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Policy design by "imaginary future generations" with systems thinking : a practice by Kyoto city towards decarbonization in 2050

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ABSTRACT

To achieve the societal goal of becoming a sustainable decarbonized society by 2050, it is essential to design visions and policies that take into account the perspectives of future generations overcoming intergenerational conflicts. In this paper, we present an innovative framework to envision a decarbonized society in 2050 and design policies by introducing "imaginary future generations," together with systems thinking, and analyze the effectiveness of these methods. We organized a series of workshops in which Kyoto City officials participated in the application of the framework. We demonstrate that by applying the framework, the policy measures proposed by the participants shifted from individual measures to proposals of new mechanisms and systems that do not yet exist, even if they present high hurdles for the current generation. Causal loop diagrams based on system thinking proved to be effective for increasing liveliness, reducing divergence, and improving the development of discussion themes. A questionnaire survey revealed that the workshop produced shifts in the participants' perceptions. We conclude that the proposed framework effectively generated "futurability" in the participants and could help facilitate policy design that aims to achieve a decarbonized society by overcoming the short-sightedness of the present society.

1. Introduction

With the growing threat of climate change, realizing a decarbonized society has become a vital challenge, both domestically and internationally. To minimize the impact of climate change, it is necessary to limit global temperature rise since the industrial revolution to 1.5 °C, and to meet this goal, it is vital to achieve net zero emissions of greenhouse gases (GHGs) worldwide by 2050 (IPCC, 2018). This means that countries at the forefront of decarbonization need to reach the stage of carbon neutrality before 2050 (Rockström et al., 2017). Under these circumstances, helped by the declining cost of photovoltaic power (PV) and other forms of

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renewable energy (Cozzi et al., 2020), many countries have recently declared it a goal to realize a net zero CO_2 emissions society by around 2050. Since the potential for renewable energy, including variability, inter-regional connection lines, and available land area, varies from one region to another, the paths to decarbonization also differ by region (Jacobson et al., 2020; Kobashi et al., 2020). This means that to pave the way to decarbonization, stakeholders must reach consensus on how to overcome the specific technical, social, and economic challenges arising from the particular characteristics of each region (Geels et al., 2017; Urrutia-Azcona et al., 2020).

Thus, it is essential for regions and local governments to set their own goals and implement their own measures. However, the visions of a decarbonized city in 2050 for different regions, the roadmaps for getting there, and the methodologies and strategies for social transformation have not yet been clearly defined or shared between stakeholders. Sharing a 2050 vision of society and a roadmap as well as policy measures that take into account local characteristics and sustainability, as well as building a consensus about the vision, are vital.

Essentially, future generations should be important stakeholders in any discussion on planning the society of 2050. However, they are unable to take part in current debates and decision-making in reality. Given the current social system, decision-making that explicitly takes into account the interests of future generations is practically difficult. For this reason, a new approach is needed to describe the images of society in 2050 and to clearly formulate the measures needed to realize it in a way that allows consideration of the perspective of future generations.

Conventionally, engaging stakeholders in policy making has been demonstrated (Pidgeon et al., 2014) and participatory approaches with backcasting and scenario planning have also been vigorously conducted in the field of sustainability science, environmental management and energy policy (Höfer & Madlener, 2020; Pereverza et al., 2019; Kishita et al., 2016; Reed et al., 2013; van der Voorn et al., 2012; Robinson et al., 2011; Mander et al., 2008; Carlsson-Kanyama et al., 2008; Quist & Vergragt, 2006). However, these studies have not explicitly incorporated the preference of future generations (Kuroda et al., 2021; Hara et al., 2019).

The people of future generations who are yet to be born obviously cannot participate in the decision-making of the current generation, and the lack of balance between the interests of current and future generations in decision-making processes can be regarded as a major factor in the failure to resolve many long-term social problems such as climate change. There is, therefore, a need to design social systems that enable sustainable decision-making by overcoming this short-sightedness and taking into account the preferences of future generations. As a response to this recognized problem, Future Design has been proposed for succeeding natural environments and social systems to future generations. A person exhibits "futurability" when he or she experiences an increase in happiness as a result of deciding and acting to forego current gains in order to enrich future generation; Future Design is the design and praxis of a society generating futurability (Saijo, 2018, 2020). One effective approach to activating futurability is to introduce Imaginary Future Generations (IFGs) who are tasked with representing future generations and participating in decision-making from the standpoint of future generations (Kamijo et al., 2017; Hara et al., 2019; Saijo, 2020). The effectiveness of introducing IFGs has been increasingly demonstrated through experiments, field experiments, and in actual practices (Hara et al., 2021; Hara et al., 2023; Hara et al., 2019; Hiromitsu et al., 2021; Kamijo et al., 2017; Kuroda et al., 2021; Nakagawa et al., 2019; Nishimura et al., 2020; Saijo, 2020; Uwasu et al., 2020).

The first such practice, held in 2015 in the town of Yahaba in Iwate Prefecture, Japan, focused on the design of a local development plan with a target year of 2060 (Hara et al., 2019). Town residents were divided into four groups—two groups representing the current generations and two groups representing IFGs. Over a period of 6 months, each of the groups independently studied the policies and measures needed to shape their vision of the future. Then, as the final step, the current generation and IFG groups formed pairs to try to build a consensus between their two perspectives. The study found that the IFG groups were more creative in their vision design and decision-making than the current-generation groups and that their decision-making put greater emphasis on future generations (Hara et al., 2019). Subsequent practice in 2017 in the same town on the theme of public facility management with a target year of 2050 adopted a different mechanism based on Shahrier et al. (2017) and Timilsina et al. (2019), where all the participants shifted their viewpoints from the current generation to future generations, leading to activating their futurability (Hara et al., 2021). The study showed that as participants adopted the perspective of future generations, their proposals shifted from a focus on solving immediate problems and meeting current needs when considering as current generation to ideas based more on consideration and empathy for "others," including future generations, when thinking as IFGs. These various precedents suggested that this new mechanism of applying IFGs had the potential to make the decision-making of an entire group more sustainability-oriented, with greater consideration for future generations. In other words, the mechanism successfully generated futurability.

These studies demonstrate the effectiveness of IFGs for activating futurability, and reconcile intergenerational conflicts by avoiding shortsightedness. However, the method of IFGs has not been applied in the pursuit of the public goal of decarbonization. Carbon neutrality as a theme has specific characteristics in that the goal in terms of carbon emission is specific and the constraint condition is thus clear. Further, while envisioning a decarbonized society entails various factors of societal dimensions and their relationships are very complex, no studies to date have attempted to incorporate systems thinking into the mechanism of IFGs in order to deal with such complex relationships. Systems thinking is an approach that considers the complex behavior of systems as a pattern. By understanding the structure that generates the pattern, the human can develop a deeper knowledge about which points in the system to work on to solve a particular problem or achieve a desirable change (Sterman, 2000). Given these backgrounds, the aim of this study is to propose and apply an innovative framework for designing the images of Kyoto City as a decarbonized society in 2050 and policies towards 2030 that will be necessary to realize the vision. The proposed framework adopts IFGs as an innovative mechanism to incorporate the perspective of future generations, as well as systems analysis to deal with the relationships among the components associated with the images of a decarbonized society in 2050 and the policy measures.

To realize the above-stated aim, we conducted participatory discussions involving Kyoto City officials adopting the method of IFGs. Furthermore, to rationally examine measures and societal visions that satisfy the constraint of decarbonization as IFGs, we applied

causal loop diagrams (CLDs), a tool of systems thinking used to graphically describe the behavior of an entire system, and examined their impact on the discussions of the IFGs in terms of the level of discussion activity. The novelty of this study is in its use of a CLD in the deliberations of IFGs and its analysis of its effectiveness. To our knowledge, such a systems-thinking approach has not previously been applied in Future Design practices. We then analyzed the effectiveness of adopting the proposed framework and treatments based on discussion results and a questionnaire survey administrated to the participants. We also investigated the effectiveness of introducing CLD into the deliberation as IFGs. This study is also pioneering in the sense that the 2050 societal images developed by officials of a "real" city from the perspective of IFGs were utilized in the actual administrative planning of the city.

