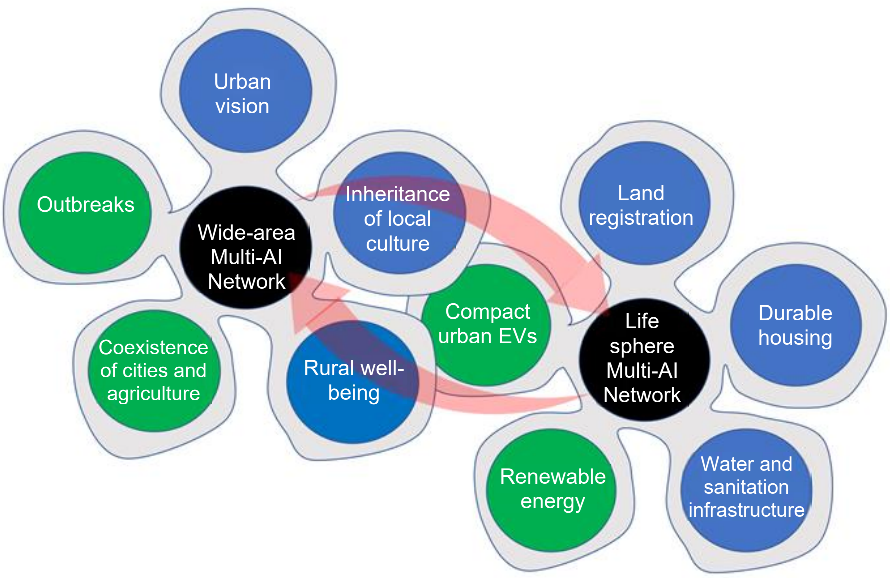


Figure 5.5.7 Challenges for DC Multi-AI Networked City (Green: issues common to developed countries, Blue: issues specific to DC)

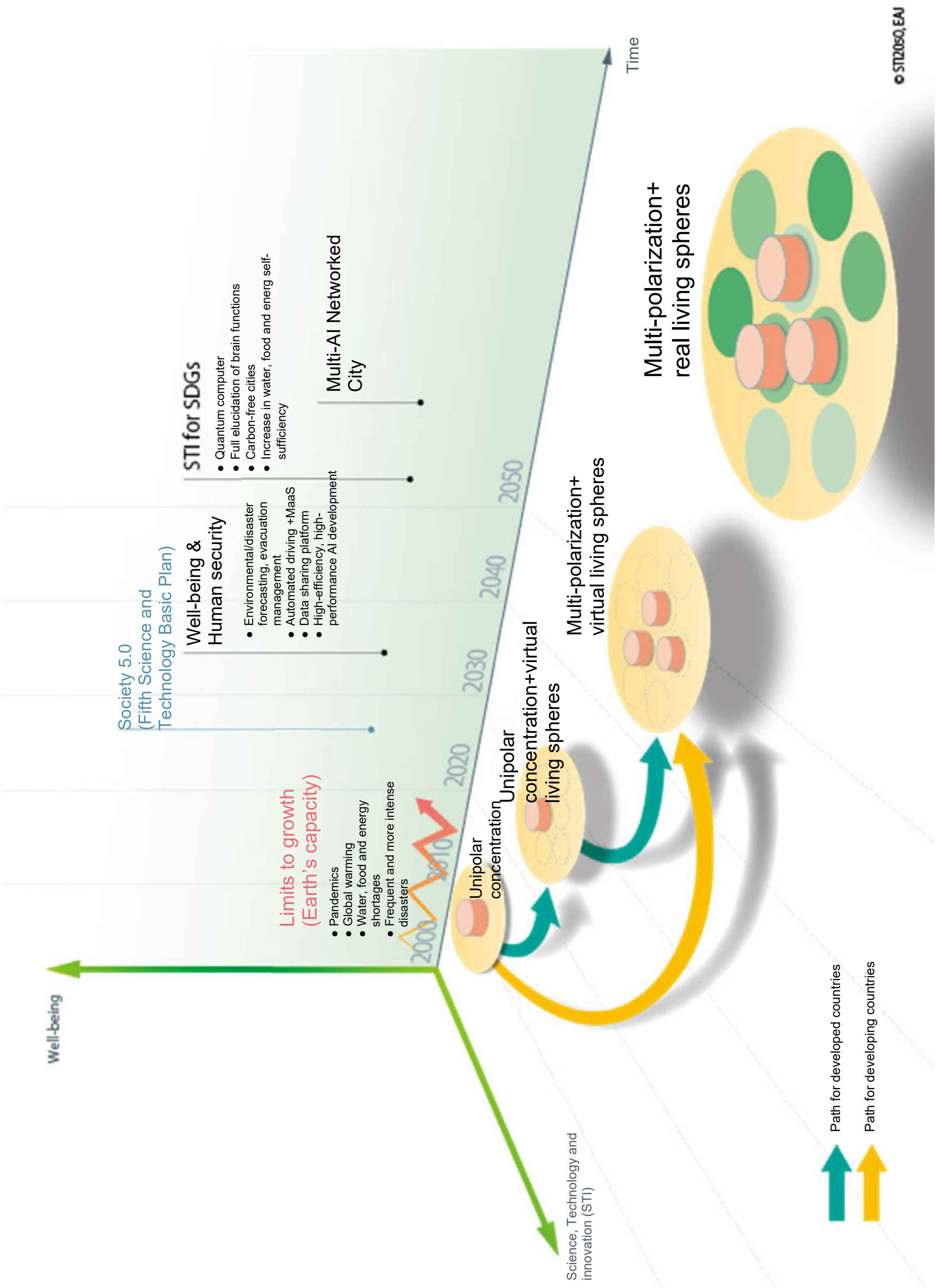


Figure 5.5.8 Future Vision of Multi-AI Networked City by STI

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6. Conclusion

After the scientific revolution of the 17th century, an industrialised society developed based closely connected to science and technology. In the second half of the 20th century saw the blossoming of an advanced information society based on electronics technology, biotechnology and computer technology. Today, the world is experiencing new growth as a data-driven society. At the same time, however, challenges to the sustainability of the Earth's systems have emerged, such as climate change, the consumption of global resources and the destruction of terrestrial and marine ecosystems. Zoonotic diseases are also seen as a consequence of the loss of the symbiotic relationship between nature and humans. Many developing countries have been unable to fully benefit from science and technology, and disparities between countries are increasing.

