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Sustainable Building Legislation and Incentives in Korea: A Case-Study-Based Comparison of Building New and Renovation

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Abstract: More than one quarter of buildings in the Republic of Korea (RoK) are aged, approaching the end of their projected lifetimes, and require renovation. Aged buildings in the RoK are generally demolished, and new buildings with higher gross floor areas are realized on the same properties. That kind of redevelopment is associated with increased resource consumption, related greenhouse gas emissions, and other environmental impacts, as well as the generation of construction waste and the displacement of existing building tenants. This study analyzes the legislative framework for sustainable building in the RoK. Legally mandated basic standards for new buildings and renovation were analyzed, and differences were identified. Calculation methods and criteria for sustainable building incentives were determined. Incentive calculation methods were applied to three case-study buildings, which represented the three most common building types in Korea. Maximum building height, floor-to-area and building coverage ratios, and fiscal incentives for energy-efficient technical systems were quantified for new buildings and renovations. The findings identified the current legislative privileges for new buildings. To increase future sustainable building renovations, the criteria and tools for improving the existing legal framework, and economic feasibility, were identified and discussed.

Keywords: building standards analysis; sustainable building certification; building scenarios comparative analysis; sustainable building incentives; building renovation; building redevelopment

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1. Introduction

1.1. The Historical Evolution of the Korean Building Stock

Between 1989 and 1997, the building construction industry in the Republic of Korea (RoK) experienced continuous and incremental growth in terms of building volume and economic added value. The aggregated value of the building construction industry grew approximately 7% per year, an almost sevenfold increase in business activity and building output over a period of nine years [1]. The rapid growth of the Korean building construction sector was caused by multiple factors: (i) the liberalization of the building market, in particular the housing sector [2]; (ii) public investment in infrastructural projects and the expansion of urban regions [3], and (iii) national policies aimed at increasing housing supply, and reaching parity with household demand [4]. To realize nation-scale plans aimed at dynamically increasing economic development and improving public infrastructure and housing supply, a program for industrialized mass-building construction was adopted [5]. However, industrialized mass construction that was aimed at rapid, maximum economic growth quickly became an instrument of real-estate speculation [6], and throughout the entire period of economic growth, the social and environmental effects of large-scale building projects were ignored. New redevelopment projects through the demolition of existing low-rise neighborhoods and informal settlements displaced previous

inhabitants through gentrification [7]. Building material quality and usage decreased to the minimum, and outdated low-efficiency technical systems were installed in new construction to increase profits through cost abatement [8,9]. Lax environmental building norms, which demanded comparably lower standards for building envelope insulation than those in other developed countries, also encouraged real-estate speculation [10].

During the period between 1989 and the financial crisis of 1997, approximately 1.30 million building construction permits were issued in the RoK, which represented 24% of all permits issued during the entire 1989–2019 period (5.38 million) [11]. On average, the lifetime of a Korean building built before the 2000s is 25 years [12,13]. The reduced operative building lifespan has been caused principally by mass industrialized construction and usage of minimal quantities of low-quality building materials to increase profitability. Mass industrialization was fueled by deregulation of the real estate market, as well as the housing shortage that dominated the Korean economy from the 1960s to the 1990s [4,14]. After 25 years, substantial degradation of both structural and envelope building components, as well as technical systems, imposes the need for extensive building renovations against potentially threatening degradation of the buildings' usability. Accordingly, of the existing 7,191,842 buildings across all uses, approximately 1.8 million buildings were approaching the end of operative life in 2019 [15]. After the financial crisis of 1997, the building construction sector in the RoK recovered its previous constant upward trend in production output only at the end of the 2000s (Figure 1) [16]. However, during the period 1997–2010, the cultural and political paradigm of the building construction industry and public urban planning changed drastically, along with greater transformations in Korean society. In 2002, the Act on the Improvement of Urban Areas and Residential Environments was enacted [17]; the new legislation reflected a principal rise in attention to, and interest in, urban renovation [18,19]. The Act focused on improving both public spaces through the modernization of the infrastructure, and neighborhood renovation programs for buildings and private shared open spaces [20]. Subsequently, a comprehensive strategy for economic development was developed in 2008 with the adoption of the Organization of Economic Cooperation and Development (OECD)-sponsored Low Carbon Green Growth (LCGG) framework [21].

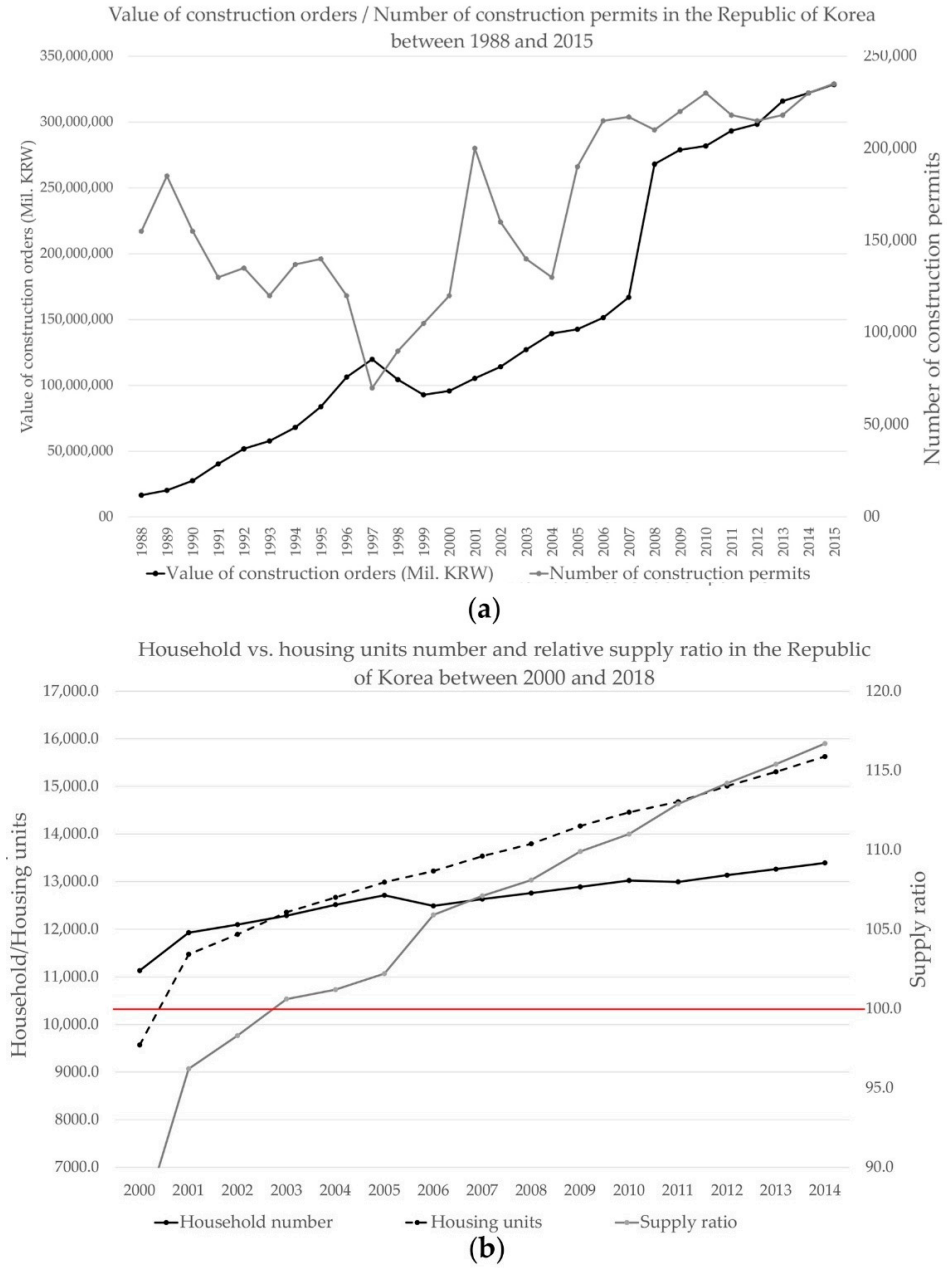


Figure 1. Evolution of housing stock in the RoK: (**a**) value of construction orders (in millions of KRW) and number of building permits between 1988 and 2015 [22]; (**b**) household demand against supply of housing units and relative ratio between 2000 and 2014; the red line indicates the 100% supply ratio threshold [22].

1.2. The Historical Development of a Legal Framework for Sustainable Building in Korea: Challenges, Conflicts, and New Standards

Initial attempts to draft policies and national regulations aimed at sustainable development were realized in mass-scale public urban regeneration initiatives [23,24], and large-scale private construction projects, in particular in the housing sector, returned to play an important role in the national economy [16]. However, the dynamic of rapid growth in the construction business tied to large-scale requalification projects repeated the same speculative pattern observed in the 1989–1997 period. Notwithstanding the more stringent regulations in terms of environmental building standards, the growth experienced by the building sectors was fueled by the market attractiveness of redeveloped neighborhoods in requalified urban contexts; accordingly, new building projects came to once again domi-

nate the Korean building market. Construction initiatives focused on demolition and the replacement of existing neighborhoods with maximum building volume, with improved comfort, as well as available facilities and services [25].

Since the beginning of the 2010s, new-building-associated redevelopment and requalification projects have continued to raise questions regarding the achievement of LCGG goals, such as increasing building environmental performance and decreasing greenhouse gas (GHG) emissions. There are also questions about the improvement achieved in terms of sustainable practices and resilience in redeveloped urban contexts and buildings [26]. The reuse of the existing building stock as an alternative strategy to new construction was weakened by drastic social changes that occurred in the period of 2000–2010. Building sector practices and economic strategies were influenced by transformations of Korean society, including: (i) an increase in the aging and aged population, (ii) a constant decrease in birth rates and household composition, (iii) national policies aimed at modernizing the technological infrastructure of cities under the "smart" city planning trend, and (iv) parity between housing supply and demand (Figure 1b) [16,27,28]. In the context of these factors, existing buildings risk becoming both technically and functionally obsolete, and unsuitable for an increasingly aging population comprising fewer members in the average household. New housing projects are built to fulfill market trends. However, with unbalanced supply and demand, unsold residential units remain on the market (Figure 2a) [29,30]. The market demand for residential spaces designed for a transformed society and for higher-quality standards of public and private services has led to increased investment in the redevelopment of existing buildings [31]. Redevelopment projects aim at the complete demolition of entire dilapidated districts (Figure 2b), inclusive of housing, public, and commercial services; such projects replace existing buildings with high-rise apartments and more expensive services and facilities. Between 2002 and 2010, more than 300,000 redevelopment projects were approved (Figure 2b) [31]. Furthermore, 70% of new building permits issued in the 30-year period between 1989 and 2019 (4.08 million) were granted in only 17 years, between 2002 and 2019. In 2019, economic and national policies for sustainable building standards reflected the reality of the building sector in the RoK; sustainable building standards were developed, focusing on new construction. Tax and floor-to-area ratio (FAR) incentives often support the construction of high-rise housing complexes that advertise low-energy demand and green spaces as added investment value [28,32]. Conversely, the renovation of aged buildings is often regarded as an economic risk by building owners, construction companies, and investors alike [33,34].

1.3. Article Purpose and Contents: Renovation as a Holistic Sustainable Building Strategy

The research discussed in this article analyzed and compared the current normative framework of new buildings and renovation of aged buildings in the RoK, focusing on the city of Seoul. Norms regulating sustainable building on national, city, and district levels were identified, and basic standards for new and renovated buildings were extrapolated from the existing legislation. Additionally, sustainable building incentives for vertical and horizontal extensions and tax and financial discounts for new buildings and renovations were identified. Based on these identified standards, it was possible to conduct a comparative analysis between new and renovated buildings for a minimum building standard scenario with maximum sustainable building incentive application. The comparative analyses included three existing case-study buildings, which were selected to represent the three most common building types in the RoK: detached multiunit dwellings of five or fewer stories (so-called Villas) [35]; solely residential-use apartment buildings with more than five stories (so-called Apartments); and Mixed-Use buildings with a varying undefined number of stories, which could accommodate commercial, industrial, administrative, and residential uses. Differences were identified in standards and incentives between new and renovated buildings, and the findings provide an in-depth overview of the effectiveness of the current legislation in encouraging sustainable building.

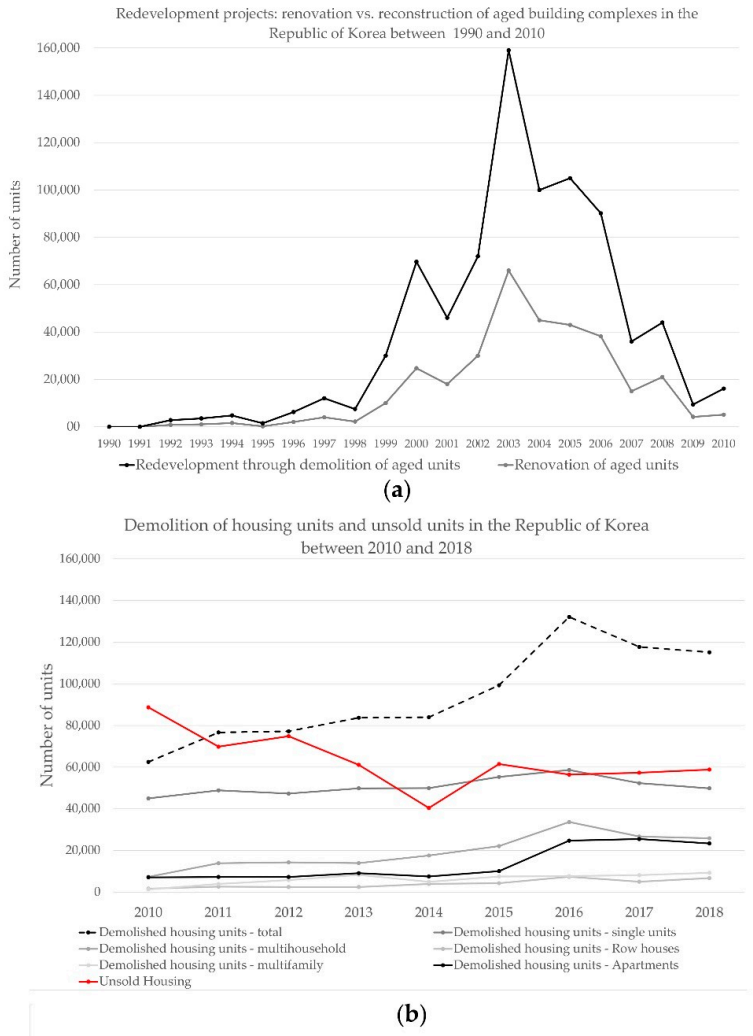


Figure 2. Redevelopment projects through demolition and new construction versus the renovation of aged buildings: (**a**) number of redevelopment projects through aged building renovation and redevelopment through demolition in the period of 1990–2010 [31]; (**b**) number of demolished housing units per type contrasted with the amount of unsold housing units in the period 2010–2018 [15]. The graphs show that, while renovation of aged units decreased continuously throughout the end of the 2000s, demolition of buildings and their eventual redevelopment through new construction was steadily increasing, potentially driving the reduction of unsold housing by replacement of older buildings to make space for modern housing with increased market appeal.

