



Article

A Future Outlook of Narratives for the Built Environment in Japan

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Abstract: The evolution of long-term sustainable societies is closely connected to the transformation of the physical built environment in which those societies operate. In this paper, we present a comprehensive set of narratives for the built environment in Japan, consistent with the shared socio-economic pathways (SSPs) framework, to assess the future evolution of the adaptation and mitigation challenges. We focus on the linkage between sustainability factors and human living environments including urban form, buildings, and basic infrastructures. We introduce a new, sixth narrative to the SSPs, an alternative interpretation of SSP1. Whereas the original SSP1 assumes high societal and environmental sustainability combined with relatively high economic growth, the SSP1 variant does not highly rely on economic growth and is oriented towards a lower and more locally oriented consumption lifestyle. Nature-based solutions are integrated and examined in the new SSP1 narrative, which is aligned with the adaptation to the digital era with freedom of location. Recent global crises such as climate change and the COVID-19 pandemic may accelerate the transformation of societies. Therefore, this study attempts to imply the benefits and trade-offs of alternative pathways for the built environment.

Keywords: sustainable development strategies; long-term scenario analysis; SSPs; cities; nature-based solutions; well-being; beyond growth; regional circular economy; resilience



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1. Introduction

The built environment constitutes the setting where human activities take place [1]. Its design, construction, and use have great influence on the general organization of society and day-by-day human activities [2]. At the same time, the evolution of the built environment reflects how society is organized and how human activities take place. The individual buildings and infrastructures drive energy use in the residential and commercial sectors, whereas the spatial organization of the built environment is an important driver of transport energy use [3]. Buildings and transport account together for 55% of current global CO₂ emissions [4] and approximately 50% of total energy consumptions in Japan [5]. Therefore, the built environment plays a central role in climate change mitigation and sustainability transitions.

There are several challenges associated with the evolution of the built environment [2,6,7]. First, the built environment evolves slowly, due to the longevity of buildings and infrastructure. Second, the final shape of the built environment emerges as the result of many individual decisions by a range of actors and cannot be governed by actions of an individual actor or authority. Third, these heterogeneous actors are driven by a multitude of interests, such as preferences for homes, access to services and to nature commuting times, or environmental impacts, which can all evolve in different directions in the future. Hence, exploring the possible future evolutions of the built environment under different socioeconomic futures is crucial for supporting strategic decision making and understanding their broader implications towards sustainability [7–9].

The built environment in Japan has historically evolved following the natural geographical environment as approximately 70% of Japanese land is covered by forests and mountainous areas. However, modern developments, specifically after the industrial revolutions, significantly changed the built environment and lifestyles. Recent overall construction decision making and lifecycles are hugely influenced by the economic growth trend [10]. Large cities increased the populations and work forces that expanded the inequalities between cities as well as urban and rural. To achieve the sustainable society, there are urgent needs to rethink the alternative key drivers to transform the fundamental organizations of infrastructure and the other components related to the built environment.

Scenarios have been widely used in environmental change research to explore future socio-economic and environmental consequences of human activities in the long term [11]. Scenario development helps to be prepared for possible eventualities and stimulates strategic thinking by creating alternative futures [12,13]. The shared socio-economic pathways (SSPs) were developed over the past decade to facilitate integrated analyses and assessment of global environmental change [14]. The SSPs have been defined very widely and open at the global level, and use narrative storylines and quantitative indicators to describe alternative global trends in society and natural systems evolution over the 21st century [15]. The SSPs have been used on a global level [16], but also national and subnational [17], cities [18], as well as sectoral [19] applications have emerged. Further extensions of the SSPs, addressing national and regional assessment would allow incorporating regional specific drivers, reflecting national policies perspectives, and being consistent with national statistics to better support assessment of climate impacts, mitigation and adaptation at national and subnational level [14,20,21]. However, when it comes to sustainable development, global environmental scenarios including the SSPs, have been dominated by globalizing, high-growth sustainability scenarios. Developing alternative future sustainability narratives would enable exploring different pathways towards achieving sustainability. This was also flagged by O'Neill et al. [22], highlighting the need to capture more perspectives in the set of SSPs as a key future development of the scenarios framework.

While the SSP framework, and more in general the scenario approach, has been applied to many aspects related to sustainability, studies on scenarios for a sustainable built environment have been limited [1,18]. Exploring plausible futures for the built environment would contribute in a more informed assessment of adaptation and mitigation strategies for strategic planning and policies [23].

In this paper, we present a comprehensive set of narratives for the built environment in Japan, consistent with the SSP framework, to assess the future evolution of the adaptation and mitigation challenges. We focus on the linkage between sustainability factors and human living environments including urban form, buildings, and basic infrastructures. In doing so, we interpret basic SSP quantitative indicators in the Japanese context. Population growth and urbanization, especially rural to urban and urban to rural migrations are key factors that determine the future built environment in Japan. This study aims to investigate the benefits and trade-offs of these alternative sustainability narratives for the Japanese context. This set of narratives can be used by policymakers, stakeholders, and researchers to assess the implications of alternative futures for the built environment.

We also introduce a new, sixth narrative to the SSPs with low challenges to both adaptation and mitigation. Whereas the original SSP1 assumes high societal and environmental sustainability combined with high economic growth, we developed an SSP1 variant with lower growth and oriented towards a lower and more locally oriented consumption lifestyle. We introduce this alternative SSP1 pathway and elaborate its details for the Japanese built environment.

The outline of this paper is as follows. Section 2 describes our methodology and provides background on the SSP framework. Section 3 provides theoretical background on historic transformations in Japan and the definition of sustainability in the Japanese context. Section 4 presents the new narratives and Section 5 discusses the differences between the growth-based and beyond-growth sustainability scenarios. Section 6 discusses the global

crisis, their impacts, and recovery strategies on reaching any of the six scenarios. Finally, Section 7 concludes the paper.

2. Methodology

In this study, we expand the framework of the shared socio-economic pathways (SSPs) to the Japanese built environment. The SSPs are a set of alternative, long-term futures for human society [14,15]. They have been developed over two axes of future climate-related uncertainties: socio-economic challenges to mitigation and socio-economic challenges to adaptation. SSP1 represents a world with low socio-economic challenges to both adaptation and mitigation, whereas SSP3 represents a future with strong challenges for both dimensions. SSP2 represents an intermediate situation, with both adaptation and mitigation challenges at a medium level. In SSP4 and SSP5, adaptation or mitigation challenges dominate, respectively. At the global level, the SSPs have been defined as minimal as needed to be able to associate them with one of the quadrants of the challenge space. The global SSPs exist of a broad narrative [14], a quantification of main drivers of global environmental change: population, GDP, and urbanization. This allows for local and sectoral interpretations and to enable developing nested storylines and quantifications [24]. Hence, while the SSPs were originally developed and applied at the global level [16], they have been extended to the regions, countries [17], cities [18,20], and sectors [19] including the buildings sector [8,10,25].