Shaping a decarbonized society in 2050 is a societal goal that cannot be tackled by merely taking the current society as a given and extrapolating it into the future. It is essential to pursue a process of consensus-building under a new mechanism that supports a form of decision-making incorporating the perspectives of future generations. This study represents a groundbreaking example of policy design involving a new mechanism that uses IFGs in combination with systems thinking.

The remainder of this paper is structured as follows. The Methods section describes the design of the framework for this workshop, the use of a CLD in the discussions, and the administration of questionnaires. The Results section presents the results of Kyoto City 2050 images and the policy proposals through 2030 that the participants, as IFGs, proposed. The policy proposals formulated by the IFGs and those proposed before the workshop from the standpoint of the current generation are compared to clarify the distinctive characteristics of the ideas proposed by the IFGs. The paper then discusses the effectiveness of the adopted framework and the treatments employing IFGs based on the discussion results, as well as the cognitive changes experienced by workshop participants, based on questionnaire responses. It also discusses the effectiveness of adopting CLDs, followed by discussion and conclusion.

2. Methods

2.1. Framework and settings of the deliberative workshop

We carried out a participatory workshop in collaboration with Kyoto City. Since the adoption of the Kyoto Protocol in 1997, Kyoto City has implemented a variety of measures to address climate change, seeing it as one of the city's most vital challenges. In 2004, it instituted Japan's first municipal ordinance specifically targeting global warming. In May 2019, in a pioneering initiative for a Japanese municipality, the mayor of Kyoto City announced that the city would aim to achieve net zero emissions of CO_2 by 2050, based on the IPCC Special Report (IPCC, 2018; Kyoto City, 2020).

A series of workshops for a decarbonized society in 2050 was held as described below, over a total of five sessions: four in 2019, on September 9 (Session 1), October 30 (Session 2), November 22 (Sessions 3), and December 26 (Session 4); and one in 2020, on January 31 (Session 5). A total of 25 Kyoto City officials were selected for participation (18 men, 7 women). The participants were in their 20 s (14 persons), 30 s (9 persons), and 40 s (2 persons). Since the purpose was to discuss to shape a decarbonized society by 2050, we decided to work with relatively young people who might still be working for Kyoto City in 2050. The participants were from a variety of departments and did not necessarily have expertize in climate change; none worked in a department dedicated to global warming.

Each workshop session was held at Kyoto City Hall and lasted for approximately 3 h. All sessions were recorded for the analyses to be conducted later. The 25 participants were divided into five groups. The members of each group remained the same throughout the workshop sessions. In the course of the sessions, they examined policies and measures for shaping a decarbonized society from the viewpoint of future generations. Fig. 1 shows a snapshot of the workshop. As support members, each group appointed one person to

Fig. 1. Snapshot of future design workshop by Kyoto City officials.

serve as a discussion facilitator and another as a graphic recorder to summarize and express the opinions of group members in visual form. Table 1 summarizes the contents of the workshop for the five sessions. Fig. 2 describes the flow of the workshop and the analytical framework. Details of the discussion content and design are shown below. In principle, we applied methods that proved to be effective in activating futurability, such as those proposed by Hara et al. (2021), which applied shifts of perspectives within individuals, and by Nakagawa et al. (2019) for retrospective analysis.

1) Session 1 (Sep 9, 2019)

In the first session, after the participants gathered and introduced themselves, they commenced their discussion by sharing their preliminary work. As preliminary work, the individual participants were asked to reflect on the policies that Kyoto City must examine and possibly implement in the next 10 years (i.e., by 2030) to counter global warming and shape a decarbonized society. In other words, all group members discussed policies for future decarbonization from the perspective of the current generation.

In the latter half of the session, participants conducted a retrospective analysis of the global warming countermeasures taken by Kyoto City in the past. Firstly, a city official presented information about the global warming-related policies that Kyoto City had begun in the 1990 s. Then based on the presented information, along with the socioeconomic, environmental, and policy-related conditions currently prevailing in Kyoto City, participants assessed the past policies and proposed messages to the people responsible for formulating and implementing the past global warming-related policies of Kyoto City. An example of the kind of message they could send was, "Past policies have had an impact on the difficult situation we are facing now." Because having a retrospective perspective by sending requests from the present to a time in the past has previously been proved to be effective in activating the point of view of future generations (Nakagawa et al., 2019), we referred to this approach. Next, participants engaged in a redesign of past policies. More specifically, the participants discussed whether it might have been possible at particular times in the past to consider alternative policies, and considered what different possibilities and developments might have occurred as a result of implementing those alternatives. Following this series of discussions, each group presented a summary of its discussions and received the opinions and feedback of the other groups.

2) Session 2 (Oct 30, 2019)

In Session 2, the participants adopted the perspective of future Kyoto City government employees who live and work in the Kyoto City in 2050 (i.e., IFGs), and engaged in discussions concerning the societal conditions in 2050. To begin, an expert gave a 15-minute lecture on the conditions for decarbonization. Information was provided on key points such as promoting energy-saving, energy electrification, the adoption of renewable energy, and the potential of a combination of PV and EV technologies from the viewpoint of cost and CO_2 emissions reduction (Kobashi et al., 2020). Then, information about Future Design was provided, including actual practices conducted elsewhere (Hara et al., 2019) and the fact that adopting IFGs is an effective means of activating futurability and overcoming shortsightedness (Saijo, 2018).

Following the instructions, to create the perspective of IFGs, the participants were asked to imagine time-traveling about 30 years into the future in a time machine (Hara et al., 2019) and working as Kyoto City officials to provide services and formulate policies as they do as of 2019. We asked them first to freely describe the socioeconomic and environmental conditions of Kyoto City in 2050, assuming decarbonization is achieved, in terms of factors such as lifestyle, work style, transport, and city buildings, from the perspective of the people living in 2050. Note that in Sessions 2–5, the participants were tasked with pursuing all discussions and decision-making from the perspective of the IFGs.

3) Session 3 (Nov 22, 2019)

For the first half of Session 3, the participants continued the discussion started in the previous session (Session 2), maintaining the standpoint of IFGs of 2050. They were asked to scrutinize and re-examine their shared images of society in 2050. Based on

Table 1
Outline of the Kyoto City Future Design workshop.

Session 1 Sep 9, 2019	**(As current generation)**
	• Examine policies from present up to 2030 • Evaluate and redesign past global warming countermeasures and policies
Session 2 Oct 30, 2019	**(As imaginary future generations)**
	• Share the images of Kyoto City in 2050 as a sustainable decarbonized society (e.g., social and economic conditions, lifestyle)
Session 3 Nov 22, 2019	**(As imaginary future generations)**
	• Using a CLD, define the images of society in 2050 and develop detailed proposals • Formulate policies to be implemented from 2020 to 2030
Session 4 Dec 26, 2019	**(As imaginary future generations)**
	• Create a roadmap (chronology) to link 2020 and 2050 • Based on the created roadmap, revise and update the polices necessary for the 10-year period to 2030
Session 5 Jan 31, 2020	**(As imaginary future generations)**
	• Conduct peer reviews of each policy proposal and hold an inter-group discussion • Based on the peer review results, create a final version of the policy proposal for 2020–2030 • Create advice for present-day Kyoto City officials