A recent publication of two of the authors of this article focused on the renovation of aged apartments in the RoK, and discussed different topics, such as: (i) the analysis and simulation of existing building-renovation strategies, (ii) the development of tools and guidelines for quantifying sustainable performance indicators, and (iii) the economic risk–benefit analysis of renovation projects. Studies on building simulations and developing construction components demonstrated the advantages of building renovation in terms of GHGs and primary energy (PE) demand reduction and improving comfort [36]. Modular components were developed for refurbishing existing Korean apartment building envelopes as part of an adaptable system for multiple building renovations [37]. Other research developed Korean building renovation guidelines for decision-making processes and the related organizational structures [32,38]. Building renovation was also addressed in the context of the Korean sustainable building certification system GSEED, with the aim of achieving higher sustainable building certification scores through better life cycle analysis (LCA) results for the impacts of building materials and building operation [39]. Tools have

also been developed to determine the optimal building renovation strategy for minimizing life cycle costs (LCCs) and environmental impacts. Integrated LCA and LCC tools address social and technical aspects in the decision-making process for renovations [40–42].

The economic analysis of renovation costs and advantages focuses in particular on construction and investment costs, and quantifying buildings' postrenovation added value [33,43]. Past economic studies were based on the statistical price fluctuation data of buildings and land. Such economic studies did not consider existing legislative policies as valid economic instruments in the renovation of existing buildings. Investigators have found that legally mandated financial incentives for sustainable building are challenged in influencing the real estate market toward environmental building practices [44]. However, developed tools and suggested policies have not been integrated into the broader legislative framework for sustainable new buildings and renovations. Past research did not refer to the existing legislation in terms of the potential advantages of compliant building renovation based on maximizing incentives for compliance. Furthermore, comparative case-study analysis based on the existing applicable legal basic conditions is still missing.

Therefore, this study aims to fill the gap between existing attempts to define strategic policies toward building renovation and tools, to simulate and measure building performance through refurbishment projects. The case-study comparative analysis provides an instrument for identifying potential legal and economic advantages of building renovation against building new. In the study, limitations of current legislative norms in promoting renovation are identified, the effective increase in vertical and horizontal building extension is quantified, and the sustainable performance of building scenarios according to mandated standards is determined as well. The results of the study offer a valuable tool for multiple objectives: (i) the realization of technical studies on building renovation components, (ii) the quantification of economic advantages for building renovation, and (iii) the potential for improving the existing legislation in favor of sustainable renovation practices. Improved legislation for building renovation would allow a reduction of the environmental impact of building projects. Furthermore, sustainable social and equitable economic practices in aged building renovation and related broad-scale district regeneration can be facilitated.

2. Materials and Methods

The comparative legal framework analysis of the Korean legislation for sustainable renovation and building new was executed through the following seven phases: (i) analyzing the existing legislation promoting sustainable development, focusing on building regulations; (ii) selecting the exemplary case-study buildings, and describing their spatial characteristics through legally relevant indices; (iii) analyzing basic required standards for new buildings and renovations according to legal technical specifications mandated for the case-study buildings; (iv) analyzing incentive regulations and schemes for overperforming sustainable new and renovated buildings applicable for the case-study buildings; (v) quantifying maximum sustainable building incentives for new and renovated case-study buildings; (vi) comparing basic standard scenario-based new and renovated case-study buildings; and (vii) comparing maximum incentives of scenario-based new and renovated case-study buildings. Figure 3 illustrates the methodological workflow that integrates the described seven phases in a structured process. The phases are described in detail below:

i. The analysis of the legislative framework entailed describing relevant national dispositions, executive directives, and technical codes that promote and support sustainable building in the RoK. In particular, the analysis focused on two types of regulations: dedicated legislation for sustainable (so-called green) building, enacted after Korea's adoption of the OECD-sponsored LCGG plan in 2008; and existing building regulations, amended to be integrated with sustainable building norms. The plan officially realigned governmental dispositions and economic strategies toward sustainable development. Therefore, for this study, the country's adoption of the LCGG was considered the official beginning of legislative action for sustainable development. Laws enacted between 2008 and 2020 have been progressively

ordered according to the year of enactment, from the earliest to the latest, and content and stated objectives have been described. The regulations were also assigned to national, municipal, or district law categories. Furthermore, the content of legal documents was classified to distinguish between general dispositions, specific directives, technical codes, and regulations related to sustainable buildings. Legal codes regulating building standards and sustainable building incentives through quantifiable indexes were specified.

ii. Following the analysis of the legislative framework, three existing exemplary case-study buildings were selected for developing comparative scenarios between new and renovated buildings. The main selection criterion was that each building should represent a typical building type of most aged residential and nonresidential buildings in Seoul, regarding building use, building size, cubature, and building age. Therefore, one apartment building, one villa building, and one mixed-use building were selected. Identifying the specific buildings resulted from an intensive search of the researchers for building owners who confirmed support for this research by providing building plans and allowing building access for on-site surveys. The buildings have been described through quantifiable spatial indices regulated by the applicable regulations in their respective districts analyzed in phase one, such as FAR, maximum distance from public street, and building coverage ratio.

iii. Based on the analyzed legislation, basic standards for new and renovated buildings were identified and structurally organized. In particular, codes with quantifiable target indices and values were selected to provide an objective basis for the comparative analysis executed in the following phases. The regulations that were categorized earlier by jurisdictions were applied by category to the different case-study building types.

iv. The incentive schemes that were identified in the analyzed legislations (in i) were structurally organized for applicability to sustainable new buildings and renovations overperforming on determined basic standards. Incentives relate to three main categories: (a) the size and floor areas of existing buildings after vertical/horizontal extension in the framework of renovations; (b) the size and floor areas of new buildings on the same properties as existing buildings; and (c) tax discounts and financial support for energy-efficiency measures and/or renewable energy generation system installations. Prerequisites for incentives were examined and explicated, and incentive criteria and calculation methods were organized and assigned to the three case-study building types.

v. Following the identification and organization of maximum incentives (in iv), the incentives were quantified for both new buildings and renovations for each of the three case-study buildings.

vi. The minimum building standards identified (in iii) were applied to a comparative analysis of new and renovated buildings, and potential applicable sustainable building incentives were also considered. The comparative analysis aimed at investigating differences in terms of minimum target values and grading level through certification systems for building envelopes, PE demand, and interventions to increase the sustainable performance of the buildings.

vii. Based on the identified laws, standards, and incentives, the final comparative analysis entailed applying the identified laws and criteria to two scenarios: the renovation of the existing building, or its demolishment and the construction of new building, for each of the three case-study buildings. The focus of the analysis was on quantifying differences between maximum building size and floor area allowed, according to the applicable sustainable building incentives. Finally, combinations between sustainable building FAR incentives were visualized to determine the range of variations for renovation interventions based on the evaluation criteria for incentive awarding.

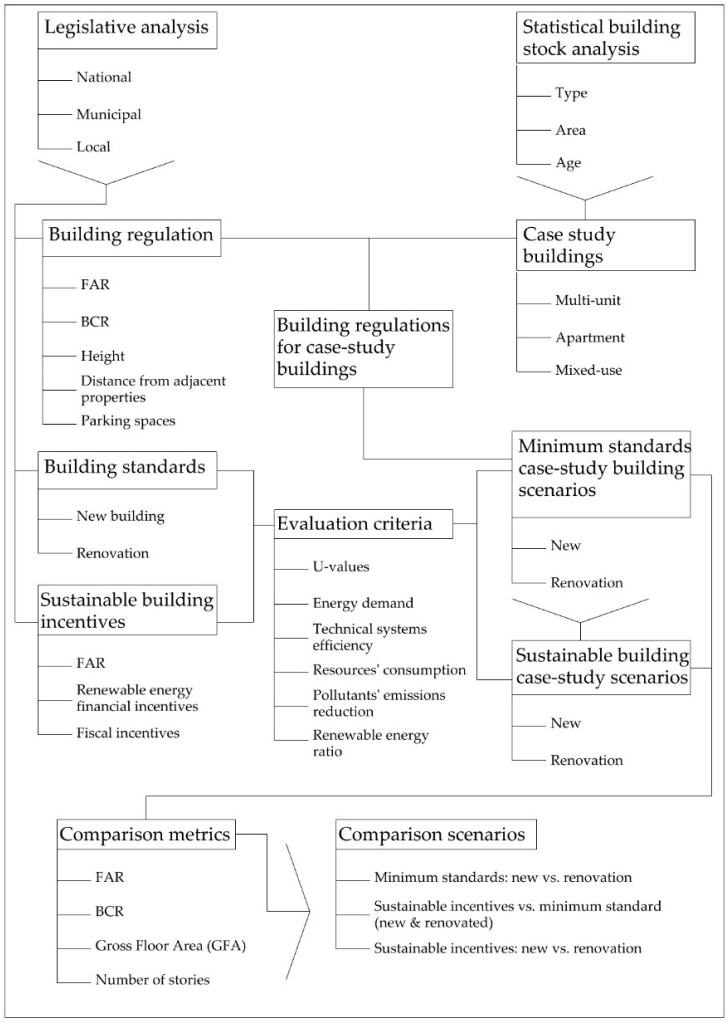


Figure 3. Methodological flowchart describing the process of legislative analysis, case-study building selection, definition of evaluation criteria for minimum standard and sustainable construction incentives, and comparison between multiple case-study building scenarios described in article. Each box indicates a phase in the legislative analysis and scenario-formulation process. Each box further lists control parameters and indices that determine the results associated to the phases indicated in the boxes, which are further described in Section 3, Results. Arrows indicate the logical and hierarchical sequence between phases, illustrating the parameter-based process of legislative analysis, identification of case-study buildings and incentives for sustainable construction, formulation of scenarios for new and renovated buildings with minimum standards and maximum incentives, and the comparison between scenarios to quantify financial, economic, and spatial advantages obtained from incentives for sustainable construction.

The analysis of the legal framework and quantification of comparable spatial indices for both new buildings and renovations aimed at investigating the effectiveness of the current legislation in promoting sustainable building renovation. This research investigated according to qualitative, and as much as possible, quantitative criteria, to what extent existing standards, regulations, and sustainable building incentives support (i) the renovation of buildings, and (ii) their demolishment, and the construction of new buildings. The following research questions were addressed: (i) Which basic standards allow the application of incentives for sustainable building? (ii) What are the differences in terms of required building properties (such as thermal insulation of the building envelope) between basic standards for new buildings and renovations? (iii) Does renovation or new building according to maximum incentives result in a higher FAR? (iv) Do specific measures required

for maximum incentive awarding need to be implemented at the same time, or can they coexist as individual renovation options? (v) Does building renovation or building new according to basic standards result in a higher FAR of the resulting building? (vi) Which incentives are assigned to specific building types, new buildings, and renovations? (vii) Do new buildings or renovations according to basic standards or maximum incentives have potential economic advantages? The research results that include answers to the questions are discussed in detail in the following sections of this paper.

3. Results

3.1. Overview of the Legal Framework of Sustainable Building Renovations

Table 1 presents the overall legislative framework for sustainable renovation of the building stock and building of sustainable (green) buildings in the RoK. The hierarchy of applicability for each norm on the national, municipal, and local levels is regulated by the Latin principle that the regulations contained in specialized laws prevail over the regulations of general law ("lex specialis derogat legi generali") [45]. Accordingly, specific local codes can supersede directives from broader jurisdictions. In particular, the principle applies to district building standards and regulations contained in District Unit Plans, which can supersede municipal building codes (Table 2) [46].

Table 1. Overall legislative framework for sustainable building in the Republic of Korea.

Name of Norm/Act/Plan	Jurisdiction-Year of Enactment/Last Amendment	Contents
5-year Low Carbon, Green Growth economic development plans [47–49]	National plan-2008–2014 (1st) 2015–2018 (2nd) 2019–2023 (3rd)	Six main strategies for sustainable economic development: (i) public investment plan for the support of research on renewable energy supply and GHG abatement technologies; (ii) (27 to 30)% GHG emission reductions across economic sectors until 2020, compared with 2009 business-as-usual levels (1st plan), raised to 37% in the 3rd 5-year plan; (iii) modernization of the national energy infrastructure to integrate with the renewable energy production supply chain through both private and public providers; (iv) cooperation projects with foreign partners to develop GHG/renewable energy technologies; (v) promotion of the RoK among the eight globally leading countries for sustainable technology development; and (vi) reduction of health hazard pollutant emissions, in particular particulate matter (PM) 2.5 and 10. The plans are main directives for the development of public budget and investment plans.
Framework Act on Low Carbon, Green Growth [50]	National Act-2010 (last amended: 2020)	Consolidation and legal formulation of the first 5-year LCGG plan directives into national law; mandate for instituting sustainable building certification systems and standard procedures for monitoring GHG emissions; mandate for defining fiscal reform instruments directed toward sustainable technology acquisition and development. The code contains general directives with legal applications.
Green Buildings Construction Support Act [51]	National Act-2012 (last amended: 2020)	Guidelines and legislative definition of sustainable building regulations; legal definition of sustainable construction and incentives for green buildings; integration of sustainable building and building standards in the Building Act; development of tax and building extension incentives to accelerate sustainable renovation projects; institutionalization of sustainable building certification systems, namely the Green Standard for Energy and Environmental Design (GSEED) and Building Energy Efficiency Certificate (BEEC); definition of financial incentives for building renovation, such as the "Green remodeling interest support project". The code contains general directives with legal technical applications for the municipal and local level.

