일반연구보고서 2025-12

탄소중립도시 실현을 위한 무탄소 에너지원 적용 방안 연구

A Study on the Application of Carbon-Free Energy Sources for Realizing Carbon-Neutral Cities

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Summary

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Introduction

This study was conducted to examine the feasibility of introducing carbon-neutral energy sources in existing urban areas by establishing site suitability criteria for each energy source, applying them to urban spaces on a pilot basis, and presenting the planning implications of the derived results. The research established a comprehensive analysis framework integrating technical, spatial, institutional, and social factors, providing meaningful practical evidence for the transition of existing cities toward carbon neutrality. The key findings of this study are summarized as follows.

The accelerating push for carbon-neutral cities necessitates the introduction of carbon-free energy sources (solar, wind, etc.). However, there is a current lack of spatial site suitability reviews for energy facilities utilizing existing urban infrastructure and facilities. Specifically, discussions on converting coal-fired power plant sites to carbon-free energy are limited to national/regional policy levels, lacking practical, spatial-centric reviews concerning local energy supply impacts. Therefore, the primary objective of this study is to propose comprehensive spatial suitability review criteria for the transition to carbon-neutral energy essential for realizing carbon-neutral cities, and to demonstrate the feasibility of applying these criteria to case study cities.

The scope of the study focused on Solar PV, Wind, Hydrogen, and Small Modular Reactors (SMRs). The research involved establishing regional-level site criteria by integrating locational characteristics and evaluation metrics derived from domestic and international literature. For the pilot application, Boryeong-si and Dangjin-si in Chungcheongnam-do, cities facing mandatory large-scale fossil fuel transition, were

selected as the spatial scope for a suitability assessment. The final deliverable includes spatial planning methodologies and integrated transition tasks for applying the site analysis results to existing cities.

Key Research Findings

The study established a clear framework of site criteria for major carbon-free energy sources. This provided a practical, quantitative basis for judging the spatial acceptance of each energy source in existing urban spaces.

Solar PV. Criteria were established considering environmental, topographical, and regulatory conditions (insolation, slope, shading, land use regulations). The analysis confirmed that Solar PV is the most widely applicable and fastest deployable energy source in existing urban areas, with broad distribution of Class 1-2 suitability zones, particularly utilizing building envelopes (BIPV), parking lot canopies, and public unused land.

Wind Power. Due to numerous limiting factors (wind speed, elevation, noise, landscape impact, protected zones), the criteria highlighted that Wind Power has extremely low applicability within urban areas. Most regions were classified as Class 3 or unsuitable, making it practically infeasible for city-centric deployment.

Hydrogen and Fuel Cells. Criteria focused on access to storage/supply infrastructure, safety buffer zones, and compatibility with surrounding facilities. Fuel cells emerged as a viable distributed power source, showing suitability (Class 2-3) primarily near industrial complexes, R&D campuses, and public facilities, contributing practically to urban electrification and thermal management.

SMRs. Criteria integrated complex requirements, including access to cooling water, grid connection, safety radius, and compatibility with surrounding land use. The analysis clearly identified industrial sites, port areas, and especially existing coal-fired power plant sites (Boryeong/Dangjin Thermal Power) as having high suitability (Class 1-2), positioning SMRs as a feasible replacement for base-load power where infrastructure is pre-existing.

Policy Implications and Recommendations

The site analysis demonstrated that carbon-free energy sources possess entirely different levels of spatial acceptance within the structure of existing cities. The overarching finding is that the transition requires differentiating strategies based on

locational criteria and linking these findings directly to urban planning mechanisms.

The most significant policy recommendations to overcome institutional and implementation limits are:

Establish a Carbon-Free Energy-Centric Urban Planning System: Mandate the inclusion of the "Energy Transition Sector" within the City/County Master Plan under the National Land Planning Act. Furthermore, establish a 'City-Type Carbon-Free Energy Planning Zone' to institutionalize the strategic placement of distributed sources like solar and storage (ESS) on public infrastructure (roads, harbors).

Reinforce Just Transition and Local Economy Linkage: For cities phasing out coal power, utilize retired power plant sites as 'Carbon-Free Industry Transition Hubs' for SMRs, hydrogen, and renewables. Implement Just Transition Funds and job retraining programs to mitigate economic and employment gaps, linking the energy transition to regional economic revitalization.

Strengthen Local Government-Led Implementation: Replace short-term, central government-led competitive funding models with the establishment of a long-term (5+ years) statutory support system for carbon-neutral cities, ensuring policy continuity. Additionally, build an Integrated Management Platform (One-Map System) that links site suitability data with urban planning, permitting, and public consultation processes.

Adopt Regional Custom-Fit Energy Mix Strategies: Avoid a uniform national approach. Instead, tailor the energy portfolio to regional conditions (e.g., Solar PV + Hydrogen Complex in Dangjin, Marine/Mountain-based Composite Mix in Boryeong), which will be essential for enhancing the competitiveness of carbon-neutral cities.

In conclusion, this research validates that the effective transition of existing cities to carbon-free energy must be predicated on clearly defined spatial acceptance criteria and realized through integration with formal urban planning and management tools.

Keywords :

Carbon-Free Energy (CFE), Carbon-Neutral City, Energy Infrastructure Siting, Energy Transition, Thermal Power Plant Decommissioning