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Low-Carbon Lifestyles beyond Decarbonisation: Toward a More Creative Use of the Carbon Footprinting Method

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Abstract: There is a growing recognition of the urgent need to change citizens' lifestyles to realise decarbonised societies. Consumption-based accounting (carbon footprinting) is a helpful indicator for measuring the impacts of peoples' consumption on climate change by capturing both direct and embedded carbon emissions. However, while carbon footprinting can propose impactful behaviour changes to reduce carbon footprints immediately, it may deflect people's attention from the much needed but time-consuming efforts to reshape the "systems of provisions" to enable decarbonised living. To propose a more constructive application of carbon footprinting, the paper examines the three cases of using carbon footprinting derived from the 1.5-degree lifestyles project, including citizens' discussions and experiments in six cities in 2020 and 2021, citizens' workshops contributing to the local policy development in 2022, and lectures and mini-workshops since 2020. Based on the examination of the cases, the article argues the broader purposes of using scientific data in citizens' engagement in climate actions, namely to help deepen understanding of the systemic causes of the incumbent carbon-intensive society, to guide discussions on the desired conditional changes to support lifestyles shifts, and to help identify possible risks or negative consequences of changes to specific groups in society. These benefits contribute to developing relevant stakeholders' essential capacities to promote changes at the individual, collective and public levels toward decarbonised societies.

Keywords: carbon footprinting; systemic changes; citizens' engagement; 1.5-degree lifestyles

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1. Introduction

The 17 chapters of the Intergovernmental Panel on Climate Change (IPCC) Working Group III Sixth Assessment Report titled "Mitigation of Climate Change" [1] provide an updated assessment of the sources of global emissions and the progress of mitigation efforts. In particular, the fifth chapter on "Demand, services and social aspects of mitigation" was the IPCC's first attempt to examine the mitigation potential of changes in consumption. According to the scientific reports cited in the chapter, demand-side mitigation efforts could reduce 40–70% of greenhouse gas (GHG) emissions in end-use sectors, such as food, mobility, and buildings. The chapter also discusses the importance of providing decent living [2] for all. While about half of GHG emissions are associated with the wealthiest 10% of the global population, the discussion on sustainable or decarbonised living tends to focus mostly on the approaches to change the carbon-intensive practices of the rich. However, recent studies revealed that average GHG emissions are higher in societies with severe economic disparities (see, for example [3,4]), indicating that developing equitable systems to provide essential services in less carbon-intensive manners will be the most effective approach to supporting people to take up low-carbon living and thus enabling the demand-side mitigation. To this end, the IPCC report stresses that "(d)emand side mitigation is about more than behavioural change. Reconfiguring how services are provided while simultaneously changing social norms and preferences will help reduce emissions and access. Transformation happens through societal, technological and institutional changes" [1].

Consumption-based accounting (carbon footprinting) is a helpful indicator in measuring the impacts of demand-side activities on climate change. As it enables us to visualise the amount of energy use and carbon emissions transferred or "leaked" by international trade [5–7], it is good at highlighting the sharp difference between developed and developing countries [8–11] and urban and rural areas in the same country [12–14]. Additionally, CFP can also be measured at the scales of organisations or households [15–17]. Therefore, CFP can indicate which regions, sectors or people's behaviours should be targeted to mitigate GHGs most effectively. However, several challenges remain for the practical application of CFPs in supporting demand-side mitigation, particularly in promoting changes in people's behaviour and lifestyles. CFP can be calculated in many scopes, from countries, cities, and organisations, to households, and can cover many sectors and various time frames. The practical use of CFPs requires us to clarify the objectives and steps for action. Moreover, it is necessary to consider the means and purposes of using quantitative data effectively to promote changes in citizens and communities. Methods to encourage consumers to change their behaviour by visualising their environmental impacts have been developed in areas such as energy conservation. Nevertheless, it is also known that simply presenting information does not have long-lasting effects on behaviour change [18–21]. Despite clear links evidenced between citizens' consumption behaviours and climate change, presenting individuals with such evidence was shown not to be the best approach to encourage them to change their consumption behaviour individually [22–25]. The paper proposes a framework for the appropriate application of carbon footprinting, particularly in supporting collaborative actions at city/community levels for demand-side mitigation through systemic changes. To this end, it first examines essential conceptual matters associated with carbon footprinting (consumption-based accounting), cities' potential in climate mitigation, citizens' engagement with climate mitigation, and the use of quantitative data to facilitate citizens' actions. Then, it introduces three approaches to using carbon footprinting in engaging urban citizens previously tested in projects under the 1.5-degree lifestyles initiative. The three approaches to applying carbon footprint data differ in purposes, time frames, and citizen group discussion designs. The use of CFP for promoting the decarbonisation of people's lifestyles and behaviours has only just begun. Above all, there are still limited empirical cases incorporating discussions and practical actions with citizens. This paper aims to clarify the benefits and limitations of using CFP in engaging with citizens to lead behavioural changes and socio-technical system transformation and contribute to the discussions and practices on demand-side mitigation, which is "about more than behaviour changes" [1].

2. Literature Review

The paper aims to contribute to the better utilisation of consumption-based accounting in promoting systemic changes for demand-side mitigation at city/community levels according to differences in purposes, approaches, partners, types of changes, and time frames. Let us examine some conceptual matters associated with consumption-based accounting, cities' and citizens' roles in climate mitigation, and the use of scientific data in facilitating citizens' engagement.

2.1. Consumption-Based Accounting

National climate targets have traditionally focused on CO_2 emissions produced on a country's territory, following a production-based accounting method. While production-based accounting covers direct emissions from domestic production activities within geographical boundaries and offshore activities, it fails to capture the emissions embodied in international trade [5,26,27]. The consumption-based analysis captures direct and embodied emissions along the entire value chain, including imported products. This is critical in addressing the carbon leakage issue associated with production-based accounting [5–7]. For this reason, CPF helps us understand the effects of globalisation and economic growth in each country on GHG emissions over time. Developed countries, including the EU [9]

and Japan [10], and especially the G7 countries [11], have larger CFPs than direct emissions in the region. The transfer of industrial production with high carbon intensity from developed countries to emerging and developing countries accounts for this imbalance. However, consumption-based emissions have also increased in developed countries and emerging economies while their economic growth and the rise of the middle class have led to increased imports [28–31]. A similar structure can be observed domestically. Recent studies identified disparities in consumption-based emissions between urban and rural areas [12–14] and issues of domestic relocation of carbon emissions [20]. While consumption-based accounting reveals the flows and imbalances of GHG emissions along with the domestic and international value chains, some forecast that it may lead to changes in urban design, economic growth, and governance regimes, such as attracting investment in urban design and business activities that can meet demand in a less CFP-intensive way [32]. Several cities have set mitigation targets covering the emissions embodied in urban consumption [33]. In April 2022, the Swedish parliament proposed the world's first reduction target as a nation which covers the emissions reduction targets associated with imported products [34].

Another attribute of CFP is its ability to show the impacts of household and organisational unit consumption on climate change. This measurement tool is vital in tackling the carbon-intensive lifestyles of wealthier people in cities and developed countries relying on importing tremendous volumes of products from developing countries. CFP allows consumers to visualise sources of GHG emissions along the value chain, shows which segments of the population and which behaviours have the largest impacts on climate change, and identifies the most effective alternatives [35,36]. For instance, applying the CFP to different socioeconomic segments of the population confirms the considerable influence of the world's wealthiest on climate change [37]. It also opens up the possibility of examining the composition of households and the reasons for increases and decreases. For example, the relationship between social attitudes held by families and individuals and GHG emissions [38], the background behind increases or decreases in household CFPs when comparing specific countries [39], and the relationship between daily household habits, demographic characteristics and CFPs [40] were studied. The ability to cover the entire value chain and to associate carbon emissions with the final consumption can help stakeholders, such as city governments, urban/community residents and the business sector, to link climate mitigation issues with individuals' day-to-day behaviours. CFP also highlights the influence of a broad range of behaviours beyond the direct consumption of fossil fuels or electricity [5,15,17,36,41,42]. Analysis has been developed for specific sector behaviours, for example, food [43–48] and mobility and travel [49]. Furthermore, the impact of reduction actions can be visualised and reflected in the projected effects of actions. For example, there are studies on possible actions in the EU [50], Japan, Finland, India, etc. [16,17]. Grabs and colleagues have studied the effects of adopting a vegetarian diet [51] and actions increasing well-being [42]. According to Mulrow et al., as of 2017, more than 30 online CFP calculators were available in the United States alone, presenting analyses that businesses and others can use [52].

