FORESIGHT FOR OUR CIRCULAR ECONOMY SOCIETY

COOPERATIVE PROJECT BETWEEN BUSINESS FINLAND AND NISTEP
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EXECUTIVE SUMMARY

Business Finland and NISTEP (Japanese National Institute of Science and Technology Policy) have a long-standing relationship for foresight collaboration. In September 2019 this collaboration continued with a project focusing on emerging circular economy, recognizing its growing global importance and impact. The purpose of this project was to share research methodology, results and compare the findings in both countries, and to eventually identify fields for mutual future innovation collaboration between Japan and Finland. The jointly executed Delphi study provided a comprehensive understanding on what are the Japanese and Finnish views on the emerging technologies related to circular economy.

This report will share the findings from the jointly conducted Delphi study and lays the groundwork for future collaboration around Circular Economy and other topics.

The summary of joint Delphi survey results is as follows:

- Competitiveness and importance of topics are pos itively correlated in Japanese results but negatively correlated in Finland.
- There was clear variation between Japan and Finland in the respondents' evaluations regarding the timeline of maturity in requested technology questions. For instance most topics on agriculture, cities and the environment were prospected to be realized earlier in Finland compared to Japan. And on the other hand, many topics of ICT and materials are prospected to be realized earlier in Japan than Finland.
- Key differencies between the results were identified for instance when comparing the importance and national competitiveness of water and disaster prevention technologies
- Mutual challenges shared by both countries are mainly related to environmental issues and bioeconomy, but food and other topics are also rapidly gaining in importance, a trend further accelerated by the COVID-19 pandemic.

Similarities between Japanese and Finnish societies, like being highly advanced countries in terms of technological development, makes comparison of results interesting. Both societies are also facing similar challenges, both on a global level and nationally. However, the two countries' geographical locations, natural resources and population densities have clearly influenced their national science and technology policies over time, and as a result Japan and Finland have different strengths in terms of technological know-how.

The result given by Delphi study is interesting and valuable in itself. The joint Delphi survey helped to deepen our understanding of Japanese and Finnish views on emerging and developing technologies related to the circular economy. We could also identify gaps between the level of advancement in certain technology areas which can point to areas of innovation collaboration between Japan and Finland. However, there is also a need for methodological considerations regarding differences between the countries.

Delphi process is usually aimed at consensus, but in a foresight exercise oriented to the future, sense making discussion of the results by experts and also alternative scenarios and visions may be even more valuable. This is particularly relevant in Finnish Delphi research setting, where the number of respondents in many cases is limited. Therefore, it can be concluded that Delphi method processes should be combined and complemented with other foresight methods in order to bring full benefit.

Having the previous in mind, it can also be argued that the full benefits of this project will be realized, when this information is utilized in the creation of a shared vision and a roadmap for the two countries. Such forward-looking activities are necessary in order to capitalize on emerging opportunities of creating and deepening co-operation between Japan and Finland. This project will foster a model for international foresight collaboration where both organizations can deepen understanding in developing technologies, innovation and business fields and thus build readiness to shape the global market.

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1 OVERVIEW OF THE COLLABORATIVE FORESIGHT PROJECT

1.1. Background

(A) BACKGROUND AND GOALS

In September 2019 Business Finland and the Japanese National Institute of Science and Technology Policy (NISTEP) continued their foresight collaboration by launching a project focused on the emerging circular economy. The project had several goals. Primarily, Business Finland and NISTEP wanted to share research methods, knowledge and results and to compare the findings in both countries, and eventually to identify fields for mutual future collaboration between Japan and Finland. The project set out to foster a model for international foresight collaboration where both organizations can achieve a deeper understanding of developing technology, innovation and business fields and so improve their readiness to shape the market.

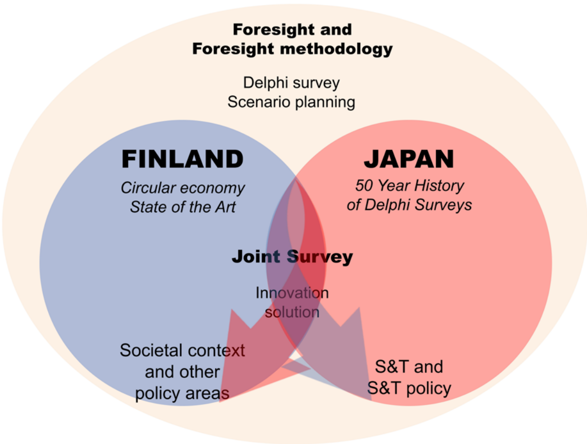

Fig. 1 Image of the joint project overview

Business Finland set the process in motion by conducting an extensive pilot Delphi survey, a method traditionally used by NISTEP in its foresight process to formulate science and technology plans. A comparison of the results in the two countries highlighted the importance of dialogue and joint reflection on differences between the two sets of results. The project strengthened the methodological capacities of both organizations and improved their ability to take advantage of long-term opportunities and build tools for continued international collaboration in foresight.

In Japan, the Science and Technology Prediction Survey has been carried out approximately every five years since 1971, and this is the 11th such survey. In response to changes in the direction of science and technology innovation policy around the turn of the millennium, the focus was shifted from describing the future of society based on science and technology developments to finding the necessary science and technology that would help to bring about the desired kind of society.

These surveys adopted the dual perspective of science and technology, on the one hand, and society, on the other, reflecting the complex relationship between the two. After reviewing science and technology and social trends based on a study of reference materials, NISTEP conducted separate investigations into “the future image of society (future image of the society we desire)” and “the future image of science and technology (medium- to long-term outlook for science and technology development)”. Finally, it investigated “the future image of society through science and technology development” and extracted cross-disciplinary areas. The time horizon was set at the approximate 30-year point of 2050, with the target year set at 2040, some 20 years ahead. This outlook period assumes the progress of the ultra-smart society **Society 5.0** initiative.

In Finland, Business Finland has extensive experience of participatory foresight processes and has built a systematic model for identifying market opportunities in both the short and long term. The process ties in with Business Finland's strategic choices and is based on an international network of market professionals. Business Finland's approach to foresight leans heavily on networking and cross-industry collaboration with multiple stakeholders. Signal gathering and horizon scanning is traditionally complemented by scenario building and other strategic foresight methods, but the Delphi method has not been included in its foresight portfolio. The project with NISTEP provided new insights and tools for long-term strategic planning and for identifying future opportunities. For the purposes of the project Business Finland decided to team up with VTT Technical Research Centre of Finland (VTT), based on its foresight experience particularly with Delphi surveys. As a multi-technology research and technology organization, VTT was also in the position to assess emerging technologies and provide insights on the circular economy using its in-house expertise.

(B) BACKGROUND OF CO-OPERATION

The co-operation between Business Finland and NISTEP dates back to 2007, when Tekes (The Finnish Funding Agency for Technology and Innovation, now part of Business Finland) and the National Institute of Science and Technology Policy of Japan (NISTEP) published a foresight pilot project report. The main purpose of the joint project in 2007 was to develop a new foresight process based on identifying policy actions with innovation needs and potential related to the specified societal themes.

The pilot foresight project provided important guidance and direction for developing a foresight method that combines the Delphi survey and a participatory panel process. For both partners, a central goal was to gain new perspectives for tackling societal challenges and for upgrading international cooperation in the foresight field.

Based on these positive experiences, the partners decided to launch a new joint project as follows:

The research started with a Delphi survey in May 2019, with VTT partnering up with Business Finland. After the results from two rounds were completed by November 2020, they were complemented by an expert workshop and expert reviews and finally compared with Japanese results. Due to the Covid-19 outbreak in March 2020, one planned workshop was only partially organized and the results were thus further validated with expert reflections in April-May.

1.2 Foresight processes in Japan and Finland

(A) COMMON PROCESSES

The aim was to implement the project following a similar process in both countries. In practice, however, the processes varied in some details due to differences in perspectives and different interpretations of the role of different methods within the process.

In Japan the process has been carried out approximately every five years since 1971: the current survey is the 11th of its kind. The survey provided a solid foundation for the process in Finland.

NISTEP provided data from a Delphi survey on a total of 702 topics covering all S&T areas and fields so that Finland was able to single out the specific fields it wanted to address (see Table 1).

Table 1: Area, fields and number of topics

AREA	FIELDS	TOPICS
Health, medical and life sciences	**1.** Medicine **2.** Medical device development **3.** Senescent and noninfectious diseases **4.** Brain science **5.** Health crisis management **6.** Information and health **7.** Social medicine	96
Agriculture, Forestry & Fisheries, and Food Biotechnology	**1.** Production ecology system **2.** Food ecology system **3.** Resource ecology system **4.** System infrastructure **5.** Next Generation Biotechnology **6.** Biomass **7.** Safety, relief, health **8.** Community	97
Environment, resources and energy	**1.** Energy conversion **2.** Energy system **3.** Resource development, reduce, reuse and recycling **4.** Water **5.** Global warming **6.** Environmental conservation **7.** Risk management	106
ICT, Analytics and service	**1.** Future social design **2.** Data science and AI **3.** Computer system **4.** IoT and robotics **5.** Network and infrastructure **6.** Security and privacy **7.** Service science **8.** Industry, business and business application **9.** Policy and institutional design **10.** Social implementation **11.** Interaction	107
Materials device process	**1.** Materials and substances **2.** Process and manufacturing **3.** Computational, data science **4.** Advanced measurement and analysis methods **5.** Application device system (ICT· nanotechnology field) **6.** Application device system (environment and energy fields) **7.** Application device system (infrastructure· mobility field) **8.** Application device system (life· biotechnology field)	101
City, architecture, civil works and traffic	**1.** Land development and conservation **2.** Architecture **3.** Social infrastructure **4.** Urban environment **5.** Construction production system **6.** Transportation system **7.** Car, rail, marine and aviation **8.** Disaster prevention and mitigation technology **9.** Disaster prevention and mitigation information	95
Space-Marine and Earth-science foundation	**1.** Space **2.** Ocean **3.** Earth **4.** Earth observation and prediction **5.** Calculation, mathematical science and information science **6.** Elementary particle, nucle-ar, accelerator-particle **7.** Beam applications: synchrotron radiation **8.** Beam applications: neutron-muon charged particles, etc. **9.** Light and quantum technology	100

(B) DIFFERENCES

In Finland the aim was to follow the Delphi process as closely as possible in order to ensure comparability with the results from Japan. However, some minor adjustments were necessary to allow for the Finnish context.

The full version of the Delphi survey consisted of 702 questions, which covered a wide variety of topics that were considered important for the future of Japanese society. However, since the primary interest in the Finnish foresight survey was with the circular economy, the aim initially was to select questions that were most relevant to understanding the Finnish point of view in this particular theme. The plan was to do this in the context of a workshop together with VTT´s circular economy experts. However these experts concluded that the circular economy is too complex a phenomenon that certain topics or questions could simply be excluded. It was therefore decided that the Finnish survey would also cover all 702 questions. In some cases the link between a certain question and the circular economy might have appeared to be relatively tenuous, but the respondents were instructed to consider their answers specifically in the context of the circular economy. The operationalization of the Delphi survey in Finland is described in Figure 2.

DELPHI STUDY QUESTIONAIRE IMPLEMENTATION PROCESS

Delphi Planning
- Creating the set of questions based on the framework.
- Formation of the set of criteria for participation selection.
- Preparing the sets of questionnaires and supporting letters.

Selection of participants
- Conceptualizing the relevant participant categories
- Identifying the major criteria for selection of participants (e.g. active in the knowledge domain of the questionnaire, Active scholar in the past 5 years, Scholar residency in Finland based institutions)
- 14,221 unique scholar regarding the mentioned criteria has been identified trough public research indexing service (Thomson Reuters web of science core collection has been utilized in this case)
- Scholars email has been retrieved from the public listing index.
- Round 1 questionnaire sent to 200 participants with VTT affiliation to test the functionality of questionnaire before mass distribution to the entire set.

Pilot study
- Conduct a pilots of the questionnaire with VTT's internal experts.
- Amend the suggestions and design related recommendations of the participants in the pilot.
- Objective: To test the functionality and feasibility of the questionnaire
- Content of the survey put in to test in front of 200 pilot participants.
- Participants time spent on the survey was observed.
- Minor modification to the survey design was implemented to enhance the speed and removing the unnecessary complications.

Delphi Round 1
- Objective: Invite participants to participate in a foresight study looking to shape the future of science and technology policy.
- Content of the invitation declares the objectives of the survey, the importance of participants role, the process of their selection as a candidate for the study, informing the data handling and insuring privacy and integrity of the study and asking the consent of participants if they want to continue the study or being withdrawn from the process.
- First step of the survey participants were asked a mandatory selection to declare their scope of their expertise in order to receive the relevant questions in regards to their domain.
- Participants were provided an option to continue their responses later in time by saving and returning back to their answering session.
- At the end of the survey participants were asked to leave their contact information for the next round of the study.
- Sending the survey in batches of 1000 two time per day (one batch in morning 9:00 AM and second batch 2:00 PM) participants for technical reasons of host server loads.
- Scheduling the survey batch to be sent with in a week
- Reminder sent via email to non readers and non respondents after all the batches was sent. 2 reminders was sent in total during a full month of Round 1.
- Return rate: (852 Responses)

Responses analysis

Progress to Delphi Round 2
- Review of the returns from Round 1
- Comprehensive analysis of the results to detect relations and aggregations.
- Documenting the results and compiling the questions for the second round of the study.
- Deciding on implementation of the survey to respondents from the first round.

Delphi Round 2
- Objective: To inform the participants of the results from Round 1 and give opportunity to review the overall scorings in the light of the average results.
- Content of the survey included the average results and insights from Round 1, comments and amendments drawn from the analysis.
- Sending the survey in one batches to all respondents of the first round.
- Reminder sent via email to non readers and non respondents after one week. In total two reminders were sent in duration of one month.
- Return rate: (214 Responses)

Analysis of the Delphi study results
- Analysis of the results from second round study
- Drafting the summary of the important findings from the Delphi study, that is to be sent to those participants that indicated their interest for the results.
- Reflecting on the experience gained from the application of the Delphi study

Fig. 2: Delphi survey process in Finland

The 702 questions that were eventually included in the Finnish survey covered nine themes and a total of 52 sub-themes. For the purposes of Japanese-Finnish collaboration it was important to identify the most interesting sub-themes for both parties. To this end each of the sub-themes was evaluated with an index variable derived from the survey questions. The importance of the sub-themes was also assessed by an expert group to confirm the survey findings.

The index variable [1] was only used in Finland to help identify the most important bioeconomy and circular economy sub-themes took into account the following parameters from all the assessed technologies: 1) global importance, 2) Finnish competitiveness and 3) estimated time of realization in society. An index variable was assigned to each sub-theme based on the average index value for the respective technologies in the sub-themes. Index variable was a methodological choice in Finland.

The number of respondents in Finland was low in some topics and because of this the result was complemented with expert validation. Index variable was a methodological choice in Finland. The expert group confirmed most of the survey-based selections, but in addition recommended that a few additional topics with strong links to bioeconomy and the circular economy to be included in the collaboration discussions, despite their relatively low index numbers. Certain themes and sub-themes were also excluded from further discussions due to their weak links with the bioeconomy and circular economy.

TOPICS SELECTED BASED ON THE INDEX VARIABLE	TOPICS SELECTED DESPITE LOW INDEX VALUE (EXPERT OPINION)
Food ecosystem, Biomass, Community, Cities & environment, Construction productions systems, Network infrastructure, Industry, Business and Economic Applications, Social implementation, Applied devices / systems (infrastructure / mobility field), Applied Devices and systems (Life & Bio field), Water, Global Warming.	Resources Development 3Rs and Land Use and Preservation.

[1] **Index values for themes:**
Competitiveness Index = Global Significance x Realization of Technology x Finnish Competence (High value when competence is high).
The index variable was only used in Finland to help identify the most important sub-themes.

Finnish scenario work (which is described in the Annex) focused on the sub-themes identified. Also in comparison of the findings from Japanese and Finnish surveys, the focus was in the identified sub-themes.

2 COMPARISON OF JAPANESE AND FINNISH RESULTS

NISTEP had already completed its 11th Delphi survey in Japan in 2019 when Finland got underway with its own study. One of the purposes of this project was to compare the differences between the responses obtained from the two countries to the same questions. Finland was therefore in the position to replicate NISTEP's survey questions and evaluations as shown in Table 2.

Table 2: Delphi survey questions for all topics

ITEM	CONTENTS	ANSWERS
Importance (single answer)	Current importance of topic for Japan/Finland to achieve the desired state of society 30 years from now	very high, high, neither high nor low, low, very low, I don't know
International competitiveness (single answer)	Japan/Finland's current international competitiveness in terms of the topic	very high, high, neither high nor low, low, very low, I'm not sure
Prospect of scientific/ technological realization (single answer)	Time by which the vision will be scientifically/technologically realized somewhere in the world, not excluding Japan/Finland	already realized, by 2025, 2026 to 2030, 2031 to 2035, 2036 to 2040, 2041 to 2045, 2046 to 2050, 2051 or later, It won't be realized, I'm not sure
Policy-means for scientific/ technological realization (multiple answers allowed.)	Policy means called for to scientifically/ technologically realize the vision	development/securing of human resources, enlargement of R&D budgets, research-platform establishment, domestic collaboration/cooperation, international collaboration/ standardization, establishment of legal regulations, addressing ethical concerns, other
Prospect of social realization (single answer)	Time by which the vision will be socially realized in Japan, following its scientific/technological realization somewhere in the world, not excluding Japan/Finland	already realized, by 2025, 2026 to 2030, 2031 to 2035, 2036 to 2040, 2041 to 2045, 2046 to 2050, 2051 or later, It won't be realized, I'm not sure
Policy-means for social realization (multiple answers allowed)	Policy means called for to socially realize the vision in Japan/Finland	development/securing of human resources, support for business/ project, establishment of business/project environment, domestic collaboration/ cooperation, international collaboration/standardization, establishment of legal regulations, addressing ethical/legal/social concerns, other

(A) STATISTICAL DATA IN FINLAND

In Finland the questionnaire was emailed to a total of 14,221 researchers. Data was not gathered prior to or during the process on gender, age or affiliation. In total 254 respondents participated in the expert panel.

