

Institutionalizing Carbon Spatial Mapping for Urban Carbon Neutrality: Legal & Policy Integration Strategies in Korea

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Abstract. Following Korea's Framework Act on Carbon Neutrality (2021), local governments are mandated to establish carbon neutrality plans. However, existing greenhouse gas inventories lack the spatial resolution required for city-scale decision-making. This paper presents a national R&D project (2023–2027) developing a Carbon Spatial Mapping Platform that visualizes emissions and carbon absorption at a 100 m grid resolution. Building on 74.7% overall project completion and a user demand survey in which 69.6% of respondents rated the platform as necessary, we propose three legal reform packages—targeting the National Land Planning and Utilization Act, the Framework Act on Carbon Neutrality and Green Growth, and the Environmental Impact Assessment Act—to embed spatial carbon analytics as a statutory evidence base for urban planning across Korea's 229 local governments.

1. Introduction

Cities account for 75% of global primary energy consumption and 60% of global greenhouse gas (GHG) emissions from urban areas, yet climate governance systems rarely supply the spatial granularity needed to translate national reduction targets into actionable city-scale decisions. In Korea, the 2021 Framework Act on Carbon Neutrality and Green Growth for Climate Crisis Response legally obligates all 229 local governments to prepare carbon neutrality plans and achieve net-zero by 2050. City-county master plan guidelines revised in December 2021 further require GHG baseline surveys and five-year reduction targets.

Despite this regulatory momentum, implementation faces a fundamental methodological obstacle: current GHG reporting relies on administratively aggregated inventories that cannot identify emission hotspots within cities, link spatial planning decisions to measurable carbon outcomes, or support scenario-based simulations for urban development. This paper argues that a Carbon Spatial Mapping Platform—providing high-resolution, legally embedded spatial carbon data—is the missing link between macro-level climate commitments and micro-level urban action.

2. Problem Statement: Three Structural Gaps

Korea's current climate planning infrastructure exhibits three structural limitations that prevent evidence-based carbon-neutral urban management:

(1) Macro GHG Inventories Only. National and local inventories aggregate emissions at the administrative-boundary level, masking intra-urban variation. Without spatial disaggregation, hotspot-targeted interventions are impossible.

(2) Two-Year Data Lag. Published GHG statistics are delayed by approximately two years relative to actual emission events, making near-real-time monitoring and adaptive management unachievable.

(3) No Spatial Planning Tool. No statutory requirement exists to incorporate spatial carbon data into city-county master plans or urban management plans. Carbon considerations remain qualitative and discretionary rather than quantitative and binding.

The consequence is that urban development decisions—rezoning, infrastructure investment, building permits—proceed without objective, spatially resolved assessment of their carbon implications. The regulatory context has changed but the planning toolkit has not.

3. Carbon Spatial Mapping Platform and Development Progress

The national R&D project 'Development of Planning Support Technologies Based on Carbon Spatial Mapping' (Grant No. RS-2023-00242291; KAIA/MOLIT, 2023–2027) is building a Carbon Spatial Map System accessible at carbonmap.kr. As of the reporting period, overall project completion stands at 74.7%, comprising three workstreams:

- Carbon Spatial Map Construction (77% complete): 100 m grid-level mapping of energy, transport, and building-sector emissions and carbon absorption across Korean cities.
- Planning Support Technology (66% complete): AI simulation tools enabling scenario-based modelling of how urban development decisions alter local emission trajectories.
- Diffusion and Institutionalization (82% complete): Development of the legal reform proposals and diffusion model (C21) and reform proposal model (C31) now ready at 95% completion.

The As-Is/To-Be transformation envisioned by the platform addresses six dimensions: shifting the data basis from administrative-boundary aggregates to 100 m grid spatial data; converting evidence from qualitative narratives to quantitative simulation; establishing an official legal mandate where none currently exists; reducing data lag from two years to near-real-time monitoring; replacing single-ministry data silos with multi-ministry sharing; and providing public dashboards in place of no public interface.

A user demand survey conducted with local government planners found that 69.6% rated the platform as necessary or highly necessary (29.2% highly necessary; 40.4% necessary), validating the demand-driven design approach.

4. Legal and Institutional Reform Proposals: Three-Act Integration Strategy

Technology capability alone is insufficient. Spatial carbon data must be embedded in legal frameworks to ensure routine, enforceable use across all 229 local governments. The project proposes a three-act reform strategy targeting Korea's core urban planning and environmental statutes.