CFP has already been used in practice in policymaking, businesses and civic actions addressing climate change, with different purposes and scopes of "changes" to be pursued. Some notable differences among the policies, businesses and civic activities utilising CFP include the following:

- Geographical scale: Existing works address different targets, i.e., behaviours, practices, or lifestyles of other groups. Many studies, including the ones mentioned above, analyse the average CFP in specific countries or cities. However, some pay attention to people, such as income groups [31,37] or engagement with grassroot environmental movements [53]. We can also take note of the differing scales. Many studies analyse the national average CFP, but some deal with differences between cities [17].
- Time frame: CFP evaluates the immediate past status of value chains and consumption patterns. Conducting a CFP analysis of specific behaviours or products provides

appropriate data to recommend immediate behaviour changes, such as reducing the use of private vehicles [16]. However, some research tries to expect future changes in CFP [37].

Since various scopes can be considered, it is necessary to sharpen them when designing the system's actual utilisation. We must consider the purpose of the change we seek, for whom and what kind of change, and the nature of the partnerships we will build with citizens, businesses, and others to achieve this goal. The analysis presented later in this paper will support practitioners in clarifying objectives and scopes. One more point should be noted: among the characteristics of CFPs, the ability to specify the "hotspots" or actions with particularly harmful impacts is not necessarily effective in bringing about fundamental changes through societal changes. For example, although it is broadly agreed that replacing internal combustion engine (ICE) vehicles with electric vehicles (EVs) could significantly reduce CFPs, presenting such information and discussing ways to encourage replacement may run the risk of leaving out the discussion on more profound transformations, such as changing the way people travel and using public transportation or bicycles, or making travel itself less necessary [54]. Similarly, the fact that the consumption of the world's wealthiest 10% of consumers is related to more than half of their CFP [55,56] indicates that focusing on their exceptionally high CFP behaviours (e.g., air travel), etc., would be effective. However, this does not mean that we do not need to pay attention to the remaining 90% in their sustainable transition. Moreover, since all human behaviour occurs as part of a socio-technical system that creates and delivers value in a country or society, behavioural changes in one group of people will be accompanied by changes in other groups' consumption and production activities. To take account of such derived effects, careful consideration of how data, such as CFP, can be presented and linked to the discussion about the positive and negative consequences of the changes.

2.2. Impact Messaging and Its Limitations

To further consider the potential drawbacks of applying CFP in promoting changes in individuals' high-impact behaviours, the section reflects on the ways of utilising numerical data in engaging with citizens on climate change action. We can learn from existing research on providing electricity consumption data to encourage households to save energy behaviour about the potential ineffectiveness of presenting such data or to divert attention from needed changes. Feedback services for energy conservation are probably the most popular method. Household energy conservation encouragement using smart meters and in-home displays has been deployed in many countries [57–62]. In the UK, plans are being made to roll out to all households and small businesses [58]. These impact messages [63] began with simply showing information, but in recent years have also incorporated techniques, such as gamification [64,65]. While much research has accumulated on the methods and effectiveness of impact messages, it has been reported that the behavioural change effects are often small or short-lived [18–21,64]. Some have suggested linking the information to pricing to cause more practical effects [66]. However, the assumption behind the approach, namely, the deficit model [22,23], which assumes that giving individuals knowledge will change their behaviour, is the reason for the ineffectiveness. Research revealed that giving normative information or environmental education has little effect on behaviour change [67]. Over the past two decades, research has shown that behaviours are not the direct consequences of people's values and intentions, as are often believed [68]. People's practices are entangled with various elements, such as social norms and values, institutional arrangements, personal and shared competencies, and material conditions, such as the natural environment, built infrastructures and available products [69–73]. Several cases illustrating such entanglements can be considered. Our practices often have more than one purpose and are constrained by complicated contexts. For instance, our need to move is almost always connected with other needs, such as working, eating, shopping, or gaining knowledge [74]. Our practices are shaped by our needs and capacities, and those of others, reflecting the role models or norms confirmed in social groups [72,75]. Some

illustrative cases include keeping our bodies and houses clean and comfortable [76] or opting for specific categories of food [77,78]. Our practices are enabled and constrained by the physical arrangements, including infrastructures, products and tools, and the shared meanings and values attached [73,79]. This point is easily understood if we consider what is needed to keep our living spaces comfortable with lower energy consumption [80]. Our practices occur at certain places, which are parts of the systems of provisions stretched globally. Our mobility with private vehicles occurs on road systems and depends on petrol supply [81]. It is difficult to promote behaviour change without considering the necessary changes in such contexts [24]. Additionally, while impact messages can direct attention to actions that can be quickly performed, it masks the surrounding context and other associated practices [74,82]. It distracts attention from the need for deep, time-consuming change that requires cooperation with others, the government, and businesses. Hence, an approach that focuses on individual behaviour has limitations [25].

Similarly, encouraging behaviours, such as energy conservation and car replacement, that can be immediately effective for individuals can easily divert attention from the issues of power and unequal distribution of resources involved in the transformation [83]. For example, the transition from ICE vehicles to EVs entails potential inequalities regarding freedom of movement among rural and urban citizens. Subsidies applied for purchasing EVs are sources from the tax that poorer citizens who cannot afford private vehicles also pay [54,84]. The energy transition also entails injustice, notably in the unemployment of those involved in the oil industry and power generation, land access and landscape in areas where new renewable energy generation is developed, and changes in electricity prices [85–88]. Practitioners and researchers involved in community transformation have noted that many people are interested in these potential impacts. Although they should be able to play a role in creating a more general view of future societies [89], simple behaviour change recommendations do not always facilitate discussions of injustice, risk, and the potential for more inclusive change [74].

Most impact messages on energy conservation and other issues provide information to individuals and households [90], with limited application to community projects [79,91,92]. However, some report the positive impacts of using messages at community-level actions. For example, according to Vita, participants in grassroots activities tend to have smaller CFPs [53]. Burchell observed that feedback services linked to community actions resulted in more proactive engagement from participants among women [91]. Information provision targeted to communities, such as neighbourhoods, workplaces, or other specific groups, combined with collective learning and actions, may have room for further pursuit.

2.3. Toward More Creative Use of Data for a Deeper Engagement with Citizens

To further consider the effectiveness of promoting collaboration and mutual learning through the provision of information to groups, we would like to focus on the discussion of what communication is for, in what areas, and what roles scientists, citizens, and other actors play in the provision and use of information.

The purposes and approaches of utilising data differ according to the various forms of citizens' engagement. Fischer et al., 2021, reviewed 67 peer-reviewed academic papers and identified the four typical patterns of communication; namely, communication as an approach to (1) behaviour change, (2) self-empowerment, (3) systems change, and (4) reflection on current discourses and practices around sustainable consumption [93]. This categorisation helps us understand the broad directions of communication, but we can further consider the specific purposes of communication with data. Concerning (1) behaviour change, it is helpful to show data on the current consumption behaviours with associated climate impacts to identify whose consumption behaviours should be addressed and what are the most impactful behaviours [36]. Concerning this approach and (2) self-empowerment, it is helpful to show the future benefits of the new practices or policies when governments ask for citizens' cooperation to take up new behaviours, participate in grassroots collaborations, or accept new policies that influence their ways of living [94].

On (4) reflection on current discourses and practices, practitioners, policymakers, and citizens can use data to understand the status of society or nature, such as the total carbon emissions, atmospheric carbon concentrations, or the increase in extreme weather events associated with climate change, to share their understanding of climate change, and share the visions and stories of the desired societal transformation [50,53].

For such varying approaches to communication, actors adopt different roles in creating and sharing data. Scientific data are presented for descriptive communication of facts or the current status and for normative communication to describe the benefits and costs associated with specific behavioural patterns and alternative patterns of desired behaviours [67]. Data are not always created by scientists and communicated to "lay people" in an easy-to-digest manner [24]. Participants in collective actions in cities and communities, such as food waste reduction activities, often play a central role in measuring progress and achievements [95,96]. Citizen science has gained momentum globally where experts and local people jointly create shared understandings of their environment, benefits and costs of their socioeconomic practices, such as conventional production methods and alternative practices [97–100]. Finally, data can be created and edited into different scales and scopes. To communicate about climate change, the general status of the global climate change or the country is often used [101,102]. However, such general data are often insufficient in shortening people's "psychological distance" from climate change [102,103]. Thus, more localised or personalised information is developed and provided [24,104].

