Energy for Sustainable Development 83 (2024) 101564

Contents lists available at ScienceDirect

Energy for Sustainable Development

journal homepage: www.journals.elsevier.com/energy-for-sustainable-development

Evaluation of photovoltaic installation potential in industrial complexes around metropolitan areas: Regulatory obstacles and geographical considerations

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A R T I C L E I N F O

Keywords:
Photovoltaic
Solar power generation potential
Greenhouse gas emission reduction
Setback regulation
RE100

A B S T R A C T

The assessment of photovoltaic (PV) installation potential in industrial complexes is critical for advancing renewable energy objectives, particularly in urbanized settings like Gyeonggi Province, South Korea. This study examines the complex interaction of geographical, regulatory, and environmental factors affecting PV feasibility across 193 industrial complexes. Employing a GIS-based methodology, the research evaluates available rooftop and general land areas totaling 47.3 km^2, estimating a PV capacity potential of 3.72 GW. Despite significant rooftop spaces predominantly on concrete structures (10 km^2), stringent setback regulations present substantial obstacles, particularly in areas such as Ansan. General land sites covering 16.6 km^2 offer promising prospects, notably in Pyeongtaek. Current regulatory challenges, including setback regulations, impede the realization of the targeted 3.8 GW PV capacity, highlighting the potential benefits of policy reforms to facilitate deployment. This study underscores PV's pivotal role in sustainable energy transitions and advocates for strategic reforms to align regulatory frameworks with renewable energy aspirations. By integrating GIS analyses with regulatory insights, the study informs spatial planning initiatives essential for scaling up solar energy contributions in industrial contexts, supporting informed decision-making toward achieving a low-carbon future.

Introduction

The Renewable Electricity 100 % (RE100) campaign is a voluntary global initiative in which companies commit to using 100 % renewable energy sources such as solar and wind power to provide their electricity. The campaign began with the participation of 13 companies and had grown to include 424 global companies as of December 2023 (RE100, 2023). As part of this international trend, domestic suppliers connected with prominent global companies such as Apple, Google, and BMW are urged to join the initiative and set RE100 target dates. The implementation of RE100 has become increasingly essential in response to these demands (Bae et al., 2021). However, South Korea faces challenges in sourcing renewable energy because of structural difficulties in the power market and obstacles to renewable energy generation (Lee et al., 2022). Countries that utilize geographical resources such as wind and hydropower tend to generate a significant share of renewable energy; in contrast, South Korea, which faces limitations in geographical resources, is actively promoting solar power generation, which are relatively free from geographical constraints (Korea Energy Economics Institute, 2022).

South Korea has a relatively low proportion of renewable energy generation (8.1 %) compared with other countries (Enerdata, 2023). To overcome these limitations and actively support domestic companies' full participation in RE100, the South Korean government has continuously supported efforts to establish the K-RE100 system. For example, Gyeonggi Province formulated the Gyeonggi RE100 promotion plan to construct 9 GW of renewable energy facilities by 2026, targeting carbon reduction and RE100 compliance for local companies. Notably, Gyeonggi Province is responsible for the highest greenhouse gas emissions in South Korea in terms of energy consumption standards, with the industrial sector accounting for the highest proportion (35.9 %) of those emissions (Koh et al., 2022). To ensure a reliable, renewable power supply for Gyeonggi Province companies, which provide services to approximately 30 % of nationwide businesses, a plan was initiated to install 3.8 GW of photovoltaic (PV) power generation capacity within industrial complexes.

However, in South Korea, the widespread installation of PV systems is impeded by setback regulations (SR). SR is a land use regulation that restrict solar power plant sites to specific distances from facilities such as

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https://doi.org/10.1016/j.esd.2024.101564
Received 13 August 2024; Received in revised form 20 September 2024; Accepted 20 September 2024
Available online 28 September 2024