The SSPs are formulated as exploratory baseline scenarios that initially describe the evolution of society without mitigation of climate change and without the impacts of climate change. Once the SSPs are combined with representative concentration pathways (RCPs) [26], the mitigation effort and the impacts of climate change can be taken into account. Contrary to this approach, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) recently presented a new set of Nature Future scenarios, which are target scenarios describe different ways of reaching a future with high biodiversity [27,28]. In this study, we followed the methodology of the SSPs and describe exploratory narratives of future evolution of the Japanese built environment.

The narratives for the Japanese built environment have been developed in several steps. We first developed a list of aspects that would be relevant to be covered by the scenarios. This list includes basic elements and drivers of the built environment (such as population, urbanization, economic growth, and inequality), which are taken further from existing global SSP [14] and Japanese SSP implementation [17]. The second aspect is the shape of cities and neighborhoods, including urban form, access to nature, access to basic services, and infrastructure. The basis was previously formulated in the city scale SSP implementations [18,20]. The third group of aspects are the buildings themselves, including evolution in building types, housing size, and energy efficiency. Finally, the scenarios should include narratives for how people behave in the cities and buildings. Summarized under lifestyle, this includes floor space, production and consumption patterns, commuting, and energy demand. In a second step, we have mapped evolutions across all SSPs to these aspects defined above. We grounded our inputs on previous works [10,18], statistics for Japan, existing literature on urban and building theory, scenario and trends that have been referred in this paper and the previous works, and expert knowledge. A third step consolidated these individual elements into consistent narratives to describe a coherent story for each scenario. Each scenario is illustrated with graphical pattern language to summarize all aspects of the scenarios in a single figure.

After developing a first version of these scenario narratives, the author team presented these for feedback to a stakeholder panel, existing of developers and users of scenarios with a range of expertise across Japanese society, history, spatial planning, built environment, and environmental scenarios. The workshop was held online due to the COVID-19 pandemic. A total of 15 experts joined the panel from Japan, Asia, and Europe. The author team presented the scenario narratives using scenario pattern languages including demographic, population distributions, urban form, buildings, lifestyle, and linkage with

society 5.0, which is described in Section 6. The discussions were focused on the benefits and trade-offs of centralization and decentralization, mitigation strategies, adaptation risks and COVID-19, building technologies, digitalization, nature-based lifestyles, and culture aspects that may influence the well-beings and long-term socioeconomic transformation in Japan. Based on feedback from this panel, the scenarios were updated and finalized.

3. Theoretical Background

3.1. Japanese Experiences of Urban and Societal Transformations

Japanese society has experienced high economic growth, as well as high urbanization, in line with large-scale new constructions and urban expansions during the 1960s–1980s, before the economic downturn in the 1990s. During this period, Japan experienced transformations in land use, administrative boundaries, and political and economic functions. It was a period of innovations and new markets were promoted globally. Average quality of life increased dramatically, and all cities were connected by an efficient high-speed train network and local public transport systems. Population of large cities increased, while the costs of basic living increased as well, specifically for housings.

The largest influence on the current land use and network of each region comes from the industrial revolutions in the 19th and 20th centuries. Following the global industrial revolution, Japan formulated an important megalopolis called Tokaido [29]. The first rapid train, Shinkansen, connected the three major large business cores: Tokyo, Nagoya, and Osaka. Based on this strong industrial zone, an intensive industrial belt was developed. Throughout these new industrial eras, developing mega infrastructures was considered the key to enhancing local economies. In addition, the increased use of concrete, steel, and glass changed the fundamental structure and functionality of urban environment and buildings. Building plans were no longer bound by structural constraints. This was a significant transformation for most existing cities in the period of modernism. At the same time, spatial planning became more precise and categorized according to function. A mixed-use strategy was developed through the vertical city concept, and a number of cities changed their skylines dramatically by making use of new technologies and materials. Postwar reconstruction dramatically changed Japanese urban areas with modern layouts. During the 1950s and 1960s, economic growth was the main priority of the Japanese government, resulting in concentration of population and productive capacity in the large metropolitan regions of the Pacific coast. At the same time, the decrease of population in peripheral areas had already started. To adapt to the rapid urbanization and population increase in Japan, the 1960 Tokyo plan was announced by Kenzo Tange, which aimed to transform the urban structures from a monocentric urban form to a more organic urban form that had a flexible road, transport, and building system network, called the cycle transportation system.

After commercialism influenced building space and functionality (in the period of postmodernism), building space became more manufactured, and space and shape were frequently used as a communication interface (e.g., Las Vegas, Broadway, New York) [30]. This global trend also influenced the Japanese built environment. In this period, the theory of metabolism was developed by Japanese architects, representing the effective production system of standardized housing. The functionalities became more focused on extensive economy and new developments, which led to the bubble economy in Japan in the 1980s.

However, after the economic bubble burst in the 1990s, the local development plans focused more on sustainability. Several sustainable communities and ecotowns were planned by private developers and engineering companies. At the same time, showcase projects were introduced. Japan also introduced many transit-oriented development projects, which were effectively integrated into regional planning and implementation schemes. Furthermore, energy efficiency for buildings became more central to urban climate change strategies and energy savings for urban resilience schemes. While such advanced technological transformation becoming more central in national environmental strategies, quality of living space and public realm were also considered to improve human well-being.

The Great Tohoku Earthquake in 2011 and more recent disasters, including the pandemic in 2020 (COVID-19) led to changes in Japan. The COVID-19 pandemic is changing lifestyles in large cities globally; alarming people that concentration of human activities and functions increases risks. High-density areas are very vulnerable for risks like pandemics or large earthquakes. Throughout these experiences, an urgent shift to efficient and sufficient new living environments is significant [31]. Aging population is another issue in Japan; old infrastructures and vacant housing stocks increase the social risks. Significant decarbonization to reduce the negative environmental impacts on the earth's system has also been a common global agenda.

