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Analysis of the Application of Slow and Advanced Technology in Living SOC Facilities from the Perspective of Carbon Neutrality

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ABSTRACT

Purpose: Considering the necessity of a comprehensive discussion through a comprehensive inspection or analysis of the living SOC thus far, and the need to change direction and realize a carbon-neutral society such as zero energy in the future, this study analyzed the application status of low-speed technology and advanced technology to the already completed living SOC. **Method:** The research method focused on previous research on low-speed and advanced technologies for application to living SOC and contents related to carbon neutrality and zero energy policies. In terms of the temporal scope, this study examined cases and major contents from 2020, when the full-scale living SOC and composite project began, to July 2022, when the living SOC promotion group was abolished. **Result:** In the case of living SOC completion, advanced technologies such as information and communication or the fourth industrial revolution technology were primarily limited to fixtures and devices rather than being applied to the entire building. Advanced technology is essential for zero and future carbon neutrality; thus, it must be actively utilized in the future. In addition, zero energy building certification for living SOC and wood utilization for carbon neutral have been partially implemented; however, the level of implementation remains low, and the use of renewable and passive energies is still in the early stages.

KEYWORD

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1. Introduction

1.1. Research Background and Purpose

Living SOC facilities, implying "essential regional infrastructure needed for daily life," can secure both practical and symbolic value when they reflect the living needs of specific local residents while simultaneously incorporating the cultural and humanistic context such as the locality's sentiment and history. The "Guidelines for the Selection of Living SOC Complex Projects" (June 2019) also emphasize "improving the design of living SOC, which has thus far been planned and designed uniformly from the supplier's perspective"1)[1], by enhancing the performance of SOC facilities through the application of green buildings (Zero Energy Building Certification) and linking with regional public architects. This highlights the need to extend beyond simple quantity supply, increasing energy efficiency, and breaking away from standardized design to emphasize differentiation from existing public buildings.

Since the establishment of the Living SOC 3-Year Plan in April 2019, the government has invested a total of KRW 33 trillion over three years to improve the quality of life for the people. Consequently, 33 major facilities have been established to an average of 97% of the 3-year plan's goals. This has somewhat resolved regional issues such as balanced regional development and job creation [2]. However, despite the positive impacts on regional revitalization and community formation through demands from local regions for necessary facilities, corresponding support, and active participation of local residents, living SOC projects have primarily focused on expanding necessary functional facilities. This focus has often been owing to budget limitations, handling civic petitions, or the urgency of construction, resulting in insufficient reflection of regional characteristics and humanistic considerations. In particular, the selection conditions for living SOC projects prioritize "site acquisition," "funding availability," and "immediate construction feasibility." As such, most living SOC projects were projects where sites had already been secured and construction could begin immediately. One resulting issue was the lack of consideration for socio-economic factors such as global warming and population decline, which require relatively long periods, and humanistic elements such as regional sentiments and historical contexts in the early stages.

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In this context, prior to this study, the need to apply current advanced technologies related to the 4th industrial revolution such as ICT and the phenomenological and humanistic characteristics of specific regions to living SOC facilities was raised. This need was defined through a preceding study titled "Concept Definition of the Slow–Smart Design Method for Applying to Living SOC" (2023) [3], which defined it as a slow–smart design. This approach posits that because living SOC facilities are fundamentally public buildings closely connected to specific regions, understanding the region is a prerequisite. The underlying theory is that to successfully implement living SOC projects, high–speed advanced technologies, which develop rapidly and have strong ripple effects, must be combined with slow technologies that are based on time and place and produce specific results over time.

However, with the dissolution of the Living SOC Promotion Team in July 2023, the continued progress of living SOC projects remains uncertain, casting doubt on the effectiveness of research or analysis on existing living SOC facilities from a slow–smart design perspective. In addition, although the Living SOC Complex Project Selection Guidelines partially mention zero–energy building certification through green buildings, they do not adequately reflect the changes in the zero–energy building certification system, which has been mandatory for public buildings with a total floor area of 1,000 m^2 or more since 2020 and expanded to public buildings of 500 m^2 or more from January 2023. Furthermore, since 2020, there have been discussions on green buildings, zero energy, and active use of wood for carbon neutrality, in accordance with the 2015 Paris Agreement. However, these aspects have not yet been presented as key guidelines. Thus, the current and future directions of the construction industry and architecture in South Korea are not being actively responded to.

Zero energy buildings are a combination of slow technologies, such as natural lighting and ventilation, and advanced cutting–edge energy–saving technologies. Carbon neutrality involves future technologies for carbon removal and slow technologies for carbon absorption, such as urban green spaces and forests. Therefore, the concept of slow–smart design used in this study is related to zero energy buildings and carbon neutrality. In addition, issues such as zero energy and carbon neutrality fundamentally apply to all buildings, including living SOC facilities, which are regional public buildings. Thus, the analysis and evaluation of these aspects could serve as foundational data for expanding applications to other public and general buildings in the future. In this study, we argued that despite the temporary suspension of living SOC projects, it is necessary to engage in comprehensive discussions based on an overall inspection and analysis of projects conducted to date. Moreover, under the premise that changes in directions and recommendations are needed to realize a carbon–neutral society, including zero energy, we aimed to analyze the application of slow technologies and advanced technologies to completed living SOC facilities and identify their characteristics.

1.2. Research Methods and Scope

This study examined the current status and characteristics of slow and advanced technologies applied to existing living SOC facilities from the perspective of carbon neutrality. The methodology of this study and aspects involved are as follows.

First, through theoretical examination, we reviewed the background of living SOC projects and changes in related policies such as carbon neutrality and zero energy buildings during the respective project period. A comprehensive survey of completed living SOC facilities as of October 2023 was conducted to examine their status by purpose and scale, overall characteristics, and problems.

Next, to confirm the application of advanced technologies and slow technologies to living SOC, we established an analytical framework in connection with carbon neutrality strategies. This framework included advanced technologies such as ICT and zero energy, and carbon absorption factors such as the use of wood. We then identified and examined the characteristics and current status of cases where each factor was applied.

Finally, from the perspective of zero energy and carbon neutrality, we identified the problems associated with living SOC facilities and proposed the need to apply slow and advanced technologies to public buildings in the future.

The research primarily focused on literature and previous studies related to slow–smart design methods for living SOC facilities. However, detailed theoretical discussions on slow–smart design were omitted in this study as they have already been covered in preceding research, such as "Concept Definition of the Slow–Smart Design Method for Applying to Living SOC" (2023). Instead, this study primarily addressed aspects related to carbon neutrality and zero energy policies. Data and indicators regarding the status of living SOC were referenced and cited from the report on outcomes of the living SOC 3–year plan published by the Office for Government Policy Coordination. Major living SOC case studies were selected and analyzed based on Case Studies of Resident Participation in Living SOC Vol. 1 (2019), Vol. 2 (2020), and Vol. 3 (2021), also published by the Living SOC Promotion Team under the Office for Government Policy Coordination. In addition, the research and case studies were temporally bounded by the period from 2020, when the Living SOC Complex Project officially began, to July 2022, when the

Living SOC Promotion Team was prematurely abolished.