Abbreviations

GHG	Greenhouse gas
GIS	Geographic information system
KEA	Korea Energy Agency
LCOE	Levelized cost of energy
MOLIT	Ministry of Land, Infrastructure, and Transport
NSDI	National Spatial Data Infrastructure
PV	Photovoltaic
RE100	Renewable Electricity 100 %
SR	Setback regulations

property boundaries, roads, and structures, implemented by local authorities, as shown in Fig. 1. Despite being an area where installation is possible under South Korean regulations, the effective area for installation is limited within a few hundred meters of certain buildings due to setback regulations varying by local governments. For example, in Anseong, one of the cities in Gyeonggi Province, PV cannot be installed within 200 m of housing. These regulations are predominantly present in areas with rural populations, leading to conflicts with local residents when PV installations are primarily targeted for rural regions. Local opposition arises from issues related to PV installations such as haphazard development, damage to natural landscapes, and visual degradation (Im & Yun, 2019). According to interviews conducted in rural areas of South Korea, the majority of residents express discomfort regarding the installation of PV systems as it involves the destruction of forests and harm to the landscape (Ko, 2023). Furthermore, he indiscriminate installation of PV systems in residential areas contributes to residents' sense of discomfort. Related research suggests that the visual impact of PV installations on the rural landscape is more significant than that on urban areas, leading to increased opposition from local residents (Agnoletti, 2014; Enserink et al., 2022; Ioannidis & Koutsoyiannis, 2020; Šťastná & Vaishar, 2020).

Due to these restrictions on the installation of solar power facilities, there are concerns about whether it will be possible to secure the targeted 3.8 GW of power generation capacity using only the land in industrial complexes. Therefore, this study aims to analyze the impact of setback regulations on the installation of solar power facilities. It evaluates whether the available area for PV installation within industrial complexes in Gyeonggi Province is sufficient to achieve the desired power generation capacity, by using geographic information systems (GIS). As mentioned above, the challenges hindering the deployment of renewable energy suggest that when installing PV facilities, not only must the efficiency of the solar facility itself be considered, but also the regional characteristics and associated regulations. As a result, many studies have utilized GIS to evaluate the feasibility of renewable energy sources by considering factors such as resource availability, geographical suitability, environmental impacts, and economic viability (Yum & Das Adhikari, 2023). Table 1 illustrates the aspects considered in recent GIS-based research on PV systems, which has been conducted in primarily geographical and social terms. In most cases, geographical considerations are associated with factors such as solar radiation, land use, and topographical features, including slope, that can impact PV efficiency. Research that considers social aspects typically address social concerns associated with PV installation in terms of proximity to specific areas or infrastructure, protected zones, cultural heritage, or criteria prohibiting installation. For example, Abdel-Basset et al. (2021) considered geographical characteristics such as climatic conditions and solar radiation when installing PV systems in Egypt as well as the potential impacts of noise and visual disturbances associated with PV installation. Furthermore, Kannan et al. (2021) excluded areas with currently restricted vegetation or those requiring protection owing to limited natural resources from a priority list for PV installation in Iran. The recent consideration of social aspects indicates a trend toward the comprehensive evaluation of PV installation impacts. South Korea in particular faces social issues including regional opposition to PV installations; it also faces issues associated with the regulatory environment arising from such opposition. However, as no research to date has considered these aspects together, this study utilized GIS data to select optimal sites for PV construction in South Korea considering legal regulations, the built environment, and geographical features. A case study of industrial complexes in Gyeonggi Province, South Korea was conducted to predict the PV capacity, solar power generation potential, and greenhouse gas (GHG) emissions reduction associated with the installation of PV facilities within. The objective of this approach was to analyze the extent to which these installations can contribute to furthering the RE100 initiative.

Next section describes the process employed to identify optimal sites for PV installations in the industrial complexes of Gyeonggi Province considering legal regulations, the built environment, and topographical features. First, it outlines the method used to determine the available area, then describes the approach for calculating the corresponding installed PV capacity, solar power generation potential, and GHG emissions reduction. The process is detailed in Fig. 2.

Investigation of PV regulations

The requirements for the installation of PV systems in the industrial complexes of each city and county in Gyeonggi Province were differentiated according to their locations on building rooftop or general land sites. The results indicated that compliance with SR distances from heights and handrails is essential for PV installations on rooftop sites. According to the Ministry of Land, Infrastructure, and Transport (MOLIT), if a PV system is installed with a setback distance of 50 cm or more from the inner side of rooftop handrails and is less than 5 m high, it