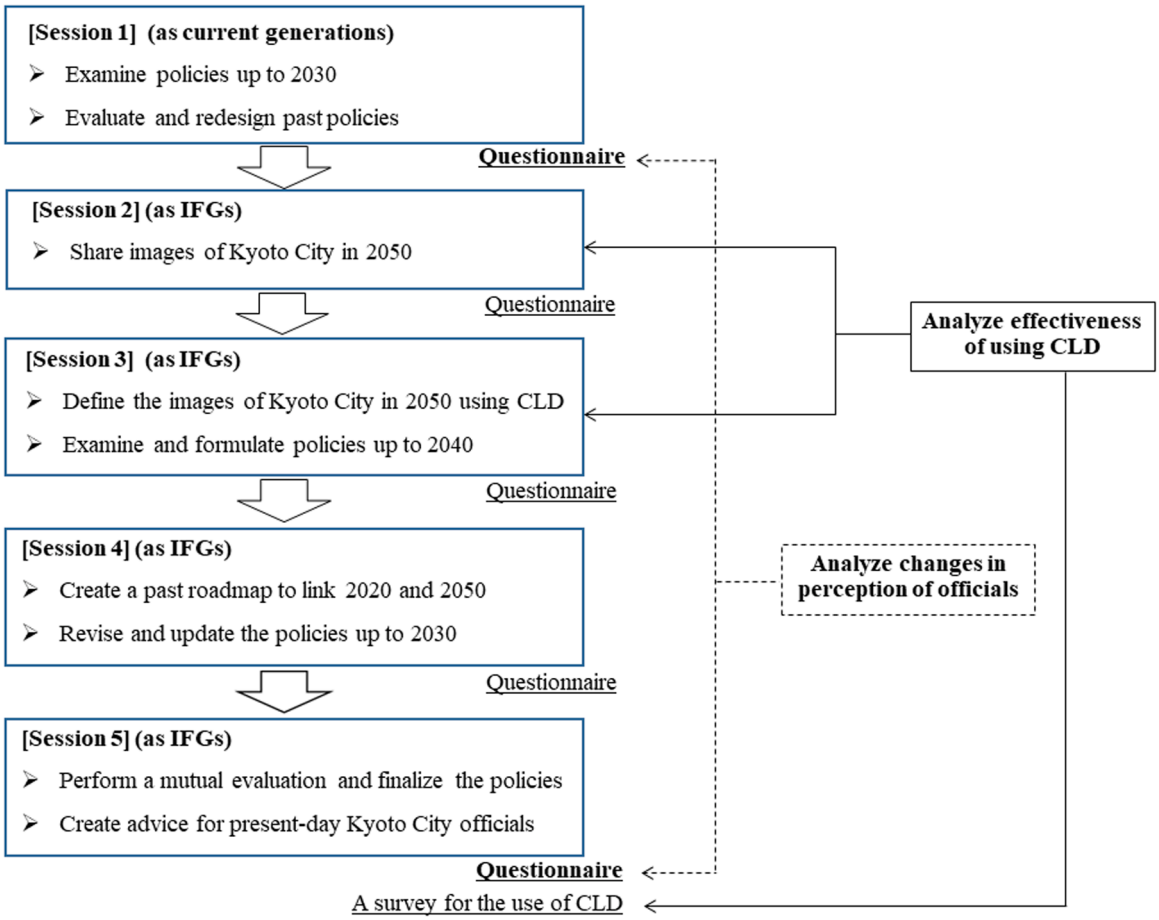

Fig. 2. Flow of the workshop and the analytical framework.

discussion results of the 2050 images of society and policy areas formulated by each group in Session 2, the researchers developed a causal loop diagram (CLD) that graphically illustrates the causal relationships between the various elements that make up the images of society in 2050 and policies (Fig. 3). The details of the CLD are further explained in Section 2.2. With reference to the CLD, the participants of each group further deepened their discussion, from the viewpoints of Kyoto City's identity and sustainability, focusing on the social conditions and necessary policies for a decarbonized society in Kyoto City in 2050. In Session 2 the groups developed images of a decarbonized society in 2050, each with its own distinct features. To explore these features more deeply, the groups examined the images of society in 2050 more concretely, concentrating on a specific feature based on a core interest expressed by each group: "Buildings" (Groups 1 and 2), "Transport" (Group 3), "Land use and green spaces" (Group 4), and "Lifestyle" (Group 5). As a condition for the realization of a decarbonized society, participants were also advised to consider such aspects as energy-saving, energy electrification, spreading renewable energy, and the co-benefits of different measures. They attempted to make the CLD more specific and detailed by adding nodes and links. Finally, each group descriptively defined their images of the decarbonized society of Kyoto City in 2050.

In the second half of the session, the groups were each asked to create advice on policy measures for Kyoto City officials working in 2020, as IFGs living in the decarbonized society of 2050. That is, the groups proposed to the people of 2020 a set of measures to be implemented in the 10-year period from 2020 to 2030 in order to pave the way to the future society of 2050, as the people living in 2050.

4) Session 4 (Dec 26, 2019)

In Session 4, each group designed a pathway or "past" roadmap to connect 2020 as the past to the 2050 present society (to design a chronology working back in time from 2050, from the perspective of an IFG) and revised the advice and proposals for the people of 2020 that they had created in Session 3. More specifically, assuming that the advice and policy proposals for 2020 created in Session 3 are accepted by Kyoto City officials of 2020 and that the relevant policies and measures are actually implemented starting in 2020, each group deepened their discussions of the following points: 1) How were the policies implemented from 2020, what kind of social and environmental changes resulted from their implementation, and what challenges and difficulties were faced in the process of implementation? 2) How did Kyoto City officials overcome the challenges faced in the process of implementing the policies? and 3) What notable differences emerge when comparing the roadmap from 2020 to 2050 with the images of society in

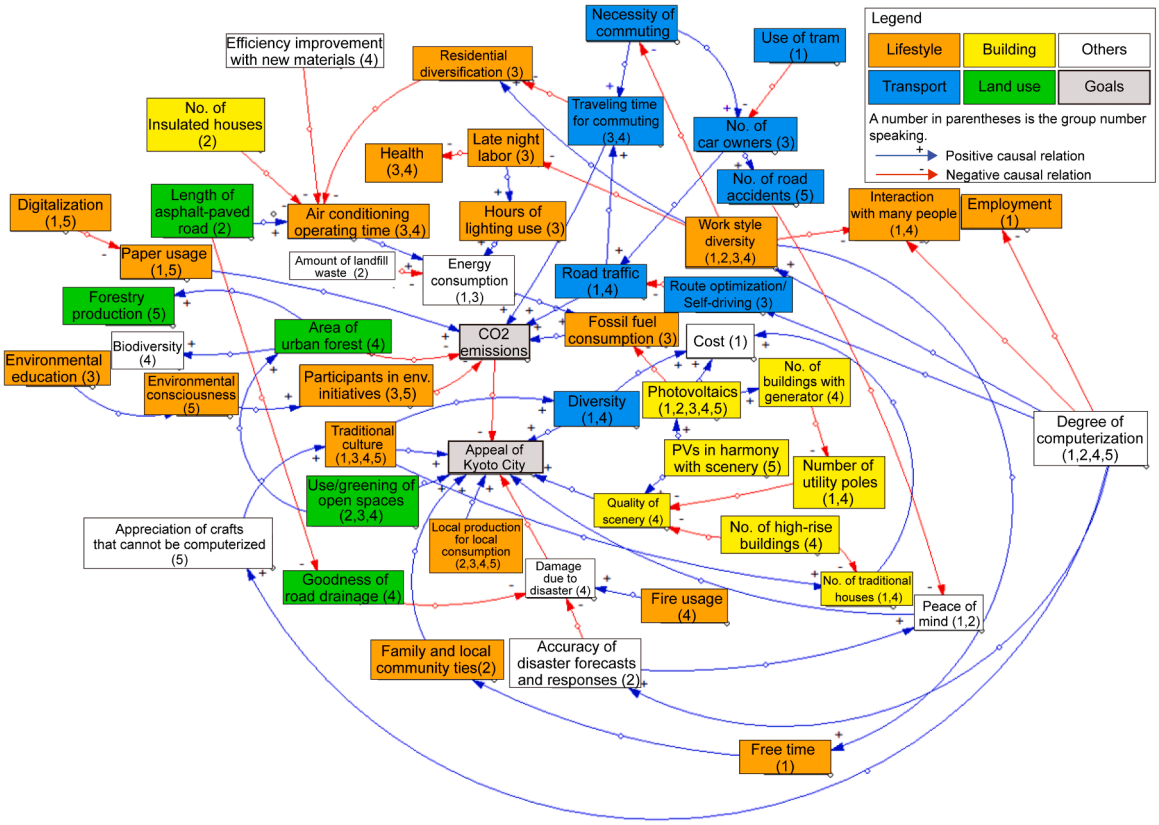

Fig. 3. Causal loop diagram (CLD) used in Session 3.