3.2. Transformation of Fundamental Lifestyle and Well-Being in the Japanese Context

During the economic and material growth of the past decade, Japanese society learned that quantity does not equal quality; more does not always mean better. This can be recognized as “diminishing marginal utility” of goods (or income). It is clear that there is no simple linear pattern that describes that more commodities and materials increase satisfaction [32]. The recent more individualistic and competitive society has increased social inequality and separation. Cooper and Layard [33] indicated that the significant causes of happiness in society are the quality of human relationships and mutual trust. To develop such quality of external social relationships, education and individual behavior are important factors. Furthermore, individual happiness is hugely influenced by one's objective status within the living norms [34]. This suggests that social equality is a key to increase overall wellbeing in a society.

Japan was mainly transformed by the market-driven development after the world war period. Large public funds were invested in infrastructures that could accelerate local economies and further development. With the increase of household income, individual consumption also grew rapidly. At the same time, this trend caused serious environmental problems. During this period in the 1960s to 1980s, rural–urban migration steeply increased, which led to urban sprawl in large cities. Bigger cities have provided more opportunities and activities, as well as the expectation of income increase [35]. Such Japanese development was mainly initiated by the private sectors; thus, the number of small-scale scattered developments was promoted and expanded. This market-led planning determined the current urban forms in cities and cultural contexts. However, public spaces were not effectively designed and managed by the public sector, which resulted in a huge lack of comfortable public and green space within communities and cities. This lack of adequate public service spaces decreased the quality of urban amenities and well-being in large cities, and shrinking local cities lack sufficient funds to maintain such public spaces. Therefore, growth-dependent planning involves huge risks of reducing the value of land and local assets, as well as increasing social and environmental problems [36].

Ancient Japanese traditions, on the other hand, still exist in housing planning and daily individual habits. Japanese traditional housing involved *summer installation* and *winter installation*. The *summer installation* would mainly use *Sudare*, which hung in front of the windows and could be replaced by a green wall with seasonal flowers and vegetables. *Sudare* has the function of a modern architectural louver to cut off the sunlight in the morning and the evening. Additionally, the Japanese traditional paper sash *Shouji* has the function of diffusing sunlight and bringing light into the room. These facilities are all made with traditional local natural materials. The space functions are also very flexible, with movable paper partitions called *Fusuma*. In winter, these partitions can effectively organize a very small space to minimize space heating. *Kotatsu* is a small, efficient space heater attached under the table. People cover the *Kotatsu* table with a *Futon* in winter, and *Kotatsu* can be used as just a table without a *Futon* in summer. Such flexible functional transformation was frequently used in traditional Japanese society. These features also vary in different regions with different climate conditions. Nowadays, many people install the same air conditioning for much larger living spaces following the LDK design, which describes a room for living, dining, and cooking in Japan, becoming the center of Japanese

house and apartments. Although cities and housing have been transformed and adapted to modern living, traditional interventions in society and communities are reflected in housing plans and the public realm. Community cooperation and sharing were traditionally inherent Japanese habits; thus, historically, the boundaries in housing, neighborhoods, and regions have not been clearly defined. Such ambiguous planning may increase social interactions and communications in Japanese society. Furthermore, because of diminishing returns of increasing consumption to human wellbeing and satisfaction, social norms might be more important, by which individuals can utilize their capabilities to realize satisfaction and sympathize with each other [37].

Location, on the other hand, may not be an essential determinant for future cities and sustainable living as a result of digitalization. Cities have played significant roles as a sort of machine since the industrial revolutions, as the physical network has been a key factor to create good economy, social interactions, and daily human activities. However, with the evolution of the digital era, the functions of cities, locations, and morphologies could change beyond all recognition, manifesting the networking and distribution of human activities [38].

3.3. Nature-Based Solution toward Sustainability beyond Growth

Natural land supports basic human needs and the ecosystem's functions and services [39]. Nature-based solutions for cities are relatively new ideas involving social, ecological, and technical innovations in urban development strategies [40]. Moreover, nature-based solutions have recognized benefits of improving urban air quality, heat mitigation, carbon sequestration, and natural hazard protections. These public ecosystem services are also more important for the well-being of vulnerable and high-risk residents [41].

At the same time, sustainable human living significantly relies on technological innovations and on the appropriate application of technologies. This suggests an increasing importance of considering the life cycle of all living needs and the positive and negative impacts on nature and on human societies. For example, technological innovation can more effectively utilize natural ventilation with passive smart systems. Smart agriculture systems can support the effective use of local natural resources and quality production systems [42]. These innovative systems are also required for regions that lack basic infrastructures or have been affected by natural destruction, such as rapidly developing regions. The balanced sustainable strategies must be framed by discursive and resource provisioning processes and involve all related actors in the innovative systems [43,44].

Recently, different visions for the future association between people and nature have been investigated by the IPBES scenario team [45]. This study investigates the changes in social-cultural values and changes in practices including indirect and intangible benefits. The scenario framework involves global ecosystem services flow as well as localization of ecosystem service flows. The framework is described in triangles consisting of 'nature for nature', 'nature for people', and 'nature as culture' [27,28]. In Japan, the *PANCES* scenario has investigated the potential changes in natural capital and ecosystem services. Its key storyline includes natural capital based dispersed/compact societies, and produced capital based dispersed/compact societies, with examining the direct and indirect drivers such as climate changes, depopulations, super-aging, and technological innovations [46]. Recently, the Ministry of Environment Japan has introduced a new integrated strategy called 'Regional Circular and Ecological Sphere' (RCES). The RCES concept incorporates the low-carbon society, resource circulation, and living in harmony with nature, which is also expected to support the Japanese carbon neutral target.

While the industrial revolutions brought great progress to humanity, it has left many vulnerable behind with the negative consequences of climate change and biodiversity loss [39,47,48]. A social transformation includes fundamental changes in norms and belief systems [49], including a mind-shift to reconnect to the Earth nature system and biosphere [50] can lead to environments built for humans—including cities and rural areas that are based on harmony with nature. People's belief systems, including sacred and

historical traditions, influence landscape transformations. These place-based landscapes are strongly connected with local natural systems and with people's customs. A bioregion organized by organic natural landscapes, local climates, and people's cultural activities can be strongly revitalized with support from local food, water, energy, and other resources [51]. In addition, innovative technologies can also help identify natural landscape boundaries and utilize local circular resource systems [52].