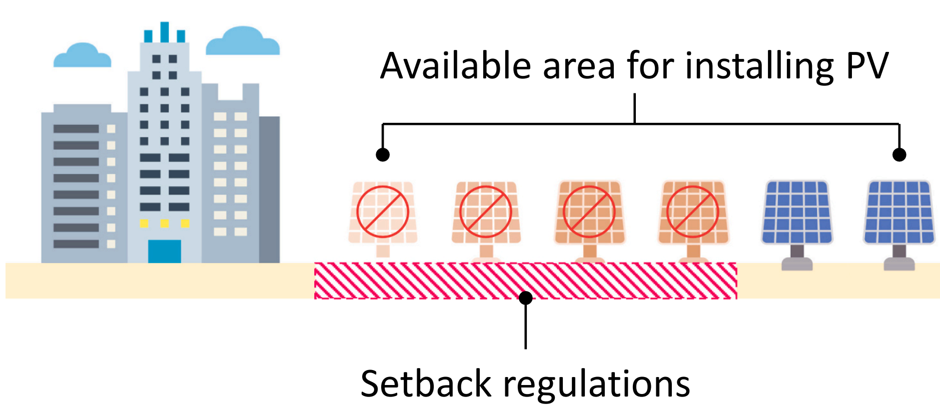

Fig. 1. Conceptual diagram of setback regulations for photovoltaic.

Table 1
Considerations in the literature when selecting optimal sites for Photovoltaic systems using geographic information system.

Reference	Categories	Considerations
(Abdel-Basset et al., 2021)	Geographical term	Solar radiation, and climatic conditions
	Social term	Technology maturity, power generation, economical dimension, infrastructural cost, operation and maintenance, payback period, noise impact, visual impact, land availability, transmission grid accessibility, pollutants and emissions, socio-political dimension, social acceptability, demand for electricity, distance from the residential region, effect on the economic progress of neighboring aera, government policies, political risk, time delay risk, economic risk, trained manpower, and environmental risk
(Kannan et al., 2021)	Geographical term	Solar radiation intensity and wind intensity
	Social term	Construction cost, maintenance cost, initial investment, distance to substation, land availability, protected areas, ecosystem destruction, distance to catchment basins, job creation, social acceptance, distance to farmlands, economic risk, time delay risk, and investment risk
(Colak et al., 2020)	Geographical term	Solar energy potential, roads, slope, location of dams and rivers, and land cover
	Social term	Energy transmission lines, transformer centers, natural gas pipelines, fault lines, and residential areas
(Marques-Perez et al., 2020)	Geographical term	Solar radiation, orientation/slope, land cover, erosion, temperature, and altitude
	Social term	Accessibility and grid connection
(Ruiz et al., 2020)	Geographical term	Land usage and topography
	Social term	Community settlement, road lines, and electrical network
(Finn & McKenzie, 2020)	Geographical term	Solar insolation and latitude
	Social term	Distance from the infrastructures
(Sun et al., 2021)	Geographical term	Climate, orography, water availability, and location
	Social term	Restrictive criteria (e.g. protected area, transport infrastructure, and orography)
(Lindberg et al., 2021)	Social term	Classification of land either suitable or unsuitable depending on the land usage (suitable land – pasture land, open land of vegetation less than 1.5 m high; unsuitable land – agricultural land, buildings, forest, cultural heritage, military areas, nature conservation, road/railways, water, and wind power, etc.)
(Agyekum et al., 2021)	Geographical term	Solar radiation, land use and coverage
	Social term	Natural and social hazards major settlement areas, protected areas, economic sustainability factors, and infrastructure proximity
(Demir et al., 2023)	Geographical term	Solar radiation rate, land use, slope
	Social term	land cost, distance to transmission line, distance to road, restricted areas, and determination of weights of constraints

Table 1 (*continued*)