2050 described by the groups? Through the above discussion, the groups examined improvements to their policies and revised their policy proposals and messages for present-day Kyoto City officials accordingly.

5) Session 5 (Jan 31, 2020)

In Session 5 (Jan 31, 2020), the groups mutually evaluated each other's policy proposals for the decade from 2020 to 2030. Then based on these peer evaluations, each group reviewed and revised its own proposals to produce final, confirmed policy proposals. In the mutual evaluation process, the groups looked over the proposals of each of the other groups, presented on sheets of art paper depicting the proposals graphically, and then engaged in an inter-group discussion of the following points: 1) Are the proposals beneficial for the generation of 2050 or later generations? and 2) Are there any proposals that could have synergetic effects if combined as joint proposals by two or more groups, and are there any improvements that could be made to policies, e.g., by adding new ideas?

With feedback from the other groups, each of the five groups finalized the design of its policy proposal for the decade from 2020 (i.e., advice from the future in 2050).

2.2. Adoption of systems thinking to future design

2.2.1. Causal loop diagrams (CLDs)

CLDs constitute a typical analysis technique for systems thinking, though various techniques have been proposed. In a CLD, to concisely express overall system behavior, parameters relating to system behavior are represented as nodes, and the causal relationships between two nodes are expressed by directional links. These directional links can be either positive or negative. A positive link indicates that the two parameters would change in the same direction, that is, an increase (or decrease) in the starting parameter results in an increase (decrease) in the linked parameter. A negative link indicates that the two parameters would change in opposite directions; that is, an increase (or decrease) in the starting parameter results in a decrease (increase) in the linked parameter. Analysts often begin a system analysis with a CLD.

Although a system model expressed using a CLD is purely qualitative, CLDs are useful for identifying factors involved in system problems and for analyzing principles for solving them. CLDs are also reported to be effective for promoting concrete discussion in workshops on policy design for sustainable societies (Hjorth & Bagheri, 2006; Videira et al., 2014).

On the other hand, since CLDs constitute a systems analysis technique rather than a system design, they have a high level of abstraction. This means that a certain level of experience is required to define and interpret them. Generally, city government

functionaries are not familiar with such tools and terminology, so it is a challenge to utilize them in this context. In addition, Future Design workshops often demonstrate specific characteristics, such as a logical leap to forego current benefits and enrich future generations. Thus, it would not necessarily fit systems thinking in that the use of a CLD might hinder lively discussion by IFGs while it would make discussion more systematic.

To deal with the above drawbacks, our Future Design workshops involved multiple sessions on different days, always with the same participants. At each session, we review the discussions of the previous session. Specifically, in the n-th session, the discussions of each group are recorded by a system modeling expert who is responsible for graphic records. Then, at the end of the n-th session, the system modeling expert creates a CLD based on the discussions of the session. It is the created CLD that is then presented during the review time of the n + 1-th (i.e., the next) session to promote discussion among the participants. Based on this review discussion, the graphic designer updates the CLD. Since system modeling experts are responsible for the creation of the initial CLD, the participants are able to focus on the discussion as IFGs with reference to the prepared CLD.

Fig. 3 shows a CLD created based on discussions in Session 2 of the Future Design workshop. The discussions of the five groups are summarized in a single diagram. We collected essential factors and identified relationships among them from the discussions of the five groups. Some factors were commonly mentioned by several groups, which made it possible to unify the causal relationships identified by the different groups. The two key themes of the discussion, "CO_2 emissions" and "Appeal of Kyoto City," are positioned at the center of the diagram and the links show the connections with the parameters discussed by each of the five groups. For example, "Traveling time for commuting," "Road traffic," and "Fossil fuel consumption" all have positive causal relations with "CO_2 emissions," whereas "Area of urban forest" and "Participation in environmental initiatives" both have negative causal relations with emissions. Also, CO_2 emissions are shown to have a negative causal relation with "Appeal of Kyoto City," i.e., a decrease in CO_2 emissions results in an increase in the appeal of the city. To show all the parameters more easily in Fig. 3, the discussion sub-themes are colored differently: "Lifestyle" in orange, "Transport" in blue, "Buildings" in yellow, "Land use and green spaces" in green, and other sub-themes in white.

2.2.2. *Analysis of the effectiveness of using CLD*

We aimed at a lively and systematic discussion based on the created CLD. We verified the effectiveness of the CLD with (1) an analysis of the changes in discussion activities during the workshop, and (2) a questionnaire survey conducted at the end of the workshop asking participants to give their impressions.

As for the former analysis, we evaluated the discussions using the three criteria. The first is the degree of liveliness; that is the degree to which the discussions proceeded in a lively manner. The next two criteria concern how systematically the participants were able to discuss the workshop topic. They include the degree of divergence (i.e., the degree to which discussions diverged to various topics) and the degree of development (i.e., the degree to which discussions related to the central topic were expanded). We set our hypothesis regarding the effects of the CLD as follows. The degree of liveliness might increase because the participants are able to clearly describe and share their thoughts using the CLD. The degree of divergence might decrease because the participants are able to better understand the causal relationships among topics using the CLD and concretely discuss them, thus avoiding a fragmentation of discussion topics. The degree of development might increase because the participants are able to integrate the various ideas represented in the CLD.

Discussion activities were quantitatively rated according to each of these criteria by applying a text mining analysis method to audio recordings of the workshop participants.

Text mining is the process of discovering information in large text collections, and automatically identifying interesting patterns and relationships in textual data (Feldman & Sanger, 2007). The basic concepts behind the method are word importance and the co-occurrence relationships between words. A word is defined as having a high degree of importance in a particular text if it occurs very frequently in the text but occurs only infrequently in all other text samples. A co-occurrence relation is a relationship in which two words tend to be present in the same text sample. If the words and co-occurrence relations are plotted on a graph as nodes and as links between the nodes, then the graph is referred to as a co-occurrence network. A group of nodes in a co-occurrence network that are connected by links is called a co-occurrence cluster, and the number of such clusters is considered to correspond to the consistency of a topic within a discussion (Fukui & Abe, 2013).

Using text mining techniques, we quantified the three discussion evaluation indices—degree of liveliness, degree of divergence, and degree of development—as follows: The degree of liveliness is measured as the total number of words spoken per unit time (per minute in this study); a higher number of words indicates a higher degree of liveliness. The degree of divergence of the discussion is measured by the number of co-occurrence clusters in the co-occurrence network within a specified time period (10 min in this study). For this evaluation, we created a co-occurrence network with a Jaccard coefficient-based strength threshold value of 50. Finally, the degree of

Table 2
Questionnaire survey about the CLD.