In this context, the United Nations has played a central role over the past half century in the debate on environmental and human rights issues, shaping various political frameworks in the form of individual treaties and joint declarations. In 2015, the UN General Assembly unanimously adopted the 2030 Agenda, which encompasses all of the above challenges and aims to create a sustainable society in which no one is left behind. The world is aiming to achieve the 17 goals of the SDGs by 2030. The values pursued here are recovery of the Planet, basic rights of People, economic Prosperity, Peace and Partnership, collectively known as the 5Ps. Needless to say, an ideal world will not be realised in 2030, but the SDGs are seen as the first step towards realising a new global society.

In Japan, the “SDGs Implementation Guiding Principles” formulated by the SDGs Promotion Headquarters in 2016, following discussions of the SDGs Roundtable Meeting, set out eight priority issues aimed at realising the above 5Ps. This set out a new direction for Japan, shifting from total commitment to economic growth to a focus on building a resilient society that ensures the safety and security of citizens and the well-being of the people. While initiatives on the part of national government, local governments, industry, academia and civil society in Japan in the SDGs have been internationally recognised, it has also been pointed out that Japan lags behind particularly in the areas of climate change, women's empowerment, conservation of marine and terrestrial ecosystems and international partnerships.

EAJ has been engaged in a variety of activities, including policy recommendations and human resource development, in our mission to design a future society that aims for human security and well-being. As part of these activities, the Board of Directors decided to establish the Science, Technology and Innovation 2050 Committee (chaired by Taikan Oki) at its meeting in November 2019. The committee’s aim was to draw up a vision of what society should be like in 2050, and to consider “what” science and technology innovation can do and “how” it can be done. This committee was proposed by an earlier EAJ project entitled, “Role of Science, Technology and Innovation (STI) in SDGs” (Project Leader: Haruo Takeda), and is designated as an ongoing activity towards the realisation of EAJ’s "Engineer the Future" philosophy.

In order to narrow down the issues to be addressed, the committee first introduced various challenges concerning the current situation in Japan and the world. Subsequently, taking into account the burgeoning domestic impacts of COVID-19, which had emerged in China in December 2019, the following three themes were chosen.

(1) Realisation of smart cities and comfortable and resilient human settlements
(2) Realisation of sustainable and equitable access to water, food and energy
(3) Realisation of governance based on visualised evidence and tolerance of diverse values

For each theme, the aim was to attempt to create an STI for SDGs roadmap, taking into account the spatial spread of the themes (global, national, local, sectoral, individual) and including a time axis in the design.

For smart cities, we examined the challenges of global population concentration in large cities in terms of sustainability, resilience, infectious diseases, and convenience, and proposed the realisation of a "New Local City Sphere" as a multi-layer, multi-scale decentralised society equipped with a multi-AI network. We also identified the technologies and systems that will be required to achieve this, and gave an indication of when these will be materialised. The creation of new local city spheres will also help to counter the “spongification” of cities due to the low birth rate and ageing population. This concept and methodology can be applied not only to the redevelopment of large cities such as Tokyo and Osaka, but also to Japan’s regional development initiatives on the SDGs, on which Japan has placed great emphasis. It also provides useful hints for approaches to cities in middle-income and developing countries, which face many challenges. In the future, it will be important going forward to implement concrete pilot programmes and to share assessment indicators for ascertaining city-level initiatives. Urban redevelopment is an issue that should be addressed as part of a 100-year plan, and we will continue to examine this issue.

The committee deemed to discuss energy, food and water as a nexus because of their close interconnectedness, spending considerable time on energy this time. We proposed five principles to achieve the two goals of realising global carbon neutrality “not long after 2050” and energy sufficiency in all regions of the world “as soon as possible before 2050" (see section 4.4), and provided concrete guidelines for developed and developing countries to work on based on international cooperation. We also developed a technology theory for putting these principles into practice. We pointed out the following: the need for engineering to cooperate with policy authorities, industry and citizens to indicate pathways to build an appropriate consensus for the overall optimisation of energy systems; the critical shortage of research personnel in the energy sector, and the need to remedy this situation; and the importance of establishing a financial mechanism to encourage investment in the social implementation of new technologies. We hope that a more in-depth examination of the nexus from a global perspective, including food and water, will take place around the focal point of realising sufficiency.

The third of the common themes in implementing future projects is the realisation of governance based on visualised evidence and tolerance of diverse values. The nature of governance was regarded as a problem following the Great East Japan Earthquake and the Fukushima Daiichi Nuclear Power Plant accident, and is an issue that has come to the fore again in the current COVID-19 measures and the creation of the new Basic Energy Strategy. Based on our discussions, we propose to reconstruct the interface between science, politics (executive and legislative) and society on the basis of push-and-pull tension and mutual respect, from the point of view that governance is not intended to be unilateral rule by government, but that diverse stakeholders with different values are also involved in the process. To this end, we urge the scientific community to transform the system for STI through provision of scientific evidence, mission-oriented science and technology policies to propose potential pathways, interdisciplinary co-creation research, and clear explanations of scientific knowledge.

The above-mentioned activities gave rise to questions on parts and the whole, and the need to quantitatively interpret the value that individual activities are creating at national and global levels became clear. Along with trying to do our best in each part, we must always maintain a holistic view, returning to the discussion of where the world is going and what contributions we can expect to make, thereby leading to greater value. Many committee members also experienced knowledge gain from regular international activities that helped them to clarify issues and consider methodologies to solve them. It is said that the Japanese are not good at international networking, but we are not born with such a genetic predisposition, and I hope that the younger generation, especially those who will lead the future, will be more involved in international activities than ever before.