A number of countries and regions show strong nature-based lifestyles. Their vernacular housings are well-adapted to local climates and resources [53]. Many of these housings minimize energy use via the maximum use of natural ventilation and have minimum space for sufficient living. Finland and Japan, for example, have similar beliefs concerning fairy-tales in natural contexts. Many people traditionally believe that god and fairies live in nature as their neighbors. They direct their settlement patterns and lifestyles to this and it prevents them from destroying the local environment. This also leads to their satisfaction with sharing local blessings of nature with their neighbors, which constitute the strong local network and communities. This suggests that the beliefs and mindsets within their lifestyles have huge potential to revitalize place-based natural systems and resources while increasing efficiency [54–56]. Nature-based solutions can increase equity and well-being for all local residents when adapting to climate change.

4. Narratives of Pathways for Japan

The six SSP narratives are developed based on the global SSPs [14] as well as Japanese interpretation of these narratives [17]. These SSPs specifically target the narratives of the built environment, therefore, the approach of scale-based investigation (National, City, Neighborhood, and Buildings) is used to downscale the macro observations to the human scale. For analyzing the built environment, urban form factors and human settlements (urban–rural migration and buildings) are the key elements that were previously analyzed for Japan in the city scale Tokyo SSPs [10,18]. Urban–rural migration and lifestyle factors are also key factors to achieve the balanced sustainable society in Japan.

Based on the nature-based solutions and traditional considerations above, we developed SSP1 along two alternative pathways: 'Growth-dependence', and 'Beyond-growth'. Growth-dependent society focuses on economy-driven sustainability with intensive upgrades of high technologies and large-scale infrastructures. In contrast, 'Beyond-growth' focuses on the local/community based circular economy with sufficient green infrastructures. These concepts are theoretically investigated within the Tokyo SSP scenarios as 'efficiency scenario' and 'happiness scenario' [18]. The efficiency scenario required the successive upgrade of new technologies and infrastructures to achieve the maximum efficiency, while the happiness scenario focused on the local assets, human capitals, and well-being with quality amenity spaces for maximizing the social equity. The scope of the efficiency and happiness factors are extended in this paper and put in the context of a growth-dependence and beyond-growth interpretation of sustainability. An overview of the scenario assumptions and their visual representation using pattern language are reported respectively in Table 1 and Figure 1.

4.1. SSP1 Growth-dependence

The global SSP1 is a scenario of commitment towards achieving sustainable development goals, increased environmental awareness in societies, and a gradual shift to less resource intensive lifestyles [14]. In Japan, the settlements in megaregions and local cities are well connected and realized compact efficient transformation. These megaregions are still the central driver of the domestic economy and keeping such annual economic growth is still significant to maintain and upgrading the basic infrastructures and quality of life. The SSP1 Growth dependence scenario has its foundation in the SSP1 with a strong focus on technological development and physical infrastructures.

Cities/Neighborhoods. A balance between metropolis, middle size, and small cities is reached. The urban form is compact for improved energy and resource efficiency, especially

in bigger settlements. Modern and efficient infrastructures serve both major and smaller cities, which are highly interconnected and provide excellent access to services. Access to green areas is limited in city centers and moderate in suburbs, however, between each urban cluster increase.

Buildings. High-rise to mid-rise buildings prevail everywhere, ensuring compact urban form. Mixed-use building increases. Housing size is relatively larger than today, following income growth. However, energy and resources requirements substantially decrease due to the use of hi-tech materials and technologies for buildings, and diffusion of smart zero-energy buildings. Demolition and new construction prevails over renovations, and robotic fabrication is increasingly used for efficient rapid construction. Low-income houses are upgraded and the living standard improved.

Lifestyle. Speed and efficiency are still keys to achieve quality of life and sufficient economy. People commute with quality public transport and these infrastructures are well connected to each urban cluster. Vertical and horizontal access increases in large cities. The vertical commutes become new neighborhood axis to create the new communications with people and goods.

Mitigation. Relatively large-scale clean energy production and large-scale renewable energy productions can effectively support the mitigation. Increase of high-rise mixed-use buildings, net-zero and energy plus housing and buildings can be strong pillars of mitigation strategies in specifically urban cores as well as advanced smart transport system such as mobility-as-a-service (MAAS) and electric vehicles (EV).

Adaptation. Urban heat islands can be effectively managed with trees, rooftop greening systems, and green facades in urban areas. However, although the heat island is not serious in rural areas, they are relatively under the risk of landslides and flooding.

4.2. SSP1 Beyond-growth

The SSP1 Beyond-growth represents a drastic transformation from the conventional sustainability concept. In comparison to the global SSP1 [14], income growth rate is lower but stable, human settlements patterns and human lifestyles are more regional and cultural oriented. Nature and local resources as well as local economy are effectively maintained and circulate within their local regions, while these local communities and assets are effectively connected with other domestic and global regions by high spec technologies.

Cities/Neighborhoods. Urban settlements are characterized by a satellite, polycentric configuration centered around communities. Community-based infrastructures prevail and are efficiently organized and maintained, providing excellent access to services. The satellite urban form provides improved access to nature and communal spaces. Ecosystem services are utilized in the cityscape and neighborhoods, which can decrease the urban heat island and increase the human well-being. These natural system networks and preservation can also prevent the natural disasters.

Buildings. Mid-rise and low-rise prevail, along with house sharing and co-housing, consistent with an improved sense of community. The housing size decreases as a result of more diffused co-housing and housing sharing, reducing energy, and resources use. Average housing size is similar across different settlements. Demolitions and reconstructions decrease, in favor of renovations, reducing resources requirements. Vacant housing and buildings are effectively reused with flexible functional changes. Local materials and wood are preferred to industrial materials with upgraded energy efficiency standard (vernacular smart buildings). Communities are involved in construction processes and local nature-based and recycled materials are predominantly used. Energy efficiency of buildings moderately increases as a result of bioclimatic building design and passive solutions, reducing the need for mechanical heating and cooling. The use of energy is more frugal, as population environmental awareness increases. Access to decent housing becomes universal, as low-income settlements are upgraded and improved with the involvement of local communities.

Lifestyle. People are more connected to their family, neighbors, and communities. The community-based movement increases instead of long distance commuting. Overall daily necessity can be obtained within community and neighborhood. Sharing local economy can enhance the community network and resilience. People are more satisfied by their ordinary life with quality of natural and public spaces.

Mitigation/Adaptation. Balanced population distribution allows creating and preserving the natural boundaries, where natural wind paths and green ways are effectively maintained, which supports both mitigation for energy efficiency and adaptation for heat impacts management. In mitigation for human settlements, ecosystem services also greatly support the creating effective shades and increase of natural ventilations. Natural disasters associated with constructions are moderated by local forest management and community park management.