1.3. Literature Review

Research related to living SOC primarily focuses on strategic aspects, such as the study "Strategic Supply and Utilization Plans for Region-Specific Living SOC" (2020) and "A Study on the Promotion of Public-Private Partnership in Seoul's Living SOC" (2022). Academic papers also predominantly explore policy aspects, such as "A Study on the Scope of Living SOC and Characteristics of Facilities by Type and Region" (2019), which presents directions for regional distribution and supply plans for living SOC, and "Critical Review on the Termination of Living SOC Policy: Focusing on the Legitimacy, Sustainability, and Substitutability of the Policy" (2023), which highlights issues arising from the early abolition of the Living SOC Promotion Team. Research from an architectural planning perspective often examines projects related to the integration of school facilities with local communities, such as "A Study on Mixed-Use of School Facilities in Line with Living SOC: Focusing on the Seoul Metropolitan Office of Education" (2021) and "School Complex with Social Infrastructure - Situations & Issues" (2020). These studies mainly focused on living SOC complex projects or facilities.

As living SOC projects are based on government financial support, most reports and studies have focused on policies and activation plans. Architectural discussions about living SOC facilities have primarily focused on the integration of facilities, which has been promoted since the 2000s. However, as mentioned in the introduction, despite the visible strategic achievements of living SOC facilities in enhancing the quality of life for local residents and reducing regional inequalities, there is a lack of discussion and research on public agendas. These include the eco-friendly features such as zero energy requirements for public buildings, the reflection of local characteristics, design differentiation, and the transition to a decarbonized society.

Against this backdrop, our research team has conducted studies on living SOC facilities, emphasizing the need to consider environmental and humanistic factors alongside the application of advanced technologies. These studies include architectural planning research like "A Case Study on the Combination Type and Type of Share Space in the Living SOC Complexity" (2022), the application of advanced technology in "Case Analysis of Smart Technology Application to Living SOC Complex Facilities," as well as "Case Analysis on the Foreign Buildings for Application of Locality to Living SOC Facilities" (2022) and "An Analysis of Environmentally Friendly Natural Materials for Regional Expression" (2022), which address the application of humanistic elements. In addition, studies on slow technology applications such as "An Analysis of Wood Usage Based on the Leading Case of Living SOC in Korea" (2022) and "Consideration of Wood Application Plan by Living SOC through Analysis of Overseas Wooden Buildings" (2022) have been conducted to prepare for an eco-friendly and decarbonized society.

Therefore, the significance of this study lies in the integration of content that has been partially addressed in prior research. Furthermore, it distinguishes itself by addressing aspects not frequently covered in earlier studies or other related research, such as advanced technological elements, environmentally friendly practices, and humanities aspects in the context of living SOC facilities. In addition, by linking the results of applying slow and advanced technologies to living SOC projects temporarily suspended since 2023 with policies on carbon neutrality and zero-energy buildings, this study provides foundational data applicable to all future buildings, an area not explored in existing research.

2. Theoretical Review

2.1. Concept and Progress of Living SOC Projects

According to Article 2 of the "Regulations on the Establishment and Operation of the Living SOC Policy Council" (Prime Minister's Directive No. 815, 2022. 6. 23. abolished), living SOC is defined as "all facilities that enhance the convenience of daily life for the public, including childcare, healthcare, welfare, transportation, cultural, sports facilities, and parks." The living SOC projects, which began in November 2018, expanded through the "Living SOC 3-year Plan (2020 – 2022)" and the Living SOC Complex Project. However, the goals set in the 3-year plan were already achieved by early 2022, leading to the abolition of the "Regulations on the Establishment and Operation of the Living SOC Policy Council" in June of that year. Consequently, in July, the Living SOC Promotion Team was prematurely disbanded. Individual living SOC-related policies, encompassing the ongoing 33 projects, have been temporarily suspended following the division of relevant departments.

According to the "Living SOC 3-year Plan Implementation Results" published by the Office for Government Policy Coordination, the Living SOC Promotion Team focused on eight key projects[2)] across three areas: leisure vitality, lifelong care, and safety assurance. These projects aimed to "construct multiple living SOC-related national subsidy projects on a single site as a single or interconnected facility" through facility integration and region-led principles. The initiative covered 33 major living SOC facilities related to the quality of life, such as cultural, sports, and welfare facilities [4]. As of the end of 2021, public libraries and cultural centers had a 100% project initiation rate, and the initiation rate for all 33 major facilities reached 97% of the target. Thus, most of the planned facilities were nearly completed by 2022. Among these, there were approximately 530 living SOC complex facilities, with 125 (24%) starting construction by the end of 2021, and 21 facilities (about 5%) completed, indicating that approximately 30% of the living SOC complex projects were either completed or nearing completion [2]. According to a press release from the Office for Government Policy Coordination (September 30, 2021), the top three types of complex facilities in 2021 were community culture centers (85 projects, 21%), sports facilities (54 projects, 13.4%), and together care centers (51 projects, 12.6%), focusing mainly on facilities frequently used by local residents[3)][4]. However, approximately 29% of the projects (146 cases) remained in the planning stage, and approximately 42% (215 cases) were under design, making the completion of approximately 70% of the living SOC complex facilities' completion uncertain owing to the early termination of the project in 2022. The project budget was initially set at KRW 30 trillion over three years. However, the actual expenditure was KRW 10.9 trillion in 2020, KRW 11 trillion in 2021, and KRW 11 trillion in 2022, totaling KRW 33 trillion, which is a 10% increase from the planned budget.

2.2. Trends in Carbon Neutrality and Zero Energy Policies During the Implementation Period of Living SOC Projects

As previously mentioned, Living SOC facilities are fundamentally community-oriented public buildings designed for local residents. The top three facilities as of 2021 are mainly those frequently used by local residents. Therefore, to enhance user convenience, advanced technological developments such as fourth industrial revolution technologies should be actively incorporated. Moreover, as outlined in the Living SOC Complex Project Selection Guidelines, it is essential to consider high-performance features such as zero energy and distinctive design and environmentally friendly design such as green architecture. Furthermore, broader contemporary agendas such as contributing to a decarbonized society post-2015 Paris Agreement and addressing regional socio-economic characteristics, including population decline and demographic changes, must be considered. Provided below is a brief review of policies directly related to living SOC buildings, such as carbon neutrality and zero energy.

First, following the adoption of the Paris Agreement in December 2015, which resolved to achieve global carbon neutrality by 2050 to limit global temperature rise to within 1.5℃, there has been an upward revision of Nationally Determined Contributions (NDCs) by various countries. This has resulted in the recent legalization of carbon neutrality and the implementation of diverse and proactive efforts across all industries to address global warming and realize a carbon-neutral society. In South Korea, the Framework Act on Low Carbon Green Growth was enacted and implemented in 2010 to establish the foundation necessary for green growth and to use green technology and green industries as new growth engines, with the goal of realizing a low-carbon society. In addition, the Act on the Allocation and Trading of Greenhouse-Gas Emission Permits was enacted in 2012, providing a legal basis for the emissions trading system. Following pilot projects, the emissions trading system was officially implemented for 525 companies starting from the first planned period (2015 – 2017) in January 2015[4)] [5].