Such differences in purposes (approaches), actors' roles in creating and sharing, and scopes and data scales reflect a wide array of citizens' engagement in climate change actions. Research has identified various areas where citizens' roles are vital in addressing climate change. In public spaces, citizens can drive political movements, take position on key political matters by voting in elections, and participate in citizens' assemblies or public consultation meetings [22,105–107]. Citizens can lead collaborative actions for sustainable production and consumption, formulate collective visions, goals and activities, and co-create knowledge on climate change and desired actions [22,108–111]. Citizens can also adopt climate mitigation actions in their private life by changing their consumption behaviours and learning and sharing knowledge with others [22,112]. As mentioned above, the usages of numerical data cover all these domains of citizens' engagement, namely private, collective, and public [22]. Table 1 below summarises illustrative cases of applying numerical data in citizens' engagement in the private, collective and public domains.

In summary, numerical data can help various types of citizens' engagement in climate actions by promoting individual behaviour changes, encouraging collective actions, and inviting people into decision-making. However, the interventions based on the "deficit model", which assumes information will lead to changes in cognition and behaviours, are ineffective in facilitating change, as they deflect our attention from the opportunities for systemic transformation requiring deeper engagement and from the inequalities and injustice associated with sociotechnical transitions. Thus, such approaches are not likely to cause the transformation of systems of provision [113]. Three points should be considered to utilize scientific data, such as CFPs, for deeper transformational engagement.

First, we should explore the possibility of transforming CFP-intensive lifestyles; it is necessary to re-examine the technology, social norms, and economic conditions surrounding current lifestyles in the context of society. Approaches targeting individuals to change high-impact behaviours in isolation are not often practical. Systemic transformations are needed, covering social norms related to how people work, care for their families and behave appropriately in public, choice of locally available products and services, energy and transport infrastructures, shopping practices, public services, etc. People living in local societies understand best which socioeconomic, technological and other contexts enable or constrain actions in a given area [114]. Holt asserts that "entering their lives, understanding their dreams and anxieties" [115] is needed to identify real-world concerns, needs and opportunities for change. Arguably, we should consider the benefits of scaling down, in addition to or instead of scaling up ideas and actions to reflect better the diverse

and dynamic framings of climate actions among citizens [116] and pay attention to the creativity of actions anchored in people's everyday lives, which are sometimes not as "conspicuous" as tangible movements but are still influential in shaping climate mitigation and adaptation on the ground [117]. Local people play a vital role in generating knowledge by linking their ideas of their living world to broader issues [114] and enabling the creation of alternative systems providing essential services supporting local well-being and mitigating negative impacts.

Table 1. Illustrative types of data provision for engaging citizens with climate mitigation in the private, collective, and public domains.

	Private	**Collective**	**Public**
	Ex 1: Energy Feedback Service [60,62]	Ex 2: Collective action for food waste reduction [96]	Ex 3: Policy plans/visions or governments' appeals for energy saving
Approach	Descriptive and normative data encourage energy users' behaviour change. Descriptive data: current energy use patterns, gaps with national or city average energy consumption levels Normative data: personalised behavioural advice for potential energy savings, benefits of energy savings.	Descriptive and normative data encourage citizens' proactive participation in collective actions. Descriptive data: current amount of food wasted in schools or communities. Result of collective actions Normative data: behavioural advice for food waste reduction, benefits of reduction achieved through collective actions.	Descriptive and normative data encourage energy users' behaviour change. Descriptive data: current energy use patterns, gaps with national or city's average energy consumption levels, or limits to energy supply. Normative data: general behavioural advice for potential reduction, benefits of reduction
Actors' roles	Experts from the utility company, sometimes supported by advisors certified by the authorities, create and send data to users.	Experts and participants jointly measure the current and reduced amount and calculate the additional benefits, such as reduced GHG emissions and financial savings.	Experts from the authorities create and communicate data through mass media or social media.
Scales and scopes	Personalised data are compared with the local or national average.	Personalised and community-scale data can also be combined with national or global data.	Local or national average data are given in comparison with the desired status.

(Source: author).

Secondly, it is vital to facilitate learning to capture the socioeconomic and technological contexts, linking the global and local contexts. CFP allows us to visualise the systemic elements associated with global trade and economic development impacting the embodied and leaked GHG emissions and the unequal impacts among countries, regions and income groups [7,28,90]. With such understanding, it is possible to examine why local societies depend on imported energy and food from other regions and what costs they pay. In other words, learning with CFP leads to a re-examination of the socioeconomic and technological factors surrounding an individual's behaviour [69,70].

Thirdly, such a re-examination allows us to envision changes in lifestyle and society in the broadest sense rather than individual behaviour. Lifestyle change is a shift in norms and ideas about a "good life" [118], as well as in capabilities, infrastructure, and access to sustainable alternatives [41,119]. Whitmarsh et al. [119] suggest that Carbon Capability for transformation to decarbonised societies comprises the ability to make decisions, act, practice, and engage in deep change. Thus, the changes must go beyond what can be addressed by individual and household consumer behaviour and include broader engagement, such as community actions and civic movements [70,115,120,121]. However, such crosscutting collaboration and mutual learning with actors from diverse backgrounds can bring about conflict in framing, including reasons for various actions,

concerns, and desires for the future society [100,101,103,109,116,122,123], reflecting the diverse resources and capacities [74,110,112,124].

The three points presented here also correspond to the concept of Carbon Capability introduced by Whitmarsh et al. Carbon Capability refers to the capabilities of local citizens, communities and other actors in making decisions, taking actions to combat climate change, and engaging deeply in the transformation of the societal and governance structures [22,125].

Engagement with citizens for deeper changes in socioeconomic systems is even more critical in a post-COVID-19 society. COVID-19 has changed several aspects of daily energy use, including mobility [126], and how we work and spend our time at home [127]. It is expected that the sudden changes in behaviours will lead to the transformation of the urban system [126]. If the post-COVID urban transformation is carried out without regard to the safety and liveability of residents, especially those most severely exposed to health and economic risks, the urban supply system may become even more vulnerable, which could have implications for future transformations [128]. Therefore, it is more necessary than ever for actors with different backgrounds and capacities to learn from each other to create the context for future livelihoods and liveability.

Given the issues above, the approach of using CFP to promote individual behaviour change has a few drawbacks. It will have limited effect, as was seen in the cases of IHDs in household energy saving. It cannot take advantage of the characteristics of CFP in visualising the embodied emissions and the inequality associated with international trade and economic growth. It may leave out the issues of the unequal distribution of impacts associated with the transformation and specific barriers or enabling conditions [20,129,130] for uptaking alternative practices. Thus, we should explore using CFP and other scientific data more creatively. Instead of (or in addition to) nudging individual behavioural changes, these data could also facilitate collective knowledge creation to revisit the day-to-day experiences and practices in the context of the broader socioeconomic changes [114] and thus develop the citizens' and other actors' capabilities for changes. The following discussion, therefore, reflects on three citizen engagement discussions and experiences that the authors participated in as part of the 1.5-degree lifestyles and examines the possibilities and limitations of the discussions and learning that can be enabled by engaging with citizens using data.

3. Methodology and Case

In the remainder of the article, we will examine the different approaches to using carbon footprinting toward facilitating more diversified and more profound learning and collaboration with citizens in decarbonisation. To this end, we will introduce three patterns of using carbon footprints attempted to date under the 1.5-degree lifestyles initiative in different contexts.

3.1. Data

Several researchers contributing to this Special Issue, including the authors of this article, have participated in more than two cases of citizen engagement initiated under the 1.5-degree lifestyles initiative. The initiative started in 2019 by analysing the average citizen's carbon footprint in five countries: Japan, India, China, Finland, and Brazil. In late 2019, the next stage was to organise citizens' discussions and household experiments in six cities in five countries: Japan, Brazil, India, South Africa, and Thailand. The results were summarised in the six "city visions" published in September 2021 [131–136]. In 2021, the project team members started discussing with several local governments to explore the potential application of the approach to contribute to local policy developments. As one of these opportunities, project members joined a consortium to support the development of a decarbonisation plan in a city in Japan and organised workshops and "a household decarbonisation challenge" with citizens and reported results to the discussion for the local action plans. During these years, project members were often invited to give lectures and

mini-workshops in local communities, schools and companies to share the key insights gained in the initiatives. In other words, the following three cases analysed in this paper emerged from the 1.5-degree lifestyles initiative but had different objectives and scopes as summarised in Box 1 below.

Box 1. Different objectives of the three cases (Case a: Envisioning Project, Case b: Odate City Decarboni-sation Action Plan, and Case c: Mini-workshops).