Q1. How did your image of Kyoto City in 2050 change using the CLD ?
Became very concrete / Slightly concrete / No particular change / Slightly abstract / Very abstract
Q2. How did the CLD change the discussion within the group as a person of the future generation?
Very active / Slightly active / No particular change / Slightly stagnant / Slightly stagnant
Q3. Did the CLD make it easier for you to come up with creative ideas as a person of the future generation?
I think so much / I think so a little / I can't say either way / I don't think so much / I don't think so at all
Q4. Did the CLD make it easier for you to discuss thematically as a person of the future generation?
I think so much / I think so a little / I can't say either way / I don't think so much / I don't think so at all

development of the discussions was also measured by analyzing the co-occurrence network over specified periods of time (again, 10 min in this study) to determine the ratio of the total number of words in all the co-occurrence clusters containing the word of highest importance to the total vocabulary (total words). In this case, a higher ratio indicates a higher degree of development. We used User Local AI Text Mining as a text mining tool (https://textmining.userlocal.jp/). We analyzed the data composed of participant remarks in the discussions held in Session 2, without reference to the CLD, and in discussions held in Session 3, with reference to the CLD, in order to assess the effectiveness of using a CLD.

Furthermore, following Session 5, we conducted a simple questionnaire survey of participants regarding the effect of the CLD. The questions and answers are shown in Table 2. Q2 and Q3 are intended to assess liveliness of the discussion. Q1 and Q4 are intended to assess the degree to which participants were able to discuss systematically.

2.3. Questionnaire survey analysis of perception changes

A questionnaire survey was administered to all participants at each workshop session after discussions, with the aim of assessing how their perspective and attitude changed as a result of the adopted framework and treatments. We applied the questionnaire used in Hara et al. (2021) (Appendix A). The previous study demonstrated that thinking from the perspective of future generation led to change in the perception of participants (local citizens). In the present study, we aimed to analyze if the same could occur to the participants who were all city officials and in the different treatment processes applying both IFGs and systems thinking. The questionnaire consisted of (1) a change in their perception of the relationship between current and future generations, (2) a change in their evaluation of Kyoto City as a town, and (3) their perception of the important aspects of policy-making. Regarding items in (1) and (2), responses were scored on a 5-point scale, from "1: Totally disagree" to "5: Very much agree". As for the items (3), responses to the items were scored on a 5-point Likert scale (1: Totally unimportant; 5: Very important).

At the end of each session (from 1 to 5 sessions), participants were asked to fill out a follow-up questionnaire and to select one which they consider the most appropriate out of the choices for each item. We studied the change between the first session (current generations' perspective) and fifth session (future generations' perspective) by employing a t-test analysis to statistically assess the possible changes. We evaluated the average and standard deviation to study the changes.

3. Results

3.1. Final proposals by IFGs

In this section, we present the shared images of Kyoto City as a decarbonized society in 2050 and the policy measures for the decade 2020–2030 proposed by Kyoto City officials after five sessions of workshop discussions from the standpoint of IFGs. We also compare

Table 3
Proposed images of decarbonized Kyoto City in 2050.

Group NO.	Description of images of Kyoto City in 2050
Group 1	In the world we are now living in, small communities have been formed in accordance with living style (in the inner city based on neighborhood associations of *machiya* houses, and in the outer city based on apartment buildings or blocks). Energy sharing and reuse of resources are actively encouraged. By helping both the residents of Kyoto and the people just visiting the city to appreciate the traditional Kyoto-style streetscapes and the "old world" charm to be found in inconvenience, …leading to a more "decarbonized" and sustainable Kyoto.
Group 2	In the world we are now living in, we have achieved energy self-sufficiency. Buildings are increasingly super-insulated and energy is recycled through careful water use and waste heat utilization. Energy sharing in a house or building, and on a community basis is now commonplace, …leading to a more "decarbonized" and sustainable Kyoto.
Group 3	In the world we are now living in, working from home and telecommuting have become mainstream due to technological advances. In a society that has reduced unnecessary transportation, people can better enjoy mobility-related activities through walking, cycling, and other leisure activities. In a society where transport for commuting to work and other activities is no longer necessary, private cars are no longer required. For medium to long distances, people use public transport, and for shorter distances they can use car sharing or ridesharing. All forms of transportation are powered by clean electricity, …leading to a more "decarbonized" and sustainable Kyoto.
Group 4	In the world we are now living in, Kyoto has become a "forest city" by using open spaces created by reducing roadways for planting trees. People grow up amidst a forest and the city has attracted a concentration of highly environmentally-conscious people. Also, living in close contact with the forest and growing food locally has enabled a high degree of local production and local consumption. There is extensive use of timber, and everything around us is made of wood. On top of this, wood is also effectively used for biomass power generation and waste heat utilization, ….leading to a more "decarbonized" and sustainable Kyoto.
Group 5	In the world we are now living in, Kyoto is a city of advanced environmental education. Thanks to this, the environmental consciousness of the citizens is very high, leading to greater participation in environmental initiatives and substantial reduction in CO2 emissions. Additionally, businesses understand and support measures that benefit the environment, and they help to promote participation in such measures by allowing workers diverse and flexible working styles, e.g., working at home. Consequently, citizens have more free time and are more relaxed. This has also led to fewer accidents and crime, making the city safer and more secure. Finally, because people interact more with their families and local communities, Kyoto has become more appealing. …leading to a more "decarbonized" and sustainable Kyoto.

the proposals of IFGs to those originally proposed by the participants from the standpoint of current generation.

It should be noted that the societal images of Kyoto City in 2050 developed by the participants acting as IFGs in our study was partially reflected in the city's new plan, "A Vision of Kyoto City in 2050″ (Appendix B). The workshop results were especially represented in the city's plan in areas of lifestyle changes.

3.1.1. Societal images of Kyoto city in 2050

Table 3 shows the societal images of Kyoto City as a decarbonized society in 2050 developed by the five groups acting as IFGs. The distinctive features of these images were shared among participants, particularly with respect to four aspects: "Buildings," "Transport," "Land use and green spaces," and "Lifestyle."

Firstly, as demonstrated in the proposals of Groups 1 and 2, the images portray a society that incorporates resource and energy recycling and reuse as a matter of course. Group 2 envisions energy self-sufficiency and energy sharing as commonplace within buildings and towns. This is a direct prerequisite for shaping a decarbonized society. On the other hand, several groups mentioned lifestyle changes in line with a return to Kyoto's unique traditional character. For example, Group 1 presented a city image in which people are able to feel the "old-world charm of Kyoto's unique cityscapes and quaint inconveniences," while embracing technological advances; Group 3 presented the concept of mobility for leisure (e.g., strolling, cycling) by reducing unnecessary transport; Group 4 envisioned Kyoto as a forest city, highlighting this aspect of Kyoto's uniqueness, with people growing up close to the forest, and industries and lifestyles based on the principle of "local production for local consumption" and on forestry; Group 5 stressed that maintaining a diversity of work styles, including telecommuting, and increasing interaction with local communities would enhance the appeal of Kyoto City.

From this, we can see that in addition to the use of natural resources and energy, which are essential issues involved in shaping a decarbonized society, the groups emphasized dimensions of Kyoto that relate to the city's sustainability, lifestyle, and values. The adoption of IFGs for examining the present from the standpoint of the future allows deeper discussions and leads to the identification of viewpoints that are vital to Kyoto City at all times, that is, to the identification of key points for sustainability.

3.1.2. Policy measures proposed by IFGs and a comparative analysis

Appendix C shows the policies proposed by the participants when advocating as IFGs. We see that many distinctive and concrete proposals were produced through the five sessions and that these differ significantly, both in quality and quantity, from the policy views expressed by the individuals during the preliminary work (Appendix D).

As shown in Appendix C, one of the proposals of Group 2 (Building Group) was "Kyoto-style energy sharing." Some of the specific ideas offered for achieving this goal were the generation of data to enable comparisons of energy supply/demand balance in different localities, measures to promote more efficient energy consumption, and residential energy sharing organized by elementary school district. As measures to promote a transition from private cars to public transportation, Group 3 (Transportation Group) proposed the introduction of articulated buses and other new forms of public transportation, as well as the imposition of taxes on car owners and land used for parking, to reduce car ownership.