Table 1. *Cont.*

Name of Norm/Act/Plan	Jurisdiction-Year of Enactment/Last Amendment	Contents
Energy Saving Design Standard for Building [52]	National Standard-2008 (last amended: 2018)	Technical code defining minimum building envelope U-values and building material standards, such as the thickness of insulation materials for different components in multiple standardized climatic zones of the RoK; classification of insulation standards and relative performance in terms of materials' LCA indicators; definition of a checklist for energy-efficient heating, ventilation, air conditioning, lighting, and electrical equipment in standard buildings; definition of a sustainable incentive checklist for green buildings and grading system for incentive awarding; and standards for Building Energy Management Systems (BEMS) for energy consumption monitoring and demand prediction and scheduling. The code contains quantifiable indicators and relative minimum targets for new and renovated buildings.
Seoul Metropolitan Government Ordinance on the Support of Construction of Green Buildings [53]	Municipal ordinance-2014 (last amended: 2019)	Metropolitan government declaration of intent to promote sustainable buildings: provisions on sustainable building standards, monitoring and certification of GHG emission reduction; implementation of a financial support plan for the construction of green buildings and sustainable renovation; and implementation of a program for relaxing building permits and building size and floor area limitations to incentivize green building construction on metropolitan and district levels. Contains technical documents, quantified standards, and target values for different indicators (see Section 3.3).
Seoul Metropolitan Government Ordinance to support Repair of Houses in Low-Rise Residential Areas [54]	Municipal ordinance-2016 (last amended: 2020)	Defines legal applicability criteria, evaluation methods, operation, and funding range for the "Seoul housing Retrofit Loan Support" financial incentive toward the renovation of low-rise housing in the Seoul metropolitan area.
Act on the promotion of the development, use and diffusion of new and renewable energy [55]	National Act-2005 (last amended: 2020)	Property and acquisition tax incentives for the purchase/renting of efficient, renewable energy systems and technologies: photovoltaic (PV) systems, hot water (solar thermal) systems, and geothermal and fuel cell supply systems; definition of renewable energy point credits for reselling renewable energy surplus from PV systems. Contains the legislative mandate for the definition of quantified standards and target values for different indicators (see Section 3.5).
Seoul Metropolitan Government Ordinance on Establishment and Operation of Climate Change Fund [56]	Municipal ordinance-2008 (last amended: 2018)	Ordinance of Seoul Metropolitan Government to promote the reduction of greenhouse gases, development and diffusion of new and renewable energy, efficiency in the use of energy and supply of urban gas, etc., containing the "Building Retrofit Project" (BRP) program to finance interventions on existing buildings toward the improvement of energy efficiency and energy demand reduction.
Enforcement Decree of the Special Local Taxation Act [57]	National Act-2011 (last amended: 2020)	Technical dispositions for tax incentives and discounts for sustainable building construction; and financial support for PV systems in private buildings through nationally authorized private and public resellers. Contains technical documents and quantified standards and target values for different indicators (see Section 3.5).
Restriction of Special Local Taxation Act [58]	National Act-2010 (last amended: 2019)	
Standards for Certification of Building Energy Efficiency Rating and Certification of Zero Energy Buildings [59]	National certification system-2017 (last amended: 2020)	Legal formulation for the Zero Energy Building (ZEB) certification. Includes evaluation criteria and methods. Definition of ZEB levels according to primary energy demand (for new buildings), and reduction rate after renovation (for building remodeling). Technical documents with binding certification regulation.

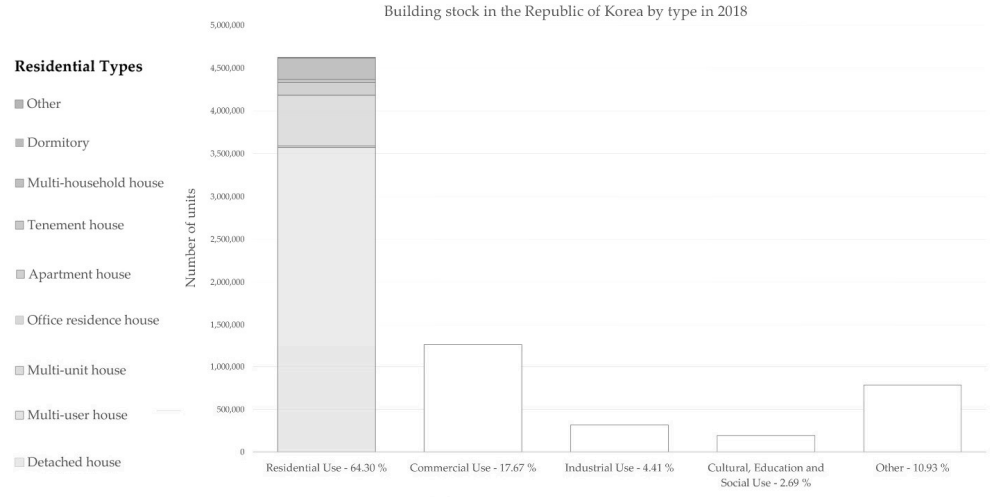
Table 2 lists the existing national and municipal standard and sustainable building legislations for the three case-study buildings. Building codes are progressively ordered primarily from national to municipal scale, and secondarily by the year of the most recent amendment.

Table 2. Existing standard and sustainable building legislations for Korea and Seoul.

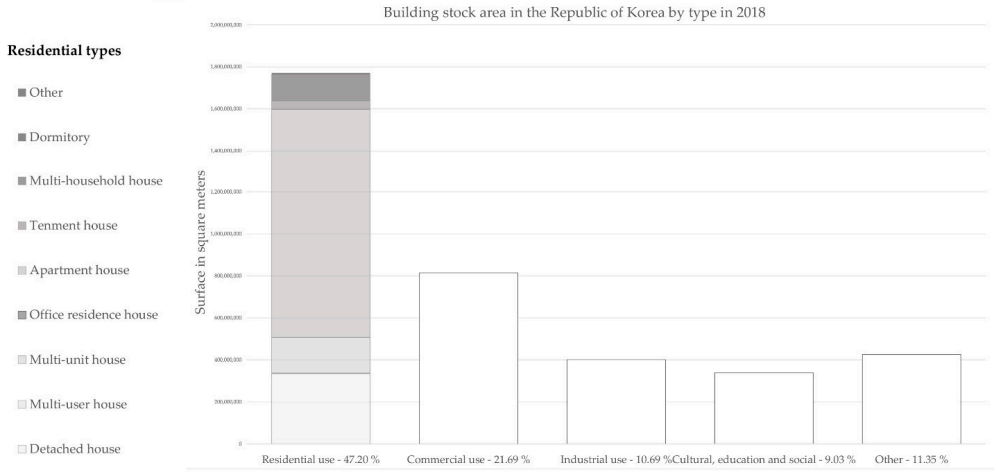
Name of Act/Plan	Jurisdiction-Year of Enactment (Last Amended)	Contents
Building Act [60]	National Act-1962 (last amended: 2020)	Provision of building construction code relaxation procedures and incentives toward sustainable building renovation (see Section 3.5).
Enforcement Rule of the Building Act [61]	National Act-1962 (last amended: 2020)	
Enforcement Decree of the Building Act—amendment [62]	National Act-1962 (last amended: 2020)	
Housing Act [63]	National Act-2003 (last amended: 2020)	Legislation regulating construction of residential buildings and neighborhoods in urban planning documents. Under Article 75—Establishment and operation of municipally managed remodeling support centers toward building renovation projects. Article 76—special regulations for multifamily house remodeling.
Enforcement decree of the Housing Act—amendment [63]	National Act-2003 (last amended: 2020)	
Building Management Act [64]	National Act-2020	Regulation for building management monitoring through the metering of active technical system and building lifetime data. Contains indications of building performance, including seismic performance, fire safety, and energy performance.
Seoul Metropolitan Government Ordinance on urban planning [65]	Municipal regulation-2009 (last amended: 2019)	Regulation on maximum size and floor area of new and renovated buildings through quantifiable indices: maximum FAR and BCR, allowed incentives, criteria relaxation through sustainable building, and minimum distance from public and private roads and neighboring buildings according to the 5-year LCGG plans (see Section 3.2).
Seoul Metropolitan Government Ordinance on Building [66]	2015 (last amended: 2019)	
Seoul Green Building Design Standard [67]	Municipal regulation-2013 (last amended: 2019)	Defines building standards specific to green buildings in the city of Seoul. Institutes relaxation criteria and incentive schemes for sustainable new construction and building renovation to the allowable FAR and building height limits. Defines quantification criteria for incentives based on GSEED and BEEC certification grading of buildings. Quantifies incentives for using recyclable materials in construction. Defines property tax incentives for the construction of new buildings (see Section 3.5). The document is the technical formulation of the directives included in the Seoul municipal ordinance on the support of construction of green buildings (see Table 1).
2030 Seoul Masterplan [68]	2014	Urban development masterplan for the city of Seoul, including designation of urban districts, neighborhood development plans, and infrastructural projects for 2030. Includes the "Seoul Metropolitan City Official book on building's maximum height regulation by district" defining specific rules that mandate building maximum number of stories, and height and distance from adjacent public and private properties.
Regulation on housing construction standards [69]	1991 (last amended: 2020)	Regulates the number of mandatory minimum parking places for building and unit GFA, as well as public infrastructure-related limitations and standards (see Section 3.2).
District Unit Plan (DUP) [70]	2011 (last amended: 2019)	Incentives for FAR, building height, and floor number for residential buildings in the specific districts of the metropolitan city of Seoul. Incentives are calculated based on the GSEED and BEEC certification systems. Defines incentive schemes for introducing decentralized water management systems, including green inserts and landscape/topsoil conservation measures (see Section 3.2).

3.2. Description of Case-Study Buildings and Legal Status

Three exemplary buildings were selected for the comparative analysis of new building constructions and building renovations. The case-study buildings were selected to represent the most common building types in South Korea. In 2018, detached multiunit houses (called Villas in the framework of this article) represented 8% of the entire Korean building stock, and 4% of the entire Korean building area (13% of residential building stock, and 9% of residential building area). Apartment buildings (called Apartments in the framework of this article) covered 2% of the building stock, and 29% of building area (3% of residential building stock, and 62% of residential area). Mixed-Use buildings (called Mixed-Use buildings in the framework of this article), assigned to commercial use, and industrial use building categories belonging to the normal apartment or office building (commercial use in Figure 4), according to the Korean Building Code (Figure 4).



(**a**)



(**b**)

Figure 4. (**a**) Number of units of building stock and percentage of total building stock assigned to different types of use in the RoK in 2018. (**b**) Building area assigned to different types of use in the RoK in 2018. Specific residential types are included in the residential use type, while parts of mixed-use buildings are assigned to commercial use and industrial use building types [22].

Table 3 presents the spatial descriptions of the three case-study buildings through relevant legal indices. The table includes the specification criteria and construction limits of existing case-study buildings, and the mandated limits for new buildings on the same property.

Table 3. Case-study building type descriptions and spatial analysis according to the applicable legal criteria.

Building Type Criterion	**Villa (Multiunit House)**		**Apartment (Apartment House)**		**Mixed-Use (Neighborhood Living Facilities)**	
Legal status of the case study building plot	Quasi-residential area		Class II general residential area		Class III general residential area	
District (Korean: *Gu*)	Gwangjin		Gwanak		Nowon	
Ownership type	Single owner–multiple tenants		Multiple owners and tenants		Single owner–multiple tenants	
Site area	178.50 m^2		3701.10 m^2		586.00 m^2	
Number of floors	a. 2 above ground b. 1 below ground (50% of floor height underground) c. 1 roof living unit		a. 12 above ground b. 1 underground parking level		a. 2 above ground b. 1 below ground	
Gross floor area (GFA) above ground level	164.96 m^2		13,133.77 m^2		482 m^2	
GFA below ground level	84.30 m^2		3701.10 m^2		241 m^2	
Total building gross area	249.26 m^2		16,834.87 m^2		723 m^2	
Floor-to-area ratio (FAR) [a]	139.65%		354.86%		123.20%	
Construction Limits According to Existing Standards and Sustainable Building Legislation for Korea and Seoul (see Table 2)	**Villa**		**Apartment**		**Mixed-Use**	
	Mandated Limit	**Existing**	**Mandated Limit**	**Existing**	**Mandated Limit**	**Existing**
Maximum building coverage ratio (BCR, % of land plot area)	60%	47.22%	60%	29.72%	50%	41.12%
Standard FAR	300%	139.65%	200%	354.86% [b]	250%	123.20%
Maximum building height (max. number of floors, if required/max. height in m)	40.00 m	8.60 m	25 floors–max. 150.00 m	36.00 m	35 floors–max. 77.00 m	9.00 m
Minimum building distance from public road border: above/below ground level (m)	0.50/0.50 m	2.00/2.00 m	3.00/0.00 m	3.00/0.00 m	3.00 m (from two-lane primary traffic roads) 0.00 m (from secondary traffic roads)	West: 1.54/1.54 m South: 0.5 m

Table 3. *Cont.*

Minimum building distance from adjacent buildings [c] (m)	0.50 m	1.50 m	1.50 m (if h < 9 m); $\frac{1}{2}$ of building height (if h > 9 m)	13.36 m (incl. public road width– 6 m)	1.50 m (if h < 9 m); $\frac{1}{2}$ of building height (distance from single floor boundary when h floor > 9)	1.50 m (from adjacent buildings)
Required number of parking spaces on private premises (unit per gross building area)	1/75 m^2 (for a total usable floor area below 85 m^2) 1/65 m^2 (for a total usable floor area for residential purposes above 85 m^2)	0 (building construction predates parking area regulations from 2010)	1/65 m^2 gross residential floor area for exclusive use space	110	1/134 m^2	8

[a] FAR calculations do not include underground parking levels and safety areas established in vertical extensions of stair shafts (required in apartment and high-rise buildings). [b] Construction of the case-study apartment building predates the legal definition of district-wide FAR limits for private properties. However, when buildings exceed 15 years of service life, renovation and extension for buildings that exceed FAR limits can be approved by submitting a request to the district council [62]. A special evaluation committee evaluates the request, and eventually approves or rejects the request. Notwithstanding the approval for renovation and due to the exceeding of FAR, building extension through renovation incentives is denied. [c] Subordinated to the requirement of ensuring more than 2 h/day of unshaded sunlight for neighboring buildings between 9 a.m. and 3 p.m. The regulation applies only to residential districts, and therefore does not impose restrictions on the villa type located in a quasi-residential area [71].

Legally mandated construction limits were retrieved from existing standard and sustainable building legislation (Table 2). Figure 5 illustrates an isometric view of the existing case-study building volumes according to the specified construction limits within their urban context.

In contrast to the investigated case-study buildings' locations and related legal status of the building plots, buildings with a similar typology can be located on building plots with different legal statuses that can significantly influence the maximum incentives for sustainable building renovations. For example, in Seoul, villas and apartments are very often located in the so-called General Residential Areas. Over time, the legal status (zoning) of building plots could change, as in the Apartment and the Villa cases, which originally had the legal status of a General Residential Area. Therefore, parameters such as the minimum building distances to public borders and FAR incentives based on special programs for the remodeling of general residential areas can be different, and offer potentially attractive incentives. According to the Housing Act 2020 Seoul Housing Master Plan, Seoul Remodeling Promotion District, originally implemented in 2010, the FAR of buildings can be increased by 30% in the framework of sustainable building renovations. However, due to conflicts with parking-place-related regulations, incentives for only two buildings were permitted in the period of 2010–2018. By September 2020, the guideline was still under revision [72].