(B) STATISTICAL DATA IN JAPAN

In the seven fields of S&T, 702 S&T topics were identified for investigation by subcommittees in each field (comprising a total of 74 specialists). It is expected that the S&T topics will be realized by 2050, and are research and development issues considered vital for the future. An expert questionnaire was conducted from February to June 2019. Responses were received from 5,352 people on the importance of S&T topics, international competitiveness in Japan, the achievement outlook, and policy measures for achievement (see Fig.3). Number of registrants: 8,636
Number of respondents: 6,698

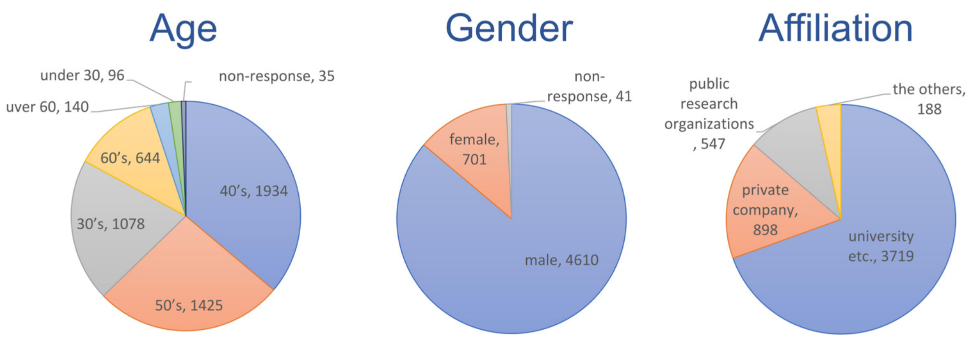

Fig. 3: Japanese respondents in 11th Delphi survey

(C) RESULTS

The results for the years of expected realization are as shown in Fig. 4. The key findings are as follows:

- Competitiveness and importance are positively correlated in Japan. The technologies that were considered highly important for future society in Japan were also considered to be highly competitive in that field.
- The results are very different for Finland in that competitiveness and importance are negatively correlated. According to this data the Finnish respondents considered Finland's competitiveness to be lower in those technology areas that were also considered to be important.
- Most agriculture, cities and environment topics are expected to be realized earlier in Finland.
- Many ICT and materials topics are expected to be realized earlier in Japan (Fig. 5).

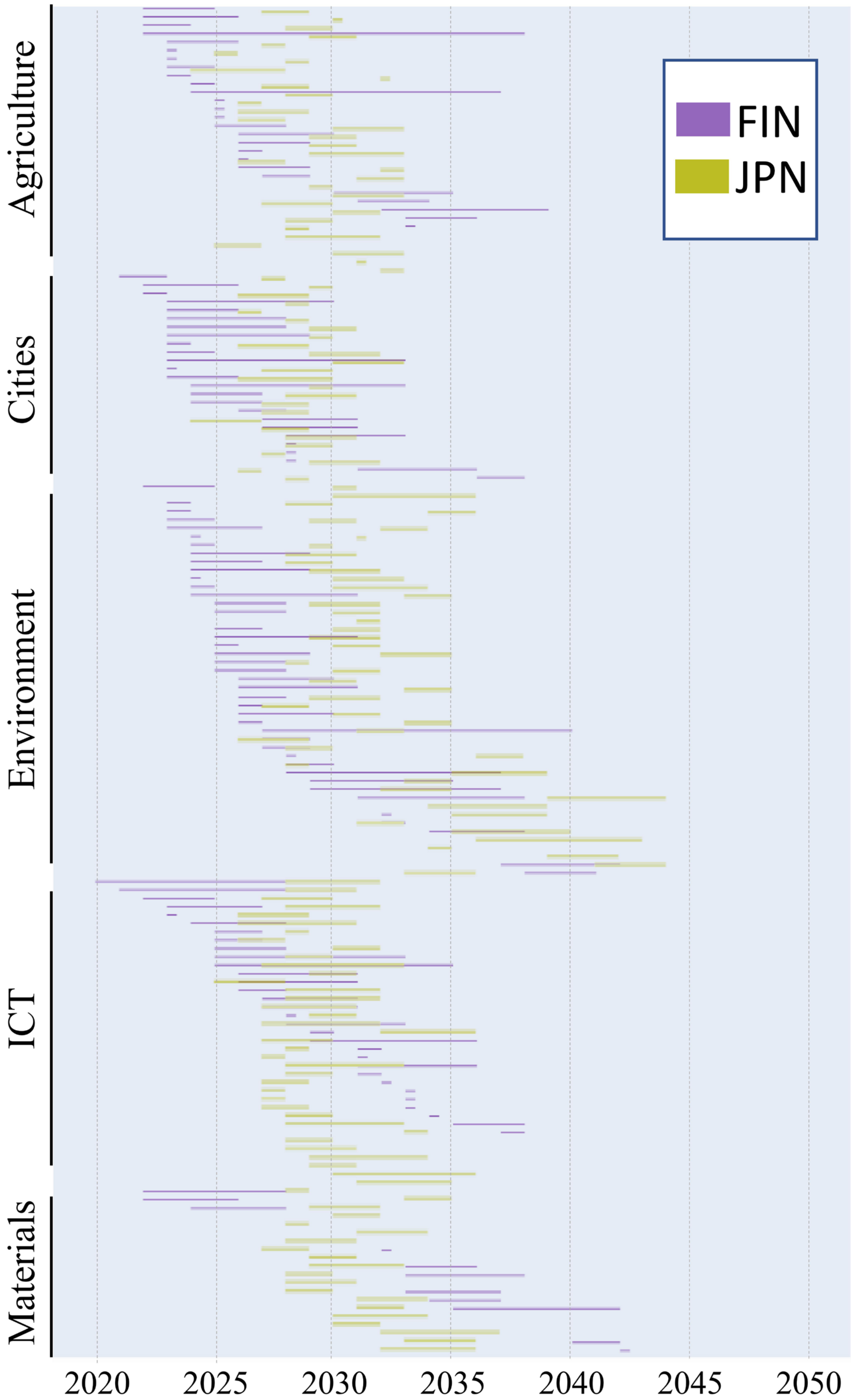

Fig. 4: Overall comparison of years of realiza-

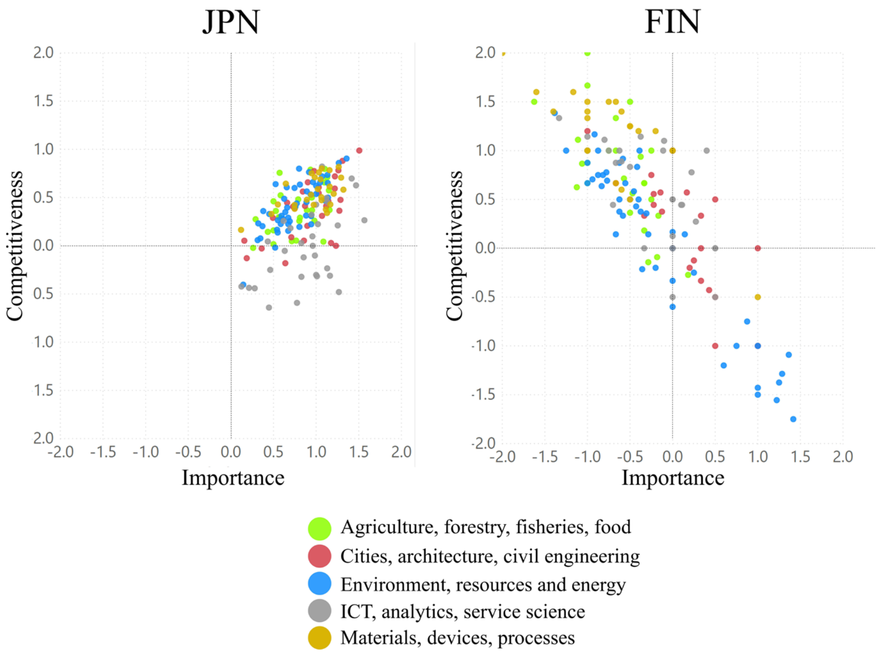

Fig. 5: Comparison of all featured topics

For Finland, we identified a discontinuity between current knowledge and required knowledge after the forecasting period. A high negative correlation ($r(57) = -0.653$, $p = .001$) between the subcategories current knowledge and importance of the subcategory suggests that the forecasting period created an actionable metric for knowledge development.

The scatter plot is very different for Japan, where the trend is opposite and creates a cohesive cluster. In order to better understand the macro-level differences between the two countries it is imperative to know whether these differences are due to true perceptions or a secondary impact that should be controlled for.

2.1 Theme: Agriculture, forestry and fisheries, food and biotechnology

A. FOOD ECOSYSTEM

Table 3: Topic list in the sub-theme

ID	TOPIC
116	Flexible cooking system applicable to various menus for restaurants
117	Technology for detecting entry of organic matter (hair, etc.) in food production lines
118	Creation of an international database of research results, using an approach that integrates fields of research including cognitive science, linguistics, chemistry and AI, considering taste, fragrance, and mouthfeel (texture), for convenient reproduction of "taste".
119	A system that quantitatively analyzes the quality (components, properties, maturity) of agricultural, forestry and fishery products on a production site in a non-destructive manner and in real time
120	Technology for producing food that does not cause allergies based on allergen measurement technology
121	Various functional foods based on the concept of a food mix that is conscious of the aging society
122	Technology for monitoring and analyzing the food value chain to reduce food loss
123	Short-term storage technology to maintain the freshness and quality of fresh foods without freezing
124	Production processing technology for new protein sources including insect resources
125	Manufacturing, processing and cooking technology to achieve mass customization to shorten the distance from the place of production to the place of consumption (improving carbon footprint)
126	New resource generation technology based on the reuse of waste food (e.g. a food 3D printer)
127	Complete circular food value chain throughout the processes of production, distribution, processing and consumption

***White;** Number of respondents in Finland was above **2. Light blue;** Number of respondents in Finland was **2.**

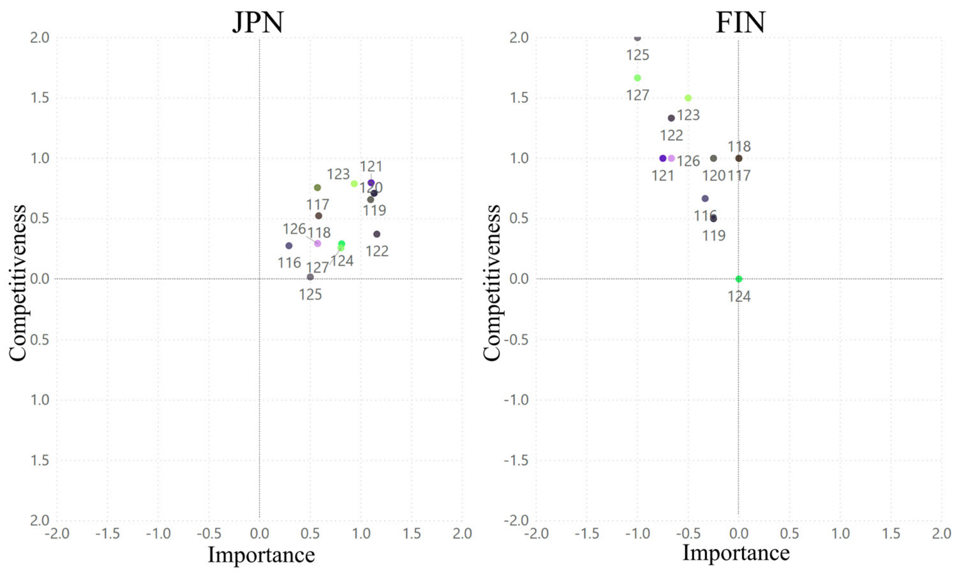

Fig. 6: Comparison of indexes

Key findings

- Creation of an international database on research results, using an approach that integrates different fields of research including cognitive science, linguistics, chemistry and AI, considering taste, fragrance, and mouthfeel, for the convenient reproduction of “taste”. The number of respondents in this category was so low in Finland that result is anecdotal.
- The topic with the greatest perceived importance in Japan was ID122, “Technology for monitoring and analysing the food value chain to reduce food loss”.

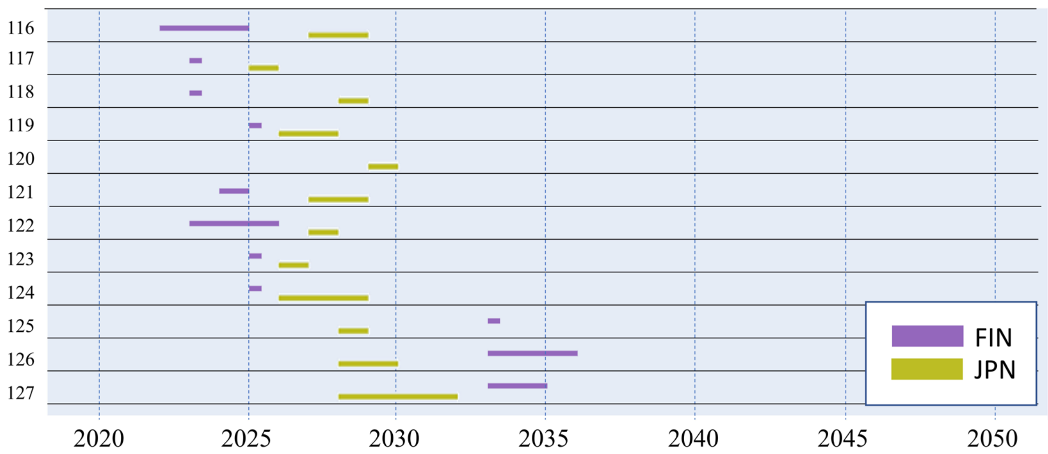

Fig. 7: Comparison of forecasts for years of realization

Key findings

- It is expected that many topics will be realized earlier in Finland.
- The topics where Finland was expected to be furthest ahead of Japan in terms of realization was "Technology for monitoring and analysing the food value chain to reduce food loss".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2023	2026
Japan	2027	2028

- The topic that was predicted to be realized earlier in Japan than in Finland was "New resource generation technology through the reuse of waste food (e.g. a food 3D printer)".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2033	2036
Japan	2028	2030

Discussion and qualitative commentary

In Japan, it was expected that topics such as "Manufacturing, processing and cooking technology to achieve mass customization to reduce the distance from site of production to site of consumption (reducing carbon footprint)" and "New resource generation technology based on the reuse of waste food (e.g. a food 3D printer)" would be realized earlier than in Finland. These fields are relatively advanced in Japan.

Finland ranks very high globally on indicators of food safety and trustworthiness. One explanation for this is that Finnish food industry already makes extensive use of sensor technologies, which together with food quality analysis are still continuing to grow in importance. The raw materials used for food production in Finland are also of high quality, which is reflected in high levels of trust in the export markets. Finnish brands are also supported by safe and clean material production systems. The respondents' low assessments regarding the importance of food technologies might be attributable to the fact the Finnish food ecosystem is already of a high quality.

Even though the Finnish food ecosystem is in good shape, there is still room for improvement. Currently Finnish people are not particularly active users of consumer data. Also, megatronics and IoT technologies are highly relevant for Finland, but the use of these technologies in the food domain is lagging behind. It is also noteworthy that the Finnish food industry is rather small and does not have a sizeable R&D budget.

Covid-19 has disrupted the food system and is expected to influence consumer behavior, food consumption and supply and delivery systems. Agile manufacturing technologies might gain increased importance as a way of minimizing human contact in food production and delivery. It will also help reduce the problems caused by the shortage of labour.

In Japan's case, results for the food ecosystem showed high competitiveness scores for functional foods (ageing, allergies, etc.), storage technology and quantitative quality analysis.

Population ageing and food safety and security are important concerns not only in Japan but in many countries around the world. Especially in Japanese society where population numbers are declining, it is expected that the automation of cooking and the development of artificial foods and food storage technology will continue to be promoted with the advance of AI.

Furthermore, the continued ageing of society will require efforts to develop electronic commerce (EC) in the food sector to support home deliveries. Technological advances and social implementation addressing the problems facing Japanese society will also contribute to strengthen the country's international competitiveness and the growth of international business in the future.