Appendix D summarizes the responses by the participants to the question, "What measures do you think Kyoto City needs to take over the next 10 years to achieve zero CO_2 emissions by 2050?" which was included in the questionnaire survey conducted before the workshops started. This means that the proposals in Appendix D were created from the perspective of the current generation before any treatments were adopted. The proposals are rather sectional and organized into categories of items relating to energy and climate change, education, influencing citizens and creating mechanisms, lifestyle, transport, international exchange, industry, resource recycling, technology, culture, disaster prevention, and cityscapes. The proposed measures consisted mostly of opinions about reducing fossil fuel use, promoting renewable energy, citizen education, improving public transportation, reducing waste, and promoting greenery. These views are similar to individual governmental policies, but undeniably different from the proposals described by the IFGs.

The above comparison reveals one of the salient features of the discussions conducted from the standpoint of IFGs—that they allow the proposal of measures that would be considered somewhat difficult from the perspective of the current generation, as well as new, inexistent systems. From previous studies, we know that the content and ideas of discussions can change dramatically when there is a shift from considering visions or policy proposals from the perspective of the present to considering the same things from the standpoint of IFGs (Hiromitsu et al., 2021; Hara et al., 2021; Hara et al., 2019; Uwasu et al., 2020). In this study, after five workshops in which we employed a mechanism for activating futurability, we observed a substantial evolution in many of the measures initially proposed.

Based on the final proposals and the above comparison, we noted three main features when the participants deliberated as IFGs: (1) a greater tendency to make use of Kyoto's uniqueness and special features; (2) a greater tendency to propose cross-sectional solutions combining new mechanisms, as opposed to individual measures; and (3) a greater tendency to propose new mechanisms or systems that do not yet exist, even if they present imposing hurdles. Regarding the first point, while Sessions 2 and 3 attempted to explore Kyoto's uniqueness and sustainability, we observed that participants tended to identify and prioritize local resources of Kyoto city. This tendency is consistent with past research (Hara et al., 2019). As for the second point, people who assumed the role of IFGs tend to gain an overarching perspective of both current and future generations (Hara et al., 2021; Nakagawa et al., 2017). We argue that such a perspective has to do with the tendency to propose cross-sectional solutions as IFGs. We consider that the third point is related to the activation of futurability (Saijo, 2020): participants representing future generations tended to propose measures that could present hurdles for the current generation so long as the proposed measures would benefit these future generations (Hara et al., 2019; Uwasu et al., 2020.).

Appendix E shows the messages of support sent by Kyoto City employees living in 2050 to the city employees of 2019 at the final stage of the workshop (Session 5). The messages reveal the gratitude that the city employees of 2050 feel for the climate change countermeasures considered by the past Kyoto City employees, as well as the distinctive thinking of the future generations, reflected in their ability to propose policies that face high hurdles and include new mechanisms not yet in place as of 2019 for paving the way to achieving a decarbonized society in 2050. Importantly, these messages also suggest a substantial difference in the participants' perception of policymaking between the proposals they considered before the workshop and those they ultimately decided on after the series of sessions from the perspective of IFGs. This indicates the activation of futurability after the series of sessions.

3.2. Effectiveness of adopted framework and treatments

In this section, we examine the effectiveness of the adopted treatments based on the discussion results (3.2.1) and questionnaire survey (3.2.2).

3.2.1. Analysis of discussion results

As described in Table 1, the workshop featured an assessment and redesign of the past (Session 1), the introduction of IFGs (from Session 2), the introduction of a CLD as systems thinking (Session 3), the creation of past roadmaps (Session 4), and mutual evaluation/peer review between groups (Session 5). With regard to the activation of futurability, we particularly look into the results from Sessions1, 2 and 5, all of which would have a direct impact on the activation of futurability. Session 3 will be discussed in detail in Section 3.3. The following briefly discusses how each of these treatments affected the content of the discussions, and what kinds of discussions resulted from them.

Appendix F shows the content of the discussions held during the session on past analysis and redesign conducted during the second half of Session 1. Firstly, the session on sending messages about past policies for assessing them makes evident the importance of three things: 1) the timing of addressing policy needs, 2) the "mechanisms" for driving policies, and 3) the deployment of ways to guide transformations in human behavior.

In terms of the second and third points, for example, there were discussions of the importance of incentivizing residents to adopt measures by enabling the visualization of individual activities and the effectiveness of measures in connection with cutting CO_2 emissions. There was also a suggestion to introduce goals (targets) and indicators to assess the effectiveness of policies, as an approach to policymaking. Given that the content and intentions of city policies often failed to penetrate effectively to residents, the importance of raising public awareness was reaffirmed.

Another noteworthy argument was that longsighted measures with a focus on leveraging Kyoto's uniqueness, such as cultivating forestry industry leaders, should have been taken. There was also some discussion suggesting that unpredictable major events in the future might bring about dramatic shifts in the essential assumptions of society, as well as on the importance of engaging in planning based on a future outlook, as opposed to just extrapolating the present. Notably, the value of considering things from a long-term perspective arises naturally from insights into past social changes. Interestingly, Groups 1 and 3 both came up with proposals inspired by a reflection that it might have been better for Kyoto to keep its old streetcars than to become so dependent on its subway service. This is evidence that the participants recognized that to combat global warming, it is important to consider not just efficiency but also Kyoto's uniqueness.

After the analysis of the past, in the session on redesigning past policies, a past scenario was proposed in which Kyoto's uniqueness was preserved as part of an approach to countering global warming, with discussions based on the analysis and assessment done in the first half of the session, on maintaining the city's streetcars, and on constructing city government buildings out of wood. New ideas and perspectives, such as utilizing underground spaces as well as aboveground spaces, were also presented in this session. There were proposals on concrete support policies (levying and cutting taxes) to accelerate and promote the adoption of PV and other renewable energies after the Great East Japan earthquake in 2011, on introducing mechanisms for setting targets and verifying policy effectiveness, and on promoting selection and concentration based on outcomes of verifications of policy effectiveness.

The above suggests that the sessions on analyzing and redesigning the past helped participants to acquire a long-term perspective (viewing past generations as a "future citizen") and a recognition of the importance of Kyoto's uniqueness as values that should be preserved throughout the generations, in addition to sustainability. Previous studies show that perspectives acquired by analyzing the past have important value in acquiring the perspective of future generations (Nakagawa et al., 2019), and this was borne out in this session as well.

Most importantly, the ideas and perspectives acquired in the session on assessment and redesign of the past are reflected in the content of the discussions of subsequent workshop sessions in which participants acted as IFGs, and, to some degree, in the final "List of Policies to be Implemented by 2030″ (Appendix C). For example, the above-mentioned point about visualizing the effectiveness of countermeasures is reflected in the visualization of energy use (Group 2). Another example is the above view that constructing city government buildings out of wood should have been considered, which is reflected in the proposal to construct wooden structures (Groups 2 and 4). The view about the importance of human resource development led to proposals to cultivate leaders (Group 3) and to raise public awareness through environmental education (Group 5).

Appendix G shows the various elements of a decarbonized Kyoto City as envisioned by the participants in Session 2 from the standpoint of IFGs in 2050. The images of Kyoto in 2050 developed by the participants in each group acting as IFGs shared many common features. In connection with advances in science and technology to support society, common points included the replacement of human labor by AI-equipped machines, wearable devices to support daily life, advances in communications technology, the use of drones for advanced transportation and traffic technology, and development of 3D display technology. There was also discussion about

how many aspects of people's lives were changed by this technological support. In terms of work, the takeover by AI has led to humans doing much fewer simple tasks, and fully remote work has enabled a free work style unconstrained by work type or work location. This shift has resulted in fewer working hours and more time for personal activities. With more spare time at their disposal, people have taken on side jobs, farm work, hobbies, and the pursuit of health. Additionally, since people no longer need to commute to work, traffic has declined and areas that were once roads are now green belts. The complete transition to telecommuting has increased the value of face-to-face communication, interaction, and experience, since there are fewer opportunities to meet people. Also, the use of recyclable glass and wood products has increased with a decline in the use of plastic.