Reference	Categories	Considerations
(Abdel-Aziz et al., 2023)	Geographical term	Slope, solar radiation, and visibility
	Social term	protection of vital places, and prohibited criterion of lithology
(Rekik & El Alimi, 2024)	Geographical term	Global solar irradiance (GHI), slope, ambient temperatures, average of cloudy days, aspect, land use, and soil texture
	Social term	Proximity to power lines, road network, water resources, and residential areas
(Soha et al., 2024)	Geographical term	Orientation and global irradiation
	Social term	heritage protection regulations and street-level visibility
(Hasan et al., 2024)	Geographical term	settlement roofs, lands, and water bodies
	Social term	PV system implementation practices
(Liang et al., 2024)	Geographical term	Solar radiation, building surfaces, taking into account various geographical constraints such as the location, orientation of buildings, and the impact of shading from surrounding structures
	Social term	–
(Benalcazar et al., 2024)	Geographical term	Excluding geographical constraints such as lakes, rivers and streams, marine waters, forests, slopes, and elevations
	Social term	Excluding social constraints such as power transmission lines, roads, railways, airport, urban areas, industrial areas, bird protection areas, flora, fauna, and habitat-protected areas, designated areas of national and international importance, mineral extraction sites, dump sites, construction sites, non-irrigated arable land, and permanently irrigated land
(Fakharizadehshirazi & Rösch, 2024)	Geographical term	Solar radiation, vegetation, water bodies, land aspect, soil erosion, and land slope
	Social term	Proximity to power lines, streets, settlement, military zones, and public-law and other determinations
(Li et al., 2024)	Geographical term	Solar radiation, average temperature, rainfall, slope, land use cover, and land aspect
	Social term	Electricity network and transportation network
(Almasad et al., 2023)	Geographical term	Global Horizontal irradiance, average temperature, precipitation, air pressure, relative humidity, slope, and land aspect
	Social term	Distance from transmission grids, power lines, highways, major cities
(Asrami et al., 2023)	Geographical term	Radiation, land cover, and slope
	Social term	Distance to main roads, railways, natural resources, water bodies, historic areas and stations, and protected area
(Bawazir et al., 2023)	Geographical term	Horizontal solar radiation, ambient temperature, relative humidity, wind speed, elevation, slope, and orientation
	Social term	Power network, urban area, shoreline, road network, protected areas such as crops areas, water bodies, and flooded vegetation areas
(Shriki et al., 2023)	Geographical term	Global solar radiation, temperature, relative humidity, elevation, slope, orientation, land use and land cover
	Social term	Proximity to electrical grid and road, distance to residential/built-up

(*continued on next page*)

Table 1 (*continued*)

Reference	Categories	Considerations
		areas, substations, distance from fault lines, and prohibited installations such as natural reserves, national park, forest, fire zone, heritage sites, and etc.

is considered an accessory building facility and can be installed without being subject to any special-purpose area regulations. Compliance with these requirements implies that PV installation on building rooftops is possible without restrictions on the building's purpose, LBR, floor area ratio, or similar regulatory requirements. However, according to the Korea Energy Agency (KEA) PV construction criteria, the PV panels must be fixed directly to concrete or steel structures to support their loads.

To install a PV system on a land site in Gyeonggi Province, the municipal ordinances on urban planning within the region must be verified to ensure compliance with the restrictions specific to each special-purpose area. According to the enforcement decree of the South Korean Building Act, PV installations on land are classified as "Type 25" power facilities, which are subject to restrictions on usage, type, scale, and other characteristics in a similar manner to buildings. The regions where PV installations are permitted are outlined in Table 2 according to special-purpose area for each city and county. Depending on the categorization of special-purpose areas, regions where PV installations are not permitted include exclusive residential (classes I and II) and green conservation areas; areas where the permissibility of PV installations varies with city and county include general residential (classes II and III), quasi-residential, neighboring and circulative commercial, conservation control, and natural environment conservation areas.

The LBR values varied according to the type of special-purpose area, with those for residential, industrial, and commercial areas showing minor differences across cities and counties but generally falling within 60–70 %. Green, agricultural and forest, control, and natural environment conservation areas all allow PV installation; however, the total installation area is typically restricted to only 20–40 % of the total area.

In addition, 12 municipalities in Gyeonggi Province require adherence to SRs governing distances from surrounding facilities (Gapyeong, Gwacheon, Dongducheon, Suwon, Anseong, Yangju, Yangpyeong, Yeoju, Yeoncheon, Icheon, Paju, and Pocheon), as indicated in Table 3. These SRs are specified by the municipal ordinances on urban planning corresponding to each city and county in Gyeonggi Province and apply to residential areas, roads, and other structures.

For example, in Gapyeong, PV installations must be located more than 500 m away from any residence unless consent is obtained from all residents living within 500 m. Thus, when installing PV systems on a general land site, all available special-purpose areas within the industrial complex must be identified such that specific SRs from certain facilities can be met, as outlined in Table 3.