- Development of 2030 visions for decarbonised living, based on the discussion and household experiments.
- Contribution to the 2050 net-zero local development plans through the citizen's discussion and "challenge".
- Lectures and mini workshops on climate change and lifestyles for learners.

The following description and analysis are based on the documentation of the preparatory processes, workshops and household experiments, and discussions with other project members, participants and local government officers. Some documentation is already published [131–136], while others are not.

3.2. Focus

As examined in the literature section, climate mitigation programmes and projects engaging citizens have diverse objectives, scopes, time frames, and actors' roles. There are many potential tensions in their engagement, such as the power imbalances regarding the framing of issues, injustice and inequality associated with changes in behaviours and systems. In looking back at the documentation and discussions with participants, special attention was paid to several aspects as follows:

Objectives of the engagement: as seen in the previous section, citizens' engagement with climate mitigation in cities and communities can occur in a variety of domains (public, private or collective) with different purposes (policy development, behaviour changes, collective learning, and actions).

Scope and time frame of the aimed "change": transformation of behaviours or socioeconomic contexts can aim at different levels (individual, organisational, local, or national) and time frames (immediate changes, medium-term or long-term).

Discussions with participants utilising carbon footprint data: carbon footprint (and other data) can be used for discussions on a broad range of themes, such as gaps between the current and desired status of decarbonised living; priorities of behaviour changes to attain immediate and most significant carbon reduction impacts; and locally specific conditions that enable or constrain the application of specific behaviours (such as infrastructure or population).

Achievements, non-achievements, and other learnings through engagement: these may include the knowledge developed with participants, behaviour changes that occurred in their households, or other unintended effects observed by team members and reported by participants at the workshops or their responses to questionnaires.

These points will help us identify the critical points to be considered in designing the use of carbon footprinting to foster discussions, learnings and possible behaviour changes among participants and other stakeholders toward facilitating decarbonisation as a systemic change.

4. Using Carbon Footprinting to Foster Citizen Engagement with Climate Change

This section introduces three different cases of citizen engagement under the 1.5-degree lifestyles initiative. The description of each case starts with the overview, followed by the purpose, including scope, time frame and target process, actions taken, achievements, and learning.

Case (a). *Development of 2030 visions for decarbonised living, based on the discussion and household experiments in six cities.*

Overview: The Envisioning Future Lifestyles project was the first attempt in the world to organise discussions and household experiments with citizens utilising lifestyle carbon footprints. The project was launched in 2019 by research institutes and non-governmental organisations in Japan, Thailand, India, South Africa, and Brazil. These organisations collaborated with six cities (Cape Town, Delhi, Nonthaburi, São Paulo, Kyoto, and Yokohama) and citizens to conduct the planned activities. The primary purpose was to create inputs for local governments to suggest policies to help citizens to adopt low-carbon lifestyles. To this end, the project teams in each country analysed the average carbon footprints of residents of each city. They identified 40 to 65 "options" of behaviour changes to reduce carbon footprints with specific reduction potentials. Then, 30 to 40 citizens in each city were invited to the workshops to consider the "adoption rate" decarbonising behaviours toward the 2030 target of "2.5 tonnes of carbon footprint per person", contributing to the achievements of the 1.5-degree target set in the Paris Agreement.

Participants were then requested to test the presented "options" of decarbonising behaviours at home and record their implementation and difficulties. Targets were re-examined based on the experiment results, and measures to support further behaviour changes were considered. The results were compiled into six different 'visions' for each city. Due to the COVID-19 pandemic, workshops were organised online in five of the six cities, except Nonthaburi, Thailand.

Purpose: The project had two primary purposes. Firstly, it aimed to influence the local governments by showing carbon reduction potentials through behaviour changes and recommending effective policies to promote the uptake of decarbonised behaviours based on the knowledge developed through discussions and experiments. Secondly, it aimed to prompt participating citizens to revisit their behaviours by considering climate change impacts. In other words, the process started with discussions and experiments mainly in the private domain and then shared the knowledge to the public domain to develop concrete recommendations.

Actions: the following steps were taken.

Analysis of the average carbon footprint and identification of decarbonising behaviours: the project team in charge of each city calculated the current carbon footprint per capita (assuming years around 2015–2017) by referring to consumption statistics for the city and carbon intensity data for each country. The team also calculated CFP reduction effects of adopting "options" of decarbonising behaviours and compiled them into "catalogues" presenting them in an easy-to-understand manner. The "options" covered 40 to 60 actions, such as the shift to electric vehicles, reduction of travel, use of renewable energy at home, reduction of meat consumption, food waste reduction, and extended use or sharing of products.

- *Analysis of the carbon footprint of participating citizens:* 20 to 40 citizens were invited to the workshops in each city. Participants responded to a questionnaire survey about their current living conditions and behaviours, covering the topics of mobility, housing, food consumption, purchasing of products and services, and leisure. The collected responses were used to analyse the citizen's current carbon footprint.
- *1st Workshop to share the basic knowledge and decarbonising "options"*: Participants were provided with basic knowledge about climate change and decarbonising behaviours in the first workshop. Then, they exchanged views of the desired future of the city—what conditions or characteristics they wanted to keep and what they wished would change. Then, the main session started. Participants shared their expectations on how much per cent of the citizens in 2030 can adopt specific decarbonising options. The organising team inputs the participants' ideas to an excel sheet that shows the average carbon footprint with the increased adoption of decarbonising "options" immediately. The discussion targeted 2.5 t CO_2e/person/year, which was presented as the result of the previous study to identify the footprint to support the achievement

of the 1.5-degree target. However, even after putting in many participants' ideas, it was impossible to achieve a 2.5 t average reduction. Thus, participants were at times requested to propose more ambitious expectations to reduce the final result.

- *Household experiments:* Following the first workshop, a series of documents were provided to the participants to prepare for the experiments. They selected several "options" of decarbonising behaviours that they can try at home over 2 to 4 weeks. During the experiment, participants were requested to record the results (whether they could carry out the behaviour on the day). After the 2 to 4 weeks of the period, they filled what they felt and learned through the trial of decarbonising behaviours, such as the challenges faced, unexpected benefits or costs, and desired conditions to support the uptake of the behaviour.
- *Second Workshop:* The organising team summarised the results of the experiments, including the implementation ratio and other learnings, such as the challenges faced by participants and desired supportive conditions or measures shared by participants in the experiment diary. Participants also provided further feedback on the summary.
- *Future vision of decarbonised living in 2030*: The project team develops the future vision of decarbonised living in 2030 based on the discussions on the desired city, the potential of uptaking decarbonised behaviour by 2030, difficulties of behaviour changes faced during the experiments, and the desired supportive conditions and measures suggested by participants. The future vision represents the results of the discussion and learning with some graphs, figures and illustrations (Figure 1).