Subsequently, on September 24, 2021, the Ministry of Environment enacted and promulgated[5)] the Framework Act on Carbon Neutrality and Green Growth for Coping with Climate Crisis (Carbon Neutrality Framework Act). This act builds upon the Framework Act on Low Carbon Green Growth and includes legal procedures and policy measures to achieve the national goal of carbon neutrality by 2050. The enforcement decree of this act has been in effect since March 20, 2022. In March 2022, as part of this framework, the carbon reduction target for 2030 was revised. Originally set at a 24.4% reduction from 2017 levels, the target was updated to a 40% reduction from 2018 total emissions, ultimately aiming to achieve a carbon-neutral society by 2050. This revision provides the legal basis for carbon neutrality and supports diverse, active efforts across all industries to address climate change [5].

Further, the Ministry of Land, Infrastructure and Transport has enforced the Green Buildings Construction Support Act since 2013, which specifies the requirements for establishing green buildings according to the Framework Act on Low Carbon Green Growth. To promote the proliferation of zero-energy buildings, the Zero Energy Building Certification System was introduced in January 2017. Furthermore, to accelerate carbon neutrality and reduce greenhouse gas emissions in the building sector, the Enforcement Decree of the Green Buildings Construction Support Act was partially amended on July 1, 2022. This amendment expanded the mandatory certification of zero-energy buildings (ZEBs), initially applied to public buildings with a total floor area of 1,000 m^2 or more since 2020, to public buildings with a total floor area of 500 m^2 or more (Grade 5) and public rental and sale apartments with 30 or more units (Grade 5) starting from January 2023. Moreover, from 2025 onwards, the certification will be mandatory for public buildings with a total floor area of 500 m^2 or more (Grade 4) and

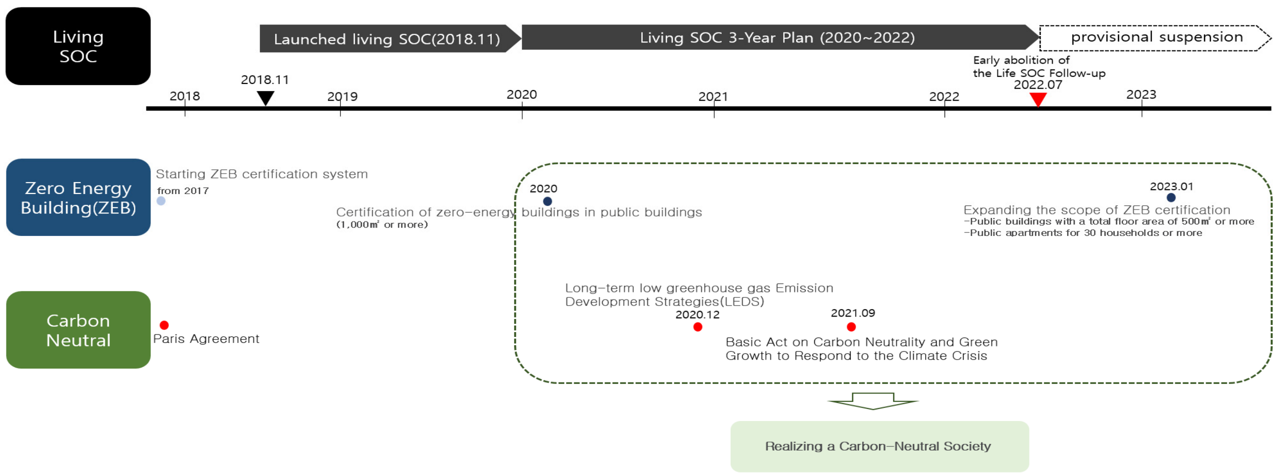


Fig. 1. Time schedule of the key policies related to living SOC and carbon neutral society

private buildings with a total floor area of 1,000 m^2 or more, including public apartment complexes with 30 or more units. The plan is to achieve Grade 1 energy efficiency certification for all buildings by 2050. Considering that 2050 is the target year for achieving carbon neutrality as outlined by the Paris Agreement, the zero-energy policy is linked to decarbonization policies in the construction sector, which has relatively high carbon emissions.

The above indicates that during the implementation of living SOC projects in 2020 to 2023, it was necessary to respond appropriately to the higher-level legal frameworks such as the 2050 Long-term Low Greenhouse Gas Emission Development Strategy (LEDS, 2020) and the Framework Act on Carbon Neutrality and Green Growth for Coping With Climate Crisis (2021). Moreover, as the criteria for the Zero Energy Building Certification System, applied at the start of the project, were significantly reinforced starting from January 2023, appropriate measures had to be taken to comply with these updated standards. Fig. 1. shows the timeline of living SOC and key policies related to carbon neutrality and zero energy.

3. Analysis of Application of Slow and Advanced Technologies in Living SOC Facilities

3.1. Premise and Method of Analysis

This study is based on the premise that community-oriented living SOC facilities should not only respond to the public needs and technological advancements of specific regions but also actively incorporate the phenomenological and humanities-related needs of the area, such as its sense of place, historical context, and climatic characteristics. These are defined respectively as advanced and slow technologies. Previous research, such as "Concept Definition of the Slow-Smart Design Method for Applying to Living SOC" (2023), has examined the extent of slow technology application and the integration of advanced and slow technologies in living SOC facilities.

Advanced technology refers to advanced or sophisticated technologies, such as those associated with the fourth industrial revolution, including IT and artificial intelligence. These technologies ensure real-time or near-future applicability, rendering them immediately applicable to various public buildings or individual structures, including living SOC facilities. In contrast, slow technology encompasses concepts that are generally opposed to advanced technology. It includes phenomenological aspects such as the natural environment, climate, landscape, and materials, as well as intangible and interpretive elements such as regional characteristics, history, culture, and traditions. This concept covers both technologies and non-technologies that require specific time and space for growth, production, and yield, with outcomes and directions influenced by temporal changes (2020/2023) [3].