Act 01 — National Land Planning and Utilization Act: City-County Master & Management Plans

This Act is the primary legal instrument governing land-use change in Korea. Proposed amendments (legal basis: Arts. 3 and 56; City-County Master Plan Guidelines, December 2021 amendment) include:

- Mandate Carbon Spatial Map as statutory evidence in City-County Master Plans.

- Add GHG emission and absorption inventory to baseline survey items.
- Require five-year GHG reduction targets in city planning goals.
- Designate Carbon-Neutral Special Zones in urban management plans.
- Integrate carbon simulation into development permit review (Art. 56).

Act 02 — Framework Act on Carbon Neutrality and Green Growth: Carbon Neutrality City & Data Integration

This Act mandates local carbon neutrality plans and 2050 net-zero targets. Proposed reforms (legal basis: Arts. 12, 29, and 36; Act No. 18469) include:

- Art. 12: Link carbon neutrality targets to spatial land-use plans.
- Art. 36: Mandate Carbon Spatial Map in the national GHG information management system.
- Art. 29: Define Carbon Neutral City designation criteria via spatial maps.
- Standardize spatial indicators for local climate crisis response plans.
- Establish citizen participation procedures with spatial data visualization.

Act 03 — Environmental Impact Assessment Act: Climate Impact Assessment Tool

EIA procedures apply to large-scale developments and are a critical decision point for carbon-intensive projects. Proposed reforms (legal basis: EIA Act No. 20518, October 2024 amendment; Enforcement Decree and Rules) include:

- Designate Carbon Spatial Mapping as a mandatory climate EIA tool.
- Require carbon absorption potential assessment for large-scale developments.
- Establish objective, data-driven carbon impact prediction procedures.
- Integrate spatial carbon data into strategic environmental assessment.
- Link post-development carbon monitoring to the spatial map platform.

5. Policy Implications and Governance Model

Effective institutionalization requires not only legal mandates but a supporting data governance architecture. The proposed model positions the Carbon Spatial Map based Planning Support Platform (100 m grid · AI Simulation · Real-time Monitoring) as the shared data infrastructure mediating between two ministerial domains:

- MOLIT (Ministry of Land, Infrastructure and Transport): Spatial platform, land-use plans, city master plans.
- MCEE (Ministry of Climate and Environment): GHG inventories, EIA system, climate targets.

This bi-ministerial convergence feeds a unified platform that ultimately serves 229 local governments for carbon neutrality plans, hotspot monitoring, and citizen dashboards. Five expected policy impacts follow from this architecture:

Evidence-Based Land Use. Hotspot-targeted carbon reduction replaces intuition-driven planning.

Cross-Sectoral Integration. Unified data across energy, transport, buildings, and green infrastructure enables coherent mitigation strategies.

Legal Enforceability. Statutory embedding ensures policy continuity beyond political cycles.

Citizen Engagement. Neighbourhood-scale carbon footprint dashboards support informed public participation.

National Scalability. The diffusion model (C21) is complete and ready for nationwide rollout.

6. Development Roadmap and Phase 2 Outlook

The project follows a five-year development roadmap: 2023 Legal Review; 2024 Demand Survey; 2025 Reform Proposals (current stage, marked as critical milestone); 2026 Pilot Cities demonstration; 2027 National Scale-up. Phase 2 activities (2026–2027) will focus on:

- Pilot city demonstration and real-time AI monitoring in selected municipalities.
- Platform UX refinement through user-centred design with local government planners.
- International knowledge transfer and global scaling of the Korean institutionalization model.

7. Conclusion

Korea stands at an inflection point: ambitious carbon neutrality legislation is in place, and a technically mature Carbon Spatial Mapping Platform is approaching completion. The critical remaining challenge is institutional—transforming spatial carbon data from an optional analytical aid into a mandatory statutory evidence base embedded across the National Land Planning Act, the Carbon Neutrality Act, and the EIA Act.

The three-act integration strategy presented here operationalizes carbon-neutral urban management by closing the gap between macro-level climate targets and micro-level spatial planning. With 95% of the diffusion and reform models ready, and 69.6% user demand confirmed, the conditions for nationwide institutionalization are in place. Legal embedding of spatial carbon analytics creates a governance model that ensures evidence-based land use, cross-sectoral integration, and an enforceable path to 2050 carbon neutrality for Korea's 229 local governments.

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