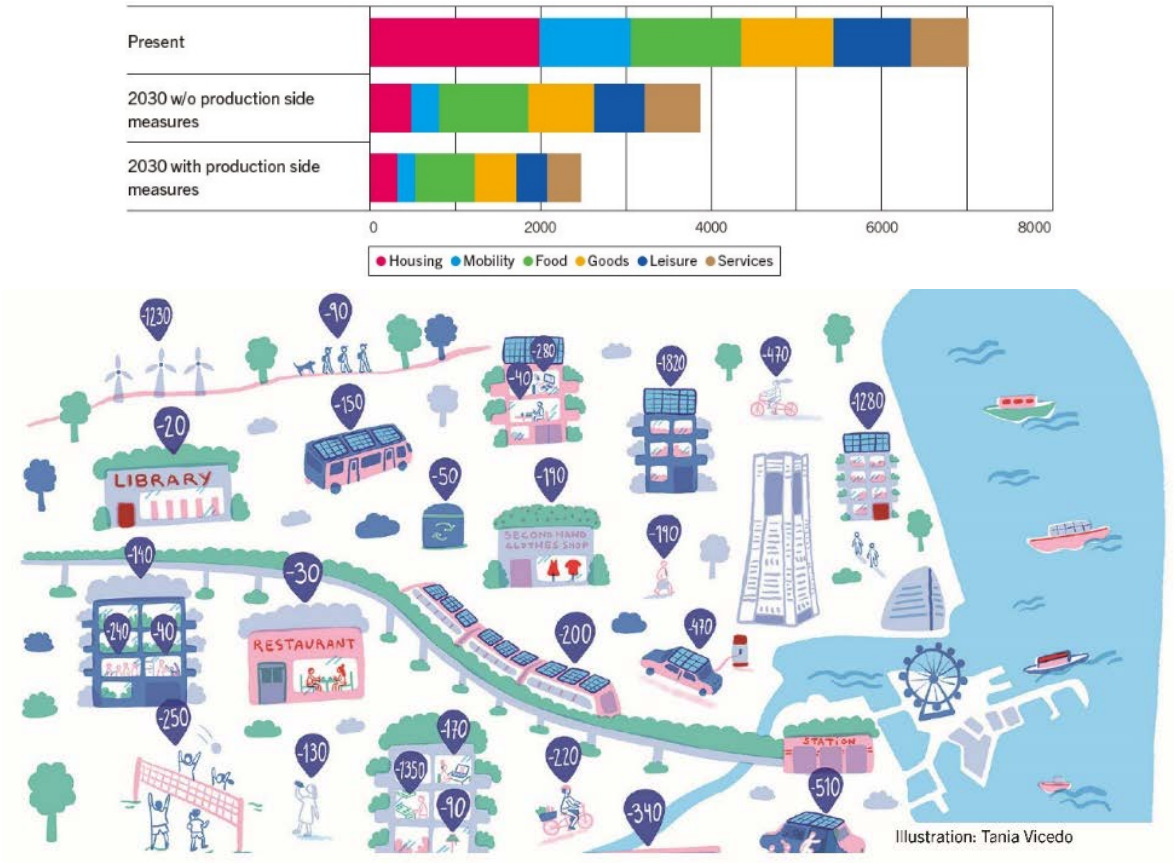

Figure 1. The prospected CFP reductions resulting from the workshop discussion (**top**) and the illustration identifying CFP reduction opportunities in Yokohama by 2030 (**bottom**).

Use of figures (including carbon footprinting): Several figures were created and shared with participants at different project stages. The project team created the following figures and presented them to the participants (Box 2).

Box 2. Figures created and used before and during the workshops in the Envisioning project.

- Average carbon footprint in the city and the reduction target.
- Reduction potentials of adopting specific decarbonising behaviour "options".
- Individual carbon footprint of the participants.
- Expected adoption rate of the decarbonising behaviour "options" in 2030.
- Implementation rate of the decarbonising behaviour "options" during the household experiments.

These facilitated the participants' discussions on various topics, such as the gap between the current status of living and the 1.5-degree target, behaviour options with the most significant reduction potentials, whether these behaviour options are easy or difficult to promote in the city, and desired conditions to promote further uptake of behaviour changes.

Achievements, non-achievements, and other learnings through engagement: In this project, participants discussed and tested which "options" of decarbonising behaviours are feasible and which are not, based on the current context of the city. The results showed that it would not be possible to achieve the target of 2.5 t CO_2e/person/year in cities solely through behaviour changes assuming that cities' current conditions would remain the same. These results should not be seen as "failures" since they indicate some vital elements to develop the future visions of cities.

Above all, the difficulty of taking up some behaviour options and the supportive conditions were identified through the discussion and experiments. To illustrate, the participants of the Kyoto workshop and experiments often discussed mobility conditions. As a megacity, Kyoto has well-developed bus and subway systems. However, buses and subways have increasingly become crowded with tourists over the past two decades. Thus, participants expressed the need to develop public transport further and prevent the increase in private cars. Participants who tried using buses and subways during the experiment reported that they learned that transferring to different lines and means of public transportation was often very time-consuming and hard to understand. As such, participants could start considering the desirable arrangements to support further use of public transports, by suggesting, among other examples, improved routes and the provision of easy-to-understand information.

The potential carbon footprint reduction examined by participants helped the project team continue discussions with local governments and other stakeholders. Local government officers were highly interested in some of the results, such as the behaviours with significant reduction potentials and the implementation ratio of options during the experiments. These results could potentially contribute to examining the policies promoting decarbonised behaviour. Some cities, including Kyoto and Yokohama, have already started exploring new policy initiatives to utilise CFP.

This approach had some limitations. Firstly, the household experiments required participants to use their own time and financial means to adopt new behaviours and record the results. Thus, it was not easy to spread the approach to citizens who do not have a high interest in climate change. Secondly, only very few participants tried behaviour change "options" with high reduction potentials, such as changing vehicles and introducing renewable energy (e.g., solar PV). These options needed some preparation time and initial costs and were unsuitable for a short-term experiment. Going forward, it will be more productive to consider a different approach to identify appropriate supporting conditions and measures to promote them. Thirdly, the discussion on the expected adoption rate turned out to be difficult and not attractive to many participants. Accurately estimating the level of "behaviours adoption" necessitates considering complex factors, such as the expected changes in the city's infrastructure and environment.

Moreover, since the discussion was designed to attain the CFP target of 2.5teCO_2e/person/year, some participants felt pressured by the facilitator to propose more ambitious ideas to reduce the final carbon footprint result displayed on the screen.

Similarly, participants were unable to sufficiently share their thoughts on the potential risks or benefits associated with changes to carbon-intensive behaviours. Even when potential risks or benefits were mentioned during the discussions, these issues were often dismissed to prioritise the primary purpose of agreeing with the target of behaviour changes.

Records of the household experiments were taken individually by participants and analysed by the organising team. Thus, the project could not take full advantage of the learning potential from the experiment which could have been gained from sharing the results, ideas and feelings among participants to build their motivations and capacities for continuous or more ambitious uptake of decarbonising behaviour options. Conducting follow-up surveys would provide key information to see the extent to which the actions tested were sustained after a specific amount of time. Additional opportunities for exchanges among participants could have been created to learn from one another. In other words, the experiment could aim to shift from a "household" experiment to a "communal" or "collective" experiment and learning experience.

Finally, the discussion at the workshops highlighted the needs of a wider variety of products and services enabling low-carbon behavioural options. Thus, follow-up dialogues were planned between the workshop participants and local business sectors who are planning or are interested in providing alternative products and services. The dialogues between local citizens and businesses indicated some areas of collaboration toward broader uptake of alternative services, such as bicycle sharing. However, it turned out to be difficult to launch collaboration without continuous funding.

In summary, the project enabled participants and team members to consider personal and local possibilities and constraints. However, more steps are necessary to broaden collaborative actions and facilitate changes beyond individual behaviours for both medium- and long-term time frames.

Case (b). *Contribution to the 2050 net-zero local development plans through the citizens' discussions and "challenge" in Odate, Japan.*

Overview: Odate city, Akita prefecture, Japan, is located about 500 km north of Tokyo. The mining sector in the modernisation era has driven the city's growth. However, since the 1980s, its primary industry has shifted to manufacturing, recycling, and services. Like many cities and towns in northeast Japan, Odate's population has been on a long trend of declining and ageing—now, about 40% of the 70,900 residents are above 65 years old [137]. In 2021, the government of Odate city started formulating a local action plan aiming for net-zero carbon emissions by 2050. Many Japanese municipalities developing similar plans focus on achieving net-zero carbon emissions through changes in industry and infrastructure systems, sometimes with forest protection to increase carbon sinks. However, Odate city emphasises the development of a net-zero society which ensures the well-being of its citizens. Therefore, a citizen participation process was carried out in parallel, with the expert team's analysis of the current situation and the development of the future vision of other vital conditions for a decarbonised industry, energy supply, transportation systems, and forest protection.

The team collaborated with the Odate city government to plan the workshop and aimed to invite around 30 citizens to participate in two workshops. However, due to the spread of COVID-19, many participants were absent from the workshops. Participants discussed the possibilities of adopting decarbonised behaviours. It was also suggested they try some of the decarbonising behaviours at home. Finally, they gathered again and discussed the societal contexts enabling decarbonised and happier living in Odate. They also exchanged ideas of actions to be adopted immediately to trigger the long-term changes in cooperation with the government and local businesses. The citizens' "challenges" results and discussions were reported to the experts' panel which examined the Zero Carbon Plan and provided substantial material for the final planning process.

Purpose: The project had two purposes for citizens' engagement. Firstly, it aimed to provide input to the local action plans under planning by facilitating citizens' discussions

and mutual learning about decarbonising behaviours and future socioeconomic conditions of the city. Secondly, it also aimed to invite citizens to exchange their ideas of actions to start the long-term transitions in collaboration with local governments, businesses, and non-profit groups. In other words, the project started with exchanges of views in the private domain leading toward the creation of knowledge informing public policies and facilitating collective actions.

Actions: the following steps were taken.

Carbon footprint analysis: Participants were requested to respond to a questionnaire about their current housing, mobility, diet, and leisure activities. Based on this, a simplified carbon footprint diagnosis was provided.