4.3. SSP2

SSP2 represents a development pathway consistent with a continuation of historical trends [14]. Japan experiences significant population reduction, decline in birth rate, and population aging, along past trends [17].

Cities/Neighborhoods. Urban settlements become more monocentric, with increase of large cities and shrinkage of smaller cities. Infrastructures are well developed in big cities, but collapsed in many small suburban communities. Access to nature is limited to urban parks in large cities and rural areas lack the maintenance.

Buildings. Current trends continue, with high-rise and apartment buildings dominating major cities and floorspaces per capita moderately growing. Continuous modern technologies and materials are used in construction, where demolitions and reconstructions prevail over renovation. Energy efficiency of buildings moderately increases following current trends.

Lifestyle. People in large city can easily access the effective public transport, while people in local cities and suburbs more use their own cars. Young people prefer moving to larger cities for education and jobs. The daily works are conventional office-base, thus, the peak demand for energy and transport is high in large cities.

Mitigation. Updated construction of buildings and infrastructures increases energy efficiency. A well-connected efficient urban transport network also contributes to the mitigation. However, buildings stocks and conventional car use in rural areas are not effectively improved. Therefore, the overall mitigation is moderate.

Adaptation. Urban spaces still suffer from urban heat island and waste heat from the buildings. Natural disasters occasionally happen, mainly in coastal areas and foothills, however, the prevention systems have not covered all of high-risk areas.

4.4. SSP3

SSP3 is a scenario of regional rivalry, international fragmentation, and reversal of globalization trends [14]. In Japan, the theme of SSP3 is social division, with strong migration to urban areas and decline of rural areas, where many communities disappear [17]. Technology advancement is delayed, resulting in declined competitiveness and economic stagnation. Challenges are high in both mitigation and adaptation.

Cities/Neighborhoods. Social division is reflected by the increased disconnection between monocentric big cores and small communities. Domestic migration from rural areas to major cities leads to augmented disparities, impoverishment of local communities and disappearing of smaller cities. Infrastructures are poorly maintained and access to basic services limited. Cities have reduced green areas and increasingly larger abandoned land.

Buildings. High-rise buildings in the big core clash with extended slums and poor quality buildings in the suburbs. Many buildings are abandoned as effect of population shrinkage. Low maintenance of buildings leads to a rapidly aging building stock, while new construction stagnates and technological improvements are only marginal. Use of

low-cost and energy intensive materials prevails and improvements in the energy efficiency of buildings are modest.

Lifestyle. Because of huge social segregation occurring, social communities are also separated. Daily goods are only sufficient in large core cities. Education and jobs are also concentrated in such cities. Only centers of large mega cities have effective access to public transport, however, capacity cannot be matched with their residents.

Mitigation. Large rural–urban migration increases the demand of housing stocks and energy use in large major cities, which accelerate the new constructions as well as reuse of old building stocks. While new constructions partly contribute to mitigation, huge energy inefficient old stocks are not renovated. Large cities expand to suburbs where public transport cannot be effectively linked, which increase the car-oriented dwellings. Therefore, overall mitigation challenges are high.

Adaptation. Shrinkage decreases the maintenance of all infrastructures, which significantly increases the disaster risks and decreases the resilience. Overall adaptation challenges are high.

4.5. SSP4

SSP4 is characterized by inequality, both across and within countries [14]. In Japan, the disparity increases between urban areas, occupied by the political economic elite, and other areas, where more socially vulnerable live [17].

Cities/Neighborhoods. Cities reflect this fracture and are characterized by rich and dense city centers served by modern infrastructures, opposed to vast suburban areas dominated by poor infrastructures and lack of urban planning. The urban form is compact in the city centers, providing excellent access to services and moderate access to nature. Sprawls and slums denote other areas, which suffer from insufficient access to services and nature.

Buildings. High- to mid-rise buildings in major cities are face-to-face with slum and modest buildings elsewhere. Demolitions and new constructions accelerate in major cities, driven by rapid technological development and automation. In other areas, construction stagnates and poor-quality construction prevails. Housing size increases moderately in central areas and decreases elsewhere. Moderate energy efficiency improvements occur in central areas only, leaving the remaining part of the building stock largely inefficient. Energy intensity remains relatively low, as the poor cannot afford properly heating and cooling their energy inefficient homes, resulting in diffuse fuel poverty issues

Lifestyle. High education and white-collar jobs are concentrated in large cities. Thus, the lifestyle in large cities has a variety of social services and selections of goods. The city center becomes more highly dense and mixed use with housing for specifically high-income residents. However, local cities and suburbs suffer from inadequate conditions of infrastructures and services, which are under the risk and sometimes increase the criminals. Disaster risk management is not well organized, thus, the heavy rains and snows often prevent daily activities and local economies.

Mitigation/Adaptation. Mitigation is overall improved thanks to the technological progress and positive political wills. However, inequality seriously exists. Therefore, between cities and social clusters there are large differences in both mitigation and adaptation. Specifically, adaptation risks are seriously high in the coastal areas, river-bed areas, and foothills under the high mountains. The social vulnerable remain in these high-risk areas.

4.6. SSP5

SSP5 accelerated globalization and development occur. Challenges to mitigation are high due to fossil fuel-driven development [14]. Challenges to adaptations are low as a result of the attainment of human development goals, economic growth, and highly engineered infrastructures [17].

Cities/Neighborhoods. High urbanization leads to compact city centers with high-rise buildings and growing suburb areas. Infrastructure development accelerates everywhere

along with improved service accessibility. Access to green space is limited as urbanization increases with lower attention to nature.

Buildings. New mid- to high-rise buildings flourish everywhere. Demolitions and new constructions accelerate, driven by the economic growth. Housing size moderately increases along with rising income levels. Energy efficiency moderately improves, but is counterbalanced by larger housing size and intensive use, resulting in higher energy demand.

Lifestyle. Increase of both international and domestic migrations to the major cities. Globalization is accelerated, which leads to the diversity of lifestyles. However, at the same time, the social disparities among citizens and cities increase. Owing to the high economic growth, most of large cities can access to the variety of goods, however, the overall quality of life is not increased due to the social inequality. Moreover, the deployment of new artificial intelligence increases the social inequality with serious job losses.