On the whole, the participants seemed to imagine that Kyoto in 2050 would not only be a sustainable society, but also a city where technological advances have enabled people to live in a more human and leisurely way, with an attractive lifestyle and cityscapes that take full advantage of Kyoto's charm. Previous studies suggest that the concept of IFGs is about more than just solving current social issues; it also aims at enhancing the strengths of local resources, and examining creative ideas based on specific assumptions of future technological changes in society (Hara et al., 2019, Hara et al., 2021; Kuroda et al., 2021). The content of the discussions as IFGs in this study is consistent with the results of these previous studies.

In Session 5, the groups mutually peer reviewed the lists of policies for 2020–2030 proposed by other groups from the perspective of IFGs. As Appendix H shows, the opinions expressed in the peer reviews can be broadly divided into four categories: (1) new proposals, (2) suggestions to address points that require further consideration, (3) comments expressing agreement with a proposal, and (4) questions or calls for fact confirmation with regard to the proposed policies. The Appendix summarizes the review comments from other groups for each group's policy proposal, along with responses about proposed improvements by the reviewed group after receiving the comments. The value of the peer review is not only that proposals supported by other groups are organized as individual proposals, but also that they become more concrete and detailed as a result of the comments and feedback received.

3.2.2. Perception change: questionnaire survey

Here, we analyze how the viewpoints and perceptions of participants changed over the course of the workshop, based on the results of a questionnaire survey conducted after Sessions 1 and 5. The total numbers of respondents were 21 and 17 for Sessions 1 and 5, respectively. Since there were some respondents who did not answer both questionnaires, we conducted an unpaired t-test (Appendix I). Although the number of respondents is limited, the results showed that for the following five questionnaire items, there was a statistically significant change in the mean score between Session 1 and Session 5.

- Q1-7 What was concluded in this discussion is something that future generations would also hope for.
- Q1-13 The members of my group shared goals that seemed desirable for society as a whole.
- Q1-15 In today's discussion, I thought about things from the perspective of a person living in the present day.
- Q1-16 In today's discussion, I thought about things from the perspective of a future generation.
- Q2-6 Kyoto City will be a comfortable place to live in 2050.

For questionnaire items Q1–7, Q1–13, Q1–16 and Q2–6, the mean score increased between Session 1 and Session 5 to a statistically significant degree, whereas for item Q1–15, the mean score decreased between Session 1 and Session 5. The change in scores for items Q1–15 and Q 1–16 clearly indicates that the treatment of IFGs was effective and resulted in a shift in the participants' perspective.

For the 15 individuals who responded to both questionnaires (after Sessions 1 and 5), we analyzed whether there was any change in their response to each question between the two questionnaires. We found that for each of items Q1–13, Q1–15, and Q1–16, around half of the respondents changed their responses between Sessions 1 and 5. In addition, although the t-test did not reveal a statistically significant difference, for questionnaire items Q1–2 and Q2–7, 47 % and 53 % of the respondents, respectively, expressed a higher level of agreement after Session 5. In other words, it seems that around half of the participants felt a stronger concern for future generations by the end of the workshop.

- Q1-2 Failure to implement the policies talked about in the discussion will lead to a serious crisis.
- Q2-7 Feeling a sense of one's own individual importance will also be important for people in the Year 2050.

The responses to item Q1–2, which is about a sense of crisis about the future, item Q1–13, about the common goal of realizing a carbon-neutral society, and item Q2–7, about weighing current and future issues, suggest that participants developed a stronger willingness to consider important future issues as their own. It seems that fostering awareness in this way supports the fact that policies that may require mechanisms not yet available and face high hurdles were proposed, as suggested by the messages from the IFGs to past generations described in Appendix E.

Furthermore, the responses to item Q1–7 indicate an awareness of the closer relationship between current and future generations, implying that futurability has been generated.

The responses to item Q2–6 suggest that after thinking about issues from the standpoint of IFGs during the five workshop sessions, the participants felt more hopeful about the future of Kyoto City. This effect is consistent with the findings of Hara et al. (2021).

The responses to items Q1–16 and Q1–15 suggest that the participants themselves recognized that they had acquired the perspective of future generations in the course of the workshop. This is an indication that Future Design treatments turned out to be effective for instilling the perspective of future generations.

All of the above results imply that over the course of the five treatments, the adoption of IFGs and other methodologies changed the perception of participants, suggesting the generation of futurability in policy design discussions focused on the dual goals of shaping a

decarbonized society and preserving Kyoto's uniqueness. As discussed in Section 3.1.2, the final policy proposals created after Session 5 tended to place greater emphasis on Kyoto's uniqueness and special features compared to the first proposals formulated from the perspective of the current generation. This seems to relate to a development in perception expressed in item Q2–6 above, "I think Kyoto City will be a comfortable place to live in 2050." That is, by discussing issues from the perspective of the future, the participants appear to have realized the importance of leveraging Kyoto's uniqueness, as a result of which they discovered a fresh sense of potential and hope for the future.

3.3. *Effectiveness of using CLD*

This subsection assesses whether the CLD used in the framework activated systems thinking without hindering lively discussion among the IFGs. Using the method described in Section 2.2, we analyzed the data for participants' remarks in discussions held in Session 2 (without CLD), and in discussions held in Session 3 (with CLD). Figs. 4, 5, and 6 show respectively (1) degree of liveliness, (2) degree of divergence, and (3) degree of development of discussions by Groups 1–5 in Session 2 (without CLD) and Session 3 (with CLD) of the workshop. The results of one-tailed t tests of the hypothesis that it cannot be said that the mean values of (1) to (3) for the with-CLD datasets are larger (or smaller in (2)) than the corresponding mean values of (1) to (3) for the without-CLD datasets showed that the hypotheses must be rejected for all three criteria, at significance levels of 5 % for (1), 5 % for (2), and 1 % for (3). The p-values for the one-tailed test for the degree of liveliness, the degree of divergence, and the degree of development are 0.033, 0.085, and 0.0035, respectively.

These results demonstrate that at these levels of significance, the use of a CLD in the Future Design workshop discussions was effective in improving discussions by (1) increasing the degree of activity, (2) decreasing the degree of divergence, and (3) increasing the degree of development in connection to a central theme.

We also report the results of a simple questionnaire survey of participants regarding the effects of the CLD (Table 2). Responses were collected from 15 participants for Q1 and 13 participants for Q2, Q3, and Q4. The results of the survey are as follows: Regarding Q1, three people (20 %) answered "became very concrete", ten people (67 %) answered "slightly concrete", two people (13 %) answered "no particular change". There was no answer that it became abstract. Regarding Q2, three people (23 %) answered "very active," eight people (62 %) answered "slightly active," and two people (15 %) answered "no particular change." There was no answer that it became stagnant. Regarding Q3, three respondents (23 %) answered "I think so much," nine respondents (68 %) answered "I think so a little," and one respondent (8 %) answered "I can't say either way." There was no negative answer. Regarding Q4, four people (31 %) answered "I think so much," eight people (61 %) answered "I think so a little," and one person (8 %) answered "I can't say either way." There was no negative answer.

From the above results for Q1 and Q3, it was found that use of CLD made the discussions as IFGs more livelily. From the results for Q2 and Q4, it was found that the CLD made it easier for the IFGs to discuss their views more systematically.