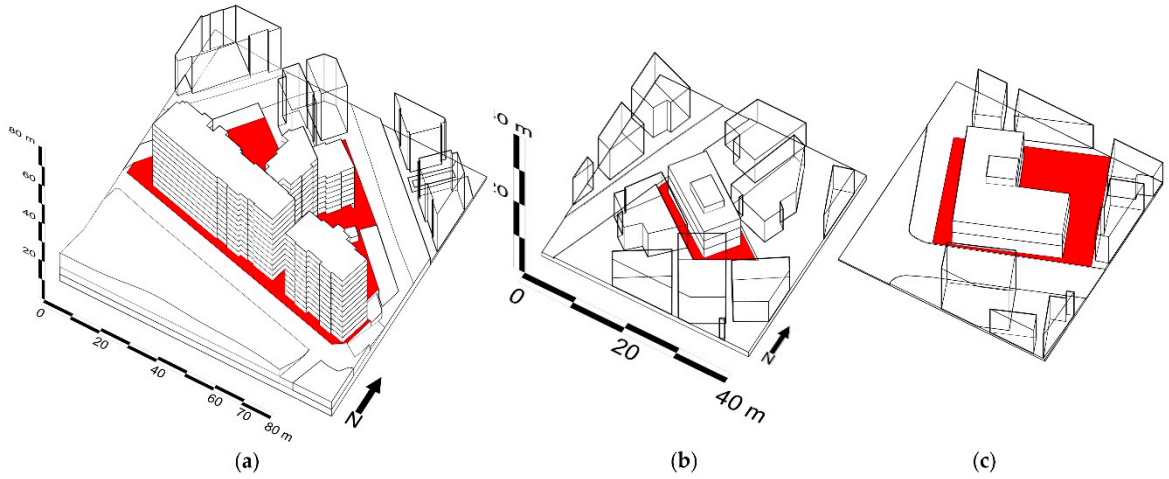


Figure 5. Isometric southeast view of the three existing case-study building volumes and construction limits in their urban contexts. (**a**) Apartment building (90 m × 90 m quadrant); (**b**) Villa; and (**c**) Mixed-Use building (40 m × 40 m quadrants). The red areas represent the case-study building properties.

3.3. Basic Standards for New Buildings and Renovations

The basic building standards specify minimum target values for determining components related to the building envelope, and technical systems for heating, cooling, ventilation, lighting, water management, and electrical equipment. Furthermore, some standard classes also address the building's primary energy (PE) demand and energy-conversion efficiency for technical systems and renewable energy production systems through minimum thresholds. Standards for new and renovated buildings apply to buildings with a GFA of 500 m^2 and above. The application of such standards is not mandatory for buildings with less than 500 m^2 GFA.

Basic building standards in the Seoul municipal jurisdiction are assigned to different building types through a four-class allocation system, ranging from the most demanding A-class, through B- and C-classes, to the least-demanding D-class. The classification into one of the four classes for residential buildings is based on the number of occupying households per property, and the total GFA per property for nonresidential buildings. Household number and total GFA are calculated cumulatively for all buildings constructed

on a legally distinct land property. Table 4 describes the allocation methods, household numbers, and GFA thresholds for the four standard classes.

Table 4. Basic building standard classes and thresholds for residential and nonresidential new buildings and renovations.

Building Standard Class	Household Threshold (Residential Buildings)	Total GFA Threshold/Range (Nonresidential Buildings) *
A	Above 1000 households	Above 100,000 m^2
B	Between 300 and 1000 households	Between 10,000 and 100,000 m^2
C	Between 30 and 300 households	Between 3000 and 10,000 m^2
D	Below 30 households	Below 2000 m^2

* Applies if the ratio of the total GFA being heated and cooled through technical HVAC systems is above 50% of the total GFA. Conversely, only the actively technically heated and cooled are considered for building allocation in the relevant standard class.

Notwithstanding the predetermined criteria for building standard class allocation, the Seoul building code foresees exceptions for renovation interventions. Basic building standard classes for renovated buildings are downgraded, irrespective of whether their numbers of households or total GFA exceed the required allocation thresholds: Building renovations (substantial repairs) are downgraded one class below the predetermined allocation for new buildings (from A to B, B to C, and C to D), while building extension parts are assigned to class D.

Each building standard class requires meeting determined performance targets for building services and components mandated by three main systems: the Green Standard for Energy and Environmental Design (GSEED) certification [73], Building Energy Efficiency Codes (BEEC) certification [74], and the Energy Performance Index (EPI) [75] accreditation systems. The three systems were developed on the national scale, and apply to all four climatic zones.

The GSEED certification evaluates a building's performance according to criteria that are assigned to seven main categories: (i) land-use and transportation, (ii) energy and environmental pollution, (iii) material and resource utilization, (iv) water-circulation management, (v) maintenance, (vi) ecology and environment, and (vii) indoor environment. Each category contains multiple subcategories for specific building services and components graded on a point system into one of four grading levels: from 1, the highest, for 100% of the maximum allowable points, to 4, the lowest, for 40% of the maximum allowable points. The subcategory scores are tallied for each of the seven main categories, and the cumulative score for each category defines a percentage ratio of the total score achievable in the GSEED certification. The maximum weight achievable for each category as a percentage ratio of the total GSEED score is predefined, and it varies based on the relevance of each category and its cumulative subcategory point score. In addition to the scores for each of the seven categories, bonus points can be assigned for interventions under the distinct "Innovative Design" (ID) category, which encompasses sustainable building interventions that greatly overperform in the seven main categories. ID bonus points are assigned for meeting performance objectives, such as achieving zero-energy status and realizing full building LCA in the planning phase.

The total GSEED score comprises the scores for each of the seven main categories added to the ID bonuses; and that final score is assigned to a GSEED level based on total point ranges. Based on the total combined points, the GSEED score is assigned to one of four grades that range from Green 1st Grade for 74 or more points out of 100, through Green 2nd and Green 3rd Grades, to Green 4th Grade for 50 to 57 points. Buildings with 49 points or less do not receive any certification.

The maximum percentage ratios for the seven category scores and the numbers of graded subcategories vary between new buildings and renovations. New buildings are evaluated in all seven categories, with further bonus points assigned for ID, whereas renovation interventions are graded exclusively on GSEED category numbers (2, 3, 4, 5, and

7), because it is regarded as difficult to incorporate categories 1 and 6, infrastructure and soil conservation, as well as ID features in existing buildings. However, the different weighting systems (i.e., changing the amount of points awarded) of the evaluation categories allows both new construction and renovation projects to achieve a maximum cumulative score of 100 total points.

The BEEC evaluates a building's PE demand for heating, cooling, and hot-water production; levels range from 1+++ (highest) to 7 (lowest), with PE demand limits per square meter annum for each BEEC level varying, depending on building use. For example, for residential buildings, BEEC level 1+++ requires a PE demand of 60 kWh/(m^2a) or less, while the requirement for nonresidential buildings is 80 kWh/(m^2a) or less. BEEC level 7 requires a PE demand between 370 and 420 kWh/(m^2a) for residential, and between 610 and 700 kWh/(m^2a) for nonresidential buildings.

The EPI accreditation system evaluates a building's performance according to criteria that are assigned to three main categories, each with multiple subcategories: (i) building envelope and components, (ii) technical heating and cooling systems, and (iii) electrical systems. Similar to the GSEED system, each EPI subcategory is graded on levels: from 1 for 100% of maximum points, to 0.6 for scores of 60%. The maximum achievable points differ according to building usage and climate zone. However, the EPI accreditation allows for buildings to achieve mandated minimum grading levels for individual (sub)categories, and does not require a minimum total sum for accreditation. Table 5 presents the assignation of each case-study building to its respective standard class with its required minimum performance targets. In addition to the GSEED, BEEC, and EPI grading levels, further interventions, e.g., those related to urban heat island mitigation, indoor noise reduction, and air filtration, are included. Renovation standards include mandated minimum requirements for a range of interventions that include vertical/horizontal expansion, partial renovation, and partial reconstruction of aged buildings. Required interventions for building structural reinforcement, such as seismic retrofitting of constructions, are not included in the list of basics standard renovation interventions for building permits issued before 2009, albeit mandated by law. However, building extensions need to be constructed according to the legal seismic-resistance requirements. Furthermore, requirements for energy efficiency, such as by the Seoul Green Building Design Standard, and incentives for the achievements of sustainability benchmarks are only provided for buildings with more than 500 m^2 usable floor area.

Table 5. Allocation of case-study buildings to their respective classes based on parameters defined in Table 4. Presented data refer to the climatic zone of Seoul (Zone 2), and specific case-study building use.

Basic Building Standard	**Villa**	**Apartment**	**Mixed-Use**
New building	D (if the floor area is more than 500 m^2, and in the case of building type different from detached house)	C	D (if the floor area for each type of use more than 500 m^2, and in the case of multiownership, for residential use)
Renovation	Not applicable if the renovated/extended area is below 500 m^2 D (if above 500 m^2 of renovated extended/area for building type different from detached house)	D	D (if the floor area is more than 500 m^2, and less than 3000 m^2 of total floor area)
Legal Criteria Basic Standard	**Class C**	**Class D**	
Minimum U-values (W/[m^2K])	Exterior walls: 0.170; roof slab: 0.150; base floor slab, with floor heating: 0.170; without floor heating: 0.200; windows: 1.00; front doors: 1.40		

Table 5. *Cont.*

Minimum effective U-value ($W/[m^2K]$) (cumulative U-value of wall and windows)	Not applicable	EPI category (1.1 to 1.3)/0.8 grading class and category 1.5/0.9 grading class-building envelope: exterior walls: (0.560–0.620) (nonresidential), (0.380–0.420) (residential); roof slab: (0.100–0.110); base floor slab: (0.130–0.150); linear thermal transmittance (in case of exterior walls with window-to-wall ratio < 50%): (0.400–0.440)
GSEED level	4 (above 50 total points)	Different subcategory performance grading level for each of the GSEED 7 categories: Cat. 3.4—use of materials and components with Environmental Product Declaration: grade 4 or above Cat. 4.3—use of water-saving devices: grade 3 or above Cat. 7.1—use of materials with low pollutant emissions: grade 4 or above Cat. 7.7—noise insulation systems (only for residential): grade 3 or above Cat. 7.9—Noise-reduction system for water supply and drainage (only for residential use): grade 4 or above
BEEC level	For single-unit net floor area (NFA) below 60 m^2: 2 or above (150–190 kWh/m^2a or less); for single-unit NFA above 60 m^2: 1 or above (120–150 kWh/m^2a or less)	Defined by minimum U-values (no specific regulation)
Reduction of particulate matters	Installation of certified low NO_x (nitrogen oxides) production for decentralized systems (individual boilers)	
Energy management and control systems	Installation of energy-monitoring devices (meters) for each unit, and for each energy source	Not regulated
Heating-system efficiency (ratio of final/PE demand)	Within required BEEC certification level for PE demand	EPI category 2.1/grading class 0.9—heating systems: 90% or above (for oil boiler system); 86% or above (for centralized gas boiler systems); energy efficiency class 1 (for decentralized gas boiler systems/other heating equipment): monthly energy demand of 38.9 kWh/m^2
Cooling-system efficiency	Within required BEEC certification level for PE demand	EPI category 2.2/grading class 0.9—cooling systems: heat pumps with centrifugal compressor: coefficient of performance (COP) between 4.51 and 5.18; Carnot cycle-based systems: (0.73–0.75) (single effect); (1.1–1.2) (double and triple effect, absorption chiller with hot water production); Other systems: energy efficiency class 1 (monthly energy demand of 38.9 kWh/m^2)
Ventilation systems	Installation of mechanical ventilation system with PM filters—Standard KSB6141-2017: 90% capture rate of PM 10/2.5	
Heat-recovery systems	Within required BEEC certification level for PE demand	EPI category 2.6—heating technical systems: installation of heat-recovery systems for 60% of total airflows. Minimum coefficient of efficiency of 8 for cooling and 15 for heating; 45% recovery rate for cooling, 70% recovery rate for heating
Heat island prevention	(Recommended) installation of roof systems for the reflection of solar incident radiation (white paint) or green roof system	

Table 5. *Cont.*

Lighting systems	Within required BEEC certification level for PE demand	EPI 3.11/grading level 0.8—lighting equipment: installation of light-emitting diode systems for 70–80% of all outlets; EPI 3.12/grading level 0.8—lighting equipment: installation of power cut-off, dimming systems for 60–70% of all outlets
BIPV installed nominal power (kW_p) required	Calculated as: building land property area [m^2] × 0.01 [kW_p/m^2]	Not applicable
Primary renewable energy demand ratio on total PE (% of building demand)	10% for residential 9% for nonresidential (as of 2020)	Not applicable

3.4. Analysis of Sustainable Building Incentives

Legislation for sustainable building incentives expands the existing basic standards with dedicated support programs to encourage increased investment in multiple solutions for sustainable building. Green building solutions include, among others, improved building envelope insulation, increased wastewater reuse and decentralized management, higher renewable energy supply ratios to total building PE demand, and lower cumulative PE demand than required by basic standards. Incentives are in turn calculated based on the same GSEED and BEEC certifications and EPI accreditation levels for minimum building standards. Table 6 presents the criteria for sustainable incentive awarding assigned to the respective jurisdiction of each case-study building; specifically, the DUP of the Gwangjin district for the Villa and the Seoul municipal regulation for the Apartment and Mixed-Use buildings define distinct incentive programs for the case-study building types. However, DUP regulations are developed for the special legal status of quasi-residential area, and do not apply for generic Villa type-buildings. In the absence of DUP regulations, Seoul green building design standards regulating sustainable incentives for the renovation and new construction of residential Apartment buildings can be applied as well to Villa-type buildings. Accordingly, it is possible to calculate incentives for generic Villa buildings, considering the same schemes applicable for the case of the Apartment case-study building. Table 6 presents the minimum and maximum applicable incentives for building FAR increase for sustainable renovation and new construction. Incentive schemes are determined according to case-study building district regulation. Table 7 provides financial support for sustainable building construction and renovation, and financial incentives for the installation of efficient and renewable energy production systems applying indifferently for all districts in Seoul. Unless otherwise stated, incentives apply to both renovated and new buildings. Unique criteria for the award of exclusive incentives are additionally described. Calculations of incentives are provided considering single-building interventions, excluded from district-wide renovation interventions. Financial incentives toward building energy performance improvement and building envelope retrofit exclude one another. Financial incentives for PV-module installation and acquisition do not exclude one another, if incentives can apply separately at the single-household and building levels. Incentives for energy-efficient technical systems and multiple renewable energy sources can be combined. In the table, FAR calculations refer to the baseline FARs determined in Table 2.

Table 6. Sustainable building incentives for new and renovated buildings in the jurisdictions of the three case-study buildings.

