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생애주기 관점에서의 노후계획도시 공동주택 재건축에 따른 탄소배출저감 정책 방안 연구

Carbon Emission Reduction Policies throughout the Lifecycle of Buildings for Reconstructed Apartment Complex of Old New-town

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SUMMARY

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This policy research was conducted at a time when the redevelopment of aging new towns is necessary, particularly as redevelopment and reconstruction policies are increasingly being driven by the private sector. It emphasizes the need for measures to achieve the overarching goal of carbon neutrality. For the early new towns, referred to as aging planned cities, to transition into carbon-neutral cities, it is critical to develop not only technical solutions but also policy alternatives that induce carbon emission reductions throughout the entire lifecycle of buildings.

The first part of the study reviewed literature and policies related to carbon emission reduction in aging planned cities. The findings can be summarized as follows: Carbon emissions from buildings can be divided into operational carbon, which is emitted during the operational phase, and embodied carbon, which is generated during raw material production, transportation, construction, and disposal. The proportion of carbon emissions by lifecycle stage shows that approximately 30% of emissions occur during the construction phase, and around 70% during the operational phase, with recycling construction waste reducing emissions by about 0-2%.

Reducing operational carbon emissions is essential for increasing energy self-sufficiency, which necessitates the production of new and renewable energy. Therefore, it is necessary to consider both the installation of passive systems like insulation and active system technologies like high-efficiency boilers, as well as the production of new and renewable energy.

Next, policies, technologies, and planning techniques that could serve as benchmarks for reducing carbon emissions in aging planned cities were selected based on their proven effectiveness. Among domestic and international policies related to carbon emission reduction, green building certification programs have been shown to effectively reduce energy consumption and greenhouse gas emissions in buildings. Furthermore, using a framework for planning tools, the study categorized technologies and planning techniques identified in case studies and classified those applicable to reconstruction projects as follows: First, in terms of energy transition, there were renewable energy installations, smart grids and energy storage, energy-efficient buildings, district heating and cooling, electric vehicle charging infrastructure, waste-to-energy facilities, and carbon capture technologies. Second, technologies related to carbon sinks included green roofs and vertical gardens, urban farms, building-integrated urban agriculture, rainwater management infrastructure, and urban resilience infrastructure. Third, regarding resource circulation, there were waste recycling and carbon emissions trading, and in terms of management, there was the establishment of energy management systems.

In the midsection of the research, a model was developed to predict energy consumption based on the architectural structure and site design of Bundang's apartment complexes. This model estimated the total energy consumption and carbon emissions that would result from an expected 150% increase in floor area ratio during future reconstruction. The study then applied technologies and design techniques derived from prior research and case studies to estimate changes in total energy consumption and carbon emissions, assessing how much carbon reduction could be achieved and how these results could be linked to policy alternatives for apartment complex reconstruction. The results are summarized as follows:

First, the lifecycle of 122 apartment complexes in Bundang was divided into three stages: demolition, material production and construction, and operation. Carbon

emissions were calculated for each stage, and reduction measures were proposed. Carbon emissions from the 'demolition' and 'material production and construction' stages were calculated using a basic estimation method based on anticipated material quantities. The demolition stage emitted approximately 24.06 kton-CO2/㎡ of carbon dioxide, while the construction stage, assuming the maximum increased floor area ratio of 150%, resulted in an emission of approximately 420.43 kton-CO2/㎡.

Carbon emissions during the 'operation' stage were estimated based on projected energy consumption under various scenarios, comparing pre- and post-application of reduction measures. The model accounted for variables such as building and socioeconomic characteristics. The results indicated that, following redevelopment, electric energy consumption would increase by 73.9%, gas energy consumption by 83.8%, and heating energy consumption by 54.9%. Consequently, post-redevelopment, the Bundang apartment complexes under analysis were estimated to emit a total of 558.61 kton of carbon dioxide, a 66.9% increase compared to the pre-redevelopment total carbon emissions. The change in total floor area was 82.3%, and the change in energy consumption was 62.1%. Among the total carbon emissions, electricity accounted for 300.74 tons, or about 53.8%, while gas accounted for 2.4%, and heating 43.8%.