Methods

Within Gyeonggi Province, there are 193 industrial complexes where PV installations can be considered for building rooftops and nearby land

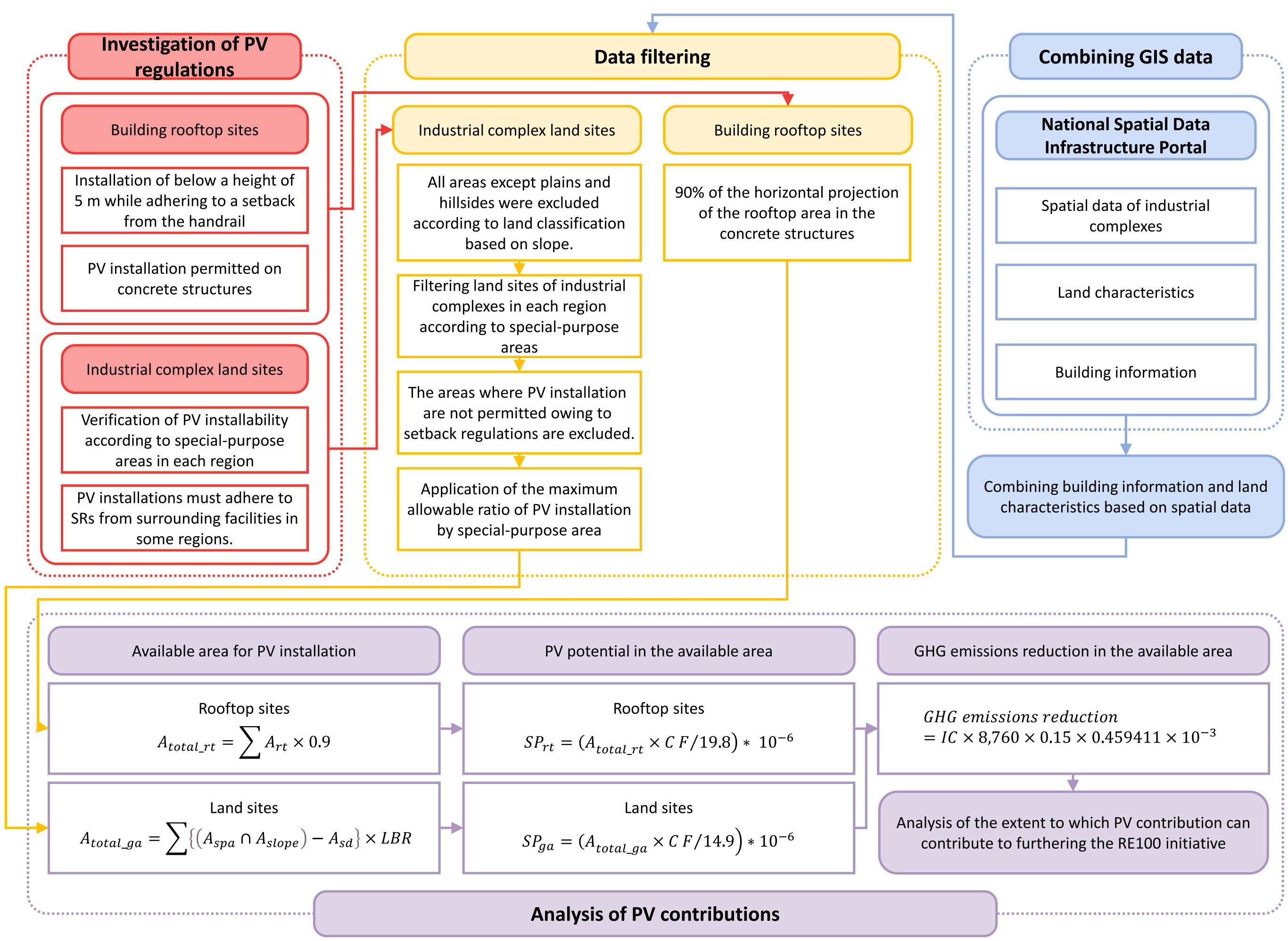

Fig. 2. Research flow.

Table 2
Feasibility and land-to-building ratio of photovoltaic installation according to classification of special-purpose area.