Building-Type-Specific Applicable Incentives Incentive Criteria	Villa (According to Specific DUP) (Max. to Min.)	Residential (Nonspecific Villa and Apartment) (Max. to Min.)	Mixed-Use (Max. to Min.)
GSEED score	Max: 1st Green–FAR × (1 + 0.12); Min: 3rd Green– FAR × (1 + 0.02)	Combined GSEED and BEEC grading levels: Max: GSEED 1st grade & BEEC 1 + – FAR × (1 + 0.09); Min: GSEED 2nd grade & BEEC 1– FAR × (1 + 0.03)	
BEEC level	Max: level 1– FAR × (1 + 0.08); Min: level 3– FAR × (1 + 0.04)		
Renewable energy supply rate on building PE demand (for PV-systems)	Max: above 20% of energy independence rate on PE–FAR × (1 + 0.12); Min: between (3 and 5)% independence rate on PE– FAR × (1 + 0.04)	Max: zero-energy building (ZEB) level 1, 100% energy independence rate on PE– FAR × (1 + 0.15); Min: ZEB level 5, (20 to 40)% of energy independence rate on PE level– FAR × (1 + 0.11)	
Overperformance bonus	If all three GSEED, BEEC, and renewable energy supply ratios reach the maximum levels: FAR × (1 + 0.4)–replaces single incentives for the three criteria	Not applicable	
Ratio of recyclable building materials	Max: 25% or more of used material recyclable and low life-cycle impact – FAR × (1 + 0.15); Min: 15% or more of used material recyclable and low life-cycle impact – FAR × (1 + 0.05) (Only applicable for new construction of more than 500 m^2)	Not applicable	Max: 25% or more of used material recyclable and low life-cycle impact – FAR × (1 + 0.15); Min: 15% or more of used material recyclable and low life-cycle impact – FAR × (1 + 0.05) (Only applicable for new construction of more than 500 m^2)
Wastewater infrastructure	Reuse guaranteed for a minimum of 10% of the annual volume– FAR × (1 + 0.04)	Not applicable	
Rainwater management infrastructure	Decentralized system for up to 2% of the site area or more than 5% of the building area– FAR × (1 + 0.04)	Not applicable	
Green roof	Maximum 30% of site area; excludes private green areas– FAR × (green roof area/site area) × (1 + 0.1)	Not applicable	
Natural soil conservation	Porous pavement for rainwater infiltration in groundwater unobstructed by underground installations– FAR × (intervention area/site area) × (1 + 0.2)	Not applicable	
Green parking	Parking places with porous surface for stormwater infiltration in groundwater-FAR × (intervention area/site area) × (1 + 0.2)–maximum incentive: FAR × (1 + 0.05)	Not applicable	

Table 7. Financial support for sustainable building construction and renovation, and financial incentives for renewable and efficient energy systems.

Building-Type-Specific Applicable Incentives Incentive Criteria	Villa (Max. to Min.)	Residential (Apartment) (Max. to Min.)	Mixed-Use (Max. to Min.)
Tax reduction	BEEC level 1+, GSEED 1st grade, ZEB level 1, GHG reduction of 55% compared to standard buildings– acquisition tax reduction: 20%; property tax: 10% for 5 years; criteria applies exclusively to new buildings or extension		
Expected primary energy demand reduction on existing demand (LH Green remodeling project)	Max: more than 30% PE demand reduction–3% loan interest support rate; Min: 20–25% PE demand reduction–1% loan interest support rate (only applicable in the case of the official building value of less than KRW 900 million)	Max: more than 30% PE demand reduction–3% loan interest support rate; Min: (20–25)% PE demand reduction–1% loan interest support rate	
Seoul BRP loan support program-Installation of high energy-efficient components (high-performance windows, insulation et al) *	Long-term (8 y) low-interest (0.9%) loan: KRW 2,000,000 to 15,000,000 up to 100% of investment expenses (with ZEB certification: max. KRW 4,000,000,000 per project)		Long-term (8 y) low-interest (0.9%) loan: KRW 10,000,000 to 2,000,000,000 up to 100% of investment expenses (with ZEB certification: max. KRW 4,000,000,000 per project)
Housing retrofit loan program for low-rise buildings	Renovation: low-interest loan (2%) (max. 80% of total expense, up to KRW 30,000,000 per unit (max. 4 units)); new construction: low-interest loan (2%) (max. 80% of total expense, up to KRW 50,000,000 per unit (max. 6 units)); (in the case of the villas in the remodeling promotion area, the interest rate is reduced to 0.7%)	Not applicable	Only applicable for residential units Renovation: low-interest loan (2%) (max. 80% of total expense, up to KRW 30,000,000 per unit (max. 4 units)); new construction: low-interest loan (2%) (max. 80% of total expense, up to KRW 50,000,000 per unit (max. 6 units)); (in the case of houses in the remodeling promotion area, the interest rate is reduced to 0.7%)
Housing retrofit Subsidy for low-rise buildings	Subsidy up to KRW 15 million (12 million for retrofit and 3 million for demolishing walls); max. 50% of total expense	Not applicable	Not applicable
PV system integration –acquisition incentive by MOTIE	System capacity below 2 kW–KRW 1,037,000/kW (max. incentive: KRW 4,148,000); System capacity between 2 and 3 kW–KRW 838,000/kW (max. incentive: KRW 5,028,000)	System capacity up to 30 kW– KRW 908,000/kW	System capacity up to 50 kW–KRW 940,000/kW

Table 7. *Cont.*

Building-Type-Specific Applicable Incentives Incentive Criteria	Villa (Max. to Min.)	Residential (Apartment) (Max. to Min.)	Mixed-Use (Max. to Min.)
Seoul PV mini power plant subsidy	System capacity below 500 W–KRW 1200/W; System capacity between 500 W and 1 kW–KRW 700/W System capacity between 1 and 3 kW–KRW 700,000/kW	System capacity below 500 W–KRW 1200/W; System capacity between 500 W and 1 kW–KRW 700/W System capacity over 3 kW–KRW 800,000/kW	System capacity below 500 W–KRW 1200/W; System capacity between 500 W and 1 kW–KRW 700/W System capacity between 1 and 3 kW–KRW 700,000/kW System capacity over 3 kW–KRW 800,000/kW
PV feed-in tariff for systems below 30 kW	Applicable through authorized resellers and guarantee to produce energy surplus: KRW 173,981/MWh for detached systems; KRW 212,136/MWh for building integrated photovoltaic (BIPV) installations		Not applicable
Solar thermal installations	Flat type covering up to 14.0–20 m^2 and 7.5 MJ/(m^2day)–KRW 431,000/m^2 Water piping system connected to boiler for hot water production with 6 m^2 single installation type–KRW 3,368,000/unit	Flat type covering up to 14.0–20 m^2 and 7.5 MJ/(m^2day)–KRW 433,000/m^2 Water piping system connected to boiler for hot water production with 6 m^2 single installation type–KRW 2,728,000/unit	
Geothermal installations	Min.: system capacity between 10.5 and 17.5 kW–KRW 637,000/m^2 Max.: system capacity up to 10.5 kW–KRW 691,000/m^2		System capacity up to 1000 kW–KRW 587,000/kW
Fuel cell installations	Up to 1 kW–KRW 15,578,000/kW		KRW 15,380,000/kW

* A BRP loan support incentive can be requested to fund the following energy efficiency interventions: high-efficiency windows, exterior insulation, window films, reflective roof painting (cool roof), combined heat and power (CHP) energy production systems, high-efficiency heating and cooling technical systems, waste heat recovery systems, regenerative brakes for elevators, building energy-monitoring systems, high-efficiency lighting, high-efficiency air conditioning systems, high-efficiency transformers, renewable energy systems, water-saving facilities, and green walls.

3.5. Quantifying Maximum Sustainable Building Incentives for New and Renovated Case-Study Buildings

The sustainable building incentives defined in Section 3.4 were quantitatively calculated for the three case-study buildings in both renovation and new building scenarios according to scenarios that allowed for the award of the maximum incentives for building materials, processes, components, and technologies employed. The calculations encompassed the existing available areas on the case-study buildings' properties.

Notably, the Korean legal framework limits the maximum incentive by size and floor area extension of new and renovated buildings: Even if they could achieve larger size and floor area extension incentives, overperforming buildings that achieve sustainable building incentives cannot exceed the limits imposed by the law; the calculation of maximum incentives was therefore compared with the maximum allowable size and floor area of new and renovated buildings by the legislation. Table 8 provides an overview of limiting norms for size and floor area extension incentives; limitations apply identically to both new buildings and renovations. The size and floor area limitations integrate with the existing building codes analyzed in Table 3. Cases where relaxed regulations apply through the awarding of sustainable building incentives are also reported.

Table 8. Relaxed regulations for the renovation and new construction of the three case-study buildings through maximum incentives.

Building Type **Building Limits According to Normative (cf. Table 3)**	**Villa**	**Apartment**	**Mixed-Use**
Allowed max. FAR increase through incentives [a]	From 300 to 360% (+60%)	From 200 to 230% (+30%)	From 250 to 287.50% (+37.50%)
Vertical extension [b]	Regulated by the DUP (Table 2–height and border limits)–cumulative number of above-ground stories must remain below 3 to maintain multiunit-type status; above 3 stories, the building type is changed to multihousehold, and follows the specific regulations; above 5 stories, the building type is changed to apartment, and follows specific regulations	+2 floors, within 25 floor and 250 m height limit per regulation	Regulated by the building regulations (Table 3–height and border limits)–no additional exemptions
Horizontal extension [c]		Up to 30% of unit floor usable area above 85 m^2/40% below 85 m^2	

[a] Cumulative vertical and horizontal extensions cannot exceed the maximum allowed FAR through incentives. [b] Vertical expansion subordinated to regulations regarding the shading of adjacent buildings (see Table 3); cumulative vertical and horizontal extensions cannot exceed the maximum allowed FAR through incentives. [c] Horizontal expansion is limited by regulations for adjacent building shading and distance from public road and neighboring properties (see Table 3).

Table 9 presents the maximum incentives for all three case-study buildings in both new and renovated scenarios. Tables 6 and 7 define the criteria for the awarding of maximum incentives. Calculations are based on incentive schemes mandated by district and municipal regulations, and when not contrarily stated, incentives apply without distinction between new and renovated buildings.

Table 9. Maximum incentives for sustainable new building and renovation of the three case-study buildings.

Building Type **Incentive Criteria**	**Villa** **(Max. to Min.)**	**Apartment** **(Max. to Min.)**	**Mixed-Use** **(Max. to Min.)**
GSEED score	FAR × (1 + 0.4): + 214.20 m^2	FAR × (1 + 0.09): + 666.20 m^2	FAR × (1 + 0.09): + 131.85 m^2
BEEC level			
Renewable energy supply rate on building PE demand (for PV-systems)		FAR × (1 + 0.15): + 1110.30 m^2	FAR × (1 + 0.15): + 219.75 m^2
Overperformance bonus		-	
Ratio of recyclable building materials	FAR × (1 + 0.15): + 80.325 m^2 Only for new construction above 500 m^2	Not applicable	FAR × (1 + 0.15): + 219.75 m^2 (Only for new construction above 500 m^2)
Wastewater infrastructure	FAR × (1 + 0.04): + 21.42 m^2	Not applicable	Not applicable
Rainwater management infrastructure	FAR × (1 + 0.04): +21.42 m^2	Not applicable	Not applicable
Green roof (calculated considering the whole roof area as installation surface)	FAR × (green roof area/site area) × (1 + 0.1): +24.96 m^2	Not applicable	Not applicable

Table 9. *Cont.*

Building Type Incentive Criteria	Villa (Max. to Min.)	Apartment (Max. to Min.)	Mixed-Use (Max. to Min.)
Natural soil conservation (calculated considering the existing available free infiltration surface)	FAR × (intervention area/site area) × (1 + 0.2): +11.9 m^2	Not applicable	Not applicable
Green parking	Not applicable (free surface not available)	Not applicable	Not applicable
Tax reduction	Acquisition tax reduction: 20% (Mixed-Use) only for new construction and extension; property tax: 10% for 5 years;		
Expected primary energy demand reduction on existing demand (LH Green remodeling project)	3% loan interest support rate		
Seoul BRP loan support program—installation of high energy-efficient components (high-performance windows, insulation et al.) *	Long-term (8 y) low-interest (0.9%) loan: KRW 15,000,000 up to 100% investment expenses		Variable incentive with single Long-term (8 y) low-interest (0.9%) loan: KRW 2,000,000,000 up to 100% of investment expenses
Housing retrofit loan program for low-rise buildings	Renovation: low-interest loan (2%) (max. 80% of total expense, up to KRW 30,000,000 per unit for max. 4 units); New construction: low-interest loan (2%) (max. 80% of total expense, up to KRW 50,000,000 per unit for max. 6 units)	Not applicable	Only for residential units Renovation: low-interest loan (2%) (max. 80% of total expense, up to KRW 30,000,000 per unit for max. 4 units); New construction: low-interest loan (2%) (max. 80% of total expense, up to KRW 50,000,000 per unit for max. 6 units);
Housing retrofit Subsidy for low-rise buildings	Not applicable	Not applicable	Not applicable
PV system integration–acquisition incentive by MOTIE	KRW 5,028,000	KRW 908,000/kW	KRW 940,000/kW
Seoul PV mini power plant subsidy	KRW 700,000/kW	KRW 700,000/kW (KRW 800,000/kW more than 3 kW)	KRW 700,000/kW (KRW 800,000/kW more than 3 kW)
PV-feed-in tariff (FIT) *	KRW 173,981/MWh for detached systems; 212,136/MWh for BIPV		Not applicable
Solar thermal installations *	KRW 3,368,000/unit or KRW 10,320,000 for 20 m^2		KRW 2,728,000/unit or KRW 527,000/m^2
Geothermal installations *	KRW 691,000/m^2		KRW 587,000/kW
Fuel cell installations *	KRW 15,578,000/kW		KRW 15,380,000/kW
Sum of GFA increase through incentives (increase on standard FAR)	+293.9 m^2 (+134.40%)	+1776.5 m^2 (+48.00%)	+571.35 m^2 (+97.50)

Table 9. *Cont.*

Building Type Incentive Criteria	Villa (Max. to Min.)	Apartment (Max. to Min.)	Mixed-Use (Max. to Min.)
Maximum allowed GFA increase according to maximum FAR extension (maximum incentivized FAR–max. standard FAR extension)	107.10 m^2	1110.30 m^2	219.75 m^2
Max. vertical extension for renovation according to regulation (cf. Tables 3 and 8)	1 floor m^2	0 floors (0.00 m^2)–building FAR exceeds maximum threshold	2 floors
Max. horizontal extension for renovation according to regulation (cf. Tables 3 and 8)	0–mandated limits already reached)	0–building FAR exceeds maximum threshold	0–mandated limits reached due to existing structure and parking area (on-site)

* Incentives for installing decentralized energy systems apply exclusively for one selected system among the four options provided.