B. BIOMASS

Table 4: Topic list in the sub-theme

ID	TOPIC
169	Cultivation of biomass producing crops exceeding 50 tons/ha/year with dry matter
170	Technology for decomposing and using vegetable fibers by using artificial proteins to relax the crystallinity of cellulose
171	Livestock cooperative production system using ingredient-stable fertilizer production technology through concentration of methane fermentation digestive juices
172	Technology to design fire-proof timber structures based on the development of high-strength timber materials for the construction of mid-to-high-rise timber buildings, which can be expected to reduce CO2 emissions by replacing steel and cement (reinforced concrete) structures
173	High-durability timber that can be used outdoors for a long period of time (around 50 years), with the aim of expanding demand in fields such as civil engineering
174	High-efficiency, low-cost power generation, thermal utilization technology using biomass such as wood
175	Biodegradability and photodegradable materials for the food ecosystem
176	Technologies for replacing fossil fuel products with forest resources (road paving and construction materials, clothing materials, paints, consumer goods)
177	Technology for adding value to wood by-products (technology for reusing, refining, separating and extracting lumber remnants and non-standard logging products, and edible waste on processing lines)

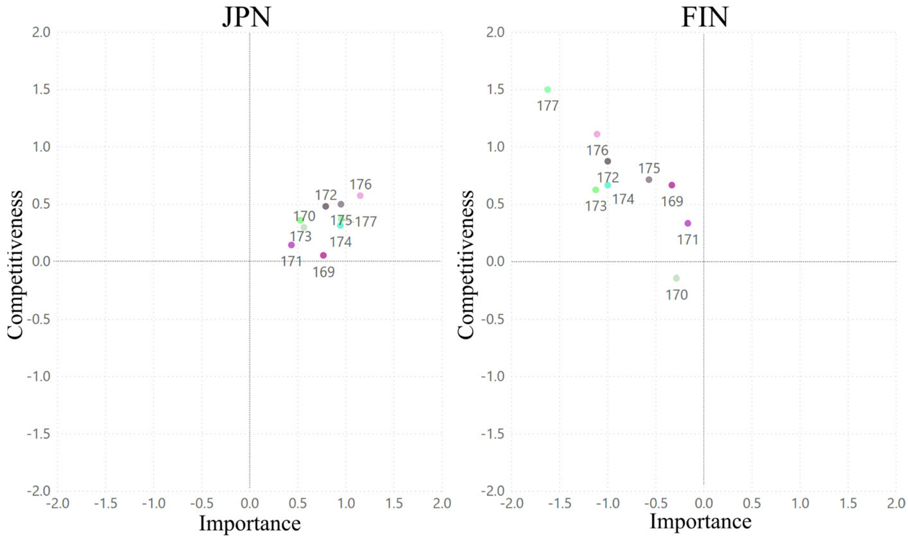

Fig.8: Comparison of indexes

Key findings

- The topic with the greatest perceived importance in Finland was "Livestock cooperative production system using ingredient-stable fertilizer production technology for the concentration of methane fermentation digestive juices".
- The topic with the greatest perceived importance in Japan was "Technologies for replacing fossil fuel products with forest resources (road paving and construction materials, clothing materials, paints, consumer goods)".

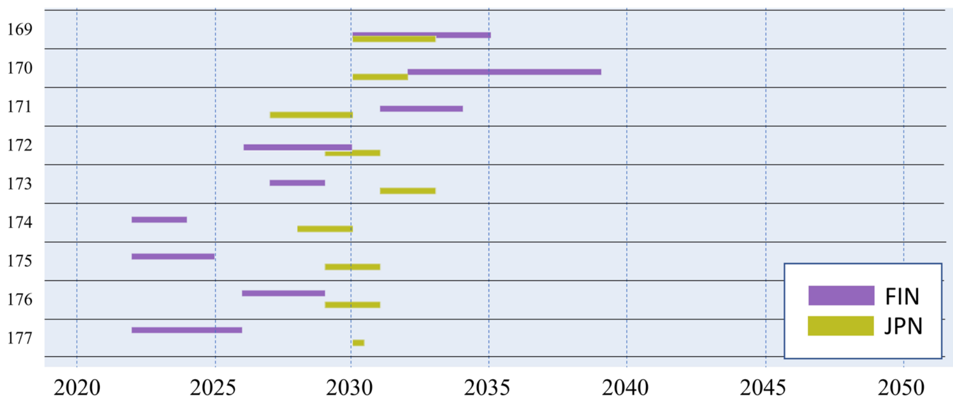

Fig.9: Comparison of forecasts for years of realization

Key findings

- It is predicted that many topics will be realized earlier in Finland.
- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was "Technology for adding value to wood byproducts (technology for reusing, refining, separating and extracting lumber remnants and non-standard logging products, and edible waste on processing lines)".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2022	2026
Japan	2030	2030

- The topic where Japan was expected to be furthest ahead of Finland in terms of realization was "Technology for decomposing vegetable fibres by using artificial proteins to reduce the crystallinity of cellulose".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2032	2039
Japan	2030	2032

Discussion and qualitative commentary

In Japan, it is expected that manufacturing topics (e.g. organic synthesis or chemical reactions related to the crystallinity of cellulose), will be realized earlier than in Finland. This is possibly because these fields are relatively advanced in Japan.

The respondents regarded the Finnish biomass domain as highly competitive globally. This comes as no surprise since the forestry sector is a longstanding cornerstones of the Finnish economy. The growth of the Finnish forestry sector has brought increasing Finnish competitiveness in biomass-related technologies. The Finnish biomass industry has also been very good at utilizing industrial sidestreams, an important part of the circular economy paradigm.

One important observation in this context is that nanocellulose is food grade in Japan, but not in Finland, reflecting the country's less flexible legislation. Nonetheless Finnish IPR are strong in this field. Cellular agriculture and circularity in the food chain are interesting emerging fields for the future.

Key biomass topics are (1) biomass production, such as production technology for high-yield crops, (2) the expanding demand for biomass, such as fire-resistant wood structure design technology based on the development of high-strength wood members, (3) biodegradability related to the food ecosystem, and (4) the substitution of fossil resources such as photodegradable materials.

The latter, i.e. the substitution of fossil resources, is rated as more important in Japan than in Finland. A key next step for expanding demand, this will be important for the increased use of biomass as a way of controlling fossil resource use and so reducing CO_2 emissions and preventing global warming. This will contribute to strengthen Japan's agriculture, forestry and fisheries industries as well as its agricultural and mountain village societies.

C. COMMUNITY

Table 5: Topic list in the sub-theme

ID	TOPIC
187	Forest therapy based on physiological elucidation of the comfort enhancing effect of forests and woodlands
188	Food supply and demand prediction system based on an increase in world population; economic development and trends in crop production technology
189	Technology to evaluate the economic vitality, social impact and environmental burden of a society using renewable energy such as biomass
190	A social system utilizing humanities, social sciences and AI for fishery resource management
191	System for reevaluating traditional recipes
192	Social system to establish traceability of marine products
193	Community visualization monitoring technology using state-of-the-art digital technology

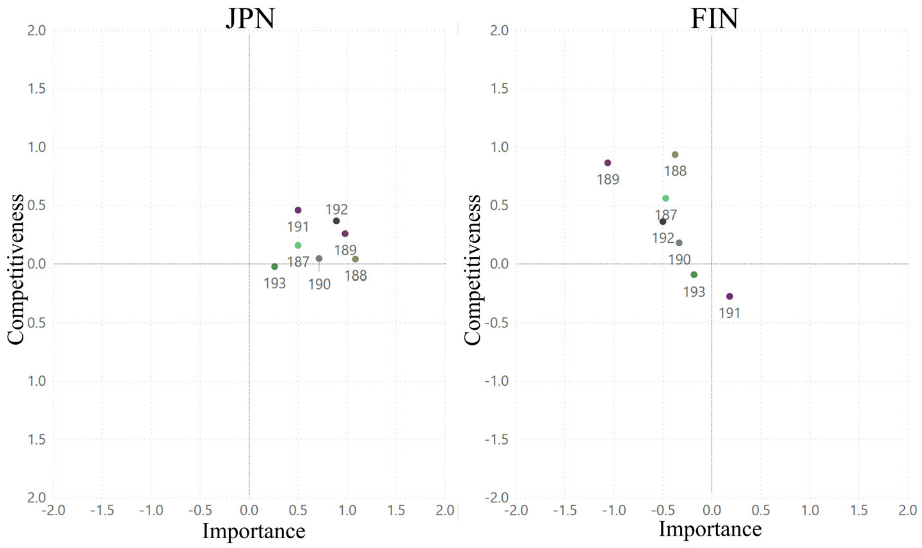

Fig.10: Comparison of indexes

Key findings

- The topic with the greatest perceived importance in Finland was "System for re-evaluating traditional recipes".
- The topic with the greatest perceived importance in Japan was "Food supply and demand prediction system based on world population growth; economic development and trends in crop production technology".

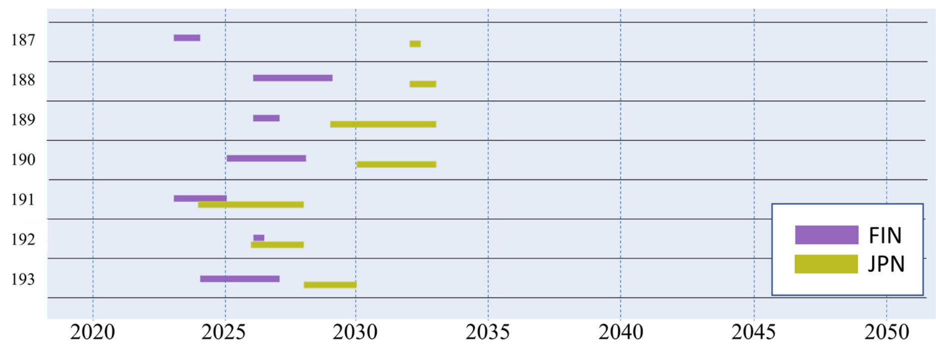

Fig.11: Comparison of forecasts for years of realization

Key findings

- It is expected that many topics will be realized earlier in Finland.
- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was "A social system utilizing the humanities, social sciences and AI for fishery resource management".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2025	2028
Japan	2030	2033

- None of the topics will materialize earlier in Japan than in Finland.

Discussion and qualitative commentary

None of the topics under this theme were expected to be realized earlier in Japan than in Finland. The only topic expected to materialize sooner than others in Japan was the topic of traditional cooking.

In this sector data ownership, sharing and transparency will be crucially important factors in the utilization of these technologies. Currently the retail sector does not have a very open policy in sharing consumer data, which can slow and hinder development. It can be argued that the re-evaluation of traditional recipes is already underway.

In the future, Japan will have to be able to supply food without generating waste, based on individual needs and the supply and demand forecast for each community. Local production for local consumption will be required along with circular economy. Convenience stores and restaurant chains are also expected to flexibly change their forms and offerings according to their micro societies. On the other hand, major advances are expected in online recipes and nutrition management as well as in preventive health monitoring, prediction, advice and dietary interventions. The balance between the data-driven virtual community and real community will be reviewed on an ongoing basis.

Global population growth will require a highly efficient and sustainable food ecosystem, and the importance of the corresponding technologies will no doubt increase accordingly. The re-evaluation of traditional recipes can emerge as an extremely important area in the future, particularly in view of the need to reduce animal protein consumption and the need to find plant-based substitutes. Plant biotechnology is expected to become an even more interesting field in the future.

Finland is highly self-sufficient in terms of food production, so from the Finnish point of view the importance attached to these technologies in these survey results still appears quite low. One important technological field in this domain is the utilization of augmented reality.

In Japan, it is expected that the diversification of values will lead to a shift from food production/supply as an economic activity to an exercise that enhances people's sense of purpose and happiness. It is thought that individual lifestyles will change in different ways in different regions and social environments, which will prompt the development of more fragmented markets.

Furthermore, Japan's declining birth rate and ageing population coupled with rural depopulation and the increasing proportion of single households mean that connections with neighbours are becoming weaker, especially in urban areas. In this situation it is important to encourage and support local food supply chains and to create self-sufficient systems for the eventuality of a disaster, and that neighbourhood support mechanisms are created through agriculture, forestry and fisheries.

Food is expected to play a pivotal role in all these respects and it will have a close relationship with the community network from production activities through to supply, cooking and consumption. The emerging micro society will be led by consumers rather than governments or industries.

2.2 Theme: city, architecture, civil engineering, transportation

A. LAND USE AND CONSERVATION

Table 6: Topic list in the sub-theme

ID	TOPIC
508	Floating structures compatible with preserving the marine environment (traffic, communication, production, activity base, etc.)
509	Sewage technology for recovery of resources such as precious metals from sewage and to achieve energy self-reliance
510	Technology for estimating and observing underground water quality and flow
511	Estimation of global groundwater reserves (fossil water) that can only be used non-continuously for appropriate international management
512	Early warning technology for levee breaches using a combination of prediction and observation
513	Technology for emergency restoration, including the rapid closure of riverbank breaches in the event of river levee deformation
514	River channel design technology integrating long-term environmental conservation and maintenance
515	A sediment transport system for predicting geographical changes of land, including mountain and coastline regions, estimations and technology to appropriately conserve land
516	Tourists from all countries who are traveling in Finland are able to receive information and support related to sightseeing spots and may travel anytime and anywhere, to ensure that inbound tourism can be enjoyed smoothly and comfortably
517	Technology for quantitatively determining real-time changes in land, large structures and deformation during disasters using the positioning data from quasi-zenith satellites
518	Technology for elucidating the mechanism at which microplastics are generated and the actual load in public waters, in order to implement appropriate pollution source control

***White;** Number of respondents in Finland was above **2**. **Dark Blue;** Number of respondents in Finland was **1.**

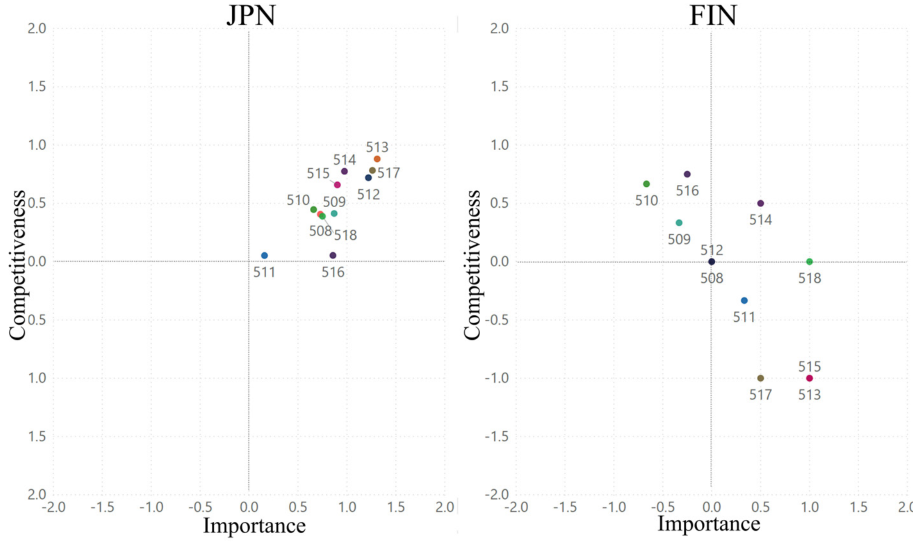

Fig.12: Comparison of indexes

Key findings

- The topic with the greatest perceived importance in Finland was “Technology for emergency restoration, including the rapid closure of riverbank breachs in the event of when river levee deformation”; ”A sediment transport system for predicting geographical changes of land, including mountain and coastline regions, estimations and technology to appropriately conserve land”; and “Technology for elucidating the mechanisms through which microplastics are generated and the actual load in public waters, in order to implement appropriate pollution source control”.
- The topic with the greatest perceived importance in Japan was the same as in Finland, “Technology for emergency restoration, including the rapid closure of riverbank breaches in the event of river levee deformation”.

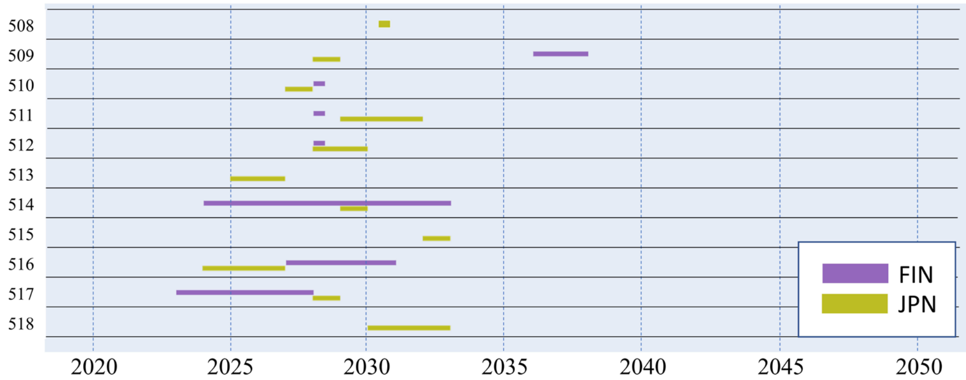

Fig.13: Comparison of forecasts for years of realization

Key findings

- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was “Technology for quantitatively determining real-time changes in land, large structures and deformation during disasters using positioning data from quasi-zenith satellites”.

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2023	2026
Japan	2027	2028

- The topic where Japan was expected to be furthest ahead of Finland in terms of realization was Sewage technology for the recovery of resources such as precious metals from sewage and for the achievement of energy self-reliance”.

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2036	2038
Japan	2028	2029

Discussion and qualitative commentary

In Japan, it was expected that topics related to sewage treatment would be realized earlier than in Finland. Japan suffers frequently from floods and it has also experienced water pollution in the past. These problems have prompted the country to invest in the development of flood control technology and water purification methods, where it has reached a high level of advancement.

Finland's geographical location, natural resources and low population density are central to explaining Finnish views on competitiveness and technological sophistication in the fields of water and land use. There has always been an abundance of fresh water and land to build on, which helps to explain why related technologies and competitiveness in Finland lag behind those in Japan. Similarly, land degradation has not been a significant issue in Finland due to the country's low population density. Even though these technologies do not have the same overall importance in Finland as they do in Japan, there are some niche areas worth mentioning from the Finnish point of view, including water flow monitoring technologies in nuclear energy settings or urban runoffs. It is projected that technologies for the recovery of metals from sewage water or microplastics from fresh water will gain increasing importance in the Finnish context, too. Disaster management, on the other hand, is an area that will probably not achieve the same kind of importance as in Japan.