4. Discussion

The features of final policy proposals developed through the course of the five workshop sessions turned out to be very different in terms of quality and contents, compared with the policy proposals that were formulated from the perspective of the current generations. As a result of the discussion treatments aimed at generating "futurability" and adoption of systems thinking, the policy proposals shifted from individual content to (1) proposals that take advantage of Kyoto's uniqueness and special features, (2) cross-sectional proposals combining new mechanisms as opposed to discrete measures, and (3) proposals of new mechanisms and

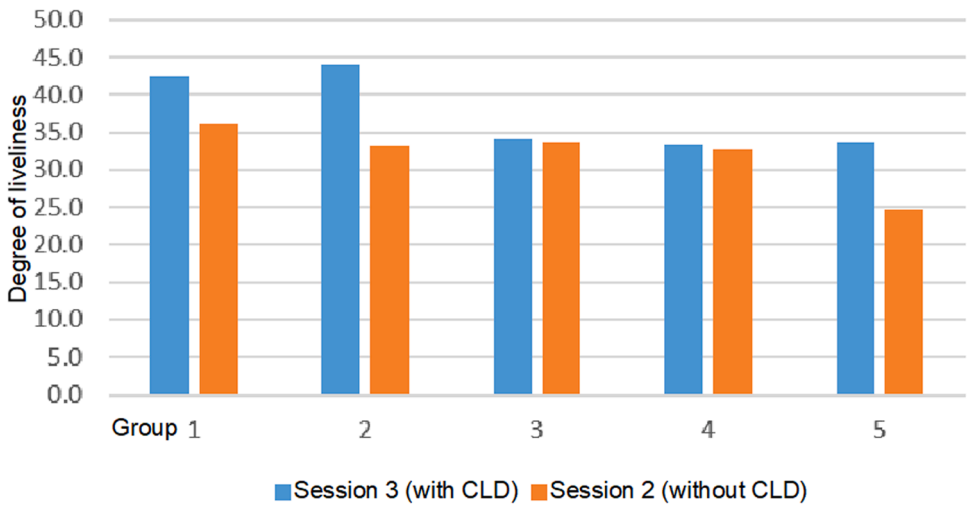

Fig. 4. Comparison of degree of liveliness in discussions for each group.

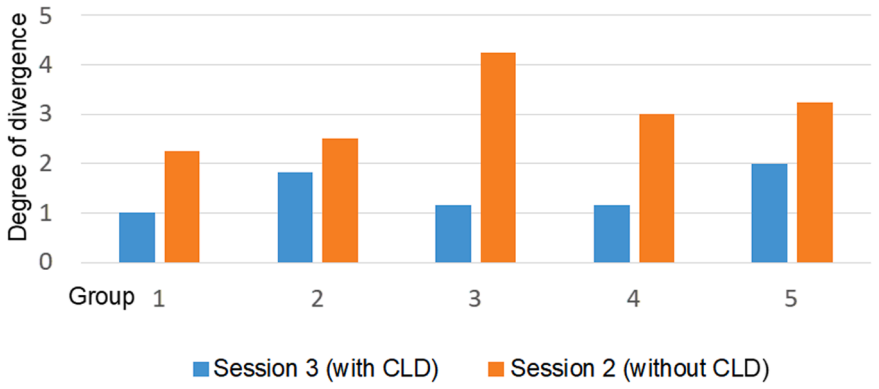

Fig. 5. Comparison of degree of divergence in discussions for each group.

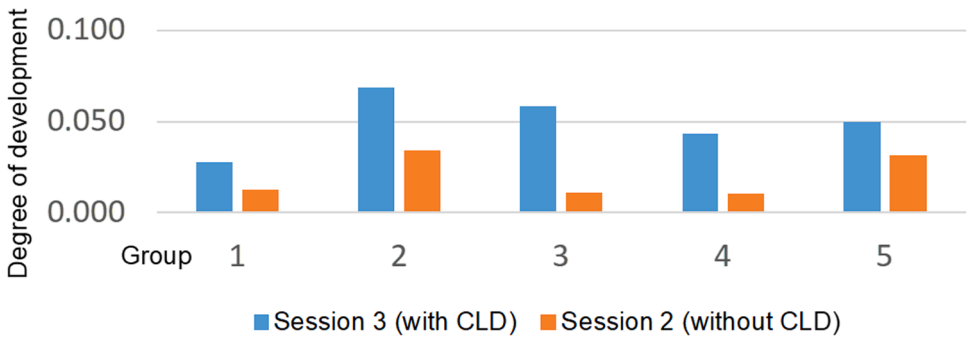

Fig. 6. Comparison of degree of development in discussions for each group.

systems that do not yet exist, even if they present high hurdles. These facts indicate that IFGs do not necessarily take the current conditions and social systems as given. They tend to consider policy measures required to achieve societal goals (i.e., a decarbonized society) from a higher perspective (Nakagawa et al., 2017; Hara et al., 2021). This means that policy measures being addressed by policy makers could possibly be insufficient for realizing a decarbonized society by 2050. If we consider the future state of a decarbonized society from the perspective of our current reality, measures that imply any obligations or difficulties to present generations are very likely to be overlooked, even if they are essential for meeting future goals. It is vital, therefore, to define a clear pathway to and offer incentives for the goal of a decarbonized society. In this study, we proposed a mechanism capable of doing this.

We also analyzed the impact and effectiveness of each treatment on the discussions and decision-making of the participants. Findings from the questionnaire survey demonstrated that discussions from the perspective of IFGs can help people participants to develop a greater awareness of the goal of creating a decarbonized society, greater awareness about the dangers of the future, and a greater sense of hope about the future of Kyoto City. We argue that such shifts demonstrate the activation of futurability (Saijo, 2020, 2018) by applying the proposed framework.

We also verified the effectiveness of employing CLDs for the discussions. We defined the degree of liveliness, the degree of divergence, and the degree of development of discussions as indicators of discussion activity, based on a text mining analysis. By evaluating the transcripts of the participants' discussions in each workshop session, we analyzed the impact of a CLD in a Future Design workshop. Our results showed that CLDs are effective in workshop discussions for increasing liveliness, reducing divergence, and improving the development of important themes. These effects were corroborated by the questionnaire surveys of participants.

It is also indispensable to systematize the flow of workshops so that the framework can be easily applied to policy design at any level with regard to achieving a decarbonized society by 2050. We would argue that our proposed framework, which combines IFGs and systems thinking, can be applied to other complex sustainability issues, such as energy and resource problems. To confirm this, it is vital to examine additional case studies.

5. Conclusion

The realization of a decarbonized society in 2050 is a societal goal that cannot be reached by merely extending current systems and ways of thinking. To steadily achieve social transformation toward this goal, we need to design visions and policies that take into account the perspectives of future generations, as well as incentives to help pave the way to the decarbonized society of 2050.

In this study, we proposed an innovative framework to envision a decarbonized society in 2050 and design policies by using a combination of IFGs and systems thinking. Kyoto City officials participated in a workshop to formulate images of Kyoto City as a

decarbonized society in 2050 and to develop a set of policies for the decade ending in 2030. In the workshop discussions and debate, they adopted the perspective of Kyoto City officials living in 2050, as IFGs, whose effectiveness has been proved in previous studies for generating futurability. We demonstrated the effectiveness of the framework in terms of systematically identifying the images of 2050 society and the policy measures to be taken in the coming decade, and activating the futurability of participants.

Our plans for furthering this line of research are as follows: Firstly, to make Future Design practices aimed at realizing a decarbonized society more practical and effective, we need to link participatory discussions, such as those described in this study, with quantitative models and different kinds of data. This study did not concern itself with quantitative estimates of the degree to which the proposed policies can lead to greenhouse gas reductions; its focus was limited to the impact of IFGs as a new mechanism for policy design. Further along, we plan to link these different approaches to propose more effective methods of promoting a decarbonized society. We also plan to generalize the findings of this study by conducting more case studies on the effectiveness of CLDs and other systems-thinking tools. The CLD used in this study was created by systems engineering experts who did not participate in the workshop discussions, but there is plenty of scope for further study on how to utilize CLDs more effectively. It may even be possible for workshop participants to create their own CLDs during discussions, for example. In this case, a preliminary lecture on how to create a CLD would be necessary. Although we focused in this study on analyzing the impact of using a CLD on the liveliness of discussions, it is quite possible that the use of CLDs affects the content of discussions as well. In future studies, we will examine that possibility.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.futures.2023.103272.

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