3.6. Comparative Analysis between Basic Standard Renovation and New Building Classes

The comparative analysis between new construction and renovation for the three case-study buildings based on achieving basic standards focused on the differences in certification and accreditation system-mandated performance targets between distinct building classes. In particular, differences in minimum targets relate to two main categories: whether building component and system sustainability performance is graded on GSEED versus EPI criteria, and differences between BEEC and EPI PE demand limits and energy supply system performance.

In terms of basic building standards for sustainable interventions, to achieve at least GSEED 4th Grade, Class C requires that buildings achieve the minimum grade range in all seven GSEED categories. Conversely, for Class D, minimum performance grading classes are required for only a selected number of intervention categories in both GSEED and EPI systems. However, achieving the minimum GSEED category performance grade ranges required for Class D requires meeting the standards needed to achieve GSEED 4th Grade. Accordingly, both C and D standard classes would require the same GSEED level, except for a lower number of categories that require grading to achieve Class D. Furthermore, EPI accreditation defines additional building intervention performance minimum targets for Class D; in particular, minimum EPI standards for HVAC and lighting systems exceed the minimum required performance for Class D interventions. The inclusion of criteria beyond those encompassed in the GSEED certification system aimed to define focused partial interventions required in building renovation, such as modifying energy supply systems to increase PE supply efficiency. Notably, the minimum EPI performance criteria integrate with financial incentive programs for installing renewable and/or efficient energy-supply systems (PV, solar thermal, geothermal, and fuel cell) described in Section 3.5, Table 6. Accordingly, buildings can achieve the minimum performance targets required by Class D through fiscal incentives for installing efficient energy-supply systems.

PE demand performance differences are also determined by the distinct certification and accreditation systems utilized to define minimum target values. In terms of U-values, the codes under different jurisdictions define the basic standards. For example, Class C U-value standards are mandated by the national guidelines for building energy performance, whereas EPI accreditation mandates minimum Class D U-values. However, it is worth noting that Class C's mandated minimum U-values are determined differently than the minimum standard for Class D. EPI standards calculate minimum U-values according

to the cumulative thermal transmission through the weighted mean of both wall and window areas with relative thermal transmission coefficient, while the assigned minimum U-values for class C are determined specifically for each building component. Due to the different calculation methods utilized, it is hard to compare the two standards. Therefore, the U-values mandated by the Energy Saving Design Standard for Building act only as a baseline, not as minimum targets, as required BEEC levels would require further increase in building components' performance (i.e., lower U-values) to be reached; the national code aims at providing a general standard for all buildings and the four climatic zones, which are then further determined in specific municipal and district contexts.

Furthermore, Class D PE demand limits are mandated only indirectly by the EPI accreditation system, and not directly by the BEEC certification system, as for Class C; accordingly, it is not possible to define a minimum PE demand limit for Class D interventions, which depend on a single building size and type. Similar to differences in adopting either GSEED or EPI to define minimum targets, the selection of EPI categories is motivated by the need to address specific renovation interventions for partial building refurbishment. In particular, both required minimum EPI U-values and HVAC performance criteria define practical instructions and targets for building envelope and technical system renovations, and multiple interventions allow for reducing PE demand in renovated buildings, such as high-efficiency lighting and HVAC systems, as well as improved building envelopes. The solutions proposed under the EPI system make it possible to avoid imposing strict PE demand limits on aged buildings, and motivates building owners to progressively invest in building renovation. Accordingly, renovated building PE demand can vary within the legally allowed boundaries of Class D, and depends greatly on the outcomes across multiple interventions.

No regulations, including the Seoul Green building design standard and the Energy Saving Design Standard for Building, may be applied to small buildings, such as villas, with a usable floor area of less than 500 m^2 and house owned by a single person. Potential achievable sustainability incentives (see Section 3.4) through basic building standard scenarios encompass financial incentives for installing PV, solar thermal, geothermal, and fuel cell systems, as well as financial support for retrofits. While financial incentives for installing new and renewable energy systems are subsidized, most of the financial incentives for retrofits or remodeling are low-interest loans. Subsidy for housing retrofits can be awarded only for low-rise houses in the very specific urban regeneration and remodeling promotion area in Seoul. However, this subsidy program is irrelevant to building energy performance. Low-interest loans relevant to the building energy performance are not regulated by PE value, but by the installation of energy-efficient building components. Energy supply system incentives can be requested independently of building performance standards. Therefore, financial incentives for energy supply can be requested even for nonrenovated existing buildings.

3.7. Comparative Analysis of Incentive-Awarding Schemes for Sustainable New Buildings and Renovations

The comparative analysis of incentive schemes for sustainable renovations and new buildings was executed in two phases: (i) determining differences in building-type-related incentive-awarding criteria for building type, executed independently from the case-study buildings, and (ii) comparison between renovation and construction scenarios for the case-study buildings. The differences in the maximum sustainable building incentives between the admissible size and floor area extension of new and renovated buildings could be defined through two categories: (i) municipal- and district-jurisdiction incentive schemes developed for building renovations, and (ii) exclusive incentives for new buildings.

Regarding the applicability of regulations at different scales of jurisdiction, the DUP determines the related construction norms for Villas; conversely, the Seoul municipal guidelines for green buildings regulate building norms for Apartment and Mixed-Use buildings. The two codes differ specifically in the combined application of GSEED and BEEC criteria for awarding sustainability incentives While interventions on Villas are

awarded exclusive incentives for achieving the different performance grading levels under each certification system, Apartment and Mixed-Use buildings are evaluated based on combined BEEC–GSEED criteria. Furthermore, Villas earn overperformance bonuses based on combined certification levels, but such bonuses for Apartment and Mixed-Use buildings require an additional reduction of GHG emissions to the highest grading level on GSEED, BEEC, and ZEB grading scales.

The rationale behind the different application criteria for awarding incentives is based on three distinct characteristics of the case-study building types: (i) age, (ii) district urban density, and (iii) legislative and regulatory focus between renovation and building new. More Villa buildings were constructed before the 1990s [76], and are therefore older on average than apartment buildings; furthermore, Villas tend to be distributed in districts with reduced property dimensions and lower distance between buildings, resulting in higher population densities than for residential districts of apartment complexes that underlie more severe regulations in terms of available public space and minimum building distance from public and private adjacent properties [77]. Accordingly, building regulations for Villas focus on providing improved flexibility in the choice of renovation intervention. Single incentives range from improving building LCA and indoor comfort (GSEED criteria), to renovating technical systems (BEEC and ZEB criteria); through these incentives, building owners can profit by investing limited economic resources in low-intensity, reduced, or progressive building renovation.

For Villas, the regulations are aimed at supporting the renovation of small properties, which is further demonstrated by the complete equivalence between renovation and new building incentive schemes in the DUP. The pronounced focus in the existing standards on building renovation as the preferred intervention is also stressed in the ZEB incentives, which require a lower renewable energy supply-to-total building PE ratio than those required for Apartment and Mixed-Used buildings. ZEB incentives focus on installing renewable (PV) energy-supply systems, or renovating existing systems. However, ZEB incentives are based on the strategy of reducing long-term energy-supply expenses for new buildings, as opposed to maximizing building size and floor area through FAR incentives. The different approach to incentivization is due to the limitations imposed by the existing district density regulations regarding extending Villa buildings. Additional incentives are awarded for green roofing and parking, as well as for property landscape maintenance and improvement, which require no intrusive alteration of existing buildings, and which serve to improve areas more at the district than building levels.

The focus on Villa renovation is related to the DUP limits for size and floor area of new and renovated buildings (see Table 3). These limits are based specifically on building maximum height, minimum distance from adjacent buildings, and decreased shading of neighboring constructions. Accordingly, despite a potential increase of 60% in the allowed FAR, the actual size and floor area of new and renovated buildings can be consistently constrained by property size and urban density limits; under these circumstances and according to the existing urban form, the size and floor area of new and renovated buildings would be similar. Accordingly, owners were more encouraged to renovate existing buildings and eventually raise rents for higher profits, than to invest in new constructions.

Different from Villas, Apartments and Mixed-Use buildings are constructed in urban districts where the dimensions of properties allow for increased building size and floor area through the demolition of old and construction of new buildings. The focus on new buildings is reflected in exclusive tax discounts for achieving sustainability overperformance in new building projects through consistent GHG reduction, increased renewable PE supply ratio, and usage of materials with low LC impact. In particular, the standards make precise distinctions between renovated and new buildings. For example, apartment building renovation is limited to two additional floors and maximum horizontal expansion of 30 to 40% of the existing GFA (see Table 7). The combined GSEED/BEEC incentive award system was developed to mandate building renovation standards across all technical systems and components to reach the predetermined renovation standards,

and the applicable incentives under the combined system dictate the range of investment required to meet the building extension basic standards. Considerations of the applicable incentives determined by the combined GSEED/BEEC system allow building owners to establish both benchmark renovation procedures and predictable revenue streams from building extension. In short, renovation of Apartment buildings is integrally regulated, with baseline performance increases achieved independently of the levels of sustainable construction and grades achieved by single building renovation interventions. In contrast to Villa buildings, owners of Apartment and Mixed-Use buildings are not encouraged to invest in specific renovation interventions to achieve incentives. Owners and construction companies are instead encouraged to invest in renovation under a tightly regulated scheme with calculations of risk and revenue outcomes.

In parallel, incentives for new buildings aim to encourage owners and constructors to maximize sustainable practices and achieve overperformance bonuses. Similar to renovation incentive schemes, overperformance incentives are awarded based on meeting precise incentive targets, and therefore require predetermined investments and tax discounts aimed at urban regeneration, and new construction projects are also calculated to compensate for the increased investments in property redevelopment. Accordingly, building owners make the choice between renovation and new construction based exclusively on the availability of economic resources, and on the preferred revenue scheme to be achieved through predetermined interventions. Notably, renovated buildings must achieve the same performance level of new constructions to earn the same incentives, resulting in lower revenue ratios for investing in renovation projects than in new buildings.

Finally, incentives for installing renewable energy supply systems fall under a separate class determined based on the building function over the existing building dimensions. Incentives for PV systems are regulated to fulfill the required quotas imposed by the LCGG economic plan mandated as a national economic development strategy; accordingly, incentives for apartment building energy systems are integrated with the basic building standards to impose a minimum investment quota. Furthermore, interventions for residential buildings are limited by the maximum ratio of public investment to private expense, which supports interventions and projects that achieve basic standards. Conversely, FAR incentives awarded through ZEB certification were developed to passively encourage increased investment in renewable energy supply technology, without the need to provide financial support.

Differences in terms of price per kW and total investment between Residential and Mixed-Use buildings are defined by building functions. Accordingly, Residential buildings can receive public financing for decentralized renewable energy supply system installations within single households in a residential building or complex, and the target quota is based on the system capacity reached by each single unit. Conversely, Mixed-Use buildings receive a cumulative investment that supports broad-scale expenditures on centralized systems, and increases energy supply independence of the building scale. Investments in Mixed-Use buildings are therefore independent of the type and shift in activities and the spatial distribution of functions and ownership of single units within a building, allowing a long-term and stable renewable energy supply throughout the entire building life cycle.

4. Discussion

4.1. Comparative Analysis of Maximum Spatial Incentives for Renovation and New Building Scenarios of the Three Case-Study Buildings

Calculating the maximum incentives under different scenarios allowed for defining the spatial configurations for both renovation and new building scenarios. Specifically, limitations due to current restrictions on size and floor area extension of new and renovated buildings can be determined (Table 10), and visually represented (Figures 5 and 6). Accordingly, factors that affect the attractiveness of building renovation in terms of economic profitability obtained through increased GFA could be identified. The comparison was based on the premise that both renovated and new buildings met the highest evaluation criteria for sustainable renovation/construction, and achieved the maximum incentives

allowed. Accordingly, renovated and newly constructed buildings present comparable environmental performance in terms of construction (same U-values, envelope composition, etc.) and PE demand. Therefore, advantages in terms of cost reduction due to the reduction of energy costs are considered equal in both scenarios.

Table 10. Comparison of building size and floor area extension of new and renovated buildings scenarios for the three case-study buildings through relevant spatial indices (cf. Table 3).

Building Type Index	Villa		Apartment		Mixed-Use	
	Renovated	New	Renovated	New	Renovated	New
Typical floor GFA (m^2)	84.30	107.10	1094.48	654.81	241.00 (up to 3rd floor) 213.12 (4th floor)	293.00 (up to 3rd floor) 253.36 (4th floor) 212.15 (5th floor) 170.42 (6th floor) 133.68 (7th floor) 36.14 (7th floor)
Total GFA (m^2–excluded parking area)	333.56	464.32	13,133.77	8512.53	936.12	1684.75
Typical floor GFA difference: new–renovated (total GFA difference in m^2)	22.80 (130.76)		−439.67 (−4,621.24)		52 (up to 3rd floor) 40.24 (4th floor)	
BCR	47.22%	60%	29.72%	17.69%	41.12%	50%
Number of floors	3 above ground 1 underground (50% of height below ground)	4 above ground 1 parking floor (ground floor) with access to building	12 above ground 1 underground (parking)	13 above ground 1 underground (parking)	4 above ground 1 underground	7 above ground 1 underground (parking)
Building height above ground (m)	9.10	15.00	32.4	35.1	13.00	21.00
FAR	188.90%	260.01%	354.86%	230.00%	159.74%	287.50%
Ratio of allowed FAR incentives built (ratio of extended/new constructed GFA on incentives allowed GFA extension)	0.00% (FAR below maximum allowed standard)	0.00% (FAR below maximum allowed standard)	0.00%	100.00%	0.00% (FAR below maximum allowed standard)	100%
Number of parking spaces	1	6	110	80	8	13
Limitations to horizontal extension	Existing accesses to living units located on the building sides; required space on ground floor for additional parking space [a]	Minimum distance from adjacent properties of 1 m (for multihousehold type)	Exceeded FAR allows no further extensions	Maximum standard FAR limit reached	Parking area required on-site; Existing building structure	Building minimum distance from neighboring constructions
Limitation to vertical extension	Required parking space for total usable floor area	Required parking space for total usable floor area	Exceeded FAR allows no further extensions	Maximum standard FAR limit reached	Building structural capacity	Maximum FAR with incentives

[a] In the case of renovation, increase of parking spaces is calculated only for the extension area. In the case of new construction, regulation for parking spaces applies to the entire usable area of the new building.

The renovation scenario is based on the principle of the complete conservation of existing buildings; the increase in spatial extension of both vertical and horizontal building

components due to improved renovation envelope systems, such as increased insulation and building integrated PV modules, is included in the admissible building extension.