As for Japanese competiveness and the importance of these technologies from a Japanese point of view, the respondents attached high importance to topics related to disaster prevention and river conservation, such as technologies for the emergency restoration of river dikes and monitoring of land and large structures using positioning data from quasi-zenith satellites.

It seems that great importance is attached to technologies related to disaster prevention, reflecting the frequent occurrence of floods in Japan and the expectation that natural disasters associated with climate change will become increasingly severe in the future.

At the same time, there is a high level of interest in topics related to the conservation of the river environment. It is thought that progress in these areas will require human resource development and domestic collaboration, as well as researchers and engineers with diverse areas of expertise.

B. CITIES & ENVIRONMENT

Table 7: Topic list in the sub-theme

ID	TOPIC
542	Platform for sharing, linking and using data held by various organizations in order to open up city-related data
543	Technology for comprehensive and efficient provision, maintenance and quantitative evaluation of green infrastructure, developed using nature's diverse functions
544	Nudge-type housing information provision system promoting rational residential selection behavior (Housing information provision system with a mechanism to urge voluntary desired choice by using knowledge of behavioral science)
545	Residential district independent of wider infrastructure
546	Technology for creating highly accurate disaster hazard maps to enable detailed city planning
547	Consensus-building support system that enables discussion and decision-making on urban planning without time and place limitations
548	A system for monitoring changes in land use and for proposing appropriate urban planning methods to enable detailed city planning (zoning and development of urban facilities)
549	Environmental assessment technology to accurately evaluate micro changes brought about by development
550	Technology for extensive maintenance and management of low-use or unused areas caused by depopulation

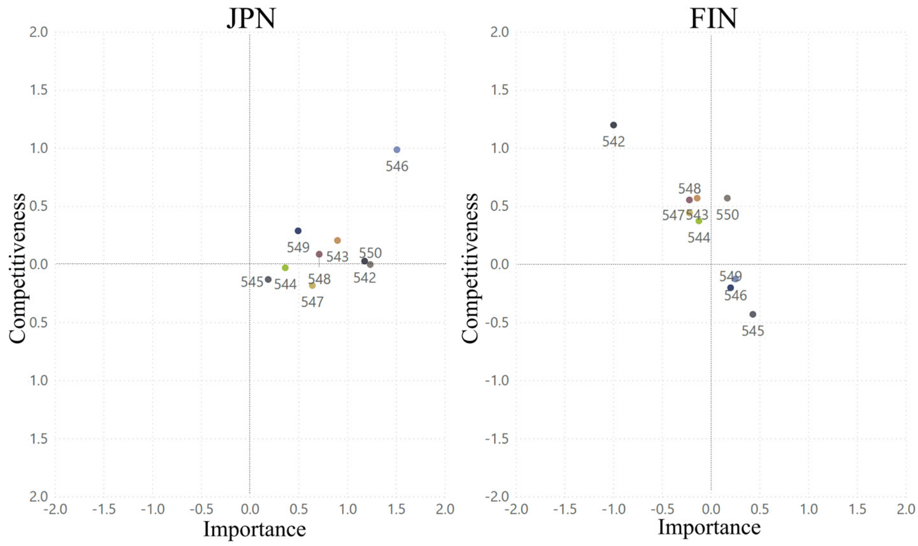

Fig.14: Comparison of indexes for sub-theme

Key findings

- The topic with the greatest perceived importance in Finland was "Residential district independent of widee infrastructure".
- The topic with the greatest perceived importance in Japan was "Technology for creating highly accurate disaster hazard maps to enable detailed city planning".

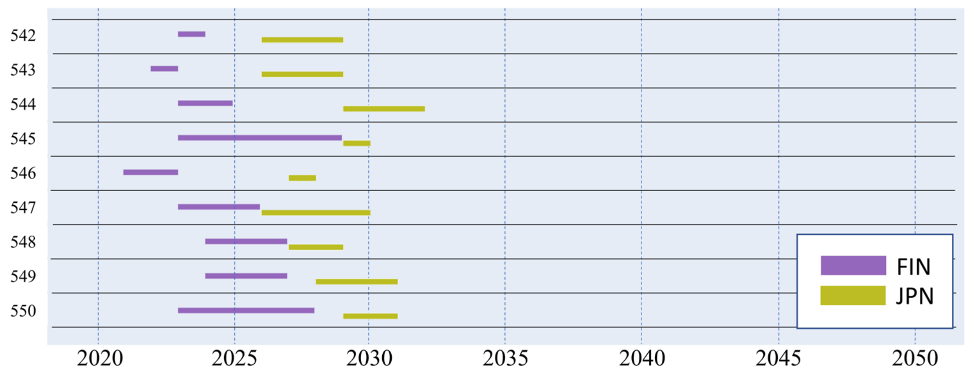

Fig.15: Comparison of forecasts for years of realization

Key findings

- All topics are expected to be realized earlier in Finland.
- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was "Technology for extensive maintenance and management of low-use or unused areas caused by depopulation".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2023	2028
Japan	2029	2031

Discussion and qualitative commentary

It is easy to agree with the respondents' assessments of the realization of these technologies. One possible reason why the Finnish respondents seem to think that these technologies will be realized and picked up earlier is that Finnish cities and infrastructures are smaller, more sparse and less complex than in Japan - meaning that simpler solutions can work and be effective. Also, information sharing is one of the strengths of Finnish society, which can contribute to the rapid development and take-up of technologies in the city and environment domain.

Finland has developed a world-class test environment for 5G technology based urban digital infrastructures, like digital-based pilots in many smart city initiatives, for instance Mobility as a Service demo area (Smart Otaniemi, Lux Turrim project etc). This is crucial for the development of new systemic urban services, such as smooth traffic urban information flows and monitoring systems, especially in dense urban areas.

As for the prospects in Japan, there are two urban planning topics that are expected to be realized at an early stage, and there are also high expectations in the ICT field. Regarding green infrastructure technology, which attracts relatively high importance and international competitiveness ratings, the imperative of developing and securing human resources for science and technology and social realization is clearly recognized.

None of the topics in this theme were expected to be realized earlier in Japan than in Finland. The overall trends seem to be similar in both countries, but Finland was expected to reach realization earlier. In particular, the realization of behavioural science themes will happen relatively late, underscoring the importance of data sharing.

As already noted, Finland can be seen as a global frontrunner in the use of open and smart city data, which is clearly reflected in the responses. Finland also has longstanding traditions in building green urban areas. This tradition is central to explaining Finland's high competitiveness in urban planning. Disaster prevention is not very significant in this context either, but maps and navigation technologies are highly advanced in Finland and used extensively for example in fire safety planning. Airborne survey technologies such as laser scanning have been developed and are used in forest inventories and in the collection, mapping and monitoring of urban planning platform data. Overall, it is fair to suggest that Finland's overall competitiveness in this area could be rated as higher, particularly in view of Finnish expertise in energy and circular economy technologies.

Finnish competitiveness in monitoring urban air quality could also be given a higher rating in this survey based on the number of successful export business cases, high levels of research competence and ecosystem-based solutions and pilots, which can be scaled up for international business.

As regards to Japan, due to the frequent occurrence of natural disasters in Japan, technologies for disaster hazard map creation receive high scores both for importance and international competitiveness. Items that are important but less competitive internationally are the open data platform and maintenance technology for unused land, which s uggests that these are unique to Japan.

Topics related to independent residential districts and residential selection have average importance and low international competitiveness scores. These assessments partly explain the expectations of slow technology realization.

C. CONSTRUCTION PRODUCTION SYSTEMS

Table 8: Topic list in the sub-theme

ID	TOPIC
551	Technology to search for and notify the existence of abnormalities, where robots and sensors automatically and autonomously check and diagnose abnormalities based on design, construction and past inspection data
552	Electronic map that becomes the basic national map, including dynamic information, and collection of automatically updated information
553	Unmanned construction machine capable of autonomous construction based on design data, while recognizing changes in working conditions and surrounding construction conditions, etc.
554	Technology that constantly ascertains the work environment of workers (high place work, crane turning range, heat stroke, etc.) based on camera and biometric sensor information and automatically issues alerts
555	Technology to constantly ascertain and analyze the status of work progress at the construction site using AI, which properly manages and automatically optimizes and modifies processes
556	Automation of on-site assembly by unitization of concrete structures such as bridges
557	Construction of an infrastructure data platform that enables automatic accumulation and integrated utilization of 4D data (including time series) for the entire construction process from surveying and investigation through to design and construction, supervision and inspection, maintenance and management.
558	Technology based on BIM data which manages construction projects from design to construction through to confirmation of form, and to maintain and manage projects with sensors and robots
559	Futuristic streamlined construction methods for structural framework and finishing and fitting-out, including on-site production of parts with a 3D printer, autonomous transportation of building materials by robots and drones.

***White;** Number of respondents in Finland was above **2. Light Blue;** Number of respondents in Finland was **2.**

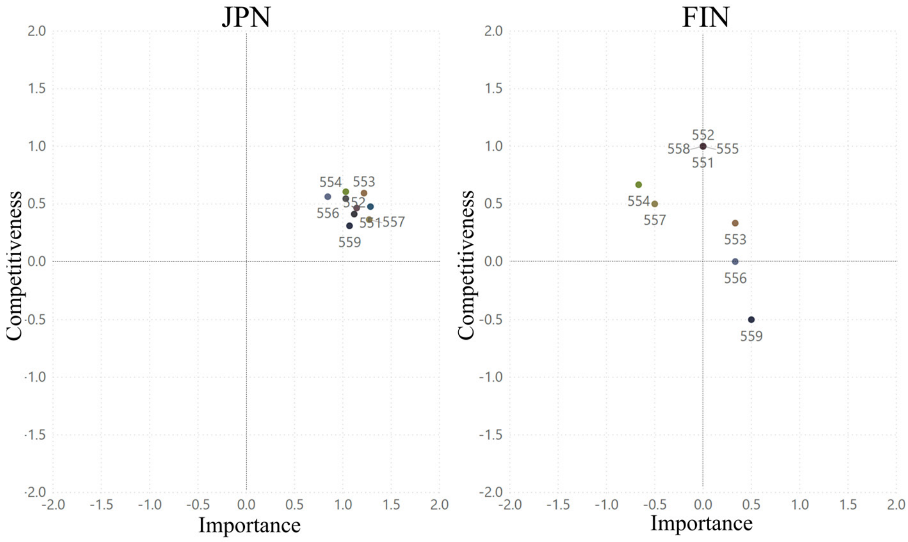

Fig.16: Comparison of indexes

Key findings

- The topic with the greatest perceived importance in Finland was “Futuristic streamlined construction methods for structural framework and finishing and fitting out, including onsite production of parts with a 3D printer and autonomous transportation of building materials by robots and drones”. But because of the low respondent number, this result need further validation.
- The topic with the greatest perceived importance in Japan was “Technology to search for and notify the existence of abnormalities, with robots and sensors automatically and autonomously checking and diagnosing abnormalities based on design, construction and past inspection data”.

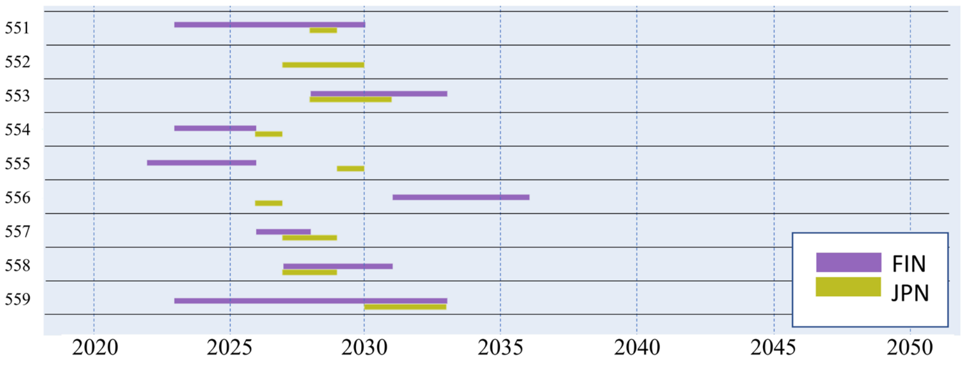

Fig.17: Comparison of forecasts for years of realization

Key findings

- The topic that where Finland was expected to be furthest ahead of Japan in terms of realization was “Futuristic streamlined construction methods for structural framework and finishing and fitting out, including onsite production of parts with a 3D printer and autonomous transportation of building materials by robots and drones”

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2023	2033
Japan	2030	2033

Another topic where Finland was expected to be ahead was “Technology that constantly ascertains and analyses work progress at construction sites using AI, which properly manages and automatically optimizes and modifies processes”.

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2022	2026
Japan	2029	2030

- The topic where Japan was expected to be furthest ahead of Finland in terms of realization was “Automation of on-site assembly of concrete structures such as bridges”.

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2031	2036
Japan	2026	2027

Discussion and qualitative commentary

Finland has a large number of ongoing R&D&I pilots in these technologies, but large-scale commercialization has not got underway.

The respondents' assessments of the realization and adoption of technologies can be viewed as accurate. The Finnish respondents seem to think that taking mature technologies to adoption will will take a long time. One potential factor behind this view is that subcontracting chains in Finnish construction productions systems are long and complex, which might hamper the adoption process. This also means that an emerging technology will need to clearly demonstrate its value before it is taken onboard more widely.

Finnish competence levels are very high in many areas, yet export performance continues to disappoint. This can be explained by the local nature of the business logic in the construction sector. Some Finnish companies are clearly world-class performers in this field; one example is the global elevator and escalator company Kone. In Japan, it was predicted that all topics would be realized by 2035. The direction and goals of technological development in these topics are clear, appropriate R&D funding will be allocated, domestic collaboration will be promoted, and human resources and business environment will be improved. It is thought that all this will support early realization.

In Japan, it was expected that topics such as robotics, especially for large buildings, would be realized earlier than in Finland. This may be explained by the relatively high demand for large buildings in Japan and the relatively high level of advancement of this field.

Expectations for the role of robots and sensors in construction production systems are overly optimistic. However, software use and development in planning and project management are strong areas in Finland, and there is reason to believe that this trend will continue in the future. Digital planning data can also be used for accurate monitoring of infrastructure construction processes. The introduction of AI in the mix is also a reasonable assumption. In the future construction processes of buildings and built areas will be increasingly based on digital twins created from Building information models (BIM). This enables optimization of the construction process and the life-cycle maintenance of buildings.

2.3 Theme: Environment, resources and energy

A. RESOURCE DEVELOPMENT 3R

Table 9: Topic list in the sub-theme in Food ecosystem

ID	TOPIC
231	Efficient mine exploration technology using ICT and satellites
232	Mining and pumping technology required for mining ocean mineral resources
233	Non-polluting shale gas mining technology
234	Technology to smelt titanium at ≤50% of the current cost
235	Technology to treat and store arsenic in copper mines
236	Technology to mine methane hydrate
237	Technology to economically recover rare metals such as uranium from seawater
238	Technology to develop resources up to a temperature of 250°C and pressure of 500 atom
239	Technology to enable economical extraction of deep-sea metal resources from hydrothermal deposits
240	Technology to effectively recover helium from the air
241	Technology for economically separating and recovering useful metals from used products such as low-grade rare metal special steel
242	Technology to reasonably collect and use rare metals from small electronic devices, waste and sewage sludge from incineration fly ash
243	Biomass refinery format that enables production of various basic industrial products
244	Sorting sensor technology to further improve waste selection and sorting systems
245	Technology to drastically reduce the amount of waste with nuclear transmutation of radionuclides in high-level radioactive waste using an accelerator
246	Using digital technology for strata analysis, resource reserve estimation, development plan formulation, etc., in resource development
247	New EOR/ EGR (enhanced oil and natural gas recovery) technology using bio nanotechnology
248	Elucidation of the cause and actual conditions of induced earthquakes associated with resource development
249	Innovative dismantling and design technology that maintains function to promote reuse
250	Physical separation and enrichment technology to promote advanced recycling of metals
251	Technology for dramatically improving the efficiency of the supply chain for resource circulation, such as collection and transport, using information technology
252	Technology to utilize steam generated from waste incineration for factories and power generation, implemented for more than half the incinerators
253	Management of resources and hazardous substances through creation of a common database for material flow
254	Automatic operation of waste disposal and recycling facility maintenance, including self-diagnosis using AI
255	High-temperature in-ground equipment for utilization of geothermal resources, with a view of utilizing supercritical geothermal resources
256	Geothermal power generation technology using supercritical water located at a depth of about 5000 m
257	Artificial recharge technology for depleted geothermal reservoirs
258	Nationwide expansion of potential geothermal maps based on a groundwater flow model

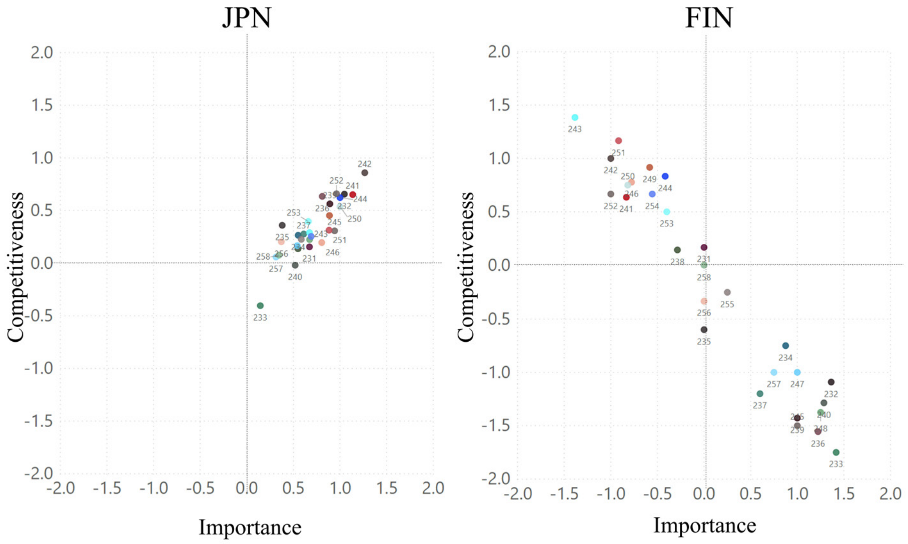

Fig.18: Comparison of indexes

Key findings

- The topic with the greatest perceived importance in Finland was "Non-polluting shale gas mining technology".
- The topic with the greatest perceived importance in Japan was "Technology to reasonably collect and use rare metals from small electronic devices, waste and sewage sludge from incineration fly ash".