However, as previously mentioned, the disbandment of the Living SOC Promotion Team in July 2022 and the temporary suspension of living SOC projects have cast uncertainty on the continuation of subsequent projects. As such, the findings from the analysis of the application of advanced and slow technologies in existing completed living SOC facilities must be expanded to public buildings and other types of structures. During the living SOC project period (2018-2022), significant policy changes occurred, such as the "2050 Long-term Low Greenhouse Gas Emission Development Strategy" (LEDS, 2020) and the "Framework Act on Carbon Neutrality and Green Growth for Coping With Climate Crisis" (2021), which aimed at achieving a carbon-neutral society to prevent global warming. Despite these changes, the existing living SOC projects did not actively incorporate these carbon-neutral policies. Moreover, performance enhancements through the application of green building technologies, as stipulated in the Living SOC Complex Project Selection Guidelines (November 2021), did not progress with trends such as the application of the zero energy building (ZEB) certification system to public buildings with a total floor area of 500 m^2 or more (from 2023) and its expansion to all buildings (from 2025). Consequently, the analysis of existing living SOC facilities should be conducted in a manner consistent with these overarching policies. Thus, the analysis of living SOC projects and facilities can provide useful insights if it can be expanded and applied to public buildings and all types of buildings in the future. It is particularly important to select and analyze elements that can actively respond to key issues such as carbon neutrality, which is a global and national agenda.

As previously mentioned, the concept of zero energy, which reduces carbon emissions through the passive or active utilization of natural environments such as natural lighting, ventilation, and geothermal energy, inherently combines slow elements of the natural environment with advanced technologies like ICT and precision technologies. Thus, linking this concept with slow technologies and advanced technologies is appropriate. According to the Carbon Neutral 2050 Implementation Strategy, buildings should "enhance insulation and airtightness, and expand the use of high-efficiency energy products to minimize energy consumption and promote the adoption of renewable energy sources such as solar and geothermal within buildings to achieve energy self-sufficiency."[6] They should also strengthen the carbon absorption function through the use of ecological resources such as forests and tidal flats for low-carbon land and urban development, aligning well with the Long-term Low Greenhouse Gas Emission Development Strategy (LEDS).

Therefore, this study aimed to analyze the application of slow and advanced technologies in completed living SOC facilities by maintaining the framework of the creative combination of the aforementioned advanced and slow technologies, while also referencing the five strategic elements outlined in "LEDS for Carbon Neutrality by 2050," such as carbon neutrality and energy self-sufficiency. These strategies will be linked with the items specified in the Living SOC Complex Project Selection Guidelines, such as the application of zero energy and green buildings, and the incorporation of regional characteristics to avoid standardized design. The goal is to derive insights that can be applied to all future buildings.

As specific analysis indicators, the study selected key technologies that represent the diverse and extensive range of advanced and slow technologies. For advanced technologies, the focus was on current high-tech advancements such as ICT and other fourth industrial revolution technologies. For slow technologies, considering the global agenda of mitigating global warming and achieving a carbon-zero society, the study emphasized the importance of wood utilization technologies owing to their carbon absorption capabilities. Thus, the analysis of living SOC facilities primarily centered on the extent of wood utilization for phenomenological slow technologies. In addition, as this study pertained to living SOC projects, it considered the application of green building elements specified in the Living SOC Complex Project Selection Guidelines, such as achieving zero-energy certification. This inherently involves the integration of advanced technologies like ICT and slow technologies such as natural lighting and ventilation, ultimately adopting a carbon-neutral stance. The analysis included the combination of slow and advanced technologies, and a schematic summary of this approach is illustrated in Fig. 2.

Phenomenological elements such as specific regional materials, climate, and environmental conditions, as well as interpretive

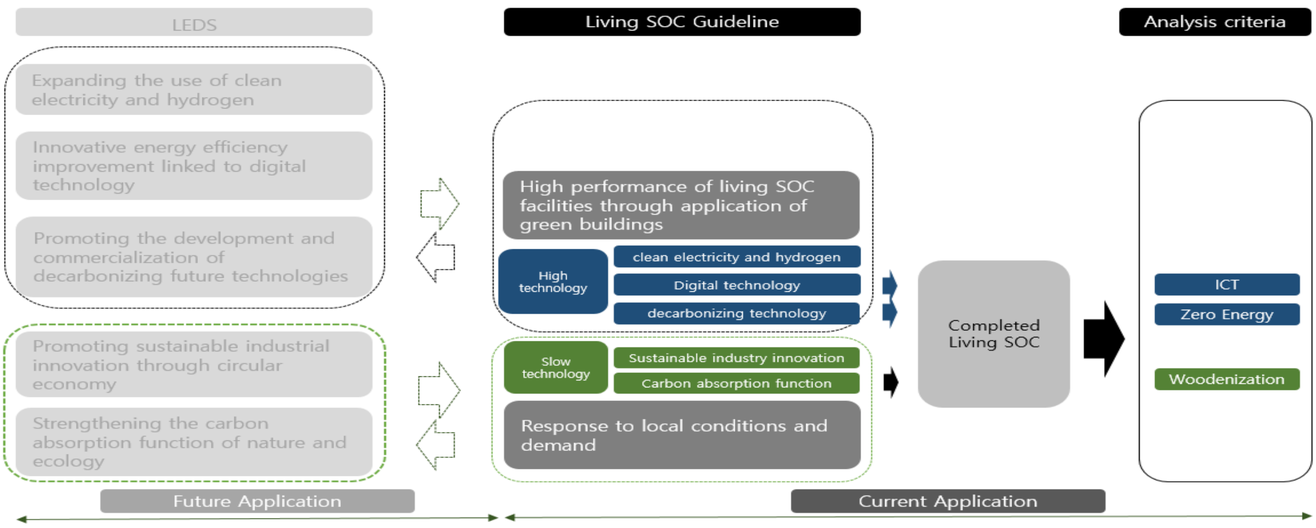


Fig. 2. Analysis premise and criteria

elements like local culture, traditions, and regional characteristics, have ambiguous application ranges and are non-visual. These factors necessitate the consideration of unique regional conditions, and thus, such discussions are limited to the necessary minimum. Instead of conducting a comprehensive review of all 88 cases, this study focused on selected criteria: the extent of application of advanced technologies, primarily ICT and other fourth industrial revolution technologies, the use of wood and incorporation of regional characteristics as slow technologies, and the adherence to zero-energy green building indicators as outlined in the living SOC guidelines. The analysis involved citing and reviewing relevant cases based on these criteria.

3.2. Status of Living SOC Among Completed Facilities

As of October 2023, out of the 530 previously selected living SOC complex projects, 88 projects have been completed. Thus, excluding the 21 projects already completed earlier, 67 of the 125 projects that had commenced construction have been finished, resulting in an overall completion rate of approximately 17%. Considering that approximately 30% of the projects were either completed or nearing completion as noted earlier, approximately 13% of the projects are still under construction.

When examining the progress and completion status of the projects by year, there were 5 projects in 2020, 18 projects in 2021, 38 projects in 2022, and 32 projects in 2023.[7] This indicates a significant increase in the number of projects from 2022 onwards. The initially low completion rate of the living SOC projects, which began in 2018 (only 5 completed by 2020), saw a substantial increase in both living SOC complex project selection and budget allocation following the implementation of the Living SOC 3-Year Plan (2020-2022) in 2021. This surge in project execution and completion was reflected in the increased figures for 2021 and subsequent years (Table 1.). The overall completion rate of living SOC projects, if including those expected to be completed after October 2023, is anticipated to continue rising.