Next, considering lifecycle energy consumption and carbon emission reductions, 22 reduction elements were identified within five major categories—'Resource Recycling Specialization,' 'Sustainable Construction,' 'Renewable Energy,' 'Energy-Efficient Buildings,' and 'Climate Change Adaptation and Carbon Sink Expansion'—based on expert FGI (Focus Group Interview) feedback and applicability. Three reduction packages for energy consumption and renewable energy production were proposed: 'Core,' 'Expanded,' and 'Comprehensive.'

The estimated reduction results from applying these package elements are as follows: First, during the 'demolition' stage, based on the current construction waste recycling rate, which approaches 98.9% with only 0.8% being landfilled, carbon emissions from demolition could be reduced through 100% recycling of construction waste. Next, during the 'material production and construction' stage, assuming a maximum recycling rate of 25% as incentivized, a reduction effect of 1.64 kton, 25% of the initially calculated 6.57 kton carbon emissions during material production and construction, was estimated. Finally, during the 'operation' stage, carbon emissions were expected to

be 558.61 kton before applying the carbon reduction package. After applying the core package, emissions were estimated to reduce to 261.95 kton, 177.69 kton with the expanded package, and 167.68 kton with the comprehensive package. In summary, applying the core, expanded, and comprehensive packages could reduce carbon emissions from redevelopment by approximately 53%, 68%, and 70%, respectively.

In the latter part of the study, based on these findings, policy measures for reducing carbon emissions in the reconstruction of multi-family housing complexes were proposed. The summary of the results is as follows: The policy goals proposed in this study are suggested from three perspectives: environmental, social, and economic sustainability. Detailed policy measures regarding the goals and directions were listed and specified through expert FGIs, and were summarized into three key items: 'Incentive Provision Measures,' 'Activation of Certification Systems,' and 'Securing On-site Space for Facilities Related to Carbon Emission Reduction and Carbon Sinks.'

First, in terms of incentive provision, it is necessary to utilize floor area ratio relaxation as an incentive, but also to consider integrating financial support measures such as subsidies and tax deductions. Second, regarding the certification system, it is necessary to go beyond the current mandatory Zero-Energy Building Grade 5 certification and introduce measures like reducing acquisition and property taxes after Grade 4 certification, while providing income and corporate tax deductions to suppliers. Additionally, public support for the costs associated with obtaining certification during construction is needed. Lastly, in terms of securing on-site space for facilities related to carbon emission reduction and carbon sinks, it is worth considering new standards and regulations for installation obligations, designating carbon-neutral cities and providing support, and establishing specific types of carbon-neutral facilities under the supervision of the Ministry of Environment.

The significance of this study lies in four main aspects: First, it estimates current carbon emissions in 1990s new towns centered around apartment buildings from a lifecycle perspective and develops a model to predict future carbon emissions based on these estimates. Second, assuming the maximum floor area ratio permitted under the Special Act on Aging Planned Cities, it quantitatively estimates the increase in carbon emissions using the model developed in this study. Third, it selects passive and active technologies and policies applicable at this stage, proposing unit standards for the amount of carbon emissions that can be reduced in urban and architectural fields, and providing examples

of the potential carbon reduction that can be achieved in the future. Finally, it offers various policy ideas for guiding the reconstruction of multi-family housing complexes into eco-friendly buildings with high levels of carbon emission reduction elements, focusing on special laws connected with multiple regulations and policies.

Given the current market structure, increasing density through higher floor area ratios in full-scale redevelopment is inevitable. This leads to greater carbon emissions during the lifecycle stages of demolition, construction, and operation compared to the existing structures. Therefore, as reconstruction begins in each complex in the future, efforts from both private and public sectors, as well as suppliers, are required to create high-level eco-friendly buildings by applying energy-saving, resource-circulating, and carbon reduction technologies across the entire lifecycle of buildings.

Keywords :
Old New-town, Carbon Emission Reduction Policies, Lifecycle Assessment, Energy Consumption