- *First workshop:* An in-person workshop was organised. Participants learned the basic knowledge of climate change, carbon footprint, practical decarbonising behaviour and associated reduction potentials in the city. Then, participants discussed which behavioural changes they viewed as most attractive (or likely to be tried) for Odate citizens and which were unattractive (or unlikely to be adopted). They also justified their choices, considering the changes in the local situation by 2050. For instance, some participants said alternative mobility services, such as ride-sharing, were attractive, but others also said such services might accelerate the decrease in bus services. Dietary change is another area where participants' opinions diverged. Some participants had already tested meat alternatives and responded favourably to the opportunity to test them at home, while others seemed reluctant to try them.
- *The household decarbonised lifestyle challenge*: Participants took part in a 'decarbonised lifestyle challenge' at home. They responded to the second questionnaire to identify a few decarbonising behaviours they would try over two weeks. Participants tested several behaviours contributing to carbon footprint reduction, such as using public transportation and bicycling, eco-driving, home renovation for better insulation, families gathering in one room to reduce air-conditioner use, dietary changes, etc. The "challenge" was not designed as an experiment to analyse the implementation ratio scientifically. The project team considered that societal contexts may change substantially by 2050, thereby making "experiment results" largely irrelevant for the discussion on long-term action plans. Thus, the challenge was planned as an opportunity for individual and mutual learning on low-carbon lifestyles.
- *Second Workshop*: The second workshop started with reflections on participants' experiences during the decarbonised lifestyle challenge. Participants reported what they could and could not do and what support they would need for their continued actions. Some participants also shared their thoughts about the benefits of alternative behaviours to their life and the challenges they faced in implementing them. Then, they revisited the benefits and difficulties associated with the uptake of low-carbon behaviours and ideas for overcoming the difficulties. Finally, they exchanged ideas about actions they could start in collaboration with other citizens, local governments and businesses to ensure that broader citizens can benefit from decarbonised lifestyles, considering those who might be disadvantaged. Based on these suggestions, the project team compiled the discussion into a proposal to the experts' committee for the local action plan 2050 net-zero carbon Odate (Table 2).

Use of figures (including carbon footprinting): several figures were created and shared with participants at different project stages (Box 3).

Achievements, non-achievements, and other learnings through engagement:

Participants of the Odate workshop did not aim to set numerical targets for behaviour changes. The current carbon footprint of citizens can be calculated based on their consumption patterns (e.g., electricity use) and carbon intensity (e.g., average carbon intensity of electricity in Japan). However, carbon intensity will fundamentally change by the target year of carbon neutrality, namely 2050, with changes in social, economic, and technological conditions (e.g., increasing share of renewable energy). Thus, it is impossible to estimate the carbon footprint reductions enabled by behavioural changes accurately.

Table 2. Workshop participants' proposals for collaboration toward a net-zero society in Odate in 2050.

Theme	Example of Actions
Spaces of experiencing decarbonised living	- Model Zero-Energy House where citizens can stay for a short time. - Electric vehicle driving event. - Citizen farm/shared farm.
Matching of resources for better utilisation	- Matching services for vacant houses. - Matching services for vacant farmlands. - Enhanced services of ride sharing (mobi).
Collaborative learning	- Eco-driving classes. - Smart phones classes for the old. - Development and sharing of low-carbon and healthy diet. - Visualisation of CFP reduction through behaviour changes (e.g., web applications).
Dialogues	- Exchange with farmers toward increased consumption of locally produced food. - Dialogue sessions for envisioning future city and lifestyles.

Box 3. Figures created and used before and during the workshops for Odate decarbonisation action plan.

- *Participants' carbon footprints.* The calculation was significantly simplified to limit participants' efforts. Thus, the result was not as detailed as the ones provided in the previous case.
- *Characteristics of local living in terms of carbon footprints*. For example, the region has weaker public transportation systems, making the footprint associated with mobility larger than in megacities, such as Yokohama. Footprints related to housing are also prominent due to the larger size of houses and the common use of kerosene for heating purposes in the particularly cold winters.
- *Carbon emissions and sinks*. A few participants questioned if Odate has already achieved net zero emission because of its abundant forest cover. The organising team presented that emissions from industry, transportation and households substantially exceed the forest's carbon capture.
- *Rough calculations of the reduction potential based on the "challenge"*, assuming the continued uptake. The figure was presented for reference to the discussion but was not used directly to discuss the future of society.

Instead, CFP is presented as a baseline to invite participants to the starting point of the discussion for future lifestyles and society. As mentioned above, some participants considered climate change to be an issue to be dealt by the government and big companies. Experts introduced baseline data, such as citizens' CFP in Odate, which is estimated to slightly exceed the CFP of Tokyo residents, and the amount of GHG absorption by the forest, which is far from equivalent to the GHG emissions in the city. Following this, participants exchanged their understanding and remaining questions with other participants and experts. These helped participants better apprehend why they were discussing the future lifestyles and society for decarbonisation in Odate.

At the centre of the discussion were two topics: behaviour changes for decarbonisation and the social, economic, and technical contexts to enable them. Participants could not discuss behaviour changes for decarbonisation without seriously considering several issues threatening the sustainability of society and people's well-being, namely depopulation, ageing and a shrinking economy. For example, the experts proposed many ideas for behaviour changes in mobility, including the use of public transportation, bicycling, and

ride-sharing services to reduce private car use. However, some options were considered unrealistic in a city subject to reduced bus services. Some participants raised concerns about whether the ride-sharing service may lead to a further reduction of buses and taxis, the primary means of transportation for residents unable to drive. Bicycling was also seen as a challenging option due to the snowy winters and the longer commuting distances due to the reduction of workplaces and schools.

Participants often shed light on the potential negative consequences and benefits of transitions for a specific group. As an ageing population characterises the area, discussions about the possibility of changing behaviours around transport, shopping, and food evolved into debates about the extent to which options are elderly friendly or suitable for people living alone. Considering the need to reduce travel, it was seen as desirable to reconfigure the city's urban planning by forming clusters of residences, workplaces, schools, shops, hospitals and other centres in the city's central areas. Odate city plans to create centres in several areas to make it easier for citizens to access public services, workplaces or other locations for daily living and lower the cost of infrastructure development. However, to this end, the city should ask some people to relocate, which could result in losing their socio-cultural ties with natural resources and neighbourhoods. As for dietary changes, such as reducing meat consumption, participants discussed the attractiveness of alternative diets and the potential negative impacts on local producers. Regarding the feasibility of reducing meat consumption, many raised concerns for the health of kids and the elderly, who are encouraged to consume more animal protein. When car sharing was discussed, some participants were concerned that it might accelerate the reduction of already-decreasing taxi services and make it more difficult for the elderly to go out. Still, others were hopeful that AI-driven car sharing services would provide an innovative solution to the mobility of the elderly.

Interestingly, such discussions about the potential negative impacts did not necessarily lead to negative prospects for behaviour changes. Some participants considered the reduction of private car use to be unrealistic. However, considering segments of the population who may face challenges in mobility to access basic needs in the near future, such as elderly people who can no longer drive, participants realised the urgent need to redesign the local transport system.

Furthermore, testing behaviours as part of *the household decarbonised lifestyles challenge* helped ascertain the benefits and difficulties of the attempted behaviours. More than 30 behaviour changes options were declared to have been adopted by participants, including eco-driving, cycling, travelling by public transport. reducing food purchases to eliminate waste and simple renovations to improve their homes' insulation. Many benefits were observed through their challenges of alternative behaviours. For example, a student who tried cycling to school said she felt good about moving in the morning without always having to rely on her parents to drive, but she felt worried at night because it gets dark in the city. Her experience indicates the need to ensure safety by improving lighting and other facilities. Coincidentally, a demonstration of a ride-sharing service had started three weeks before the second workshop. Though participants demonstrated interest in this initiative, none of them had used the service due to the limited serviced areas and operating hours.

After these experiences, participants gathered again at the second workshop. They shared their experiences, revisited both benefits and difficulties of alternative behaviours, and examined practical steps to make the benefits of alternative behaviours available to a broader scope of citizens. They discussed the necessity of promoting alternative mobility services to help those who cannot drive. Some constraints of the ride-sharing service under trial were identified. Above all, it turned out to be vital to make it easier for users to request the ride through the mobile application and provide training to use the service. Concerning dietary changes, participants observed that meat alternatives were not always available in local supermarkets. A few participants found meat alternatives not as tasty as meat when cooked similarly. Thus, they suggested sales should be expanded and cooking lessons should be organised. Participants pointed out that citizens need to

become familiar with the benefits and difficulties of alternative means of mobility (such as ride-sharing and electric vehicles), housing and energy use (renewable energy and zero-emission houses) and nutrition (meat alternatives). They proposed setting up facilities or organising events where people can experience them. They also suggested that unused houses and farmlands increasing due to the ongoing depopulation could be utilised as community spaces for citizens' experiences and collective learning. As a result, a more constructive discussion was organised at the second workshop. Rather than individuals holding back and changing their carbon-intensive behaviours, they proposed that they need changes in the local systems of providing services for a better quality of life to citizens while simultaneously reducing their carbon footprint and that, to this end, they needed collective experimentation and learning among citizens, local government and businesses.