Upon examining the regional performance of the living SOC complex projects, the number of completed projects was as follows: 8 in Seoul, 4 in Busan, 1 in Daegu, 6 in Incheon, 9 in Gwangju, 3 in Daejeon, 2 in Ulsan, 2 in Sejong, 10 in Gyeonggi, 3 in Gangwon, 4 in Chungbuk, 4 in Chungnam, 3 in Jeonbuk, 8 in Jeonnam, 9 in Gyeongbuk, 11 in Gyeongnam, and 1 in Jeju. While a significant number of living SOC complex projects have been implemented in regions such as Gyeongnam, Gyeonggi, Gyeongbuk, and Gwangju, regions such as Ulsan, Jeju, and Daegu have fewer than two projects, indicating regional disparities (Table 1., Fig. 3.). As of October 2023, the completion rate of the selected projects averaged below 20%. Regions such as Gwangju and Gyeongnam showed higher completion rates relative to the number of selected projects, while regions such as Gangwon and Jeonbuk had completion rates below 10%, further

Table 1. General table of the status of living SOC by region, facilities, and main structure

Region	Selected (canceled)	Completed		Facilities					Main Structure			Annual completion		
		number	%	Child/ Elderly	Educational	Neighborhood living	Sports	Business	RC	SRC/S	Wood	2021	2022	2023
Seoul	54(3)	8	16	3	3	1		1	6	2	-	6	2	
Busan	37(1)	4	11	2		1		1	4	-	-	1	2	1
Daegu	9	1	11			1			1	-	-			1
Incheon	26(1)	6	24	2	1		1	2	6	-	-	1	3	2
Gwangju	28(1)	9	33		3	1	1	4	8	1	-	1	6	2
Daejeon	17	3	18		2		1		3	-	-	1	1	1
Ulsan	10	2	20	1		1			2	-	-		1	1
Sejong	4	2	50			1	1		1	1	-			2
Kyunggi	76(4)	10	14	2	5	1		2	7	3	-	1	5	4
Kangwon	40	3	7			2	1		1	2	-	1		2
Chungbuk	27	4	15	1	2	1			4	-	-		4	
Chungnam	32(2)	4	13	1	1	1	1		2	2	-	1	1	2
Jeonbuk	35(2)	3	9	1		1	1		2	1	-		1	2
Jeonnam	40(1)	8	21	3	4	1			7	1	-	1	4	3
Kyungbuk	46(1)	9	20	2		2	3	2	8	1	-		4	5
Kyungnam	41(2)	11	28	2	5	3	1		9	1	1	4	4	3
Jeju	8	1	13					1	1	-	-			1
Total	530(18)	88	-	20	26	18	11	13	71	16	1	18	38	32

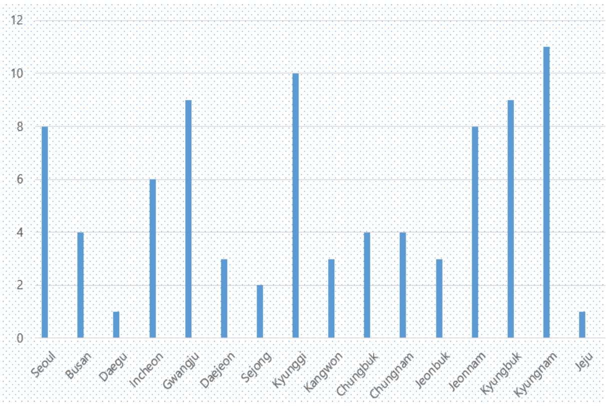


Fig. 3. Number of completed projects by each city and province

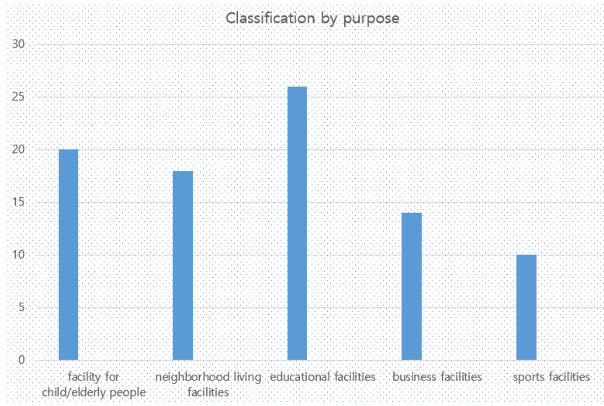


Fig. 4. Classification by purpose

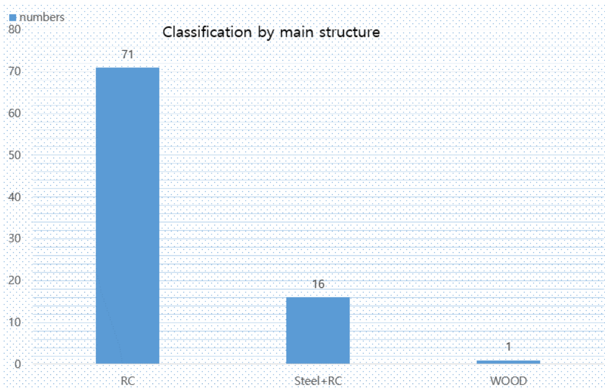


Fig. 5. Classification by main structure

highlighting significant regional discrepancies (Table 1.).

In addition, among the 88 completed projects, the classification by usage revealed that while most facilities are intended for mixed-use owing to the nature of the projects, the primary use can be identified by comparing the building lecture and detailed facilities for each case. The primary uses can be categorized as follows: 20 facilities related to elderly care, 18 neighborhood living, 26 educational and research facilities, 13 business-related facilities, and 11 sports facilities (Table 1., Fig. 4.). This distribution aligns with the earlier mentioned data from 2021, where the top three facilities were community cultural centers, sports facilities, and together care centers, indicating a concentration on facilities frequently used by local residents. The fact that many of the completed living SOC facilities are related to elderly care and small libraries, such as educational and research facilities, suggests a potential increase in demand for living SOC facilities that incorporate environmental friendliness and universal design, extending beyond their functional necessities.

In the completed projects, the primary structural systems adopted include reinforced concrete structures, accounting for approximately 81% of the total with 71 cases. Other structures such as steel frameworks and composite steel-reinforced concrete structures are used in 16 cases, and one case featured a general wooden structure (Table 1., Fig. 5.). However, steel-reinforced concrete or steel structures were primarily utilized in larger facilities or public parking lot projects, such as the Bandabi Sports Center in Buk-gu (Gwangju, Jeonnam) or the Mungyeong Town Living Center (Jinju, Gyeongnam). Therefore, it can be inferred that reinforced concrete structures were predominantly used in general buildings. This choice is likely owing to the relatively lower construction costs of reinforced concrete per square meter, ranging as approximately KRW 3.5–4 million, and considerations for economic efficiency such as reduced construction time. However, for future advancements in environmental friendliness and carbon neutrality, modular construction methods and wooden architecture may need to be considered. This will be discussed in more detail in Section 3.3.