Mitigation/Adaptation. Accelerating economic growth significantly increases the energy demand in both urban and rural areas. Intensive fossil fuel based industries are mainly located in suburbs nearby large cities. Logistics related to the industries and commutes increase, producing huge carbon emissions. Overall, mitigation challenge is significantly high. On the other hand, owing to the economic growth, disaster risk management is well promoted and number of buildings can install the disaster risk prevention systems effectively. The high-risk residential areas can be relocated to the safe sites. Adaptation is low challenge overall.

Table 1. Overview of the scenario assumptions.







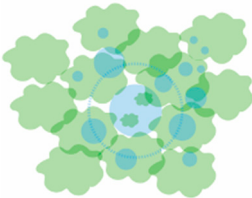
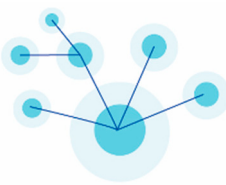



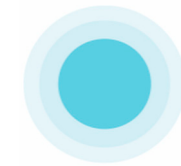
Shared socio-economic pathways (SSPs) Element	SSP1 Beyond-growth	SSP1 Growth-dependence	SSP2	SSP3	SSP4	SSP5
Basic elements						
Population [17]	Moderate decrease	Moderate decrease	Moderate decrease	Strong decrease	Strong decrease	Marginal decrease
Population density pattern (Distribution of DID * area, SSP2 represents current.)						
Rural–Urban migration	Relatively small	Increase	Increase	Stay same	Increase	Increase
Urban–Rural migration	Increase	Relatively small	Relatively small	Stay same	Relatively small	Decrease
Urbanization	Slight increase	Slight increase	Constant	Decrease	Slight decrease	Strong increase
GDP growth [17]	Moderate (Lower than SSP1 Growth-dependence)	Moderate	Moderate	Low	Moderate	High
Inequality	Decrease	Relatively decrease	Increase between large and small cities	Increase	Increase between large and small cities	Strong increase
Cities/Neighborhoods						
Urban form (Representative characteristics)	Center core and satellite clusters.	Balance between metropolis and middle-small cities.	Unbalanced monocentric with shrinkage.	Monocentric. Small cities at risk of disappearing.	Division between central and surrounding areas.	Monocentric.
Representative urban form diagram						

Table 1. Cont.

Shared socio-economic pathways (SSPs) Element	SSP1 Beyond-growth	SSP1 Growth-dependence	SSP2	SSP3	SSP4	SSP5
Access to quality of nature	Green neighborhoods with access for all the residents. Good functions for food production, green spaces, and daily activities.	Urban centers with limited access. Suburbs with more access and well conserved.	Urban areas with access limited to parks and rural areas (agriculture + forest)	Suburbs with limited green space. Not well maintained.	Rural areas with good access. Not well maintained with some disaster risks.	Urban areas with little access. Little attention paid to green spaces.
Access to basic services	High. Balanced and flexible small scales service networks are more adopted.	High. Center has better access overall.	Medium. Large cities have better and higher quality services.	Low. Service networks are old and inefficient.	Low (unequal). Large cities have high quality services. Small cities and suburbs have insufficient services.	High. Urban centers have better quality and secured access.
Infrastructure	Service infrastructure is decentralized and community based.	Centralized and heavy service infrastructures are located outside of cities.	Only center is well maintained. Maintenance is fragmented in suburbs.	Only large cities have sufficient maintenance.	Maintenance and upgrades rely on the densities and their local economies.	Further extensions occur in large cities for new residents and industries.
Buildings						
Building types	Mid-rise and low-rise. Wooden buildings increase. Local materials increase.	CC: high-rise. S: mid-rise to low-rise. Non-wooden buildings increase.	CC: high-rise. S: mid- to low-rise. Non-wooden buildings increase in large cities.	CC: high-rise. S: low-rise. Vacant buildings increase in suburbs and local cities.	CC: high-rise. S: low-rise. L: mid-rise and low-rise (wooden housing).	CC: high-rise. S: mid- to low-rise. Vacant buildings significantly increase in local cities.
Energy efficiency and technology	High. Hybrid systems (automation and natural ventilation) are adopted and improve energy efficiency and material use.	High. Overall smart automation systems are adopted and significantly increase energy efficiency.	Moderate. New updated buildings install efficient technologies.	Low. Old stocks increase and efficient technologies cannot be installed overall.	Inequal. Energy efficiency improvements and new technologies adoption heavily depend on income groups.	Moderate. Only large cities significantly improve energy efficiency and upgrade the technologies.

Table 1. Cont.

Shared socio-economic pathways (SSPs) Element	SSP1 Beyond-growth	SSP1 Growth-dependence	SSP2	SSP3	SSP4	SSP5
Building life time	Overall life time is extended with increase of renovations and reuse of vacant space, while local housings (wooden) have relatively short cycle.	Increase.	Constant with some renovations.	Short.	CC: Constant with some renovations. S: Short.	Decrease with high economic growth.
Lifestyles						
Space per capita	Relatively smaller than today.	Relatively larger than today.	Stay same.	Relatively small space in urban and large in rural.	Increase in higher income areas, decrease in lower income areas.	Overall relatively small due to the limitation of land space.
Production & Consumption patterns	Decentralized production system with local circular economy.	Centralized production system with efficient domestic and global logistics systems.	Existing production clusters and large cities that are center of consumption.	Mismatched production and consumption within the domestic markets.	Significant inequality in consumption among domestic regions.	Increased overall production and consumption with less improvement of efficiency.
Commuting	Sharing mobility as well as small scale public transport increase. Walking and cycling are promoted.	Speed and efficiency are key. Vertical access also increases with high-rise buildings.	High speed connections are accelerated within the country. However, local transport systems are not sufficient.	Only large cities maintain efficient public transport services. Small cities and suburbs suffer from daily commutes.	Public transport services are maintained only in city centers. Residents of suburbs and rural areas use individual cars.	High speed trains and all logistics are promoted to accelerate the economies. People use more cars and trains for their holidays.
Energy demand	Maximum use of natural passive systems for heating, cooling, and lighting decreases energy demand per capita. Increase in walking and cycling also decrease energy demand for commutes.	Overall, use of efficient technologies decreases energy use per capita. However, technology devices per capita increase, which contribute to increased demand.	Improved energy efficiency gradually decreases energy demand per capita. However, old stocks still largely exist and increase energy demand.	Only successful cities update the building standard. However, overall energy demand per capita is high.	Only large-scale, compact cities improve their energy efficiency and decrease overall demand. Small cities suffer from old infrastructures with high energy demand.	Areas with strong economies update to new, highly efficient technologies. However, demand per capita still increases with increases in activities, and consumption.