On the other hand, the approach had some limitations. The project did not aim to create numerical targets for reducing carbon footprints and carried out strictly scientific footprint analysis. More importantly, due to the constraint in time, additional funding and opportunities, it is not yet clear how to start collaborative actions based on the proposals made by the participants. Furthermore, the discussion on the future of society could not go deeper to explore both negative and positive consequences of the suggested measures to the local environment, economy and society. Participants' proposals, such as the enhancement of ride-sharing services or utilisation of unused houses and farmlands as experimentation spaces, would need careful planning supported by experts in transportation systems or land-use planning. That said, the fact that participants suggested areas where additional surveys and examination are required already indicates the approach's success in using CFP as an entry point for inviting citizens to discuss the future of their life and society.

Case (c). *Lectures and mini-workshops on climate change and lifestyles for learners*.

Overview: The project members of the above two approaches (Envisioning Future Lifestyles and Odate Decarbonisation Action Plan) were sometimes requested to give lectures and organise mini-workshops about climate change and lifestyle changes in schools, colleges, companies or communities. To meet their demands to learn the essentials quickly, they elaborated lecture and mini-workshop programmes. Many of these lectures or mini-workshops targeted 10 to 30 learners, which sometimes included primary or secondary school students, college students or adults. The lectures ranged from one to three hours, significantly shorter than the other approaches.

Purpose: The lectures and mini-workshops focused on quickly providing the basic concepts and knowledge of climate change and decarbonised living. The lectures also expected the learners to continue discussing the possibilities and difficulties of changing their behaviours and the need for systemic changes to enable decarbonised societies, ideally with their families and neighbours, after the end of the lecture.

Actions: The typical steps of the lectures and mini-workshops are summarised here.

The programme starts with a short lecture (presentation) on the basics of climate change and associated impacts, carbon footprints, and behaviour changes for decarbonisation. The short lectures take 20 to 40 min. Learners were given a short questionnaire to calculate their carbon footprints. This step was skipped when the time was limited or the learners' capacity was considered insufficient to conduct a quick calculation. Learners were gathered into groups of four to six participants each. They exchange their views on the behaviour change options. Options were categorised into " can be implemented immediately", "complicated to implement", and "may become feasible if participants can collaborate with others." If two sessions of lectures are planned, learners test some of the behaviour change options and record the results. Based on their results, learners discuss the possibilities and difficulties of adopting decarbonising behaviour options and desired conditions to support behaviour changes.

Use of figures (including carbon footprinting): carbon footprint was presented or calculated for the following purposes (Box 4).

Box 4. Figures created and used before and during the mini-workshops.

- To describe the status of carbon footprint in a city or a country.
- To show the gap between the current carbon footprint and the desired figure to contribute to the 1.5-degree target.
- To understand the impacts of the learners' current consumption patterns on the climate.
- To highlight the actions that result in a high carbon footprint in a specific city or country.
- To show the possible behaviour changes to reduce footprints.

Achievements, non-achievements, and other learnings through the engagement: The lectures and mini-group works to utilise carbon footprints enabled the learners to gain a deeper understanding of some of the essential concepts of climate change. Among them, the quick calculations of the learners' carbon footprint helped them understand that energy-consuming behaviours, such as driving or heating, and other essential practices to sustain a decent life, including eating, learning, purchasing goods, and caring for their health, have impacts on climate. They could also understand that their consumption behaviours influence greenhouse gas emissions in other countries where the goods they purchase are produced. Such concepts are sometimes counter-intuitive to adults with some knowledge of climate change and GHG emissions. However, using carbon footprints during lectures can support the understanding of primary and secondary school students.

The lectures and quick calculations using carbon footprints were followed by group discussions about behaviour change options' (non-)feasibility. This second step effectively assisted learners in sharing their views on additional vital aspects of the changes in lifestyles and societies. For example, when they consider which behaviour change options are feasible, which are not, and which require collaboration with others, they already start considering the locally specific conditions enabling or disabling a specific behaviour. In some cases, learners' discussions touch upon the potential risks and benefits of changes in behaviour or systems. For instance, the concern about reducing meat consumption is a popular topic at workshops held in classrooms or community care centres because workshops in these venues often have participants working on health care or physical development. Thus, it is possible to support learners (participants) to discuss broadly or specifically potential risks and benefits, even in short lectures or workshops. Participants were also able to conclude that collaborations among people or between citizens and local governments and businesses are required to enable decarbonised living without lecturers' explanations.

There were some limitations to the approach. Firstly, the discussion mainly evolved around the immediate feasibility or conditions for decarbonising behaviours, assuming the current socioeconomic contexts. It is not easy to extend the time frame to consider future possibilities of lifestyles or societies. Secondly, though some learners talk about the need for crosscutting collaboration for systemic changes, they can hardly develop concrete suggestions or proposals in short discussions.

In summary, lectures and mini-workshops can be the first step in raising awareness about climate change and its relationship to livelihoods. However, awareness and knowledge do not always lead to changes in behaviours and systems. Follow-up actions should be considered to facilitate actions/collaborations based on the discussions. For example, inviting the learners to concrete opportunities for collective actions might be beneficial. Lecturers could also consider providing documents that learners can disseminate to their families or friends to continue the discussions beyond the lectures.

5. Discussion: Examining the Different Approaches and Their Effects

5.1. Vital Elements and Steps

So far, we have examined the three approaches to using CFP in facilitating citizens' discussions and trial actions on decarbonising living and societies. Table 3 summarises the key differences in various engagement aspects, namely, the time frame, domains of engagement, topics of changes, and target processes/audiences they aimed to influence.

Table 3. Key differences among the three cases under the 1.5-degree lifestyles initiative.

	Envisioning Project	**Local Decarbonisation Action Plan**	**Lectures and Mini-Workshops**
Time frame	Medium-term changes (2030)	Long-term changes (2050)	Immediate changes (2022)
Domains of engagement	Personal behaviours Behaviours of the citizens of a city Suggestions for policies to create supportive conditions	Behaviours of the citizens of a city Collaboration to create supportive conditions and help those who may be left behind Input to local policy development	Personal behaviours Collective learning
Primary topics of changes	Citizens' behaviour changes for CO_2 reductions Supportive conditions for adopting decarbonising behaviours	Citizens' behaviour changes for CO_2 reductions Socioeconomic changes to tackle local challenges and ensure well-being while reducing CO_2 Potential risks and benefits of changes to specific groups of people	Citizens' behaviour changes for CO_2 reductions Supportive conditions for adopting decarbonising behaviours Potential risks and benefits of changes to a specific group of people
Target audience or process	Policymakers' consideration of measures addressing decarbonised living	Policy development collective actions that follow the formulation of the policy	Learners' capacity development and reflection

(Source: author).

Among these differences, two are the most vital elements in determining the design of the approach: the primary topics of change (individual behaviour or socioeconomic contexts) and the time frame (immediate, medium-term, or long-term). The envisioning project and the mini-workshops began by considering the immediate or medium-term changes in behaviours and proceeded to examine the contextual changes required to support them. The Odate city project started by considering the long-term changes in the socioeconomic contexts and followed by discussing the changing needs and feasibilities of adopting alternative behaviours. In short, various ways of citizens' engagement in climate mitigation using CFP may identify the scope between these two opposites (Box 5).

Box 5. Time scopes of change in through learning and action with citizens.

- (Scope A) Immediate behaviour changes → Supportive contextual changes
  … Applicable to the Envisioning Projects and Lectures
- (Scope B) Long/medium-term socioeconomic changes → Changes in needs and capacities to adopt alternative behaviours
  … Applicable to the Odate workshop for 2050 net-zero development plan

Once the scope is set, the target engagement process can be determined. The following three targets can be combined with differing weights (Box 6).

Box 6. Three target processes for change through learning and action with citizens utilising the CFP.