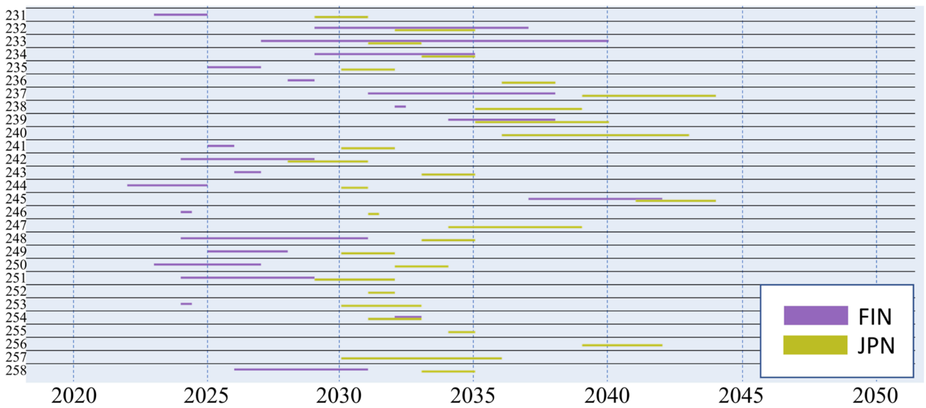

Fig.19: Comparison of forecasts for years of realization

Key findings

- The topic where Finland was expected to be furthest ahead Japan was “Sorting sensor technology to further improve waste selection and sorting systems”.

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2022	2025
Japan	2030	2031

- The topic that was expected to be realized somewhat earlier in Japan than in Finland was “Automatic waste disposal and recycling facility maintenance, including self-diagnosis using AI”.

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2032	2033
Japan	2031	2033

Much uncertainty seems to surround the technologies appearing at the top of the list in table 9. This might be explained by non-technical factors associated with the use of these technologies. Topics 242-251 appear to be emerging rapidly in Finland due to circular economy activities.

In Japan, it is thought that technology related to resource development is important to those engaged in information technology and digital technology (exploration, evaluation, etc.) and marine resource development (methane hydrate, hydrothermal deposits, etc.). However, while the former is expected to be realized relatively early, it is thought that the latter will take some 20 years to move to realization. On the other hand, the feasibility of technologies for recovering resources from seawater and the atmosphere and for geothermal development from the ultra-deep is thought to be low. In addition, ratings for environmentally friendly shale gas development technology are extremely low, both in terms of importance and international competitiveness. In the future, while IT utilization and marine resource development will continue to accelerate, resource development on land will be cautious.

Discussion and qualitative commentary

Some Finnish forerunner companies in waste management technology are already using advanced sensor technologies, robotics/automation, sorting and fractionation processes to handle different waste streams.

In Japan, it was expected that most topics under this sub-theme would be realized earlier in Finland. However, topics related to AI were expected to be realized relatively early in Japan. This is thought to be due to the importance of AI research in Japan, although the difference compared to Finland is not significant.

The descriptions of the technologies under this sub-theme are heavily focused on resource exploration. This is a domain that arguably has been and continues to remain very important in Japan, but has not reached the same level of importance in Finland. Finland has abundant reserves of resources when considering the size and type of industrial domains in the country. Furthermore, industrialization got underway later in Finland, meaning that the country has been in a better position to import resources and therefore has had less need to optimize local resource exploration.

In Finland the importance of resource development technologies related to the circular economy is almost certainly going to continue to grow. Sorting and re-use technologies are already well-established. Finnish know-how in the management of harmful substances is also continuing to develop. As for technologies related to geothermal power, only limited focus has been given to the material side, whereas there is strong expertise in geology in Finland.

In Japan, the scarcity of domestic resources means that securing access to resources is an ongoing, urgent issue of concern. Technologies for recovering rare metals from low-concentration wastes are highly rated in Japan. Accordingly, high importance scores were given to advanced physical separation / concentration technologies for improving the quality of recycled materials and for the use of steam produced in industrial waste incinerators. It is expected that both these areas will reach technical and social realization by the first half of the 2030s, and concrete measures to enhance resource circulation are expected both in terms of material utilization and energy utilization. Interest was also expressed in innovative dismantling technologies for promoting the reuse of different parts and components, and a dramatic improvement was expected in supply chain efficiency based on IT use. The topic explicitly dealing with reduce was not included in the response options, but the respondents clearly stressed the importance of promoting dematerialization through the sharing economy.

B. WATER

Table 10: Topic list in the sub-theme in Water

ID	TOPIC
259	Nationwide groundwater map through effective integration of satellite observation and ground observation
260	Technology to monitor water areas with non-contact continuous sensing of water environment quality
261	Integrated water management technology in densely populated areas, including management of urban flooding, storm surge and land subsidence due to linear rain bands and torrential rain
262	Water resource and energy optimization technology based on climate/snowfall models and observations to effectively use snow as a resource
263	Technology to continuously monitor harmful trace chemicals, pathogenic microorganisms, etc., in the water supply
264	Technology to rapidly analyze and remove residual antibiotics in treated sewage
265	Water purification technology using a reverse osmosis membrane with pressurized energy reduced by 50% or more
266	Water purification technology with an economically recyclable reverse osmosis membrane
267	Technology for recycling contaminated water that could be widely used in developing countries
268	Integrated water quality indicator that can evaluate the quality of the water environment in place of BOD, COD, T-N, etc.
269	Rapid analysis method to detect microplastics in the hydrosphere and assessment of health risks
270	Geo-engineering (environmental chemistry technology) and biomimetic technology to acquire water resources from the atmosphere

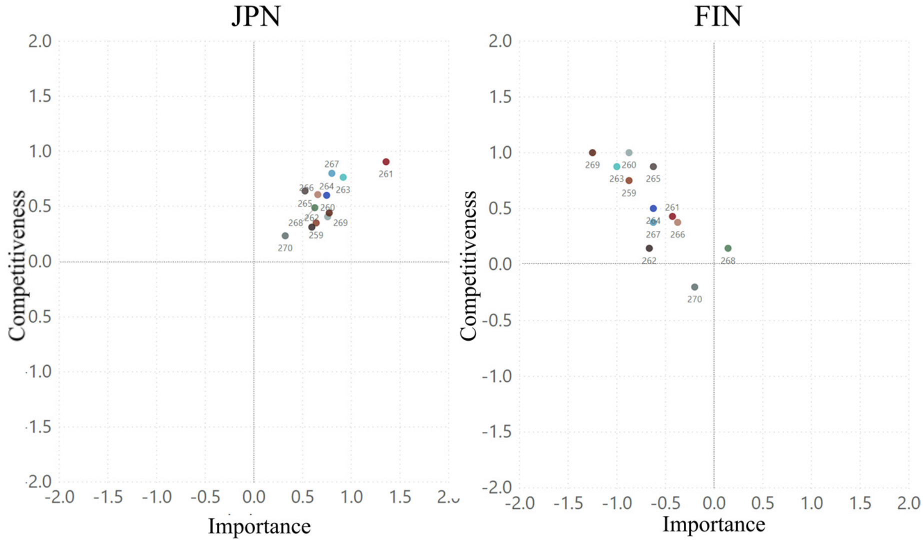

Fig.20: Comparison of indexes

Key findings

- The topic with the greatest perceived importance in Finland was “Integrated water quality indicator that can evaluate the quality of water environment in place of BOD, COD, T-N, etc.”.
- The topic with the greatest perceived importance in Japan was “Integrated water management technology in densely populated areas, including management of urban flooding, storm surge and land subsidence due to linear rain bands and torrential rain”.

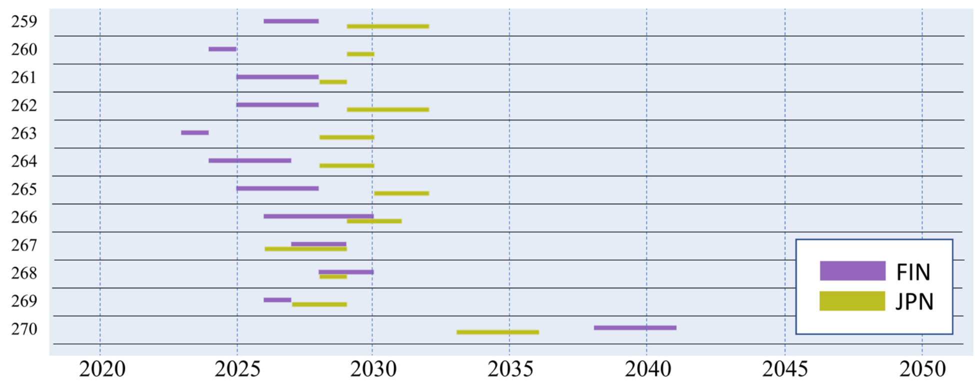

Fig.21: Comparison of forecasts for years of realization

Key findings

- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was "Technology to continuously monitor harmful trace chemicals, pathogenic micro-organisms, etc., in the water supply".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2023	2024
Japan	2028	2030

In Japan, it was anticipated that social realization would generally happen by around 2030. Looking ahead to 2050, there is some concern about the threats presented by climate change to the water environment. Since water resources can be critical to national security, there will be growing social demands on securing water resources and expanding business areas related to water. On the other hand, the UN Sustainable Development Goals (SDGs) also include the achievement of "universal and equitable access to safe and affordable drinking water for all" by 2030. The specific targets include securing access to drinking water, access to appropriate and equal sewage and sanitation facilities, and a significant improvement in water use efficiency.

Discussion and qualitative commentary

Finland has high levels of competence and advanced water purification technologies and systems in place. Municipal water systems are also highly advanced. However, the high level of national competence has not been conducive to building internationally competitive businesses in Finland. Digital monitoring of urban water supply systems is also highly advanced in Finland. The country has abundant pure groundwater reserves.

Overall, it was expected that Finland would reach realization in this sub-theme earlier than Japan. Topics related to water purification were expected to be realized relatively early in Japan. This is consistent with the result concerning "Land use and conservation".

Water technologies are in part addressed under the Land use and conversation theme. Most technologies related to water are concerned with improving water quality nationally, which is not an issue in Finland. Topics 267 and 269 can be important export prospects and therefore particularly relevant to Finland.
Water has emerged as a critical resource both as an energy and food source. There are concerns that climate change will alter the regional balance of resources. This sub-theme covers topics related to the observation and monitoring of water resources, water resource and energy optimization, economically viable water purification technologies and contaminated water treatment technologies, and environmental impact assessments of the hydrosphere. It is expected that advances in science and technology will help to prevent the expansion of regions exposed to water stress.

In Japan, topic "Integrated water management technology in densely populated areas" received high scores both for its importance and international competitiveness. Technologies for continuously monitoring harmful trace chemicals in the water supply are particularly highly rated with respect to international competitiveness.

C. GLOBAL WARMING

Table 11: Topic list in the sub-theme in Global warming

ID	TOPIC
271	Aircraft that do not use fossil fuel
272	Elucidation of the effect of seawater acidification on biodiversity, especially the impact on fishery resources
273	Technology to predict the impact of climate change on food production for each region and each item
274	System to evaluate national CO2 emissions based on observational data such as CO2 concentrations and distributions
275	Improved accuracy of climate sensitivity estimates (mean increase in global surface temperature once sufficient time has elapsed after the doubling of CO2 concentrations in the Earth's atmosphere) from 3°C to 1°C.
276	Improved accuracy of critical temperature estimates (tipping point) for the melting of the Greenland ice sheet, to 1°C or less
277	Long-term global environmental change forecasts (over 100 years) based on high-resolution atmospheric circulation models, ocean general circulation models and global environment prediction models considering material and energy circulation associated with social activities through data assimilation

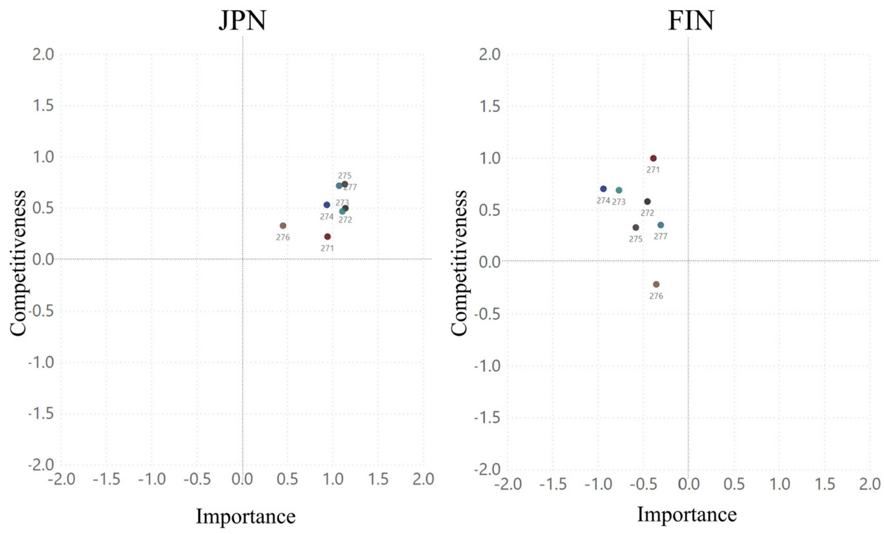

Fig.22: Comparison of indexes

Key findings

- The topic with the greatest perceived importance in Finland was “Long-term global environmental change forecasts (over 100 years) based on high-resolution atmospheric circulation models, ocean general circulation models and global environment prediction models considering material and energy circulation associated with social activities through data assimilation”.
- The topic with the greatest perceived importance in Japan was ”Elucidation of the effect of seawater acidification on biodiversity, especially the impact on fishery resources”.

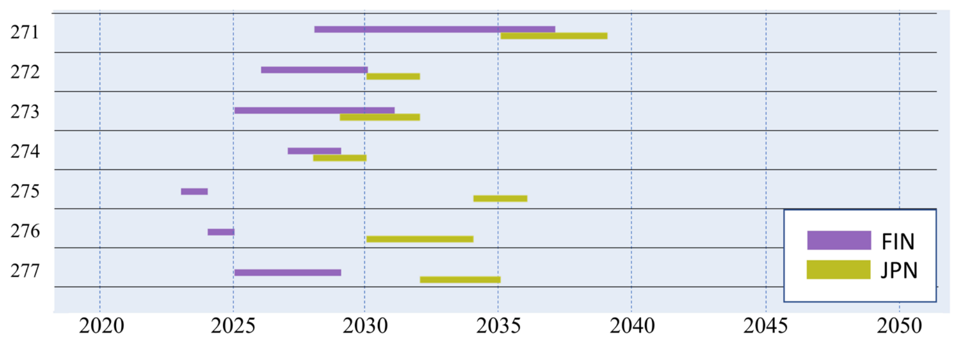

Fig.23: Comparison of forecasts for years of realization

Key findings

- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was “Improved accuracy of climate sensitivity estimates (mean increase in global surface temperature once sufficient time has elapsed after the doubling of CO2 concentrations in the Earth’s atmosphere) from 3°C to 1°C.”.

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2023	2024
Japan	2034	2036

The Japanese respondents thought that the technologies will mature and become available for use in society later than in Finland across the board. One possible explanation is that respondents in Japan might feel that we do now yet know enough about these fields, as explained earlier.

Discussion and qualitative commentary

There is strong policy support for the creation of a carbon neutral Finland. Industrial export solutions aimed at solving global climate challenges are also prominent. The Finnish government is committed to the goal of carbon neutrality by 2035.

In Japan, all topics were expected to be realized later than in Finland. Expectations of realization differ most particularly in topics related to simulation.

Most of the technologies under this topic heading are related to measurements and knowledge creation, which is interesting. One possible interpretation is that the Japanese scientific community feels that we do not yet have sufficient or sound enough information about the progress of global warming. From the Finnish point of view a more natural focus might be on solutions-driven technologies. For instance, Finland is highly competitive in the field of fossil-free aircraft fuels, with Neste corporation recognized as a global leader. Technical requirements in the aviation field are of course very rigorous, and it is very hard to develop technologies that can effectively curb climate change.

Both countries have high levels of competence in these technologies, which is natural in view of the strong technical and scientific expertise that both countries possess.