The new building scenario is based on complete building demolition, and the new construction is developed based on maximizing GFA within the mandated height and FAR limits. The new building scenario also considers regulations regarding minimum distances from public and private properties. In the case of new Apartment building construction, the maximum BCR is generally not applied. The maximum BCR is generally reduced by 20–40% to meet, among other constraints, the legal requirements for minimum Biotope Area ratios, the minimum distances between buildings, and the minimum requirements for daylighting. Figure 6 (renovation scenario) and Figure 7 (new building scenario) present volumetric spatial visualizations of both new building and renovation scenarios.

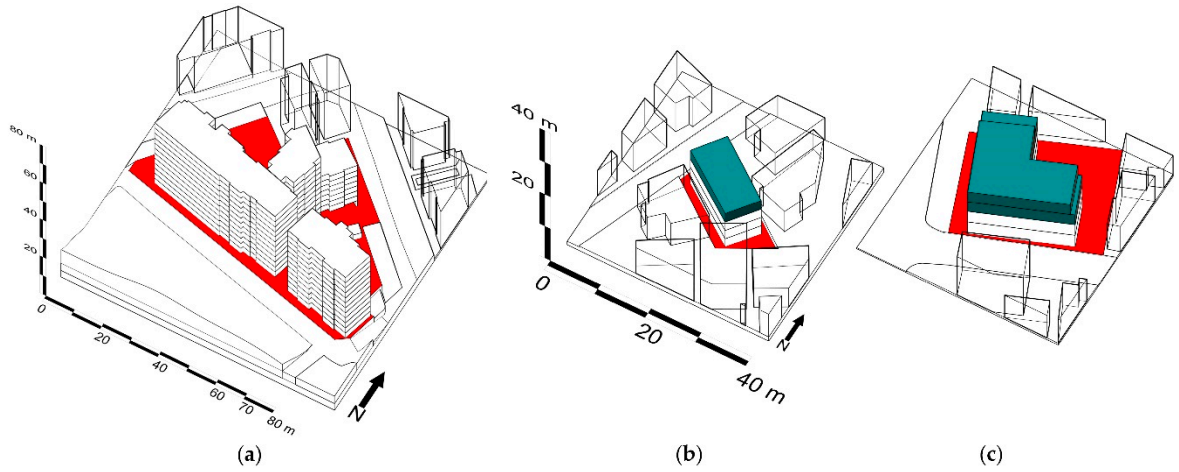


Figure 6. Volumetric visualization of renovated case-study buildings in their respective urban contexts: (**a**) Apartment building (90 m × 90 m quadrant); the building in its renovated state can be neither vertically nor horizontally extended, because the existing FAR exceeds the standard and incentivized limits; (**b**) Villa; and (**c**) Mixed-Use buildings (40 m × 40 m quadrants). The surfaces marked in red represent portions of the building properties where the three case-study buildings are located. Volumes marked in blue represent the building extensions.

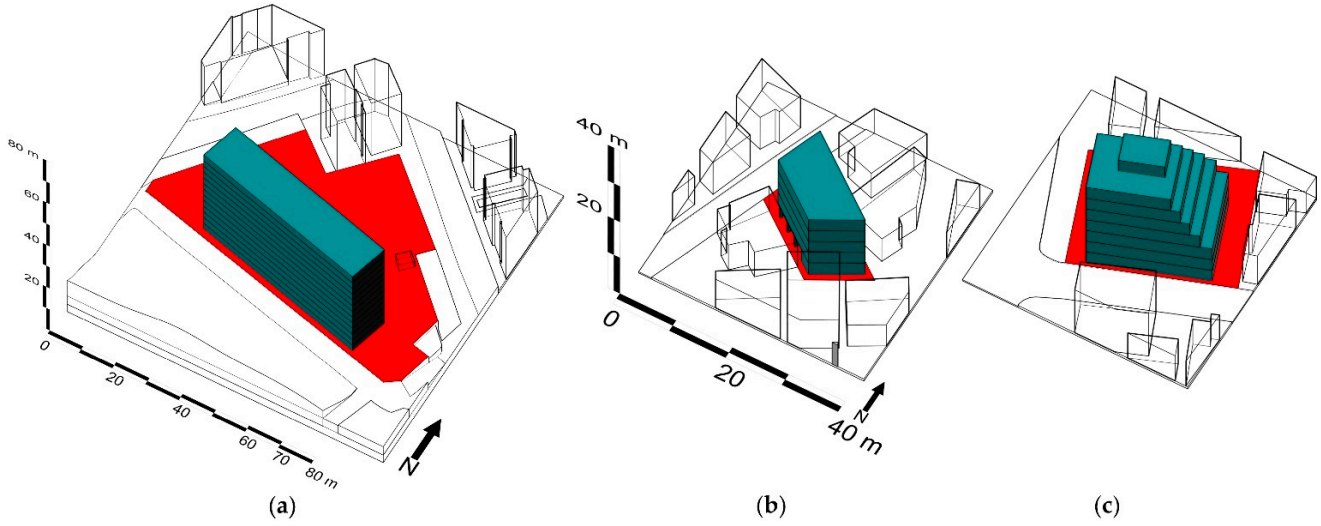


Figure 7. Volumetric visualization of new building of the case-study buildings in their respective urban contexts: (**a**) Apartment building (90 m × 90 m quadrant); (**b**) Villa; and (**c**) Mixed-Use buildings (40 m × 40 m quadrants). The surfaces marked in red represent the portions of the building properties where the three case-study buildings are located. Volumes marked in green represent the new building volumes.

The comparison between new building and renovation scenarios allows for determining the limitations to building renovation. For example, regulations defining the required parking spaces per extended area determined a specific constrain to the vertical extension of the Villa-type building. Furthermore, the vertical extension of the Villa has been limited by the required change of type for buildings higher than four stories, which would subject the construction to the set of regulations applying to apartment buildings. Apartment building regulations would further constrain the renovation due to, e.g., the size of living units and required common facility standards. The change of type from multiunit to multihousehold, as applied in the case of the new construction of the Villa, allows DUP regulations and minimum standards to apply equally for both types. Building vertical extension of the Mixed-Use type is constrained by the load-bearing capacity for the construction frame in reinforced concrete, which, according to literature research, has been set to an additional two stories [78]. However, with higher structural capacity or reinforcement construction to support the existing load-bearing construction, renovation of the Mixed-Use building could reach higher realizable surface area. Notably, building extension permitted by current regulations in case of the maximum FAR incentives could be realized within the standard FAR granted through basic building standards. Accordingly, sustainable building incentives in this analysis define no additional value for renovating the case-study Villa and Mixed-Use buildings, because the achieved increase in FAR could not translate into effective GFA extension, due to mandated building extension limitations. However, extending a building through incentives could be profitable if property sizes and a building's spatial configurations different from the case-study buildings were considered. Buildings with a larger distance from adjacent buildings, fewer floors, and a lower maximum standard FAR could greatly benefit from sustainable building incentives. In contrast to renovation, new construction of both Villa and Mixed-Use buildings allows for increased building area. In the case of the Villa-type, lax regulations in terms of building distance for quasi-residential districts allow the building of a new construction with distance from adjacent properties reduced to as low as 1.00 m. Furthermore, the ground floor destined for parking area is not counted as an above-ground story, according to regulations. Therefore, an increased amount of parking spaces allows for higher usable floor area by limiting the legally required number of stories to maintain a comparable similar type of building use (multihousehold instead of multiunit). However, both increased gross floor area for renovation and new construction can be achieved with minimum (for the new) and no (for the renovation) sustainable construction incentives, as the total GFA after both renovation or new construction nevertheless remains below the maximum allowed standard FAR. For the Mixed-Use building, the construction of a customary underground parking garage and a new load-bearing structure allows the number of floors to increase to the maximum allowed by FAR incentives.

Distinct from the Mixed-Use building and Villa, renovating the existing Apartment building is an exceptional case. Due to the existing FAR, renovation could be realized only through mediation between the owners, tenants, and district officials. The legal procedure of mediation has been established to promote sustainable building renovation, despite violations of district codes having been committed before the enactment of FAR-limiting regulations. However, neither vertical nor horizontal extensions would be allowed, because the existing FAR already exceeds the limits according to both maximum standards and incentivize schemes. Accordingly, both total building GFA and FAR need to remain unchanged (Figure 6a), apart from the eventual increase in building envelope thickness and the installation of energy supply systems that alter the existing building spatial configuration. Building new would also not be profitable, because the building size and floor area would be legally constrained to a lower FAR than in the existing situation (Figure 7a). Therefore, the only advantages from renovation would derive from reducing long-term energy demand and related costs due to an improved building envelope and the installation of efficient and renewable energy systems. In short, neither renovation nor new building would bring considerable economic advantages for the case-study Apartment

building. In general, the circumstance of a building exceeding FAR limitations established after its construction is resolved through two methods: building owners and developers donate other properties to the public government, or green public areas are established on the premises of the redeveloped properties [17]. Both procedures allow for exemptions to legal restrictions on building extension, and for higher FAR and building volumes. However, the case of extending FAR above the mandated limits would favor demolition and new construction, because current limitations on maximum additional floors and horizontal extension would still apply to the renovated building. Furthermore, additional interventions, such as the ones required for building structure seismic reinforcement, could increase the required investment for building renovation, in particular depending on the state of decay of the existing building. Therefore, further incentive for building demolition and new building is provided. The construction of a new apartment would furthermore be subject to additional regulations for green areas and sustainable roads, which in this paper are not the object of research. The volume associated with the new apartment (pictured in Figure 6a) has been produced in order to achieve a comparable spatial configuration to that of modern apartment buildings.

4.2. FAR Incentive Options According to GSEED-, BEEC-, and ZEB-Based Renovation Scenarios

Figure 8 presents a visualization tool for determining multiple renovation scenarios and the related FAR incentives for sustainable buildings under multiple combinations of variable FAR incentives. The tool enables visualization of the achievable incentives through different combinations and grading levels of the three main criteria for incentive assignation: GSEED, BEEC, and ZEB.

The table does not include examination of additional incentives because they provide only determined, nonvariable increments in FAR. Accordingly, the tool allows the range of applicable incentives to be calculated according to the variations in grading levels for the three criteria. The tool was developed to provide an overview of the different possible interventions in building renovation, and their related achievable incentives. The aim of the visualization tool was to allow investment costs for building renovation to be minimized, and relevant interventions for different renovation scenarios to be focused on according to the condition of existing buildings and the maximum incentives based on legal building extension limits. Toward that end, multiple renovation scenarios can be devised by combining multiple interventions, and sustainable building performance can be maximized by addressing the critical building components and systems according to each case.

Based on the information and indications provided by the tool, it is possible to evaluate the potential for renovation for single buildings and assess it against spatial constrains imposed by current norms in terms of FAR, BCR, and building distance from adjacent public and private properties. Therefore, the tool allows the comparison of different regulations and standards in order to optimize multiple parameters and resolve conflicts between norms (e.g., the increase in building envelope thickness with insertion of insulation against building minimum distance regulations) to achieve an optimal solution for amended district and municipal guidelines. The tool further allows, through the chromatic coding, to weight the relevance of the incentive award criteria (BEEC, GSEED and ZEB) in producing a higher FAR increase through incentives, determining if environmental and energy evaluation criteria toward sustainable construction are balanced in terms of contribution to the building extension.

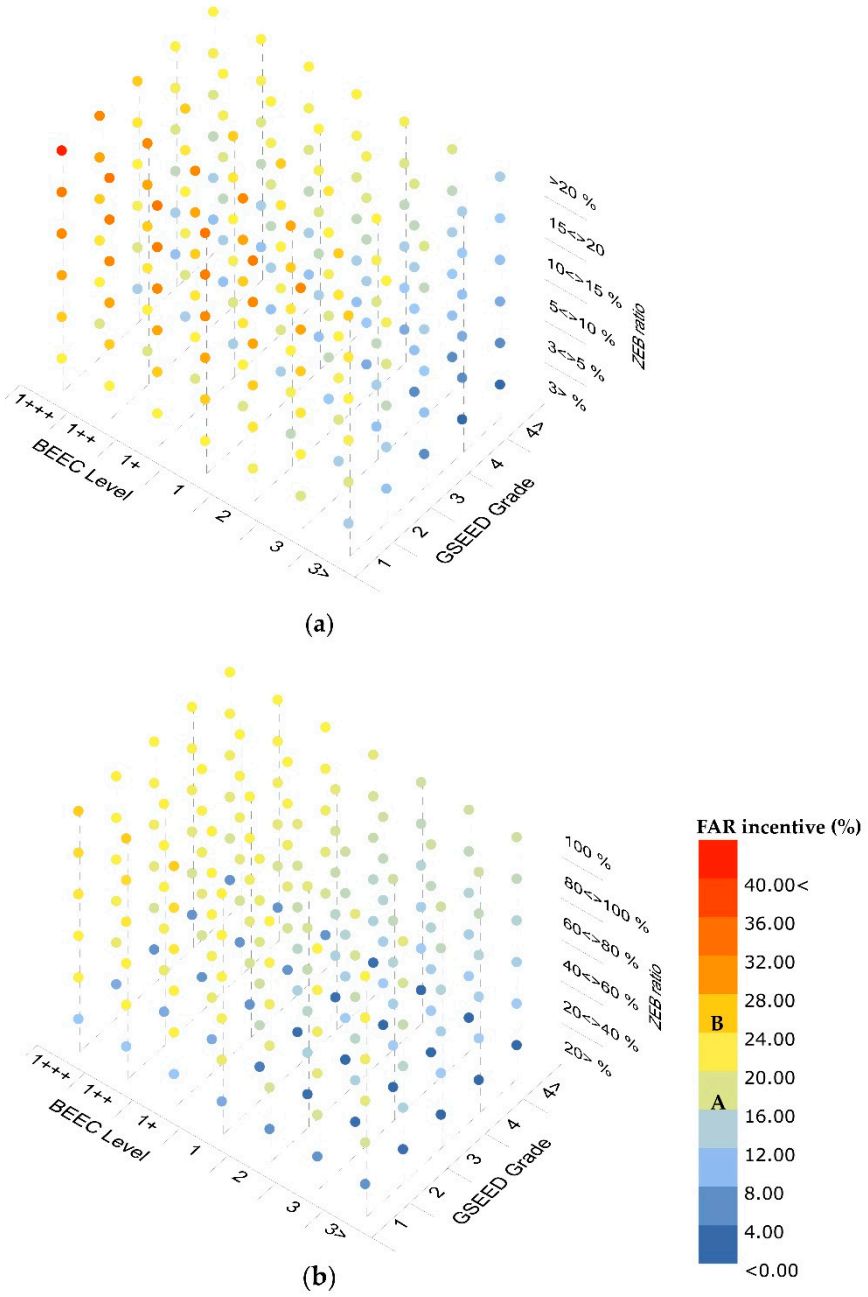


Figure 8. Combinatory three-dimensional gradient evaluation tool for calculating FAR incentives in percentages from the basic standard under BEEC, GSEED, and ZEB criteria: (**a**) incentive scheme for Villa type; (**b**) incentive scheme for Apartment and Mixed-Use types. In the FAR incentive legend at the extreme right, "A" indicates the upper limit of effectively realizable floor area extension through renovation for the Villa and the Mixed-Use building within the limitations discussed in Table 10, while "B" indicates the percentage of effectively realizable FAR increase for the new construction of Mixed-Use buildings within the mandated building limitations.