- (Target process 1) Individual behaviours (and the knowledge/capacity enabling them) … Applicable to all three cases introduced
- (Target process 2) Collective learning and actions (and the knowledge/capacity/partnerships enabling them) … Applicable to all three cases introduced
- (Target process 3) Policy influence to develop the supportive contexts of immediate or long-term changes in behaviour/socioeconomic contexts … Applicable to the Odate workshop for 2050 net-zero development plan

Based on the scopes and target processes, the discussion topics and the appropriate use of numerical data, including CFP, can be set. The data to be created with or presented with participants include the following, and the possible discussion topics supported by them are summarised in Table 4.

Table 4. Data and discussion topics.

Data Presented or Created	Discussion Supported by the Data
- Present GHG balance of the country/city	- Deepening understanding of the local environment and economic systems, resulting in carbon emissions from energy, industry, transportation, waste management and other sectors and absorptions in the forest and land areas - Understanding about imbalances in the carbon cycle
- Citizens' average CFP	- Gaps between the current and desired target CFP
- Visualising the sources of GHGs along the value chain - Potential reduction of CFP by adopting specific behaviours	- Deepening understanding of the linkage between lifestyles and climate change - Deepening understanding of the consumption patterns depending on imported products and services - Priorities in decarbonising behaviours
- The participants' current CFP	- Deepening understanding of the linkages between lifestyles and climate change
- The expected adoption rate of decarbonising behaviours at a certain point in the future - Implementation ratio of decarbonising behaviours during household experiments or "challenges." - Additional background information, such as demography, economy, and disaster risks	- Reasons for feasibilities or difficulties of adopting specific behavioural changes - Sharing a sense of accomplishment from attaining reduction objectives - Supportive conditions or measures to enable a broader uptake of behaviours - Ideas for crosscutting collaborations to create supportive conditions - Additional benefits caused by changes in behaviours or contexts - Potential negative consequences impacting specific groups caused by changes in behaviour or contexts

(Source: author).

If a project takes (Scope A) above, CFP, actions reducing CFP, and the expected adoption rate of these actions are helpful throughout the discussion. If (Scope B) is set, these data are helpful at the beginning of the discussion. Nevertheless, participants may eventually pay more attention to qualitative information, as described in the bottom-right cell of the above table. That said, additional quantitative data, such as the forecast of demography, economy and disaster risks, will substantially help the discussions.

Finally, the role of participants and experts in creating and sharing data could be considered. Among the above figures, the average carbon footprint and potential emissions reduction by adopting specific behaviours need to be provided by the expert/organisation team. The participants' current carbon footprint could either be calculated by the experts or the participants. The latter case may be more effective in deepening their understanding of the linkages between their lifestyles and climate change, as well as visualising sources of GHG emissions along the value chain. The adoption or implementation ratios must be discussed and jointly calculated with participants. Finally, qualitative information, such as supportive conditions, additional benefits or negative consequences, and ideas for cross-cutting collaborations, should be discussed among participants. Ideally, participants should be invited to the process of data creation as much as possible. However, project teams should usually consider the time limitation and participants' capacities to answer the "who leads the data creation" question.

5.2. Deeper Engagement and Learning toward Systemic Changes

The above clarification of scopes and targets tells us that the use of figures (including CFP) helps deepen the learning among all actors about the contexts linking their lifestyles and climate change, desired changes to achieve decarbonised ways of living, and the necessary actions and collaborations to induce them.

Firstly, the use of individual carbon footprint offers workshop participants a more personalised and tailored view of their consumption and lifestyle's interconnection with the more distant and global issue of climate change. The carbon footprinting method was the trigger for many participants not only to realise their individual behavioural impacts but mostly to feel like they could take an active role in designing collective solutions against the climate crisis. In other words, the method helped bridge the "psychological distance" from climate change [102,103].

Secondly, rather than individual behaviour change for decarbonisation, CFP can be used for learning and collaboration to trigger deeper changes in socio-technical systems. In a workshop of Kyoto citizens conducted by the Envisioning Project, participants shared the opinion that despite the well-developed systems of subways and buses, they are not convenient for residents' daily use. Such opinions indicate that the public transportation infrastructure could not keep up with the increasing demand due to the rapid growth of the tourism sector. Against this backdrop, the decarbonisation of mobility among Kyoto residents should be pursued through a few different means, including improving public transportation and developing alternative mobility options, such as ride-sharing services and promoting bicycling. The citizen workshop in Odate city revealed the difficulty for citizens to alter their extensive use of private vehicles, which enable them to access workplaces, shopping, hospitals, etc., solely for decarbonisation purposes, as public transportation has already been significantly cut down. However, when considering the projections of the city's ageing and shrinking population, it is evident that they need to reconfigure the spatial design of the city and introduce alternative mobility services to secure citizens' accessibility to essential services.

In addition, in the Envisioning project and Odate workshops, participants tried behavioural change options in their homes. Participants experienced and documented the benefits and difficulties of adopting decarbonising behaviours. Participants could adopt about 50 to 60% of planned behavioural changes in all cases. While some of the behaviour changes could not start immediately, such experiences helped broaden their imagination regarding the conditions under which behaviour change could be facilitated more effectively, as well as the potential adverse impacts on specific groups of people. If the goal was solely to achieve behaviour change, the entire intervention would be considered a failure if behaviour changes were not achieved. However, in the citizen-participatory challenge described here, the main objective was to facilitate learnings and discussions based on the difficulties felt by the participants.

More importantly, by linking changes in livelihoods and local social systems for decarbonisation to locally specific constraints and opportunities, participating citizens are motivated to continue participating in the discussions and actions that will shape the future local economy and society. The Odate workshop participants proposed that citizens, governments and businesses should continue to create opportunities for mutual learning and consultation on the local society's current challenges and developments.

The most apparent difference between the methods presented here and those based on the deficit model, providing information to encourage individuals to change their environmentally harmful consumption behaviour, lies in the effect of deepening such learning about the necessity of creating alternative contexts through a broader collaboration. Thus, we can broaden our scope from every single "harmful behaviour" and revisit the systemic contexts we have taken for granted, such as the ordinary conditions of mobility, working, purchasing goods, eating, or taking care of families. Such revisiting encourages citizens and other actors to unlearn the conventional systems supporting our carbon-intensive living and explore possible pathways to engage in local societal changes, either

by leading or participating in collaborative actions [22,105–107] or by joining public debate to formulate collective visions [22,108–111]. Thus, deeper learning facilitated using figures could result in the co-creation of alternative socioeconomic arrangements where people can safely fulfil their day-to-day needs with fewer adverse impacts on climate.

6. Conclusions

Consumption-based accounting has excellent potential to help advance demand-side climate change mitigation with public participation. It allows us to visualise the impact of international trade and economic growth on changes in carbon emissions and transfers between countries and regions and helps examine the social and technological institutions that supply services and goods in the context of current carbon emissions and footprints. It can also help identify the impact of specific groups' consumption behaviours on climate change and suggest the most impactful changes in mitigating climate change. However, the approach to using CFPs to propose individual behavioural changes, based on the deficit model, cannot take full advantage of the characteristics of consumption-based analysis to allow a deeper consideration of the socioeconomic conditions behind the current carbon-intensive patterns of living.

To achieve more effective and deeper change using the characteristics of CFP, we need to re-examine the meaning of "using data to engage citizens". Instead of encouraging immediate behaviour change for individuals, we should consider using the data to co-create the knowledge that links citizens' day-to-day experiences to the broader socio-technical contexts. In this way, we can support participants to re-examine the social, economic, and other factors influencing their current behaviour, to explore the potential of alternative socioeconomic arrangements, and invite citizens, government, businesses and other actors to collaborate toward realising alternative future societies. The three cases presented in the paper used CFPs to facilitate learning among the participants to envision alternative patterns of living in future societies and consider desired actions to enable the changes. In this respect, they demonstrate the potential of CFP to lead to deep change, as opposed to the approach of using CFP to propose individual behaviour change. Through their engagement in experimental actions, collaborative learning and creation of visions, workshop participants and other stakeholders, such as researchers and local government officials, are capacitated to run the cycles where action leads to decision-making, leading to further action and demands for broader involvement. Citizens' engagement happens in different domains, namely, private consumption behaviour, collective actions and learning and public actions are linked to driving a more holistic transformation at the societal level. In the case studies presented here, CFP did not only help citizens to develop knowledge about climate change and decarbonised living but also try some behavioural change options and learn from their experiences, and deepen the discussion about desired collaborative actions toward creating the sociotechnical contexts enabling further changes. On the other hand, these cases did not immediately lead to continued engagement in the systemic changes in collaboration with a broader range of actors. To connect citizen discussions and home experiments to ongoing opportunities for collaboration, resources, such as time, money, and manpower for activities, should be secured.

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