Excluding small-scale facilities such as the Dain day care center in Incheon (659.79 m^2), most living SOC facilities are large, generally with floor areas of 1,000 m^2 or more and up to 3-4 stories above ground. However, there are also several large-scale facilities, specifically, complex facilities, parking lots, and sports facilities exceeding 10,000 m^2, such as Nam-gu Cultural Arts Center in Gwangju (10,321.35 m^2), Dalseong-gun Educational and Welfare Center (13,757.14 m^2), Seoyeon Yieumteo Library in Hwaeong, Gyeonggi-do (12,344.66 m^2), Galmae-dong Complex Office Building (12,534.05 m^2), Dongbu Complex Sports Center in Wonju, Gangwon-do (10,243.09 m^2), and New Town Complex Community Center in Gyeongsangbuk-do (10,816.54 m^2). As mentioned earlier, public buildings with floor areas of 1,000 m^2 or more have been subject to ZEB certification requirements since 2020, and this has been expanded to buildings of 500 m^2 or more since January 2023. Therefore, it can be concluded that, except for certain initial small-scale projects, most living SOC facilities are required to undergo ZEB certification.

Living SOC complex facilities exist in various forms, characterized by the combination, transformation, reconfiguration, and construction of different functional facilities. This variability can be attributed to the autonomy in the integration methods outlined in the Living SOC Complex Project Selection Guidelines. However, in most cases, it manifests as a simple integration and utilization of existing local assets.

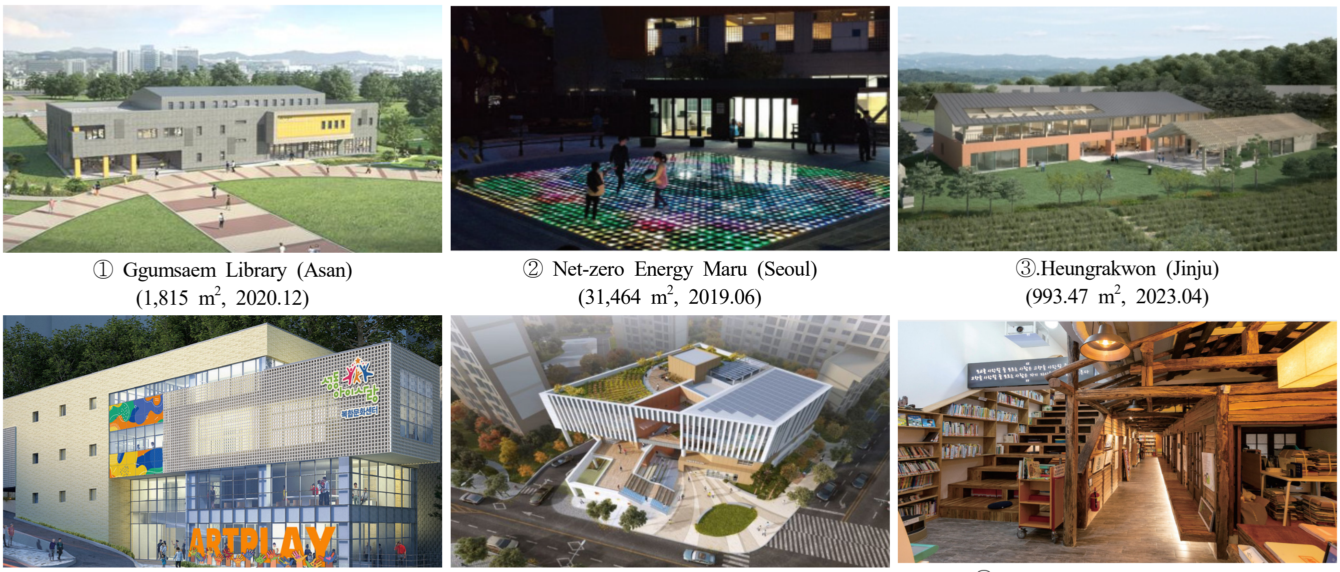
3.3. Analysis of Application of Slow and Advanced Technologies in Completed Living SOC Facilities

The application of advanced technologies, slow technologies, and zero-energy in already completed living SOC facilities can be summarized as follows.

First, advanced technologies can primarily be considered as "smart technologies," commonly represented by information and communication technologies and fourth industrial revolution technologies. Examples include smart community facilities utilizing ICT, parking space planning using robotics, automation services within residences, and other IoT devices that facilitate smart mobility technologies for enhancing the quality of life. In the completed cases, examples include smart screens (Aisarang Culture Center, Seoul), virtual reality (Daedeok Elementary School), smart walking exercise equipment (Social Welfare Center, Goseong County), and automation systems (Entrepreneurship Education Center, Jinju City), as well as big data and smart projects using CLOi robots (Ggumsaem Library, Asan City) (Fig. 6., ①). However, these are more limited to equipment or devices rather than being broadly applied across the buildings. With applications appearing in only approximately 13 out of the total 88 projects, the level of utilization remains low [6].

In the certification examples from the Korea Intelligent Smart Building Association, smart technologies such as IoT, artificial intelligence, BIM, big data, cloud computing, augmented reality, and virtual reality are being applied. This suggests that more active adoption of advanced technologies will be necessary in future living SOC facilities. Further, advanced construction technologies such as off-site construction and the integration of construction IT based on the fourth industrial revolution are largely underutilized although they allow high-quality buildings to be supplied quickly and safely. In general, region-specific living SOC projects often need to deliver results quickly within the budget to satisfied the urgent needs of local residents, which highlights the need for advanced construction technologies like off-site production. However, advanced technologies are mostly either in progress or envisioned for the near future, suggesting that gradual and natural application of these technologies can be expected as they develop.

The application of green building standards for enhancing the performance of SOC facilities based on the Living SOC Complex Project Selection Guidelines, addressing issues such as zero energy, eco-friendliness, securing regional characteristics, and departure from standardized design, has not yet yielded satisfactory results in the current living SOC projects. According to Article 3 of the Green Buildings Construction Support Act, the basic principles for green buildings include "development of green buildings by reducing the emission of greenhouse gases, development of eco-friendly and sustainable green buildings, development of green buildings that utilize new and renewable energy, and save resources, promotion of efficient use of energy in existing buildings, securing equilibrium between social classes and between regions regarding the development of green buildings." In particular, the green building certification system,



① Ggumsaem Library (Asan) (1,815 m^2, 2020.12)
② Net-zero Energy Maru (Seoul) (31,464 m^2, 2019.06)
③.Heungrakwon (Jinju) (993.47 m^2, 2023.04)
④ Aisarang culture center (Seoul) (1,292.51 m^2, 2021.07)
⑤ Shinweol 6 Dong Complex (Seoul) (6,071.03 m^2, 2021.08)
⑥ Kim Youngsoo Library (Jeju) (365.03 m^2, 2019.05)

Fig. 6. Living SOC examples of zero energy and wood application

which assesses environmental impact factors such as energy and resource conservation, reduction of pollutant emissions, and creation of a comfortable living environment throughout the entire process of building production, design, construction, maintenance, and disposal, is crucial for achieving zero energy and eco-friendliness. The guidelines address the use of environmentally declared products (EPD) in the materials and resources sector, use of low-carbon materials, use of recyclable materials, use of materials that reduce harmful substances, application rate of green building materials, and installation of facilities for storing recyclable resources, However, because obtaining green building certification for living SOC facilities is not mandatory but recommended, the use of materials that satisfy green building certification standards has been limited in most cases.