A number of committee and subcommittee meetings have been held and an online symposium on this report was held in July 2021. External activities included a side event on Future Cities at the UN STI Forum in May 2021, and the acceptance of our contribution to the UN IATT report "Emerging science, frontier technologies, and the SDGs". This report summarises the activities of the EAJ's Science, Technology and Innovation 2050 Committee over the roughly two years since its founding. We would appreciate receiving honest feedback from readers. As a standing committee, we would also like to invite not only EAJ members but also non-members to participate in continuing to design our future society.

Finally, as PO, we would like to express our sincere gratitude to Mr. Taikan Oki, Chair of the Committee and Coordinators Taro Arikawa and Miho Kamei for leading the activities of the Committee, and the leaders of the three working groups, Ikuo Sugiyama, Taikan Oki, and Satoru Ohtake, as well as the committee members who prepared reports and all members who participated in discussions with enthusiasm each time. We would also like to thank Prof. Kenji Doi of Osaka University, Prof. Yukari Takamura of the University of Tokyo's Institute for Future Initiatives, and Fellow Chieko Asakawa of the IBM T.J. Watson Research Center for their thought-provoking presentations on the nature of the future society at the workshop held in August 2021.

Appendix1　Workshop on Aug. 5th, 2020

EAJ Annual Activity Report 2020/2021, pp7-8 (in Japanese),
https://www.eaj.or.jp/?dlp_document=ar2020

- Purpose and Theme of the Workshop

Coincidentally, the pandemic caused by COVID-19 in 2020, 50 years after 1970, has forced a review of everything in society, including lifestyles. In light of the impact of COVID-19, the committee selected three issues from among various social challenges, including the elimination of poverty disparities and immigration issues.
(1) Realization of smart cities and comfortable and resilient human settlements
(2) Realization of sustainable and disparity-free access to water, food, and energy
(3) Realization of governance based on visible evidence and tolerance of diverse values

In the first workshop, we will discuss the future vision that we should aim for in 2050 with regard to these issues.

- Contents

Three invited lectures and breakout sessions were conducted online.

Invited talk 1:
" The New Normal and New Local towards smart cities and comfortable and resilient human settlements"
Kenji Doi, Professor of Graduate School of Engineering, Osaka University (Transportation and Spatial Planning, Laboratory of Civil Engineering)

Invited talk 2:
" Towards sustainable and equitable access to water, food and energy"
Yukari Takamura, Professor of Law, The University of Tokyo, Institute for Future Initiatives

Invited talk 3:
“AI for Accessibility”
Chieko Asakawa, Fellow, IBM T.J. Watson Research Center, U.S.A.

Invited talk 1: The New Normal and New Local towards smart cities and comfortable and resilient human settlements
Speaker: Prof. Kenji Doi, Graduate School of Engineering, Osaka University
(Transportation and Spatial Planning, Laboratory of Civil Engineering)

<Lecture Summary>
As shown in Figure 1, we exist within the relationship between three foundations for existence: "natural and historical infrastructure", "social infrastructure" and "social capital", all of which are indispensable. In recent years, the "social infrastructure" in the middle of the diagram has become increasingly deteriorated and vulnerable to disasters, while the "social capital" on the right side has become less community-oriented as individuals are more isolated. Even more seriously, for the "natural and historical infrastructure" on the left, we have forgotten the nature and history that underpin our cities. The number of people living in cities is steadily increasing all over the world. This has led to major floods in Bangkok in 2011 and in Chongqing in 2020. Despite the fact that urban settlements and disasters are inseparable, we have little memory of natural disasters. In order to overcome this situation, we need to strengthen the relationship between the foundations of our existence, and we must think about how humans can lead the way to build a relationship of coexistence taking advantage of the features of AI.

In terms of smart cities, there is a serious separation between facilities and infrastructure (urbs) and citizens and communities (civitas) in real society, and AI is expected to play a role in bridging this separation. Cities of the 18th and 19th centuries faced worsening public health problems associated with overcrowding. Suburban sprawl was one method to address this issue. As a huge volume of automobiles flowed into cities from suburbs, communities (civitas) were taken over by roads too wide for human scale and huge car parks, while pedestrian and cycling spaces were forgotten. There are growing hopes for cyber technology to serve as a means for rebuilding these fragmented and diluted communities and restoring cities for people. It is also important to note that values have changed in recent years. Our values are gradually shifting from the traditional instrumental rationality to recognising the importance of value rationality. Instrumental rationality is a way of thinking focused on narrowing down the means to quickly achieve objectives, while value rationality is a way of thinking that takes a long-term and multidimensional view of things. Taking transport as an example, based on instrumental rationality, travel is a means to another end, and selecting the means that will reach the destination quickly and economically is most important. On the other hand, in value rationality, mobility is an end in itself, and communities and users coexist, sharing unusual journeys and experiences, improving quality of life and enhancing disaster resilience. Policies and technological developments must be guided to respond to these changing values. It is important to note that changes in values are relatively easy to ascertain, and that rather than choosing between the two rationales, a balance between them is needed.

With regard to the right balance, the “6S” are to be emphasised in smart cities. These are divided into the 3S (Smart, Safe and Sustainable), qualities that a smart city should have, and the 3S (Shared, Secure and Scalable) that make the first 3S a reality. Here, 'shared' means sharing things and experiences, 'secure' means predicting, taking measures and preventing spread, and 'scalable' means flexible in terms of the scale of the city based on needs. Recently attention has been given to small 'scalable' neighbourhoods, based on 15-minute walking distances, where travel within the neighbourhood is on foot, bicycle and small 'shared' EVs called SSVs. The 15-minute city aims to switch from living areas to date that are based on extensive travel by public transport, to the creation of a cluster of self-sustaining neighbourhoods that can withstand long-term lockdowns based on internal travel in compact 'scalable' neighbourhoods.