Notes: Population density pattern = SSP2: current DID * (Densely Inhabited District/population density at more than 4000/km²) area from the data source of 'Geospatial Information Authority of Japan', other SSPs represent conceptual distributions, does not indicate specific locations. CC = Core cities and metros; S = suburbs and other areas; L = local small cities.

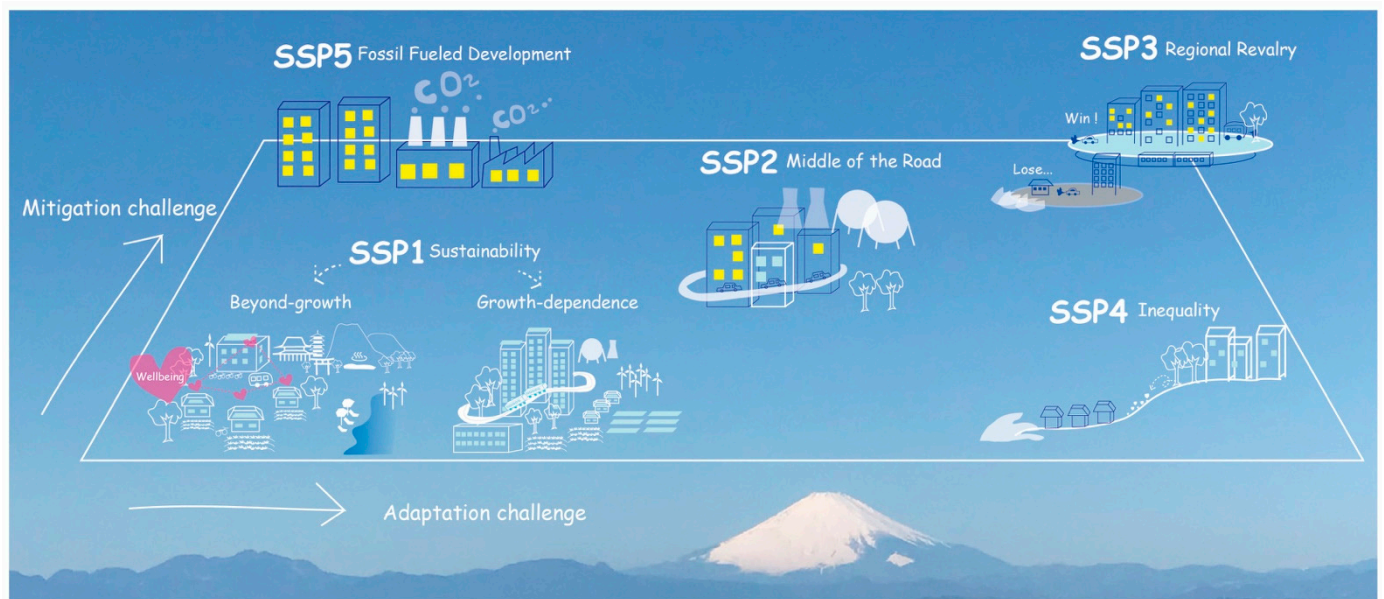


Figure 1. SSP alternative pathways, describing each scenario assumptions as ‘pattern languages’ inspired by C. Alexander [44].

5. Benefits and Trade-Offs in System Alternatives between SSP1 Beyond-growth and SSP1 Growth-dependence

Figure 2 describes alternative SSP1 Beyond-growth and SSP1 Growth-dependence scenarios. The key importance of a beyond-growth society in the built environment is an increase in resilience and self-sufficiency for basic human needs, such as food, energy, and water. As Japan faces a high risk of natural disasters and low energy security, an increase in energy-independent buildings supports both local energy security and resilience with efficient energy demand management. As building technologies and materials successively progressed through innovations and improvement, such new standardized housing and buildings became central, with reasonable prices and responsible qualities. Although the mainstream in the building sector is rapidly shifting to achieve energy efficiency, nearly net zero, even plus energy production targets, it is still limited within the relatively high-income class. The huge number of old building stocks remains inefficient and even become societal risks. Most major large cities in Japan have infrastructure problems that mainly developed in the high economic growth period. However, a growth-dependent society cannot be maintained without further accelerating such new construction with economic growth perspectives. Therefore, although an SSP1Growth-dependent society might achieve high efficiency by installing advanced technologies and accelerating the new construction of high energy standard buildings, people are still in the chains of the current production-based growth-dependent society, in which urban morphologies are organized based on their efficient functions for humans. On the other hand, in an SSP1Beyond-growth society, morphologies are organized according to natural earth systems to take care of all living things. Buildings and infrastructures are constructed following their natural biological boundaries with local materials. People can also live a healthier life with increased satisfaction. Production systems are more local oriented circular system. However, such flexible urban living functions require even more advanced technologies for buildings, transport systems, and communications. The distribution of business and innovations may increase local prosperity with production of locally based technical and economic solutions. Overall, cities will become relatively small compared with the present, and green infrastructures will be built more in urban centers and maintained in suburbs. City center functions depend on the existing infrastructures and service functions; however,

residential functions increase with increase of human interactions, rather than retail and businesses, which have more freedom regarding their locations.