In addition, regarding the ZEB certification under the Enforcement Decree of the Green Buildings Construction Support Act, as mentioned earlier in Section 2.2, most living SOC facilities are included in the scope of ZEB certification for public buildings with a floor area of 1,000 m^2 or more since 2020. Notably, from January 2023, all public buildings with a floor area of 500 m^2 or more (Grade 5) require ZEB certification. Therefore, thorough consideration and preparation for energy issues and eco-friendliness, such as green building practices and ZEB certification, are necessary from the initial stages of project planning and design.

However, as stated in section 3.2, while most living SOC facilities exceed 1,000 m^2, the ZEB certification standards are not applied to all facilities as certification may be omitted depending on the year of completion, and facilities may be smaller than 1,000 m^2. As in the case of the Ggumsaem Library in Asan, South Chungcheong (Fig. 6., ①), there are occasional examples of energy and environmental considerations,[8] such as active incorporation of recycling such as the use of recycled glass exterior finishes for passive architecture certification, ZEB Grade 5 certification, and achievement of Grade 1++ in building energy efficiency. However, there are few cases emphasizing the active use of carbon-neutral eco-friendly materials like regional materials or wood, or highlighting the local characteristics and historical significance of specific regions. Even this example remains at the minimum certification level of Grade 5 for ZEB certification. Considering the expected strengthening of building energy certification in the future, it will be necessary to enhance the energy self-sufficiency rates of buildings. However, examples such as Net-Zero Energy Maru in Gangdong, Seoul (Fig. 6., ②), which combines smart technologies with renewable energy facilities such as solar energy experiences, wind, water, power, and bio, suggest that the integration of advanced smart technologies, zero energy, and green buildings will likely increase as examples of achieving carbon neutrality.

In terms of finishes, there are examples where environmentally friendly materials with low thermal conductivity, such as clay bricks (Aisarang Culture Center, Seoul) (Fig. 6., ④), or recycled eco-friendly materials like aluminum composite panels are used (Seoyeon Yieumteo Library, Gyeonggi), and natural stones like granite (Nam-gu Cultural Arts Center, Gwangju), as well as the use of wood panels (Shinweol 6 Dong Complex, Seoul) (Fig. 6., ⑤). However, apart from these cases, most have been finished with conventional construction materials like cement bricks. To satisfy the standards for green building certification, the insulation performance of windows and insulation materials must be improved, and environmentally certified products are required for the main structural elements such as rebar and concrete to internal finishes and floor coverings. This indicates a consideration for the associated increase in construction costs [7].

With the growing emphasis on the importance of energy efficiency and minimizing greenhouse gas emissions in green buildings, the active use of wood, which is essential for creating environmentally friendly and sustainable green buildings, has emerged as a crucial task. Using materials such as reinforced concrete, which emits approximately 253 tons of carbon for 1 ton of production, or cement, which emits 1,048.4 kg of carbon per 1,000 kg, are not favorable for achieving greenhouse gas reduction or carbon neutrality. Therefore, new alternatives that do not rely on conventional materials or methods are needed. In particular, while reinforced concrete structures are often used in high-rise or large buildings to increase the rigidity of the structure, the iron ore industry emits a large amount of carbon dioxide during the process of reducing iron ore to produce molten iron. On average, approximately 1.83 tons of carbon dioxide is emitted for every ton of steel produced. Hence, to reduce greenhouse gas emissions in the future, the development of environmentally friendly, decarbonized construction materials and methods should be prioritized. Accordingly, there should be more active adoption of modular construction methods, which significantly reduce carbon emissions owing to less use of high impact materials like ready-mix concrete, despite higher carbon emissions in components like steel plates or profiles.

As highlighted in documents like "LEDS for Carbon Neutrality by 2050," wood is an important carbon sink, alongside forests and tidal flats. It is a recyclable, eco-friendly material that produces fewer harmful substances, and has minimal changes caused by temperature. It is also approximately seven times more energy-efficient than concrete, capable of storing approximately 1 ton of carbon dioxide per m^3. Therefore, to achieve a carbon-neutral society as stipulated in Section 4 of the

Framework Act on Carbon Neutrality and Green Growth for Coping With Climate Crisis, active use of wood is necessary. However, as previously mentioned in Section 3.2, most completed facilities are constructed using high-carbon materials like reinforced concrete or reinforced steel concrete structures. Among the 88 projects, Heungrakwon (Jinju, Gyeongnam) (Fig. 6., ③) is the only instance where a major part of the structure is made from wood. Even in this facility, wood construction is only partially employed in certain sections of the main building and the annex, showing that overall, there remains a lack of the active use of wood. However, examples such as the Jejubuk Elementary School, Kim Youngsoo Library in Jeju (Fig. 6., ⑥), which converted an unused dormitory into a traditional Korean wooden structure, or the Chebu-dong Community Cultural Center (Jongno, Seoul), remodeled from a church, demonstrate that the active use of wood is possible both in new constructions and existing buildings. The utilization of traditional wooden structures, such as hanok, can be useful for reflecting the traditional characteristics and sentiments of specific regions. Therefore, the promotion of wooden architecture in public buildings, such as living SOC facilities, should be actively pursued.

In the case of wood-based exterior and interior finishes, there are instances such as Yongsan Youth Town (Yongsan, Seoul) where wooden louvers were applied to the exterior walls, and Kim Youngsoo Library (Jeju), which applied traditional hanok wooden structures internally while maintaining the exterior of the existing facility. However, apart from these examples, wood has been rarely used for exterior finishes in most cases. In examples such as Songak Village Haeyu (Asan, Chungnam), wood is largely confined to interior finishes or wood decks. Recently, countries such as the United States, Canada, and Japan, which are more developed in terms of wood usage, have laws promoting the use of wood to achieve a carbon-zero society and actual construction cases. Therefore, active utilization of wood in public buildings like living SOC, as well as in all types of constructions, must be seriously considered in the future. Korea is also exerting efforts to utilize wood for carbon neutrality, as can be seen in the "Wooden Structures for Children's Facilities Project." This project, which involves replacing indoor environments in childcare facilities with eco-friendly domestic wood, was initiated by the Korea Forest Service for the purpose of achieving national greenhouse gas reduction targets by 2030. Considering this, there is a need to expand the application of wood in living SOC facilities and other public buildings, particularly those for children and elderly care.