In the area of R&D around foresight and impact assessments of global warming, simulation technologies are subject to a large-scale international comparisons according to the cycle of the IPCC a ssessment report. The volume of data generated in recent years has grown exponentially as a result of increasing model resolution and experimentation, and it is now becoming difficult to distribute and process these data. It is essential for Japan to invest in developing its data infrastructure along with supercomputers if it is to continue to contribute to this field. At the same time, the promotion of open data infrastructure and the international sharing of observation data is also expected to accelerate R&D.

2.4 Theme: ICT, analytics and services

A. NETWORK INFRASTRUCTURE

Table 12: Topic list in the sub-theme

ID	TOPIC
337	Wired and wireless mobile communication technology that simultaneously facilitates large capacity, ultra-reliable, ultra-low latency and super-multi-terminal communication
338	Communication network/ communication node technology that dramatically reduces power consumption per amount of data transferred
339	Data plane technology that achieves increased communication capacity in the cloud data center and allows for the potential for evolution of the architecture
340	Mobile communication technology that facilitates high-capacity communication with high-density multiplexing, can predict and follow the movement of the terminal, selectively perform large-capacity communication, and enables terminal-to-terminal communication
341	Optimally available communication infrastructure technology that links Cloud and Edge terminals, and organically combines dispersed computing resources, storage resources and communication resources
342	An information-oriented and content-oriented network that designates information and functions by name and carries out information processing within the network
343	Flexible information communication technology that contributes to mitigating network congestion and improving fault tolerance in normal times, enables preferential servicing of emergency communication in case of disaster, or that can be constructed rapidly from scratch
344	Optical communication technology capable of accommodating innovatively large capacity and high-density communication, such as multi-core fiber and silicon photonics
345	Innovatively secure quantum communication using quantum cryptography
346	Network device configuration technology converted to software, combining performance, flexibility and robustness
347	Slicing technology to accommodate non-interference applications and services, end-to-end

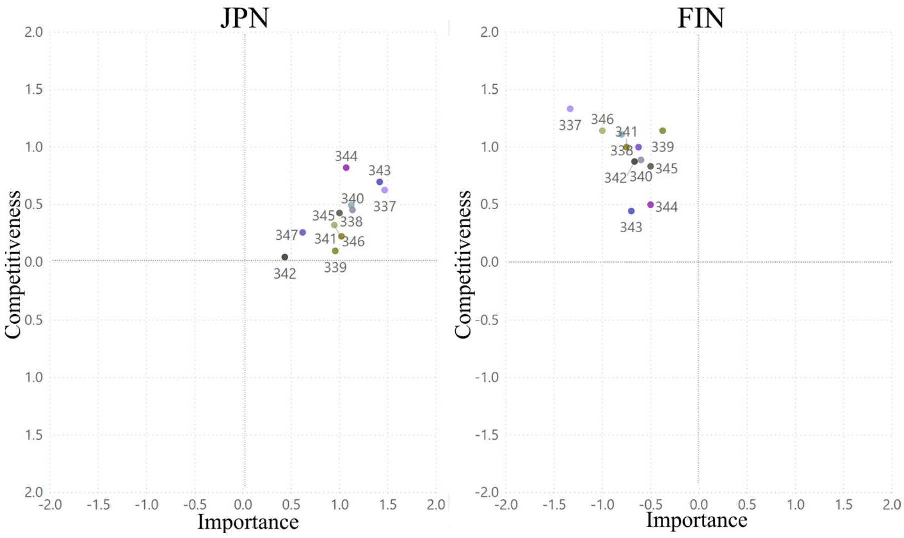

Fig.24: Comparison of indexes

Key findings

- The topic with the greatest perceived importance in Finland was "Data plane technology that achieves increased communication capacity in the cloud data centre and allows for the potential for evolution of the architecture". The topic with the greatest perceived importance in Japan was "Wired and wireless mobile communication technology that simultaneously facilitates large capacity, ultra--reliable, ultra-low latency and super-multi-terminal communication".

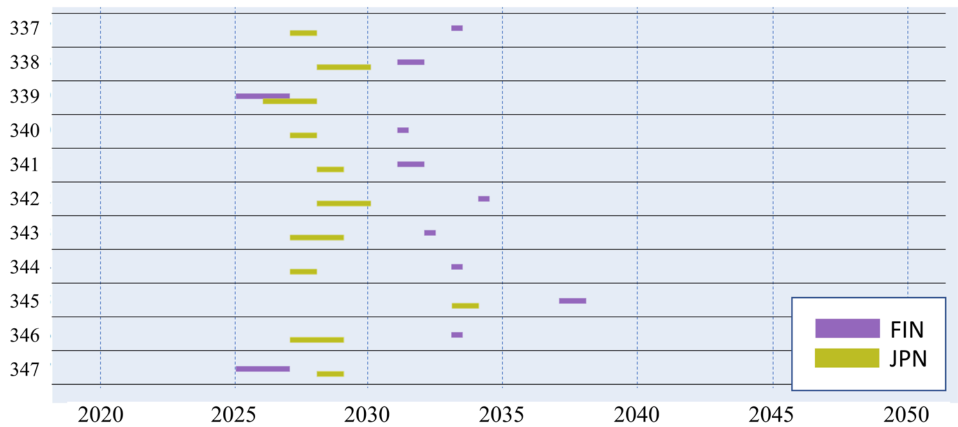

Fig.25: Comparison of forecasts for years of realization

The same chain of thought as was applied in the previous chapter can also explain this chart, which shows that Finnish respondents expect most of the technologies to become available in the 2030s, even though the technological features concerned are already available today. The next technological generation is thus still a long way away, but implementation of these technologies in society should be a smooth process, given all the experience that Finnish people have with the previous generations of technology. The interconnectedness of certain technologies may also have a bearing on the realization of other technologies. For example, the projections of late realization of topic 338 can be explained based on the strength of topic 337.

In Japan, it is expected that no topic will be realized relatively early. On the other hand, "Innovatively secure quantum communication using quantum cryptography" is perceived as highly important, but its technological realization is expected to come in 2033, later than other topics, and a long-term strategy is required.

Key findings

- Many topics are expected to be realized earlier in Japan.
- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was "Slicing technology to accommodate non-interference applications and services, end-to-end".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2025	2027
Japan	2028	2029

- The topic where Japan was expected to be furthest ahead of Finland in terms of realization was "Wired and wireless mobile communication technology that simultaneously facilitates large capacity, ultra-reliable, ultra-low latency and super-multi-terminal communication".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2033	2033
Japan	2027	2028

Another topic where Japan is expected to be ahead "Optical communication technology capable of accommodating innovatively large capacity and high-density communication, such as multi-core fiber and silicon photonics".

Discussion and qualitative commentary

Overall, the topics under this theme were expected to be realized relatively early in Japan. One possible explanation lies in the large number of major telecommunications companies in Japan.

In general, Finland has a high level of network infrastructure knowledge, which is also reflected in the dimension of competitiveness. Finland stands in a good position to utilize affordable 4G and 5G technologies, and competencies in this fields are considered to be very high. It is also worth making separate mention of data place technologies, where Finland can be considered an international forerunner. Cloud technologies are also widely used in business and government settings.

At first sight the respondents' view that these technologies will not have much importance in the future may seem strange. The explanation lies in changing technology generations. It is possible that respondents in Finland feel that Finnish competitiveness is strong for the present-day technological generation, but that the importance of this technology is bound to decline as we move forward and see the evolution of new technological generations.

Another possible way of interpreting the responses is to suggest that the respondents are not always aware of the link between network infrastructure and the circular economy, which might explain the low importance scores.

According to the results of the Delphi survey in Japan, the importance and international competitiveness ratings in this sub-theme are generally higher than in other ICT fields.

Japan suffers from relatively frequent natural disasters, and therefore not only ensuring high quality communication in normal times but also the communication infrastructure for the eventuality of disasters is an urgent priority.

For example, the importance and international competitiveness scores for "Flexible information communication technology that contributes to mitigating network congestion and improving fault tolerance in normal times, enables preferential servicing of emergency communication in case of disaster, or that can be constructed rapidly from scratch", rank among the top 10 in this field.

In recent years Japan in particular has invested not only in infrastructure development in urban areas, but also in regional information and communication infrastructures. In general, much effort is being devoted to developing technologies that have a major impact on social conditions, frequency allocation, deregulation, and the improvement of legal systems. Another area of focus is international standardization.

B. INDUSTRIAL, BUSINESS AND ECONOMIC APPLICATIONS

Table 13: Topic list in the industrial, business and economic applications

ID	TOPIC
370	The number of customers and the importance of intellectual property has increased, thus when evaluating corporate value, the evaluation ratio of intangible assets reaches on average, 70% of corporate value
371	Handling of intellectual property and the proportion of new products and services based on open innovation accounts for more than 30% of all new business
372	With widespread crowdsourcing and job matching platforms, more than 30% of the working population will work as freelancers rather than hired employees
373	Sharing economy and service conversion will progress in a wide range of fields, including mobility, leisure, dining and clothing, and purchasing will account for 10% or less of consumption expenditure
374	30% or more of the total amount of payments made by ordinary people in daily life will be conducted in virtual currency managed by block chain technology without being controlled by central banks
375	Energy systems utilizing block chain technology, etc., to conduct electric power transfers and transactions between communities and individuals
376	With the spread of AI and the ability to automate most work, about 30% of the working-age population will not be employed
377	Mass customization has become popular in a wide range of areas, including cars, clothing, leisure goods, etc. The mode of individually ordering and purchasing items to match the needs of the individual, rather than purchasing ready-made items, will become mainstream
378	As net-based sales and delivery services increase in popularity, purchases in real stores will account for 10% or less of the total consumption
379	All businesses will be offered on a small number of global platforms and almost all business, including sales, settlement, purchase, marketing, and sales analysis, will be conducted on these platforms

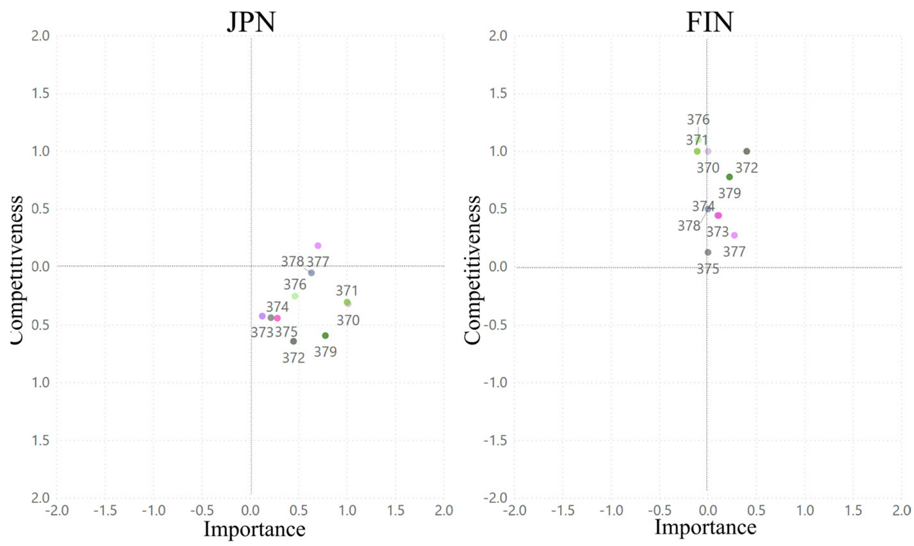

Fig.26: Comparison of indexes

Key findings

- The topic with the greatest perceived importance in Finland was “With wide spread crowdsourcing and job matching platforms, more than 30% of the working population will work as freelancers rather than hired employees”.
- The topic with the greatest perceived importance in Japan was “The number of customers and the importance of intellectual property has increased, and the evaluation ratio of intangible assets averages 70% of corporate value”.

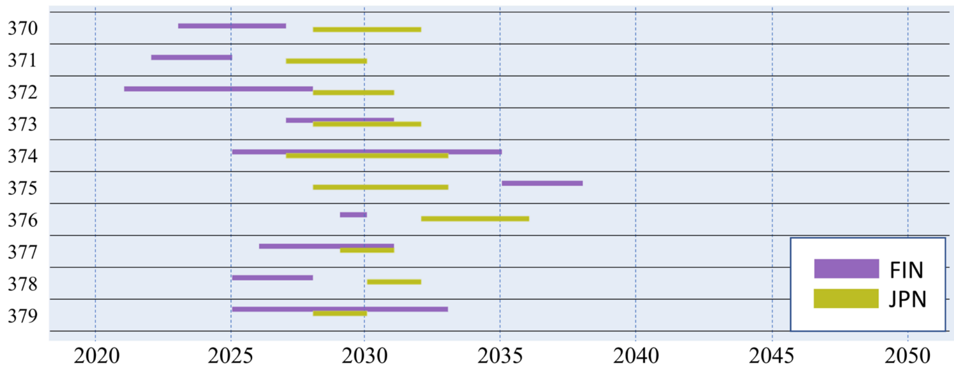

Fig.27: Comparison of forecasts for years of realization

There is a relatively long delay between reaching technological maturity and application in society. In this space it is particularly important to consider legislation and other non-technical aspects if we want speed up the introduction of technical applications in society.

The Japanese results also indicate a delay between the realization of science and technology and social implementation.

Key findings

- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was "Handling of intellectual property and the proportion of new products and services based on open innovation accounts for more than 30% of all new business".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2022	2025
Japan	2027	2030

Discussion and qualitative commentary

Co-creative open innovation between academia, industry and the public sector is a traditional strength in Finland. There is a strong culture of open collaboration culture, which supports business ecosystem development as innovation policy.

It was expected that realization of the topics under this sub-theme would be slower in Japan than in Finland. Only the block chain topic was expected to materialize relatively early, but there was no significant difference compared to Finland.

A number of different factors contribute to Finland's high level of competitiveness in this area. For example, digitalization has advanced very rapidly in Finland, and many companies are already active in the platform economy. There is a long tradition of open innovation and co-creation between academia, industry and the public sector in Finland. Finnish innovation policy also supports business ecosystem development.

Japan and Finland have very similar demographic profiles, an important driver of the early adoption of AI.

In Japan, the respondents took the view that international competitiveness in this sub-them overall was lower than in other sub-themes. In particular, low international competitiveness was notable in platform-based e-commerce and in the use of virtual currencies, supported by using blockchain technologies.

On the other hand, assessments of importance varied from topic to topic. While e-commerce was rated as extremely important, it was thought to have low importance in the practice of sharing economy and the use of virtual currency. One possible reason for this is that there is no clear consensus in Japan as to whether the image of society brought about by science and technology is desired. In Japan, national industrial competitiveness is a widely shared concern, but in the future it will be necessary to engage in a discussion about what kind of society is the desired outcome of technological development.

C. SOCIAL IMPLEMENTATION

Table 14: Topic list in the Social implementation

ID	TOPIC
388	Health maintenance system based on data linkage of information such as health, medical care, nursing care, etc., from birth to the present, using block chain technology (achieving a pre-symptomatic society)
389	Technology such as AI, IoT, and robots that dramatically improves agricultural productivity, and eliminates labor shortages and lack of personnel
390	Achievement of push-type administration, which can minimize application procedures and other work undertaken at government offices, through 100% digitalization of administrative services, and 100% openness of data held by administrative organizations
391	Build the foundation for new service creation by reducing work involved in payment and settlement through cashless procedures, and by promoting accumulation and utilization of consumer purchase history data
392	Transition to a highly productive society with highly free employment configurations, premised on not requiring to go into the office, and having multiple jobs
393	AI/ block chain is introduced into education, establishing a learning style beyond the boundaries of schools, achieving a society with lifelong skill improvement
394	Facilitate transmission of disaster information using digital technology through cooperation with My Number and streamlining procedures for rebuilding an individual's life
395	Enhance an environment that is accepting of foreigners by improving translation technology
396	Various means of transportation, such as automatic travel, drones, etc., to facilitate maintenance of local public transportation networks, and reform the field of logistics, as well as technology to support management and operation of these networks

***Light Blue;** Number of respondents in Finland was **2.**

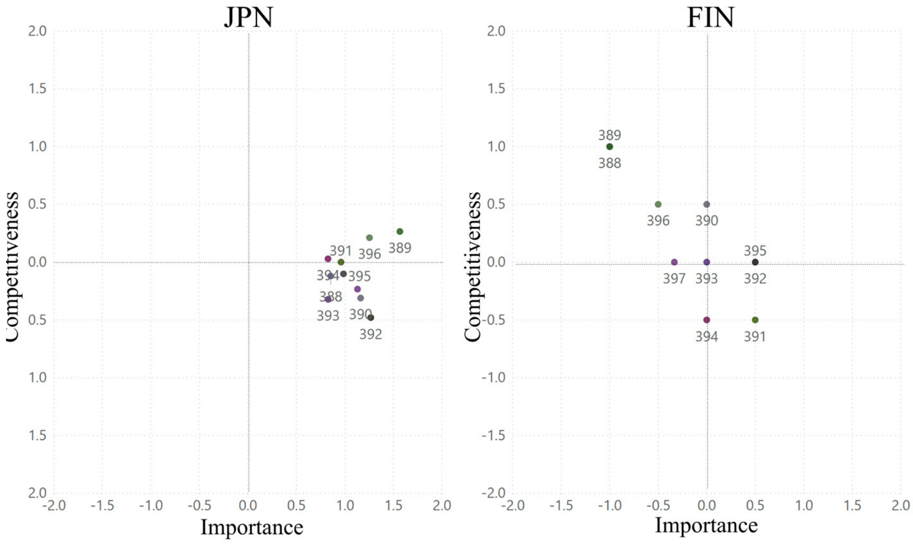

Fig.28: Comparison of indexes

Key findings

- One of the topics with the greatest perceived importance in Finland was "Enhance an environment that is accepting of foreigners by improving translation technology".
- The topic with the greatest perceived importance in Japan was "Technology such as AI, IoT and robots that dramatically improves agricultural productivity and eliminates labour shortages and lack of personnel".