In order to materialise such efforts, a platform is needed for a trial and error process and to guarantee dynamism unconstrained by current practices (inertia). Empirical studies in this platform would create new values and promote the accumulation of success stories in narrative mode. The memory of these successes would allow for the development of a system in which repeated outbreaks are not ruled out. From a “new normal” point of view, it is possible to reconstruct cities and transportation that are scalable and can be partially locked down. In addition, from a “new local” perspective in the age of “new normal”, it is necessary to create an autonomous and self-sustaining sufficient economy that does not form a trilemma between freedom of movement, safety and security, and social and economic vitality in times of disaster, as shown in Figure 2. This sufficient economy will enhance freedom of movement, safety and security, and social and economic vitality and improve quality of life not only in times of disaster but also in normal times. In order to maintain this dual-mode sufficient economy, it is necessary to utilise the qualities of AI, which can process and memorise a large volume of information. As a result, a way of coexistence between humans and AI will be revealed, and in the long run, will lead to local employment and increased productivity.

Invited talk 2: Towards sustainable and equitable access to water, food and energy

Speaker: Prof. Yukari Takamura (Law), The University of Tokyo, Institute for Future Initiatives

<Lecture Summary>
First of all, thank you very much for inviting me to this EAJ workshop. My specialty is law and jurisprudence, and I am more of a user of research results, debating legal policy based on the results of research. In my presentation, I will review the current situation according to the topic you have given me, and then after reviewing where the international community is heading with regard to these three themes, I will look at the impacts of COVID-19. Water, food and energy are all very big topics, so I will focus on energy, which is particularly relevant to climate change.

First of all, there is no dispute that water, energy and food are all essential for people's well-being, as well as eradication of poverty and sustainable development. It is also recognised that the demand for water, energy and food on a global scale is predicted to grow considerably over the period leading up to 2050 alongside population growth and economic development. However, while demand is projected to grow, it may in fact grow while access remains unguaranteed. In this case, the question of how to meet this demand also becomes a serious one. This issue is particularly acute in Africa. And on the issue of energy access, there are indications that significant populations, particularly in developing countries, have the ability to pay for energy, but do not have access to it. We are now looking at the important elements in how to build modern energy and electricity infrastructure. When it comes to air pollution, it can be argued that improved access to modern energy could also lead to improvements in health and air pollution.

In terms of climate change and the three areas of water, food and energy, naturally energy is highly relevant. If you look at the major impacts of 1.5℃ and 2℃ in the IPCC's 2018 Special Report, it is very interesting to see that impacts on ecosystems and impacts on food are quite different between 1.5℃ and 2℃. For example, climate change is predicted to affect crop yields and combined with the effects of population growth and increased demand for water will heighten water stress and increase the number of people affected. It has also been forecasted that more land will become unsuitable for agriculture in the future due to the water impacts of climate change. Moreover, there is also the issue of competition between biomass energy and food. In the IPCC's 2018 Special Report on Global Warming of 1.5°C, some of the scenarios were based on the assumption of a significant dependence on biomass energy. In fact, it has been pointed out in the UN security field that the adverse impacts of climate change and environmental change will have extremely significant impacts on the stability of regions and conflict zones. It is interesting to note that a common understanding is emerging that the risks associated with water, food and climate change amplify the frequency, intensity and prolongation of conflicts.

Meanwhile, in the energy sector, we are seeing significant changes in the context of innovation in relation to climate change. The electricity sector, which accounts for one-fifth of global energy consumption, is increasingly turning to renewable energy. However, in the heat and transport fuel sectors, where renewable energy cannot be substituted to advance electrification, we are aware of the major innovation and technological challenge. However, we recognise that the significant increase in renewables in recent years, particularly solar that is not location specific, is an extremely historic shift. Within the five years starting from around 2014, renewable energy has become cheaper than the new construction of gas-fired or coal-fired power plants in about two thirds of the world's countries and regions. Unfortunately, in several Asian countries, including Japan, South Korea, Indonesia and Vietnam, it is still cheaper to build new coal-fired power plants. In the midst of this energy transition, we have seen a gradual change in the structure of economic growth, whereby increased energy demand has led to increased greenhouse emissions, i.e. CO_2 emissions from energy sources increased. Between 2014 and 2016, the trend in economic growth was over 3% annually for the three-year period, but emissions were not increasing. This means that the phenomenon of decoupling of emissions from economic growth, which had once been merely a theory, is now becoming a reality.

Moreover, on the technology side, I find the electrification of mobility to be very interesting. There is a lot of ongoing cross-sectoral innovation in digitalisation to control the emissions of systems as a whole by reducing the emission factor of electricity or by making zero-emission electricity. This is where various non-state actors, municipalities, cities, businesses, financial institutions, organisations and universities are taking the initiative on climate action and the energy transition.

The SDGs and the Paris Agreement provide a vision of where we want the world to go, but it is clear that this will not be an extension of our current society. I think it is necessary to consider what kind of social change and innovation will be needed for an ideal future, what pathways will lead us there, and what challenges we will face along the way. Finally, I think that the SDGs approach is very important, and the core of the vision is to enhance people's basic needs and well-being. How to protect vulnerable people and societies is a challenge we all must share. I believe that this challenge is even more acute in the current COVID-19 context.