Certain projects among the 88 completed cases are consistent with the Living SOC Complex Project Selection Guidelines, which specifies the need to "improve the design of Living SOCs, which have been developed based on provider-centric planning and standardized design." For instance, Jejubuk Elementary School, Kim Youngsoo Library, Chebu-dong Community Cultural Center (Jongno, Seoul), and Gusan-dong Library Village (Eunpyeong, Seoul) utilize existing school buildings or alleys to continuously express past memories or inherit the traditional aspects of modern architecture, thereby enhancing the design quality of living SOCs through regional characteristics or the historical significance [8]. In prior research, physical or phenomenological elements such as climate, local climate, and materials, as well as spiritual or interpretive elements such as traditions and culture, were categorized as slow technology elements. However, this study focused on aspects related to carbon neutrality and zero energy, and a more detailed analysis will be conducted in a separate follow-up study.

4. Conclusions and Recommendations

In this study, based on the judgment that a change in the architectural paradigm is necessary to prevent global warming and achieve a carbon-neutral society, we partially expanded the existing slow and advanced technologies for application to living SOC facilities. The status of application of slow and advanced technologies to the 88 completed living SOC cases was analyzed from a carbon-neutral perspective, and the conclusions are as follows.

First, in the completed living SOC cases, advanced technologies such as ICT and fourth industrial revolution technologies appear to be applied more to equipment and devices rather than throughout the entire buildings. Advanced construction technologies, such as smart construction, have been rarely employed. As advanced technologies are essential for zero energy and achieving carbon neutrality, they must be actively utilized.

Next, the transformation of living SOC facilities into ZEBs and their certification are partially occurring; however, the numbers remain relatively low, and the utilization of renewable or passive energies remains in the early stage. With most living SOC facilities exceeding 1,000 m^2, they have been included in the scope of zero-energy building certification since 2020; however, most certifications are at the legal minimum of Grade 5. Starting in 2023, the certification targets have expanded to public buildings over 500 m^2, and from 2030, the minimum grade is expected to be raised to Grade 3 or higher. Thus, preparations are needed for public buildings in the future. As observed in the case of Net-Zero Energy Maru, there is a need for active integration between advanced technologies, such as ICT and solar technology, and zero-energy technologies like passive systems.

The active use of wood as a carbon sink is one of the slow technology solutions for achieving carbon neutrality. However, among the completed living SOC facilities, there is only one instance of wooden construction. The use of wood is scarce compared to reinforced concrete or steel structures. As for facades and interiors, wooden materials are limited to panels and finishing materials. Considering that there is active global discussion and experimentation on wood construction and wood integration, there is a need to actively utilize wood in public buildings, including living SOC facilities.

This study examined the current status of completed living SOC facilities and reviewed the application of slow and advanced technologies, as well as zero-energy initiatives from a carbon-neutral perspective in each case. However, owing to the early dissolution of the Living SOC Promotion Team in July 2022, the future sustainability of living SOC projects is currently uncertain. This raises questions about the practical relevance of research limited to living SOC projects. Moreover, there is a temporal gap between the implementation period of living SOC projects and carbon-neutral policies, including zero energy. Thus, analyzing the completed cases from a carbon-neutral perspective may not be logical. Nevertheless, as public buildings, including living SOC facilities, are inevitably tied to carbon neutrality discussions, examining such facilities from a carbon-neutral standpoint can be meaningful in setting the direction for future public buildings.

Moreover, while this study provides a comprehensive analysis of the application of slow and advanced technologies and zero-energy initiatives across the 88 completed cases, it does not extend to an analysis of each individual building in terms of specific elements. The examples of the living SOC projects are primarily limited to the exemplary cases published by the project promotion team. In-depth analyses of each case have not been possible owing to the lack of data on detailed floor plans and the application of zero energy. Furthermore, combining advanced technologies and slow technologies for achieving carbon neutrality involves economic risks, such as the increase in construction costs. These aspects will be explored in a separate follow-up study.

References

[1] Office for Government Policy Coordination, Living SOC complex project selection guidelines, 2019.06.

[2] Office for Government Policy Coordination, Selection of 2021 living SOC complex project and study on improvement plan for project implementation, 2020.12.

[3] Y.-H. Kim, Concept definition on to the slow-smart design method for applying to life SOC -In the view of coupling theory between symbiosis and dialectic-, KIEAE Journal, 23(1), 2023.02, pp.113-120.

[4] J.H. Lee, Living SOC 3-year plan implementation results, 2022 Life SOC Policy Conference, 2022.02, pp.1-19.

[5] Government of the Republic of Korea, Republic of Korea 2050 carbon neutral strategy to realize a sustainable green society, 2020.

[6] G.-H. Yeom, Y.-H. Kim, Case analysis of living SOC complex facilities applying smart technology and elements, Autumn Annual Conference of AIK, 2022.10, pp.99-100.

[7] N.-Y. Kang, Y.-H. Kim, A case study on the external finishing materials in living SOC complex project -Focusing on materials and resources of G-SEED-, Conference Journal of KIEAE, 2022.05, pp.56-57.

[8] J.-H. Lee, Y.-H. Kim, Analysis of regionality expression method of living SOC facilities using existing buildings -Focusing on the formation of a sense of place according to changes in use and preservation-, KIEAE Journal, 23(6), 2023.02, pp.113-120.

1) Living SOC Complex Project Selection Guidelines, 2019.06, pp.18
2) The Living SOC 3-Year Plan sets a total of eight tasks: including three tasks for the leisure vitality sector, that is, expanding public sports infrastructure, expanding cultural facilities, and expanding infrastructure in vulnerable areas; three tasks for the lifelong care sector, that is, expanding childcare facilities, expanding facilities for vulnerable groups, and expanding public healthcare facilities; and two tasks for the safety and security sector, that is, establishing safe living spaces and creating a clean living environment.
3) Selection of 2021 living SOC complex project and study on improvement plan for project implementation, Office for Government Policy Coordination, 2020.12, pp.61
4) Republic of Korea 2050 Carbon Neutral Strategy to Realize a Sustainable Green Society, Government of the Republic of Korea, 2020, pp.34.
5) The Green Growth Act is significant in that it was the first to set national greenhouse gas reduction targets and lay the foundation for the introduction of an emissions trading system. However, certain researchers have claimed that it is insufficient for setting greenhouse gas reduction targets necessary for advancing toward a carbon-neutral society, minimizing job losses and impacts on local economies and vulnerable groups that may occur during the carbon-neutral transition, and promoting green growth that harmonizes the economy and the environment. Pil-Han Yoon, Significance of Enactment of Framework Act on Carbon Neutrality and Green Growth for Coping With Climate Crisis and the Role of Local Governments, Decentralization Letters, 90.
6) Government policies and trends for responding to carbon neutrality, Innobiz Policy Briefing, 2021.05, pp.5.
7) Owing to the nature of the projects, some cases involved remodeling or expanding existing buildings. Since there is a difference between the actual completion year of the buildings and the project implementation year, these cases were further investigated and classified based on the project timeline.
8) Major achievements of Living SOC 3-Year Plan, p.20.