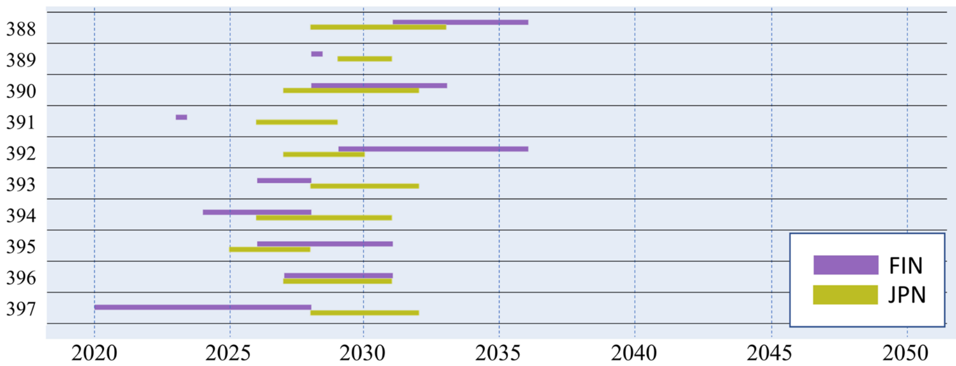

Fig.29: Comparison of forecasts for years of realization

Non-technical factors related to technology utilization also contribute to the delay between technological maturity and societal utilization.

Key findings

- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was "Build the foundation for new service creation by reducing work involved in payment and settlement through cashless procedures, and by promoting the accumulation and utilization of consumer purchase history data".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2023	2023
Japan	2026	2029

Key findings

- The topic where Japan was expected to be furthest ahead of Finland in terms of realization was "Enhance an environment that is accepting of foreigners by improving translation technology".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2026	2031
Japan	2025	2028

Discussion and qualitative commentary

The topics under this theme are so diverse that it is difficult to form a coherent picture of the overall trend in Japan. It is assumed that the reason why the topic of accepting foreigners was realized early lies in the urgency of this issue in Japan.

The Finnish graph is very scattered, making it difficult to offer unambiguous interpretations. For example, Finland has invested in large digital capability projects for decades and is a forerunner in the use of customer data in commerce and in the transformation towards a cashless society. On the other hand, Finland lags behind in the adoption of robotics, automation and digitalization in agriculture.

It can also be argued that Finnish engineering culture has traditionally focused on technology, and it seems it seems that Japan has placed more stress on the social applicability of technologies than in Finland. Shortage of labour will be one of the major challenges in Finnish society over the next 20 years.

In Japan, there was a marked tendency whereby respondents identified high "importance" but low "international competitiveness". This is the biggest issue in the social implementation of science and technology in Japan.

In addition, there tends to be a longer time lag between the prospective period of technological realization and social realization in this than in other fields. One possible explanation lies in regulatory and ethical issues.

However, it should be noted that most Japanese respondents have an academic affiliation. As accelerating the process of social implementation is a key issue for the future, it is important that the voices of industry are also heard.

In the future, effective social implementation will require the development of human resources in all nations and industries and the creation of an environment for open innovation that is based on collaboration between different organizations and across different fields.

2.5 Theme: Material device process

A. APPLIED DEVICES / SYSTEMS (INFRASTRUCTURE / MOBILITY FIELD),

Table 15: Topic list in the sub-theme

ID	TOPIC
482	High-performance hybrid structural materials (structural performance, design, corrosion resistance, etc.) made of iron and nonmetallic materials (wood, concrete, CFRP, etc.)
483	Structural materials with self-repairing functions preventing deterioration and damage over time which can maintain the function of structures such as buildings
484	High-strength steel material for construction, capable of high-heat input welding (780 MPa structural material capable of welding 100 mm thickness at once) for large buildings such as skyscrapers, etc.
485	A high-density hydrogen carrier with a hydrogen storage density of 100 kg/m3 or more and a mass storage density of 10 wt.%, for fuel cell vehicles
486	3D printer material able to manufacture arbitrarily-shaped infrastructure repair parts at low cost
487	Joining and bonding technology for simple structural material, independent of the skills of a person, considering the lack of skilled workers
488	Corrosion-resistant technology (including coating film) capable of achieving an ultra-long life of more than 50 years for structures in oceanic and atmospheric environments
489	Technology to diagnose the state of deterioration inside an infrastructure in real time
490	Mobility system that implements automatic operation of infrastructure such as energy supply (fuel / gas) and garbage collection, which will be necessary due to the labor shortages associated with the declining birthrate and aging population
491	A system that makes the conventionally centralized water supply and sewerage infrastructure autonomous and decentralized, a measure required in depopulated areas where infrastructure cannot be maintained economically
492	A system capable of contactless power supply of 20 kW or more for a passenger car running at 100 km/h, with a structure able to withstand running of a heavily loaded truck

***White;** Number of respondents in Finland was above **2. Light Blue;** Number of respondents in Finland was **2. Dark Blue;** Number of respondents in Finland was **1. Pink;** Number of respondents in Finland was **0.**

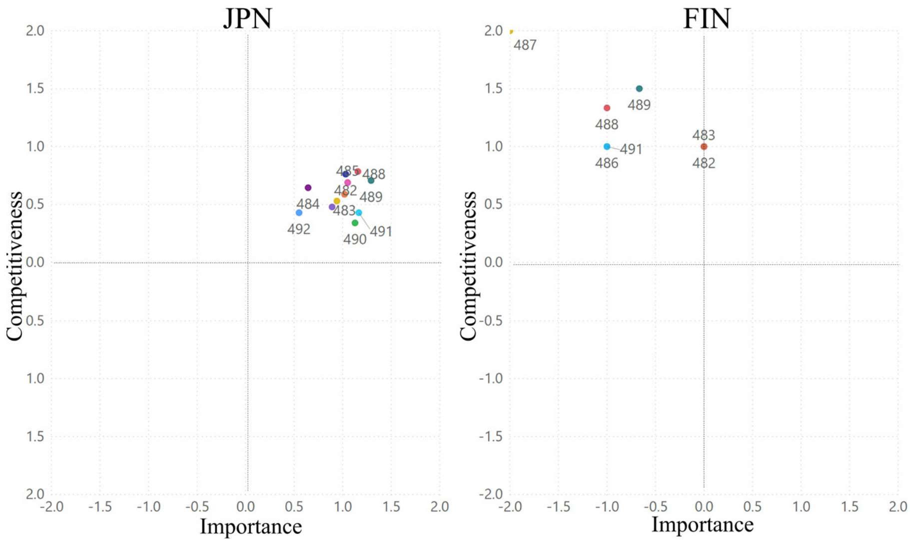

Fig.30: Comparison of indexes

Key findings

- One of the topics with the greatest perceived importance in Finland was "Structural materials with self-repairing functions preventing deterioration and damage over time which can maintain the function of structures such as buildings". But because of the low respondent rate, this result is not comparable.
- The topic with the greatest perceived importance in Japan was "A system that makes the conventionally centralized water supply and sewerage infrastructure autonomous and decentralized, a measure required in depopulated areas where infrastructure cannot be maintained economically".

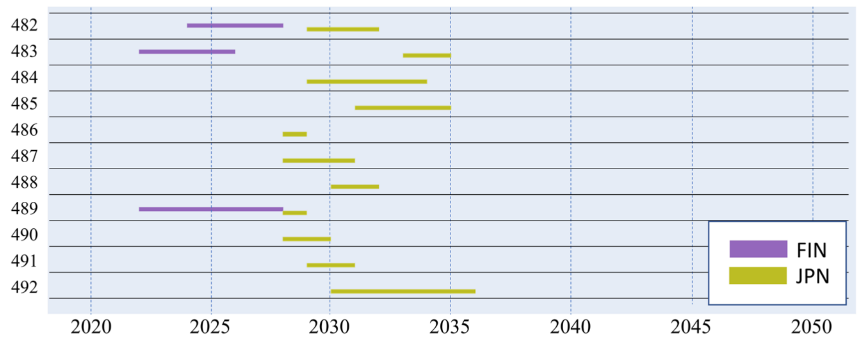

Fig.31: Comparison of forecasts for years of realization

Key findings

- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was "Structural materials with self-repairing functions preventing deterioration and damage over time which can maintain the function of structures such as buildings". But because of the low respondent rate, this result should be validated.

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2022	2026
Japan	2033	2035

Discussion and qualitative commentary

The topics under this theme were generally expected to be realized in Japan around 2030.

Finland has strong knowledge in the field of material development, which is reflected in its high competitiveness. Some of the focus areas in which Finland shows high competitiveness are metal, plastic, wood and biomaterial derivatives. With regard to material development, Finland also has strong research in material coatings. Work in this area will be a major focus in Finland when moving forward.

Japan is ageing more rapidly than other developed countries, and it is expected that Japan will be the first country in the world to create new technologies that will address these issues.

In addition, there is high demand for materials related to the infrastructure field, and technologies that focus on recycling and high durability and technologies supporting the use of renewable energy may be able to respond to population explosion in emerging countries.

If technologies such as automatic driving and automatic diagnosis systems are established, they are expected to spread worldwide, and it is thought that this will lead to the strengthening of core industries in both Japan and Finland.

According to the Japanese results, topics in the field of infrastructure and mobility are generally rated as having high importance and international competitieness. One topic attracting particularly high score concerns a technology that is used to identify internal deterioration of infrastructure structures in real time. This perceived importance, it is thought, is explained by considerations of labour shortages with the development of automatic diagnosis technology and the declining birth rate.

B. APPLIED DEVICE / SYSTEM (LIFE / BIO FIELD)

Table 16: Topic list in the Life / Bio field

ID	TOPIC
493	3D food printing technology for manufacturing (forming) made-to-order food based on artificial foods such as artificial meat
494	Nanoscale chemical analysis system to confirm food safety on the spot
495	Soft material with functions for robots to replicate the soft human touch and movement
496	Biomimetic materials for human senses, to supplement in case of loss, and to enhance senses in order to achieve a superhuman level
497	A wearable device that monitors in vivo information (pharmacokinetics, cancer markers, infection, other blood components)
498	Embedded healthcare device (examination, diagnosis, treatment) that continues operating semi-permanently with bioenergy
499	Biocompatible materials with a surface and structure based on biomimetics, which dramatically improves durability and safety
500	Biomaterial and processing technology for long-term preservation of organs for transplantation
501	System for in vitro culture of biological tissue and biomaterial
502	Production of regenerated tissues and organs using 3D printing technology (biofabrication)
503	Monitoring technology capable of tracking the dynamics of cells and intracellular proteins, amino acids, ions, etc., with a time resolution of microseconds or less
504	Technology for predicting the three-dimensional conformation of proteins from their primary sequence structure
505	Elucidation of novel biological and biochemical phenomena using ultra-high precision measurements with quantum entangled light
506	Technology for practical application of devices and daily commodities composed solely of biodegradable materials (for example, items that can be left in the body and in the environment)
507	Biodegradable materials or materials with biochemical functions that achieve CO_2 fixation and waste recycling processes

***White;** Number of respondents in Finland was above **2. Light Blue;** Number of respondents in Finland was **2.**

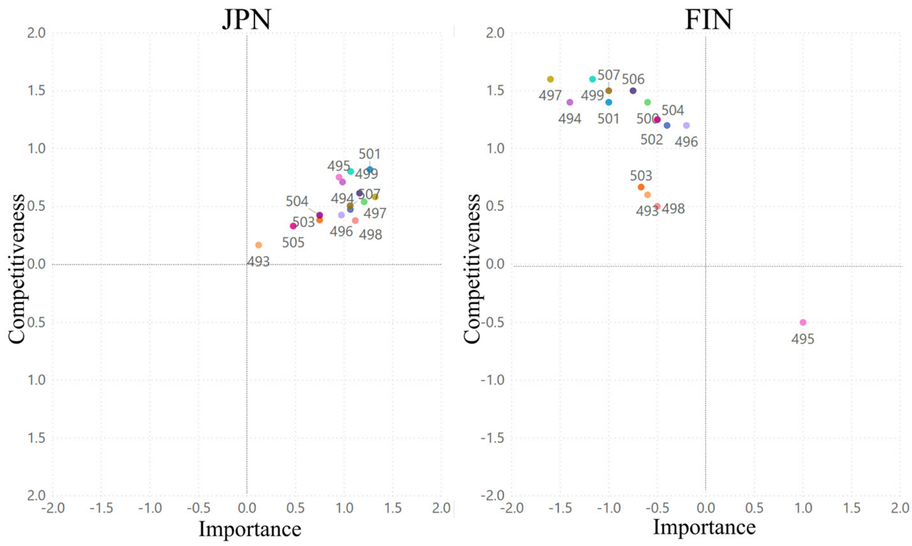

Fig.32: Comparison of indexes

Key findings

- The topic with the greatest perceived importance in Finland was “Soft material with functions for robots to replicate the soft human touch and movement”.
- The topic with the greatest perceived importance in Japan was “A wearable device that monitors in vivo information (pharmacokinetics, cancer markers, infection, other blood components)”.

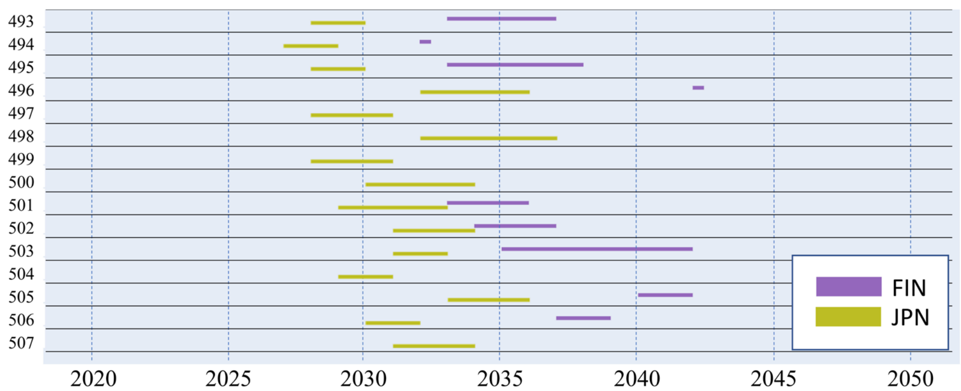

Fig.33: Comparison of forecasts for years of realization

Interestingly, it seems that the Japanese respondents believe all the technologies in this sub-theme will mature and be applied in society earlier than their Finnish counterparts, even though Finnish competitiveness was rated higher.

Quantum technology still seems to lie in the distant future for researchers in the field of life and biotechnology: in Japan it is predicted that the realization of quantum sensors will begin in the 2030s.

Key findings

- The topic where Finland was expected to be furthest ahead of Japan in terms of realization was "Nanoscale chemical analysis system able to confirm food safety on the spot".

	SCIENTIFIC REALIZATION	SOCIAL REALIZATION
Finland	2032	2032
Japan	2027	2029

Discussion and qualitative commentary

The topics under this theme were generally expected to be realized early in Japan. This may be due to Japan's strength in materials science.

The technologies selected for inclusion under this topic in this survey have not been a focal area of research in Finland. Instead, the focus in Finland has largely been on finding solutions to chronic diseases and the associated costs to society. The main tools applied in tackling these challenges have included different data-driven approaches, which are not addressed here. This might explain why the perceived importance of these technologies is lower in Finland. The Finnish respondents feel that competitiveness in Finland is relatively high, which can perhaps be contributed to certain niche areas.

In Japan, much importance is attached to wearable devices that monitor internal body information, implantable health management devices, and technologies for the long-term preservation of living tissues and transplanted organs are. In addition, biocompatibility materials and materials used in vitro are regarded as having high international competitiveness. On the other hand, the results show that international competitiveness is low for technologies dealing with living organisms, including humans.

If technological superiority is established, it is a theme that will attract high visibility in both society and industry, but delays in addressing legal and ethical issues may also lead to delays in research and development and eventually in human resource development.

Due to the emergence in recent years of problems related to the disposal of marine plastics and international waste flows, much importance seems to be attached to technologies for the practical use of devices and the production of daily necessities using biodegradable materials.

3 METHODOLOGICAL REFLECTIONS AND CONCLUSIONS

3.1. Methodological reflections

The Delphi method was originally created to enable anonymous dialogue between experts and on this basis to build consensus on emerging issues. To this end the method is highly effective, as was again demonstrated in the current project. There are, however, some important considerations that must be kept in mind when engaging in a Delphi process:

[1] The relevance of the topics included in the survey should be carefully assessed because Delphi processes can be very resource-consuming.

[2] The Delphi process is usually aimed at consensus, but in a foresight exercise oriented to the future, alternative scenarios may be even more valuable.

[3] Therefore, to address the previous point, Delphi method processes should be combined and complemented with other foresight methods.

3.2 Conclusions on international foresight collaboration

NISTEP´s questionnaire provided an excellent basis for comparing the insights from Japan and Finland. From a Finnish point of view, it would be important to make this a recurring process, provided that it is complemented with other methods. This would create greater exposure for the process in Finland and help to engage larger numbers of respondents. Furthermore, localizing the questions to fit the Finnish environment would be beneficial. Finnish experts would also appreciate the opportunity to influence the choice of technologies assessed in the questionnaire.