Invited talk 3: AI for Accessibility

Speaker: Chieko Asakawa, Fellow, IBM T.J. Watson Research Center

<Lecture Summary>

I lost my sight during my second year of junior high school as a result of a swimming injury in the fifth grade. It was very difficult for me to lose my sight, but I learned about two major problems. The first is access to information. When I lost my sight, there were no computers, no internet and no smartphones. Therefore, I lost the ability to read textbooks by myself, and I could not newspapers, magazines or books either. The other problem is mobility. I couldn't go to school or shopping by myself—I lost the ability to go anywhere by myself. I became determined to change my situation of being dependent on others and become independent, and that became my goal for the rest of my life. Then, in the late 1990s, the researchers around me started to talk about the Internet and web browsing. As part of a research lab, I was one of the first to have access to the Internet, and I still remember the shock I felt when I first saw the information on the Internet and the Web. I can still remember the shock I felt when I first saw the information on the internet and how easy it was to get all kinds of information, even newspapers, every day. This was a real turning point in my life.

There is a very old Japanese anime that I remember very vividly from my childhood, and as a researcher I have sometimes thought about this story. In the story, a little bird-shaped robot sat on a boy's shoulders whispering in his ear about enemies approaching and telling him about things out of his eyeshot. This was science fiction at the time. But now, in this age of AI and IoT, I believe that this is no longer a fiction, but realistically possible. We developed an indoor navigation system application called "NavCog" as a first step. NavCog is an iPhone app that helps visually impaired people to navigate their way around a building. Our users have told us that the app has given them new experiences, such as being able to get where they are going without having to ask anyone, or being able to walk with confidence and say “No, thank you” when offered help.

Next, we need technology that can recognise what is around us. Object recognition is one of the technologies that can achieve this goal, and it is an area that is rapidly becoming more widespread due to the development and evolution of AI. However, it still makes mistakes. Object recognition technology will no doubt become more and more advanced in the future, but there is one yet unsolvable problem—the recognition of personal items, not generic ones. We developed a Personal Object Recognition system that we train ourselves to recognise personal items along with our own memories. This POR is a deep learning-based smartphone application that is intended for use by visually impaired people.

Another interesting technology that uses this image recognition technology is Scene Captioning technology. We take a lot of business trips and travel a lot. Even the blind can enjoy the atmosphere and the sounds and smells around them, but if there were a technology that could explain the surroundings and the scenery, it would definitely improve quality of life.

I would like to move on to the next example: the AI Suitcase project. By integrating recognition and robotic technologies, we are turning the Suitcase into a new travel companion. We are now working on R&D for the fourth generation, which we have not released anywhere yet. In terms of the software itself, we have a laptop computer put onto a suitcase that can do all sorts of image processing, sensor analysis, heat, walking speed, and it can also act as a navigation robot to lead disabled people, rather than being a fully automated vehicle on its own. We are continuing our research while tackling new technological challenges.

As we currently work with engineers on research and development for technical issues, we realise that there are many barriers to the diffusion of this technology in society in any real sense. First of all, there are legal and institutional barriers. In order to use the NavCog indoor navigation system that I mentioned earlier, you need to install a Bluetooth beacon in the environment. The approval of the owner of the building is required. And in public spaces, they are difficult to install without going through a complicated approval process. So now, we need the understanding of society and the people. Broadly speaking, there are the two issues of privacy and safety. There is the issue of how to protect the privacy of all the data that is being collected in a city. Then there's safety. Of course, because the navigation robot is designed to help the disabled, there is a person beside it. But, it is still not common for robots to move about cities or inside buildings, so more understanding is needed. Lastly, I'd like to talk briefly about AI bias. AI is based on data, and that data is collected from our society. In other words, AI is a mirror of our society. In order to build a society that is diverse and where no one is left behind, AI, as a case in point, must strongly support diversity.

The need for accessibility has historically led to a number of innovations. The telephone is said to have originated in the 1800s when Alexander Graham Bell, who had hearing-impaired family members, was looking for a way to communicate with them. The keyboard is said to have been developed in the same way, to help people with disabilities who normally found it difficult to move their hands. More recently, it goes without saying that speech synthesis, character recognition and voice recognition technologies have also been influenced by the needs of people with disabilities. And then, of course, there is AI. As a researcher in this field, I would like to continue my research so that the technology that started with accessibility can contribute greatly to changing our society in the future.

Breakout session: Challenges in realising smart cities and comfortable and resilient human settlements

Discussion topics: 1) Towards optimisation of the three elements 2) What we should aim for in 2050 3) What Japan should do to realise STI for SDGs

Participant	Affiliation	Participant	Affiliation
Kenji Doi	Osaka University		
Ikuo Sugiyama	Kobe Institute of Computing		
Yoshikazu Nakajima	Tokyo Medical and Dental University		

<Main points of discussion>

Summary of Prof. Doi’s lecture

It is possible to ascertain future changes in values. It is important to take a values rational approach rooted in local and social contexts (culture and climate).

1) Smart cities: Guarantee trial and error process and dynamism based on lowering inertia (constraints). This creates meaning and fosters successful examples of narrative mode (thinking while doing) success stories. A memory system that does not rule out repeated outbreaks (LSTM).
2) New Normal: Scalable and partially lockdown-able urban and transportation structures to avoid the spread of risks are essential. Emphasis on pluralistic values and ensuring diversity of activities and mobility under constraints.
3) New Local: Sufficient economy without a trilemma between freedom of movement, safety and security, social and economic vitality (awareness of the limits of natural regenerative forces and knowing what is sufficient) → enhancement of local productivity (= enhanced level of satisfaction for oneself and others)

Report on results of breakout session discussions

・Three axes of evaluation, Appropriate as a method of explanation and thought

・Differs according to isolation/outbreak, COVID-19: Mobility of people Water disasters: Commodities, such as food

・Sufficiency Work communication is quite good, virtual accessibility is improved

・Inclusive Digitalisation makes it easier to acquire physicality through information linkage, positive and negative effects

Breakout session: Achieving sustainable and equitable access to water, food and energy

Discussion topics: 1) Towards achieving optimisation of the three elements 2) What we should aim for in 2050 3) What Japan should do to achieve STI for SDGs