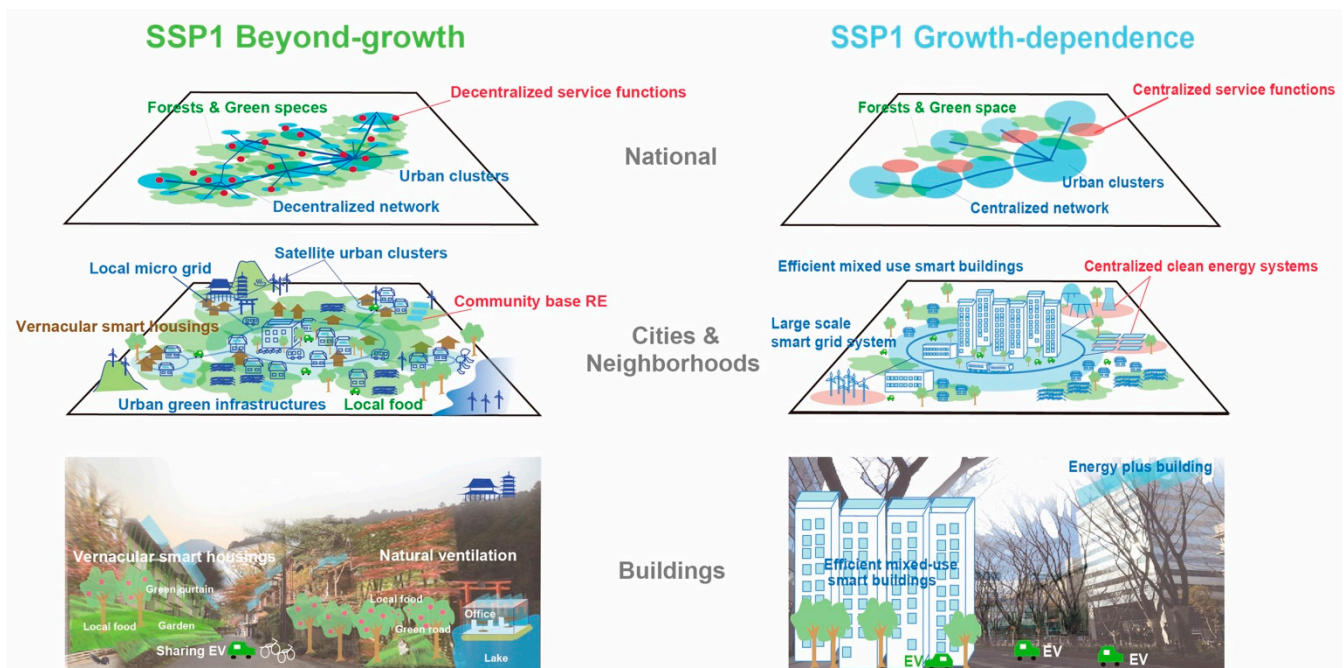


Figure 2. Alternative SSP1: SSP1 Beyond-growth vs. SSP1 Growth-dependence. (Notes: Population density pattern (national) represents conceptual distributions, does not indicate specific locations.)

6. Global Crises, Impacts, and Recovery

A number of global crises had significant impacts on transforming society and physical forms in the short and long term. Climate risk is a common global crisis. As this paper demonstrated in Section 4, different urban forms, infrastructure networks, and quality of services have huge impacts on mitigation strategies. Climate change has also seriously increased the risks of natural disasters such as flooding and landslides. Furthermore, Japan has a huge risk of earthquakes, which cause tsunami and other subsequent accidents. Japan experienced the Tohoku Earthquake in 2011, which caused serious tsunami in Tohoku regions where nuclear power stations were located. This was one of the largest unprecedented natural disasters in Japan. Before this event, nuclear power was one of the main options for decarbonizing the energy system in Japan. However, people strongly recognized the enormous and various risks, including energy security, associated with such centralized large power production systems, as well as human damage. Public opinion has greatly shifted to increase decentralized local-oriented renewable productions. The affected areas are still halfway to recovery; however, many local communities have developed grassroots strategies and ideas to create advanced recovery strategies that invite many new residents from outside of the areas. Importantly, land use structures have been transformed following the hazard map, and local renewable production can support the energy services and jobs for local residents. This local-oriented service infrastructure system and economic system can provide great insights into the SSP1 Beyond-growth sustainable society.

On the other hand, the world is currently facing the serious pandemic crisis of COVID-19. This has significantly changed the conventional thinking about human lives. First, people recognized the risks of high density, which is one of the key features of an efficient compact urban form. The lockdown situation, increased people's mental stress and promoted recognition of the importance of quality public space and green infrastructures within the living environment. The biggest change was the transition to tele-working, applying advanced ICT systems. This prompted a significant change in human lifestyle and activity patterns. If the majority of people and companies shift to such a remote-based

work environment, the freedom of locations and connectivity to services would increase, and the constraints of ordinary life would significantly decrease. In reality, many companies have decided to change the basic working regulations, giving employees more choices and flexibility in their time use, location, and even life plans. The increase of moves from the city center to the suburbs also changed the preference of housing type, space per person, neighborhood environment, and overall real estate markets. These trends are likely to continue and transform fundamental social structures dramatically. 'Society 5.0' was recently highlighted by the Japanese cabinet office, which is a new concept of the coming inclusive, balanced, and creative society with innovative digital technologies. The formulations of such a digital technology-based society may be tested in terms of the benefits and risks under the current pandemic situation. In the actual situation, some tendencies can be seen, such as the shift from an SSP1 Growth-dependent, centralized service society to a more nature-based, decentralized SSP1 Beyond-growth society. This might occur earlier than it is assumed because Japanese infrastructures are close to the period in which they need to be reconstructed or renovated [10]. Therefore, although these crises are a huge threat to society, people could create innovative recovery strategies with the increase of urgent necessity and growing political will.

7. Conclusions

The SSP scenarios for the Japanese built environment demonstrate the translation of global SSPs elements and key narratives into regional physical transformation and sustainable development strategies. The key elements are developed as further detailed indicators related to human settlement patterns, urban form, rural–urban migration, and buildings. In addition, nature-based solutions are integrated and examined in the advanced SSP1 Beyond-growth scenario narrative, which can be compared with the conventional possible transformation pattern involving a centralized service-oriented system in SSP1 Growth-dependence. The SSP1 Beyond-growth scenario represents a combination of adaptation to the digital era and nature-based solutions with freedom of location, which could possibly happen in real society within the next few decades. The comparison among five plus one SSPs narratives also describes the relatively high risks in both mitigation and adaptation in SSP2, moderate in SSP5, and the significantly high risks in SSP3 and SSP4, except two alternative SSP1 scenarios. These risks can be clearly described through the physical transformation, infrastructures, and building types. Rural–urban and urban–rural migration can be linked to local density patterns and assumptions of lifestyles. These elements can also support development of more concrete assumptions of urban infrastructures, building stock updates, and functional transformations in each scenario. However, although these narratives are developed through in-depth literature reviews and the expert workshop, the overall narratives cannot be supported by strong evidence-based assumptions because they cover very comprehensive elements related to the built environment. Furthermore, the global SSPs social elements and indicators are all aggregated, which can hardly apply to the single standardized definition. Therefore, Japanese urbanization data uses its own unique definition, which is not simply linked to other global SSPs country data. This integration of locally based definitions and specifications linked with global SSPs elements is another issue. The SSPs narratives for the built environment are expected to be used for diverse quantification analyses with further establishment of parameters that can be linked to the developed assumptions in each scenario, which are also the future works. Moreover, this developed method, which specifically focuses on the elements of the built environment, can be applied to other countries and cities to examine and develop regional sustainable development strategies based on such alternative pathways.

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