In Finland an additional focus was to identify jointly relevant areas of collaboration within the circular economy field. Potentially the method can point to areas that are considered important for building future society, in this case a circular society, and by showing the differences in competitiveness between the countries. The achievement of a circular society is much closer if more advanced technologies and business models can be shared through innovation collaboration and if the results can be put to good use in both countries.

As the Delphi method did not provide sufficient support to this end, the project was extended to include expert group evaluations. In the next stage these areas will need to be processed in more detail with a view to creating a concrete roadmap. By combining dialogue between researcher evaluations (Delphi) and business experience, foresight can move towards more actionable insights.

3.3 Summary and discussion

The joint Delphi survey helped to deepen our understanding of Japanese and Finnish views on emerging technologies related to the circular economy. This is very interesting and valuable in itself. However, the full benefits of this project will only be realized when this information is put to use in the creation of a shared vision and roadmap for the two countries. Such forward-looking activities are necessary in order to capitalize on the emerging opportunities. Japan and Finland currently have an excellent understanding of these emerging opportunities and a great opportunity to move forward together.

Japan and Finland are both highly advanced countries in terms of technological development. They are also facing similar challenges, both on a global level and nationally. However, the two countries’ geographical locations, natural resources and population densities have clearly influenced their national science and technology policies over time, and as a result Japan and Finland have different strengths in terms of technological know-how. These differences are apparent, for example, when comparing the importance and national competitiveness of water and disaster prevention technologies, or the focal areas of medical research.

Mutual challenges shared by both countries are mainly related to environmental issues, but food and other topics are also rapidly gaining in importance, a trend further accelerated by the COVID-19 pandemic. Based on this research, the introduction and implementation of new technologies in society can sometimes be a slow process due to the need to address ethical and legal considerations, which are essential to ensuring the well-being of citizens.

APPENDIX: FUTURE VISIONS AND SCENARIOS.

A-1 NISTEP's future vision

Population ageing and the declining birth rate, infectious diseases and food shortages are some of the trends and developments that are causing growing concern globally. It is no longer possible to work towards creating a better future society within one's own country. Instead it is increasingly important to tackle the challenges of the future through international initiatives.

In January 2018 NISTEP hosted a workshop that attracted the participation of some 100 specialists and experts in the humanities, social sciences and natural sciences, junior and senior researchers from industry, academia and government. The workshop discussions concerned the desirable future of Japanese society. As a result of these discussions, 50 future images of Japanese society in 2040 were proposed, from which four core values (Humanity, Inclusion, Sustainability and Curiosity) were extracted.

Under the first value of Humanity, a society was depicted that values human-like qualities and a wide variety of connections between people, as we coexist with AI and machines such as robots. Under Inclusion, a society was depicted that promotes organic connections that utilize the respective characteristics of a diverse range of humans and machines. Under Sustainability, a sustainable society was depicted that can respond to a wide variety of issues, such as energy limitations, food supply and demand, and the environment on a global scale. Under Curiosity, a society was depicted in which the spirit of adventure and curiosity can be fully manifested.

On 12 January 2018, the Science and Technology Foresight Center hosted a workshop as part of the 11th Foresight Survey, attracting approximately 100 experts from various fields in industry, academia and government. The participants represented a wide range of backgrounds in terms of specialist fields and departments. The experts from universities, research institutions, business companies, academic associations, government and research funding institutions came together to discuss their future visions of society. At this workshop, the aim was to clarify not only how to live happily, securing community, food and energy in a society resilient against disasters, but also to produce a future vision that values human curiosity.

Vision workshop

(1) Participants
The aim of the vision workshop was to project an image of future society in 2040, taking into account the potential of various social changes, developments in science and technology, and the changing relationship between society, science and technology.

The workshop participants were 96 experts from industry, academia and government. They were invited with a view to including a broad array of experts representing different age groups, research funding institutions and policy areas. Academic experts came mainly from the APS, the Japan Society of Mechanical Engineers (JSME), the Society of Instrument and Control Engineers (SICE), and the 183rd Committee on Advanced Science and Engineering of the Japan Society for the Promotion of Science (JSPS). Additionally, with the cooperation of the JSPS youth academy and Science Talks, which involve many young researchers who have contributed to Horizon Scanning and the "open science" policy, a number of young researchers also attended the workshop.

(2) Results of investigating the image of an ideal society

The results of the vision workshop were captured in the "Image of an ideal society" in 2040. A total of 53 social images were produced that were classified into four larger social visions, as shown below:

1. Humanity - changing lifestyles (changing lives of individuals/lifestyles/community)
2. Inclusive - Leave nobody behind
3. Sustainability – Sustainable Japan
4. Curiosity – Undying curiosity

For the first item, "Humanity – changing lifestyles," an image of society was depicted that values living humanely, society and humans, automation, Japaneseness, culture, happiness, and communication. The second item, "Inclusive – Leave nobody behind," depicts an image of society in which progress occurs wherein individual people with different characteristics understand individual characteristics and respective senses of values. In the third item, "Sustainability – Sustainable Japan", an image of society is depicted in which resources, energy, food, recycling, disaster measures and civil activities are valued. Finally, under "Curiosity – Undying curiosity", an image of society is depicted in which, in addition to deep curiosity, priority is given to the expansion of the activity space.

A-2 VTT Scenario

FINLAND

The Delphi results provided a baseline for further assessments of the emerging opportunities in circular economy. As technologies are always embedded in the surrounding societal environment, the project in Finland wanted to create images of future that could explain what kind of technological pathways might be connected to the emerging technologies. This analysis was done in a workshop that attracted the participation of close to 20 Finnish circular economy experts.

As explained earlier in the report, the project in Finland created an index variable that helped to identify the most important topics and technologies from the Finnish point of view. These topics and technologies were also the main focus in the workshop. In addition, the technologies were further categorized in order to build a structure that would allow the positioning of technologies in different future settings.

The aim of the workshop was to build future visions for the year 2030, which would mainly vary based on the speed of technological development and societal support for circular economy. The reasoning behind these two variables was that, based on the Delphi results, it was evident that certain technologies would require societal support, while other technologies would do well even in a more market-oriented setting. In addition, the speed of technological development would be a critical factor in determining whether we will see radically new technologies in 2030 or just more applications that are based on our existing technological capabilities.

The starting point for the workshop is illustrated in the graph below:

strong

Expansion of technologies that already exist or will become available before 2025:

- Food supply and demand prediction system based on an increase in world population; economic development and trends in crop production technology
- Complete circular food value chain throughout the processes of production, distribution, processing and consumption
- Recycling contaminated water treatment technology that could be widely used in developing countries

Transformative technologies that require fast technological development and strong societal support to be realized:

- Technology for extensive maintenance and management of low-use or unused areas caused by population decrease
- Technology to evaluate the economic vitality, social impact and environmental burden of a society using renewable energy such as biomass
- Estimation of global groundwater reserves (fossil water) that can only be used non-continuously for appropriate international management

Speed of technological development — **slow** / **fast**

Incremental increase in the use of technologies that succeed in a market-based environment.

- Highly durable timber that can be used outdoors for a long period of time (around 50 years), with the aim of expanding demand in fields such as civil engineering
- General-purpose ZEB / ZEH (net zero energy buildings/houses) system that can be used in ≥30% of new construction
- Technology to diagnose the state of deterioration inside an infrastructure in real time

Technologies that require fast technological development, but will succeed due to market demand:

- Short-term storage technology to maintain the freshness and quality of fresh foods without freezing
- Automation of on-site assembly by unitization of concrete structures such as bridges
- Technology for adding value to wood byproducts (technology for reusing, refining, separating and extracting lumbar remnants and nonstandard product at logging, and edible waste on processing lines)

weak

Societal support for circular economy

Fig.34: Scenario framework for 2030 with technology examples

Starting from this setting, the workshop participants identified drivers that could have an impact in the future of technologies related to circular economy. This set of drivers was then turned into future visions that the workshop participants considered coherent and justifiable. The final step in the workshop process was to select the most preferred and the most probable future visions.

The workshop participants voted the future vision "expansion" as the most probable and the future vision "transformation" the most desired vision. The differences between these two visions provide a fruitful opportunity to identify the steps that are needed to change our trajectory from the most probable to the most desired vision.

TRANSFORMATION (Preferred future image from the Finnish point of view)

This image of the future is founded on the emergence of broad support for the adoption of novel technologies and the economic transition it creates. This vision is based on the notion that the transition towards resource efficiency and broad circular economy occurs at an exponential rate. Catalyzed by transformative policies, economic growth will find its place in a multi-criteria model of sustainable growth that includes personal well-being and societal and environmental sustainability. The transformative policies are founded on the emergence of novel financial, regulatory and taxation changes that accelerate the development. Policies are reactive to the transformation of popular opinion towards a more sustainable world, to which industry has already reacted.

There are several main drivers towards this scenario. Political drivers include the green deal or energy policy in China. Even though the political environment remains deeply polarized, the debate on strong transitional policies remains another significant driver. In this future image we can expect a strong push towards novel public instruments enabling the transition, including government ownership of key industries. We can also expect a shift away from the taxation of labour towards the taxation of resource use, whether through taxing emissions or through mechanisms to tax even personal choices. Furthermore, under this scenario we can expect to see increasing regulation and legislation aimed at forcing increased resource efficiency, for instance by requiring repairability of products.

Regardless of whether this political drive materializes, it will inevitably feed into industrial activities. In this scenario, industry recognizes that the current technological paradigm is increasingly seen as a risk to the continuity of business. This will push industry to taking the lead in developing and commercializing new technologies enabling a paradigm shift. One example is the transformation of the food industry, which is working intently to search the most sustainable, and at once affordable, protein source. At the same time, new water technologies are emerging that are focused on reducing the impacts of global water scarcity, which is having an ever greater impact on industries and societies. All of this is linked with the ever-increasing importance of resource efficiency and the circularity of everything. This expands from everyday materials and designing urban spaces. This image of the future builds on the notion that these transformations will transition us to the next long wave of growth.

The industrial and political transition is emerging in response to end-user requirements of change. The markets, that is individual consumers, are now expecting to see an ever-increasing level of sustainability from everything that is consumed. Although there are significant global disparities in the relevance of sustainability, market changes are quickly becoming the main catalyst for political changes and forcing changes in industrial activity. We have seen that industry has been even more responsive than the policy domain to the changing expectation of markets.

Alternative scenarios in Finland

EXPANSION

The circular economy is firmly on the political agenda, and the public sector is committed to supporting its development. The public discussion revolves heavily around environmental concerns. The economy in Finland and Europe has gone through successive periods of growth with a few intermittent downturns, which has allowed for investments. Global trade relations are relatively stable, even though there are recurring disagreements between the major regions.

Public sector organizations are actively engaged in piloting circular economy solutions. The circular economy is a cross-sectoral theme in government organizations and public administration. Political setbacks have not halted the drive towards the circular economy, but different government coalitions have continued to advocate it as a priority.

Companies are making diverse use of new technologies and in technological development. Finnish circular economy companies have succeeded internationally, and there is also robust local demand for their solutions. A unified funding system supports upscaling the most promising businesses. Partnerships are critical when seeking international growth. A holistic understanding of sustainability combines environmental, industrial and consumer insights. In financial markets, sustainable investment has become a cornerstone practice.

“The Finnish model” for the circular economy has grown into an export concept, which is already being applied by other countries. Despite the strong positive tendency in circular models and technologies, there are no radical disruptions or transformations because of the strength of the near future market pull. Technological development is mainly incremental, with the exception of some major leaps in food systems.

Consumers are positive about the circular economy, and their behaviour is influenced by new legislation. Young, environmentally aware consumer generations have emerged as a major influential force, and even become a role model for older generations. Private ownership is less important than before. All products include descriptions of carbon and material footprint.

Micro-transactions are helping to control and direct the circular economy. Data analytics and open communications allow for the in-depth analysis and use of material flows. Quantum systems and organic computing are emerging. Other key technological developments include a complete circular food value chain, the mass customization of food production, technologies for food waste utilization, and 3D printing of food.

In recycling and reuse, technology is helping to improve the recovery of rare metals from electronic devices and waste. Waste processing is increasingly automated with the help of AI. Data-driven and energy self-sufficient urban planning is increasingly popular. New technologies are helping to recycle and process polluted water, especially in developing countries.

Possible wild cards in the scenario include the weakening of EU-level legislation, the questioning of democracy, failure in international climate agreements, new directions in urbanization, and immigration waves.

STAGNATION

Weak economic growth has cast its shadow on the 2020s, with several implications for the development of the circular economy. Instead of trying to find new growth through R&D investments in emerging circular technologies, the sector has taken a hit as the overall level of R&D funding has been diminishing and existing funding is not focused on supporting the development of bio and circular technologies. Lack of external funding has also made companies reluctant to focus on internally funded R&D work.

Technology development in Finland has been limited, and it is mainly taking place in collaboration with Finnish organizations, who have failed to introduce a more cross-disciplinary approach in their development work. Due to a lack of international co-operation and communication, overlapping innovations are being developed in different places - instead of building radical, systemic innovations in collaboration.

Finnish technology development has focused on finding new areas of application for existing technologies, with little effort to create novel, innovative technologies. This has made it difficult to export and scale Finnish technologies. There is an evident lack of courage to seek radical innovations.

There is an increasing number of cases where technological capabilities are not fully exploited. Sensor technologies have become widespread, but the lack of analysis of the data available has limited the benefits of sensor technologies. Finland has also built a smart electricity network that enables more efficient use of renewable energy sources, but the benefits have remained limited due to insufficient incentives to move away from fossil-based energy sources. Recycling is also affected by underutilization of technological capabilities - recycling technologies are geared towards plastics and metals recycling, leaving many opportunities untapped. This is partly because consumers do not favour circular materials in products. Consumers also prefer to buy products instead of services. So, even though the platform economy and sharing economy have become more common, they can still not be considered mainstream phenomena.

Due to the challenging economic situation, price is the leading decision factor for various actors: public procurement is largely based on price rather than life cycle assessment, for example. Most consumers also favour quantity over quality in their purchasing practices. Consumer behaviour does not push companies to manufacture durable products with a long life cycle.

Bio and circular economy continue to feature on the political agenda in Europe and Finland, but there is no concrete and measurable action plan for implementing the vision. The European Union has become weaker, and major initiatives in Europe, such as Ecodesign, Green Deal, the Waste Framework Directive and the Circular Economy Action Plan were not implemented in full and therefore did not reach full impact. Instead, political support and taxation have focused solely on protecting those industries and processes that maintain employment within the current ´old´ paradigm. Even small-scale piloting around the circular economy, which could have brought about a transition, has not been possible due to the lack of legislative flexibility.

Awareness goals have not been met, and the convenience of the linear economy means that there has not been strong enough political pressure to advance circular economy goals. In short, the market for circular products has not grown.

AGILITY

The combined effects of climate change, the degradation of biodiversity, conflicts over natural resources, disputes over international trade together with disagreements over energy and emission policies, have created a definite necessity to limit the use of resources and the extraction of new materials, thus creating an avenue to advance pragmatic circular economy solutions. As a result, many companies and businesses aim to be more resource-efficient but also more responsible in terms of sustainability.

However, as the climate and environmental crises have not reached boiling point, the essential incentives for system-level circular economy policies are mostly missing. Society lacks the ”big picture” of the circular economy, and circular solutions are thus seen merely as a factor in the process of improving the resource and cost efficiency of businesses. The development of technological solutions is market-driven as companies respond to the growing demand for tailored bio and circular economy solutions. However, because of the lack of public steering and coordination of the circular economy, system-level solutions are not developed. Furthermore, the piloting and scaling of technologies remain challenging because public funding is sporadic, short-term and fragmented. Therefore, the markets are full of agile technologies geared towards solving one-off problems in the most efficient manner.

One of the main drivers behind this scenario is the low growth of European economies, which undermines the potential of national and European political actions in the field of the circular economy. The EU has no common standards or policies for the circular economy and lacks effective funding mechanisms to advance an ambitious circular economy agenda. Additionally, the diverging policies of China, the United States and the European Union are undermining international institutions and norms, making it harder to scale circular economy agenda internationally. Protectionist policies undermine the development of international and multinational circular economy ecosystems, while national strategies lack the long-term vision and funding for RDI. In the midst of escalating geo-economic competition, the circular economy is not a central issue.

As a result, the development and creation of circular solutions and technologies is left to smaller local and national ecosystems. These ecosystems benefit from the demand-pull created by the fast-developing markets for circular solutions in Asia. These new markets provide export opportunities for companies that have acquired comparative advantage by adapting to the tight national standards for circular technologies. Tailored circular solutions are developed and optimized through new digital data-driven service businesses.

Important technologies include real-time systems for the assessment of agriculture, wood refinery and aquaculture products at the point of production; solutions for the separation, refinement and reuse of residual resources as well as high efficiency and low-cost heating technologies that use biomass. Emerging technologies include data and biometric sensory-based surveillance technology for the orchestration and assessment of construction work as well as unmanned autonomous vehicles capable of independent operation based on sensory data from different sources.

However, in the absence of adequate public RDI funding and common EU standards, the incentives for the creation of high-risk transformative technological leaps are lacking. The breakthrough technologies creating substantial profits and impact fail to materialize. Importantly, fossil fuels still maintain their status because the price competitiveness of circular economy products is not strong enough to replace fossil-based solutions.

The major unknown in this scenario is the relationship between climate policy and circular economy in terms of the actual impact of circular economy on CO2 emissions. A wild card is the possible impact of the pressure created by individuals and groups of consumers and citizens for the advancement of circular economy. Additionally, sudden changes in international politics could transform the scenario in terms of the available scale for circular technologies.

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