Participant	Affiliation	Participant	Affiliation
Yukari Takamura (guest lecture)	The University of Tokyo	Yoshifumi Yasuoka (moderator)	The University of Tokyo
Haruhiko Kusaka	Kaiteki Institute, Inc.	Michiharu Nakamura	JST
Yuko Yasunaga	United Nations Industrial Development Organization (UNIDO)	Taikan Oki	United Nations University (UNU), The University of Tokyo
Toshimitsu Komatsu	Kyushu University	Hiroaki Kashima	National Institute of Maritime, Port and Aviation Technology
Yoshihiro Shiroishi	Hitachi, Ltd.	Miho Kamei (recorder)	IGES

<Main points of discussion>
Initiatives to integrate the three themes could be action research, where lessons are learned from practice in a specific field, or international development aid initiatives by the EU and GIZ. In terms of culture, it is very important that solutions arise from the needs of society. In Japan, there are solutions, but the process of integrating into society is difficult and they often do not take root. It is important for Japan now to create the seeds of innovation from the needs of society and figure out how to materialise them. It is important to consider the relationship between science and technology and society.

It is important to think of water, food and energy as a trinity. Compared to gender and inequality issues, water and food must be distributed, and they need to be transported by technology. Compared to Japan, which is concerned about crises (major disasters), there are regions that need cheaper and easier access. As far as food and energy are concerned, local economic development is considered a necessary element, but if distribution is done well, the world's total can be secured. In order to get such distribution and access, information sharing may be necessary.

It is not only science and technology that needs to be taken into account, but also a rethinking of social systems. A total system, including legal and social systems, is important. There is also a time gap between events in science and technology and in society, so we need to understand what technology is needed in the future. We also need the efforts of Japanese companies. We must aim high. We need people with cutting-edge knowledge to challenge each other across borders. In the areas of water, food and energy, we need to bring together the wisdom of more people because these are fields that are easy to relate to as general concepts.

In addition, the fragmentation of the world is increasingly apparent. The East, including Japan, originally had philosophy that favoured integration. Inclusivity is an important element of the

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SDGs. In relationships between developing and developed countries, as well as in our coexistence with nature, can we create new values by caring for each other and enhancing the value of each other, while remaining rooted in culture and philosophy? While the global gap is widening, there is a need for solutions to achieve a global balance, such as the SDGs.

Breakout session: Achieving governance based on evidence and tolerance of diverse values
Discussion topics: 1) Towards the optimisation of the three elements 2) What we should aim for in 2050 3) What Japan should do to realise STI for SDGs

Participant	Affiliation	Participant	Affiliation
Satoru Ohtake	The University of Tokyo	Hiroshi Nagano	EAJ
Tateo Arimoto	GRIPS; CRDS, JST	Goto	Rissho University
Shibutani	Yokohama National University	Taro Arikawa (recorder)	Chuo University

<Main points of discussion>

1. Diversity: Broaden horizons and keep open minds when thinking about the future.
   Social, spatial and temporal expansion and diversity.
2. Communication is important, and we need to first establish evidence, then move forward.
3. Trust is important and governance should include trust between society and people.
   We must have not only a global perspective because building trust also needs a local perspective. It is also necessary to have a local point of view, as a variety of knowledge is accumulated locally.
4. From the perspectives of diversity and new systems, governance should place emphasis on both value and values (sense of values).
5. In relation to society, consideration for culture and making efforts a part of culture are also important to enhance trust, and the use of familiar stories and narratives is also necessary.
6. Governance should be evolving with constant feedback from society and awareness of its value. In addition, the following specific examples were given.

○ Risks

・The three pillars of communication are risk, assessment, and management.
・There is a big barrier between those with awareness and those without.
・Those with awareness should start making things.
・Invisible risks

○ Universalisation and localisation

・Dilemma between universalisation and localisation of values
・Clear up vagueness
・Universalisation and localisation

○ Communication

・The habit of free discussion is important.
・Engineers lack political literacy.
・Politics and science, time axis

○ Trust, narratives

・Sharing of time axis
・Spread in time and space

Appendix 2 STI Forum Side Event, 6 May 2021

At the beginning of the session, Chairperson Oki introduced the organiser of the event, the Engineering Academy of Japan’s Science, Technology and Innovation 2050 (STI2050) Committee. He also explained its mission to prepare STI roadmaps to realise a future vision for 2050 and the necessary technologies to achieve it, based on an understanding of the current situation, including an inventory of technologies looking ahead to 2050.

He then stated the agenda and objectives of the event, which were to identify some key concepts and key technologies to be aware of when envisioning future urban design in the face of global issues such as the COVID-19 pandemic and climate change.

Lastly, he briefly outlined a new idea to develop a new discipline on outbreak risk management by identifying the commonalities between different outbreaks, such as pandemics, floods, traffic jams and communication failures, and exchanging ideas on how to make compromises on the dilemma between redundancy and efficiency in preparations for risk management.

Summary of presenters

Prof. Dr. Daniel Karthe: In Ulaanbaatar, Mongolia, rapid urban growth has resulted in a fragmented infrastructure. Inadequate water and energy supply in peri-urban *ger* districts (where people live in traditional Mongolian tents and simple houses), combined with worsening traffic congestion, especially in the city centre, is causing a decline in environmental quality (pollution of air, water and soil, and accumulation of pollutants in the biosphere). Such environmental pollution and its negative impacts on physical and mental health need to be taken into account in a comprehensive manner when planning future infrastructure development.

Prof. Mikiko Ishikawa: Green infrastructure was created when humanity was facing crises. Green infrastructure is social common capital created by strategic planning for the sustainability of the global environment, based on protection of the natural environment, enrichment of biodiversity and respect for cultural landscapes. Accordingly, green infrastructure contributes to providing an environment safe from natural hazards and improving the quality of life of citizens through the application of climate change mitigation and adaptation policies.