4.3. Answering the Research Questions Based on Comparative Analysis of the Legislative Framework for Sustainable Building

Based on the results obtained through analyzing the existing legislation for basic standards and maximum incentives for sustainable building, the research questions stated at the end of Section 2, Materials and Methods, are answered:

1. Sustainable building incentives for FAR extension or building size do not apply to minimum building standards. Applicable incentives for installing renewable and/or

efficient energy-supply systems are awarded distinctly from the building standard class achieved. Accordingly, the size and floor area of new and renovated buildings cannot be maximized through incentives with the basic building standards.

2. The major differences between new and renovated buildings are defined in basic building standards, specifically for Apartments. The major differences lie in which certification and accreditation system criteria are used to evaluate building performance. For new buildings, the minimum grade levels must be achieved under any of the relevant criteria for all performance categories, whereas for building renovation, criteria can be selected to focus investment on specific building systems or components. However, the minimum grade levels in the performance categories require approximately the same building envelope and energy demand standards to be met.
3. Renovation with the maximum incentives does not allow for extending a building's FAR more than new building would for all three case-study buildings. FAR incentives remain the same for both renovation and new building across all building types. Conversely, exclusive tax discounts are awarded for new buildings.
4. Interventions for achieving maximum incentives entail achieving the maximum performance evaluation grade levels under GSEED, BEEC, and ZEB standards. Interventions must be executed with synergy to achieve overperformance bonuses. However, for single, nonmaximized incentives, criteria are distinct for Villas, while GSEED and BEEC standards combine in a single performance evaluation scheme for Apartments and Mixed-Use buildings. Furthermore, ZEB certification award requires the installation of a Building Energy Management System (BEMS), consisting of energy-consumption metering devices and computerized data-collection and control systems. The installation of the BEMS system is therefore tied to extensive equipment installation costs of more than KRW 30,000,000, thus constraining the opportunity for low-budget, highly subsidized renovation projects to achieve overperformance bonuses. Accordingly, integrated solutions are favored for buildings with achievable increase in building size and FAR, such as Apartments and Mixed-Use buildings, which can result in a higher return on investment.
5. Comparing Table 3 with Table 7 allows the specific FAR increases to be quantified through maximized incentives: 60% for the Villa, 30% for the Apartment building, and 37.50% for the Mixed-Use building. However, the size and floor area of new and renovated buildings are subordinated to existing regulations in terms of building height and vertical and horizontal expansions, as well as minimum distance between adjacent buildings.
6. Sustainable building incentives depend significantly on differences between district and municipal regulations over the legal distinction between new building and renovation. In particular, the DUP establishes a uniform incentive system for both new buildings and renovations to Villas, whereas there are distinct, predetermined schemes for the new building and renovation of Apartment and Mixed-Use buildings at the municipal level.
7. Renovation according to basic standards provides less economic advantages than similar interventions with sustainable building incentive awards, because standard renovations do not receive FAR incentives. However, the advantages of renovation for incentives versus renovation following basic standards vary across building types. For Villas, renovation through incentives is profitable, because it allows the building FAR to be expanded and energy-supply costs to be reduced at the same time through lower, concentrated expenses. The advantage lies in the lower performance increments required to upgrade from minimum to incentivized grading classes. However, FAR extension through incentives is constrained by regulations relating to the number of parking areas and distance from adjacent buildings, which might reduce the realizable ratio of effective building extension. In the simulated case studies, no FAR incentives would have been required for both new construction and renovation, due to the limiting parking and building type change regulations. Conversely, for renovat-

ing Apartment and Mixed-Use buildings, basic standards require a comparably lower investment than do the interventions required to achieve minimum incentives. Furthermore, incentive awards are strictly regulated by limitations in building extension and parking areas, which further motivates the making of maximum investments to achieve maximum FAR incentives, and therefore revenue from new rental contracts. An additional element is the incentives for installing renewable energy-supply systems, which are a separate category from FAR incentives, and present advantages independent of the maximum incentives for meeting the basic building standards.

4.4. Renovation as a Revitalization Strategy of Aged Districts as Opposed to New Construction and Redevelopment

Comparing quantifiable incentives between renovation and new construction scenarios does not consider the effects on the identity and the further social development of a district. This research addressed environmental and economic-sustainability criteria for the two scenarios, but not the social aspects, which are inherently more challenging to analyze and evaluate. However, the particular social advantages of renovation over new construction can be demonstrated for the three most common neighborhood configurations in the RoK: (i) dilapidated districts with low or decreasing land value, (ii) aged districts with increasing land value gap (difference between the existing value and market value of properties), and (iii) apartment districts.

While most of the first two district types consist of villas and mixed-use buildings, apartment neighborhoods consist exclusively of apartment buildings. Apartment districts lack the attractive features of commercial and cultural areas. Therefore, in decaying districts, renovation might become the only solution to revitalize the neighborhoods' social and cultural conditions. Renovation and the subsequent improvement of the existing buildings can provide a relatively cheap rentable space, where the district's low attractiveness balances a potential increase in prices. The price–attractiveness combination offers an affordable environment in which new tenants and businesses can relocate to a modernized area. Accordingly, the renovated district acquires new value by stratifying building interventions such as vertical extension and building envelope renovation, increasing its cultural value without losing its original social composition and morphological structure. A combination of low-cost renovated space for new activities and increased aesthetical value can become the engine for developing attractive vibrant neighborhoods, compensating for the lack of other features that would typically increase the buildings' values. The conservation of the existing morphology and inhabitant structure would further fasten the district's identity and guide its regeneration to a more attractive condition, where inhabitants are still actively participating, socially and economically, in its transformation.

In existing districts with increased land value and price gaps due to the proximity to (often new) attractive facilities and infrastructures, the risk for redevelopment is comparable high. Redevelopment in high-value districts can materialize in two different scenarios: (i) frequent turnover and constant refitting of commercial spaces due to increasing rent prices [79], or (ii) complete demolition of the existing buildings and new construction (integral redevelopment) [77]. Either one of the two scenarios can manifest depending on the condition of the existing buildings (the older, the higher the preference of owners toward integral redevelopment) and the presence of small commercial activities (the smaller and more significant number of activities, the higher the tendency to oppose integral redevelopment). In this case, renovation appears to be an affordable solution to increase the value of existing buildings and fight rampant speculation. Building extension allows more available space to be produced for tenants and commercial activities, competing with the hyper-inflated prices of existing areas and redistributing value. Building renovation, particularly if executed with appealing materials and technologies, can significantly influence a commercial neighborhood's character [80] and further cement its appealing character without sacrificing the existing social context. Furthermore, community organizations can invest easier due to the shared commercial interest and renovation, and produce spaces that fit visitors' and inhabitants' interests and functional needs. The case of renovating

existing buildings adds a new layer to the constantly transforming district, integrating with a rich cultural substrate of socially active neighborhoods.

Renovation of apartment neighborhoods appears to be more complex than the one profiled by mixed-use and villa districts. Apartment neighborhoods very often undergo two types of interventions: (i) single-tenant renovation, i.e., spatial and aesthetical retrofitting of interior spaces with partial or absent energy-efficient interventions; or (ii) integral redevelopment. Single renovations generally focus on indoor space reorganization and interior design without sensibly impacting the building's energy efficiency. Indoor renovations increase the value of an apartment unit only partially, and significantly depend on the building's position within the city and the neighborhood characteristics. Integral renovation replaces existing buildings with multifunctional complexes [81].

Here, the advantages of renovation cannot compete with the form and density of integral development. New apartments fit the prerequisites of modern Korean households with reduced member counts and provide the comfort of available facilities on-site instead of the zoning distinction of previous apartment complexes. Building renovation offers the advantage of creating shared spaces and areas if vertically extended, and increasing the building's economic value due to improved energy efficiency.

Social constructs in apartment neighborhoods are furthermore less cohesive than the ones in mixed-use and villa districts, as the value of shared spaces is often relegated to the mandated green areas by building regulations. In the absence of commercial spaces, apartment neighborhood renovation can only improve social conditions by intervening on the internal distribution of the spaces in order to accommodate different households than the ones for which apartment units were originally planned. Modern Korean households, having fewer members, require different spaces and functions. Renovating existing apartments, as well as providing new usable area both horizontally and vertically, can therefore increase the mixity of apartment buildings, adding to the common family clusters other types of users, such as young professionals and families with one or no children. Accordingly, the social transformations in apartment complexes and districts are more dependent on the rearrangement of interior spaces, rather than the possibility of expanding community and commercial areas through renovation. Therefore, the advantage of renovation over new construction in existing apartment districts is more complex and less evident than in the case of low-rise residential and commercial districts. The social composition of apartment districts is not cohesive enough to benefit from renovation. Therefore, only broad-scale requalification and regeneration projects can improve, often intervening on public areas, the social condition of apartment complexes. Furthermore, social constructs in apartment neighborhoods are less cohesive than those in mixed-use and villa districts, as the value of shared spaces is often relegated to the mandated green areas by building regulations. Apartment neighborhood renovation can improve social conditions by accommodating different household sizes and tenant groups than the initially planned apartment units. Contemporary Korean households have fewer members than traditional households and require other spaces and functions. Renovating existing apartments and providing additional usable areas by horizontal and vertical building extension can increase apartment building tenants' social diversity. They add to the typical traditional family clusters other types of users, such as singles and small families with one or no children. Accordingly, the social transformation in apartment complexes and districts is more dependent on the rearrangement of interior spaces and densification of existing neighborhoods, rather than on expanding community and commercial areas through renovation. Therefore, the advantage of renovation versus new construction in current apartment districts is more complex and less evident than in the case of low-rise residential and commercial neighborhoods.

4.5. Legislative and Incentive Analysis for Sustainable Construction as a Benchmark Tool for Best Practices

The analysis of incentive schemes and regulations for sustainable construction addressed two main issues in promoting the renovation of aged buildings, which apply to the RoK and other countries: (i) limitations imposed by building regulations to the prof-

itability of renovations due to spatial constrains, and (ii) the effective economic advantage of renovation over new construction. The RoK lacks comparable regulatory action toward the increase in renovation projects, such as the one promoted by the European Union (EU). Under the "Renovation Wave" strategy [82], the EU has set an ambitious renovation target for its member nations of 3%/y of the building stock, with the aim to reduce its final energy consumption by 18%, cumulating toward a total 55% GHG reduction by 2030. Similar legislative action to the one promoted by the EU should be implemented in the RoK to steer current building practices to focus on the process of building regulation. In particular, legislation for building renovation should be decoupled from incentives for new sustainable buildings, and dedicated incentives should be increased to define a strong and separated construction sector for renovations. Both the EU and RoK would nevertheless require a multiscale analysis of the applicable building regulations, such as the one described in this article, to individuate the real potential and limitations to renovations defined by both local regulations.

Norms promulgated on the national and international scale are in fact strongly limited, often being superseded by local codes and norms. Furthermore, a comprehensive re-evaluation and correction of the economic and regulatory dynamics that encourage new construction over renovation should be implemented to increase the appeal of renovation projects. In particular, renovation of aged buildings must be encouraged outside exemplary case studies located in suburbia or other areas deemed of low economic value and enforced in districts and neighborhood with higher land value. Therefore, while the implementation of stronger regulations toward renovation are necessary in the RoK, a similar approach, such as the one described in this article, is still required in other international contexts with stronger norms to concretely advance renovation projects as an economically, environmentally, and socially sustainable alternative.

The criteria and weighting of sustainable building certification systems require improvement and international context, particularly regarding resource consumption and environmental impacts related to construction materials' life cycles. Renovation and new constructions in the RoK, if executed according to high sustainability standards such as the passive house, require importing materials or components produced in other countries. The legislative analysis in this research is an excellent starting basis for comparing and connecting multiple certification systems to ensure that the building materials' life-cycle environmental impact would be consistent across countries. Therefore, this legislative analysis provides a basis for developing international benchmarks to analyze successful practices and provide sustainable renovation strategies and nongeographically dependent, legislative, and incentivization schemes for sustainable renovation.

5. Conclusions

This study presented an analysis of the legislative framework for sustainable building in the RoK, encompassing both basic standards and incentive schemes. Based on the analysis, quantifiable indices, certification criteria, and incentive quantification methods were determined for three case-study buildings located in Seoul. These included differences in performance target indices for incentive awards related to three common building types in the RoK. Three exemplary case-study buildings corresponding to the typical building types were selected to analyze and compare the maximum incentives for sustainable building renovation and new buildings.

Analysis of the legislative framework showed that the maximum incentives for building renovation exceed the maximum allowed building extensions, owing to regulations that limit the building distance from adjacent properties and height; accordingly, building owners are encouraged to invest in renovation to reach lower standards and environmental performance than the maximum achievable.

In contrast, incentives that are exclusively available for new buildings, such as the significant increase of the FAR compared with renovations, result in a higher potentially achievable economic profitability of new buildings. Accordingly, the legislation supports

the decision-making of building owners in favor of building new, rather than renovations. Furthermore, analysis of the case-study building scenarios unveils that buildings constructed prior to the enforcement of building regulations, such as maximum FAR and minimum distances to adjacent buildings, have significant disadvantages regarding their eligibility for maximum sustainable building incentives in terms of both building new and renovations. Renovations and new constructions of small buildings with less than 500 m^2 usable area are even excluded from any sustainable building incentives.

This comparative analysis of the legislative framework in the RoK and the resulting study illustrated and quantified the weaknesses of the current regulations in terms of supporting sustainable building renovations. The findings aim for the revision of existing norms to improve the attractiveness of sustainable building renovations. A revised legislative framework could significantly reduce the environmental impacts of the building sector by reducing the energy demand for building operation, as well as minimizing waste generation and resource consumption through reduction in the demolition of aged and construction of new buildings. Finally, further work will be required to quantify the feasible extent of effectively applicable financial incentives for renewable energy system installations based on the proposed case-study buildings. Additionally, the exemplary building case-study scenarios will be expanded in detailed renovation projects addressing the extent of achievable sustainable renovation incentives through the effective quantification of performance improvement of the renovated buildings.

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