Ms. Guzel Ishkineeva: Japan's smart city initiatives were introduced. Referring to the context of Japan-Russia relations and the eight-point cooperation plan proposed by former Prime Minister Shinzo Abe in 2016, she discussed the implementation of smart city projects in two Russian cities. In particular, the efficiency of the implementation of the ARTEMIS smart traffic signal system in Voronezh and Vladivostok, the urban infrastructure needs of Russian cities, the problems faced by modern Russian cities, and the feasibility of Japanese smart city solutions were presented.

Prof. Yoshikazu Nakajima: A multi-AI system can minimise infection risk by ensuring human comfort and an appropriate standard of living. This system includes a) technology to detect individual smartphone coordinates, b) technology to estimate one's physical and mental state from vital sign data, and c) technology to estimate comfort from daily facial expressions using IoT technology. Although there are many challenges in developing this multi-modal AI, we believe that the key to realising the urban systems of the future lies in developing multimodal AI that can link the diverse input data of urban areas.

Lastly, the following messages and ideas were shared:

✔ Green infrastructure is sometimes considered a new concept, but it has a long history in urban design, going back thousands of years.
✔ Green infrastructure aims to maximise ecosystem services.
✔ There are different objectives and motivations for implementing smart cities, but the ultimate goal is to improve the level of well-being by using the latest information and communication technologies to reduce environmental burdens such as energy consumption and waste, and to free people from the hardships of traffic congestion, air pollution and unsatisfactory work.
✔ Technological solutions must be appropriate to the particular environment. In developing countries, high-tech solutions have the potential to reduce costs and enhance efficiency, but they may also exceed the local capacity to operate, maintain and dispose of them properly.
✔ Technological and infrastructural advances and socio-economic development can influence each other to create and sustain a virtuous cycle of local development.
✔ When considering future urban design, we need to take into account how the cities of the future will support the development of social sustainability, leaving no-one behind.

Schedule

Date and time: 1 July 2021 (Thu), 10.00-12.00 (maximum)

1. Goals and objectives of the meeting

10:00 am - 10:10 am Aims and objectives of the STI2050 Committee (Chair Oki)

2. Presentation of results by each group (10-15 minutes each, 5-10 minutes Q&A)

WG1 10:10 am - 10:30 am Group 1 (Sugiyama)

WG2 10:30 am - 10:50 am Group 2 (Yasunaga)

WG3 10:50 am - 11:10 am Group 3 (Ohtake)

3. General discussion

11:10 am - 11:30 am (maximum 12:00 pm) General discussion

4. Overall summary (Advisor Nakamura)

1. Aims and objectives of the committee: Chairperson Oki

Although it goes without saying that science, technology and innovation are needed looking ahead to 2050, writing this report was aimed at sharing a vision within EAJ. The very busy members of the committee spent their weekends putting their ideas into writing. Today we would like to share some of these. We may not yet have reached a unified whole or a detailed technology roadmap, but we have had a great many discussions. Committee meetings have made various discoveries and found new perspectives. We would like to share these points with you today and receive your opinions and suggestions for further development of the content.

2. Presentation of each group's results

WG1: Presenter, Sugiyama

In order to realise a comfortable and resilient society, STI (the power of scientific and technological innovation) should be concentrated in cities, but new technologies such as AI also entail risks and require various precautions. Meanwhile, the COVID-19 pandemic has in some respects made us rethink the things that humans should take into consideration. In this report, we have proposed a multi-AI networked city that pursues human-centred well-being, specifically human security and well-being in both normal times and during outbreaks. The concept of the multi-AI city is that a physical city is made up of units of living spheres that are networked together. A cyber city is a city in which the data of a physical city is organised in layers, with these data re-aggregated and visualised. Their size ranges from 10,000 to 30,000 inhabitants. It is envisaged that the city would be able to withstand long-term lockdowns as it is equipped with basic urban functions. The Multi-AI Well-being Survey System (MAWSS), which would support the Multi-AI Networked City, would cover different layers, such as medical living spheres and business living spheres. In presenting a roadmap towards actual implementation, it is necessary to consider the time gap between the 2050 time frame in which the city is to be realised and the progress of science and technology. For the time being, only cyber space would constitute the network space, with partial lockdowns put in place. Futuristically, the physical side would also shift to an autonomous decentralised system. Developed countries should actively share their technologies and experiences on multi-AI networks with developing countries. The challenges of low carbon, NEXUS and infectious disease control can be overcome based on global initiatives that transcend generations and space, and are then passed on.

WG1 Discussion:

- In urban areas where lockdowns are possible and considering the number of various businesses, it would be good to have one for every 10,000 or 20,000 people. However, if the optimal unit were one for every 100,000 people, would provision of services then potentially be problematic? It would be interesting to see a list of the density of various services and the appropriate unit of service.

- If concentration in peri-urban areas progresses and the elderly are moved to urban areas where they have no previous connections, the cost of care and other expenses may become even higher due to the loss balance between physical and mental health. As nursing care accounts for a much larger share of the national budget than infrastructure, explanations will be easier to understand if nursing care is included.
- → It may be difficult for older people to travel from the suburbs to the city centre. If automated driving can replace public transport, there may be no need to transform cities. A balance between scientific and technological progress is important.

- The fractal structure is both physical and virtual. Within is a hierarchical structure in which the smallest unit is followed by another hierarchical unit. As it can be built up further, the structure allows for overall control.

WG2: Presenter, Yasunaga

The content of WG2 was organised around energy. Lastly, water and food in the nexus is described. Firstly, about 120 countries around the world want to achieve carbon neutrality by 2050. China, which emits up to 30% of the world's emissions, has pledged to achieve this by 2060. The realistic target date for global achievement is considered to be "not long after 2050". Meanwhile, there are many countries in the world that do not have access to energy. From this perspective, it is necessary to examine sufficiency level, such as DLS criteria (from the IIASA report). There is a need for mechanisms of cooperation for sufficiency in developing countries, from the perspectives of environment and stable supply. The water-energy-food nexus is examined, adding the areas of economy & industry and environment to make five areas.

WG2 Discussion:

- It is assumed that developed countries and China will be able to meet their commitments, or that they must do so. The idea that developing countries must be supported by such developed countries may be a bit biased.

- In the field of manufacturing, such as iron and steel, chemicals, etc., is it necessary to describe how much has been done in terms of energy efficiency, and where the challenges lie?

- → The technological hurdles are higher than you might think. There is a risk of upsetting the material balance and changing the structure of the chemical industry. For example, it is very difficult to know how far we can go without using plastics, and what will happen if we change the total amount of plastics in the world.

- Will cars overall shift to electric vehicles? What will happen to aeroplanes? Is it too much to ask for such an overall picture?
- → There is much more to it than just technological theory, such as cost. Research into the use of biomass to produce jet fuel is actually taking place, and progress is being made at the research level. However, costs also includes areas of cultivation, making it difficult to complete only on the basis of technology.
- → If the cost performance improves futuristically, would it be accessible to everyone in the future? If we can use all the ecosystems and technologies available today, would it be possible to transform society overall as we envision? Perhaps we should also mention that there has not yet been a comprehensive study of how the price of fossil fuel-based products will look in the future.

- How should EAJ proceed with the nexus part? We hope that this will lead to a methodology linked to optimisation.
- → Society as a whole will need human resources in the future, so there needs to be a mechanism for universities to create departments to fund research specialising in this area.

- If the poorest countries economically have a per capita GDP of about 4,000 USD in 30 years or so, they will not reach sufficiency in time.
  Are there any ideas on decoupling per capita GDP and sufficiency for 2050-2060? It will be very difficult to get there if GDP does not grow first.
- → It is true that 30 years of 5% growth will only quadruple an economy. Countries with a per capita GDP below 1,000 USD may not yet achieve sufficiency. The poorest countries, such as those in Africa, currently have nothing and need sustained economic growth. How to define and achieve sufficiency in these countries should be a shared global concern.

WG3: Presenter, Ohtake

The third group was entitled "Realisation of governance based on visualised evidence and tolerance of diverse values". Here we have discussed the role of science and technology in society, multidisciplinary cooperation and the importance of governance in this context, while also taking into account the importance of sharing diverse values based on the cultures and histories of societies, people's lifestyles and tolerance. Society’s relationship with science and technology is becoming closer and closer, and societal expectations are becoming greater as science and technology become more complex. The language of various disciplines has also become more complex. There are also the issues of AI and genes. The speed at which impacts are being felt is also increasing. As in the case of COVID-19, there must be a discussion of risks and benefits. Scientific advice must be a medium of reciprocal action in order to include the diversity of views in society. It is also necessary to verify the effectiveness of governance and to evolve the methodology of advisory systems—the development of guidelines is one way of doing this. The roadmap is a compilation of these ideas.

WG3 Discussion:

- We talk about accepting diverse values. For example, we ask the question, “how can we stop global warming and limit it to 1.5 degrees?” Science can answer that we have a 60% chance with these measures. We want economic development, we want to stop global warming, we want to do both, but science tells us that we can't do the impossible. So what can science do to address global issues when some people think it is better to prioritise economic development?
- → As a society, decisions are made by society as a whole. Traditionally, building consensus is a major challenge. It is important to show what challenges for what issues are on the table. Science provides the visual evidence. This is important, and the decisions made after stakeholders have debated are political decision. However, not all good results derived from science will be adopted, and science is only about presenting options. Ultimately, a basis on which policymakers can make their decisions is a strongly called for in a democracy. When a major disaster or accident occurs, ideally everyone should be saved, but with limited capacity, consensus is needed even for tentative decisions. The question of how to proceed in stages becomes a real policy issue. It is the role of science to be able to present such arguments.

- For scientists and engineers, there is a lot of pressure not only for problem-setting and answers, but also to give opinions on which option is better. These would include the values of the scientists who are asked. For WG3, what opinion prevails? Should we also speak on the assumption that these are personal values, or that science should be neutral? →There is potential there, and we should first make clear what our values are intended to be, and that we recommend certain options from certain points of view, based on the facts.

3. General discussion

- The discussions in WG3 seem to have been highly influenced by the COVID-19 case. There has likely never been a case where science has had such a close influence on, or relationship with, political decision-making. Nor has it ever been so visible to the public. The scientists involved in COVID-19 are not only natural scientists. They came together with experts in economics and social sciences, humanities and other disciplines, and their scientific judgements formed the basis of and influenced policy options. Going forward, we would like to see an analysis and evaluation of this process that includes the relationship between politics and science. There is probably no more realistic case study than this. It would be even more convincing if the results were summarised and recommendations such as these made on the basis of them. It would be great if analysis and evaluation of real cases could be carried out.

- In the report, we have discussed this situation up to the present as much as possible, looking at data and so on. One thing is the ongoing and varied nature of the situation, which is currently causing trouble in other countries as well. We will take this situation into account as we proceed. The report will need to be completed at some point, and we hope to discuss it as an example at that stage.

4. Overall summary: Advisor Nakamura

The committee members have spent a lot of time and effort on this project, and I think the results have been excellent. I would like to thank all of you who participated in today’s online symposium. The EAJ previously launched a project on the role of science, technology and innovation in the SDGs, and within that project, we established a study group on SDGs finance. It was then recommended that a committee should be set up for ongoing study on the nature of science, technology and innovation for the SDGs. In response to that recommendation, this Science, Technology and Innovation 2050 Committee was launched with Chairperson Oki as its head. It was very important for us to narrow down the themes to three. From the point of view of breadth and impact, This approach is right on target. It is likewise very important to visualise the kind of society we want to create and to put this vision onto a roadmap. Then we need a process for continuous review of the ongoing situation in our society. I have been very impressed by your discussions today. I would like to thank you all very much for joining us today.