Classification of special-purpose area			Feasibility of PV installation	*LBR* (%)
Urban areas	Residential areas	Class I exclusive residential area	Unavailable	–
		Class II exclusive residential area	Unavailable	–
		Class I general residential area	Conditional	60
		Class II general residential area	Conditional	60
		Class III general residential area	Conditional	40–50
		Quasi-residential area	Conditional	60–70
	Commercial areas	Central commercial area	Available	70–90
		General commercial area	Available	70–80
		Neighboring commercial area	Conditional	0 or 60–80
		Circulative commercial area	Conditional	0 or 60–80
	Industrial areas	Exclusive industrial area	Available	0 or 70
		General industrial area	Available	0 or 60–70
		Quasi-industrial area	Available	0 or 60–70
	Green areas	Green conservation area	Unavailable	0 or 20
		Green production area	Available	0 or 20
		Green natural area	Available	20
Control areas	Conservation control area		Conditional	0 or 20
	Production control area		Available	0 or 20
	Planned control area		Available	0 or 40
Agricultural and forest area			Available	0 or 20
Natural environment conservation area			Conditional	0 or 20

Table 3
Setback distances from surrounding facilities for photovoltaic installation.

Nearby facilities	Setback distance from nearby facilities (m)	Note[a]
Buffer space	2, 3	Separation distance from the PV installation
Cultural heritage	100, 300, 500	Exclusion upon intangible cultural heritage and folk cultural heritage
Housing	100, 200, 300, 500	Housing under five units: 200 m Housing from five to ten units: 300 m Housing with ten or more units: 500 m
Hospital	300	–
Mdeical institution	300	–
Natural settlement district	200	–
Nature park	300	–
Public facilities	300	–
Public sports facilities	200	–
River	200	–
Road	100, 200, 300, 500	–
Rural road	100, 300	–
School	200, 300	–
Tourist destination	200, 300	–
Training facility	300	–

[a] Different depending on the cities in Gyeonggi Province.

sites. A GIS-based approach was utilized to integrate and filter data related to the building information, land characteristics, and spatial relationships of these industrial complexes. To determine the area available for PV installation, relevant regulations were identified and the necessary geographical criteria were collected. The obtained GIS data were subsequently filtered based on the identified regulations to calculate the final available area on both rooftop and land sites within industrial complexes. Using this calculated area, the total solar power generation potential of all industrial complexes in Gyeonggi Province was determined and the corresponding GHG emissions reduction effect was assessed.

Construction of dataset for the industrial complexes of Gyeonggi Province

To obtain information on the industrial complexes of Gyeonggi Province, associated GIS-based building information, land characteristics, and spatial data were collected from the National Spatial Data Infrastructure Portal (NSDI). The NSDI is an official open-source spatial information service hub established by the MOLIT that facilitates single-source access to spatial information produced by the national, public, and private sectors (MOLIT, 2020). First, building and land characteristic information were combined according to location, and the number of industrial complexes, current building information (area, structure, etc.), and land characteristics (elevation, land-use zone, land area, etc.) within Gyeonggi Province were identified. Using these data, areas where solar installations were infeasible were filtered out considering any city or county ordinances governing installation and SRs. Areas that should be excluded owing to SR distances from specific locations were calculated by buffering and excluded from the available area.

Calculation of the area available for PV installation

The data identified in Construction of dataset for the industrial complexes of Gyeonggi Province Section were used to classify the area available for PV installation into two types: building rooftop and general land sites. For rooftop sites within an industrial complex, the calculation of area was performed for concrete structures by combining complex industrial spatial data with the building information. According to the Solar Power Generation Facility Installation and Maintenance Guidelines of Gyeonggi Province, the installable area for PV systems on rooftops can be estimated to be within 90 % of the horizontal projection of the rooftop area. Thus, the available area was calculated as follows:

$$A_{total\_rt} = \sum A_{rt} \times 0.9 \tag{1}$$

where A_{total_rt} represents the total available area for rooftop PV installation within a specific industrial complex and A_{rt} denotes to the available area for rooftop PV installation on a single building within that industrial complex.

The area of land within an industrial complex available for PV installation was calculated considering special-purpose areas, slopes, land categories, and SRs. A special-purpose area refers to land designated by the government for efficient and economical land use. Special-purpose areas where PV installation is not allowed were excluded from the available land area within the industrial complexes of each city or county. As PV installation is impossible if the slope of the site exceeds 15°, land was classified according to its slope as lowland, plains, hillside, steep slope, and upland, as shown in Table 4, and all areas except plains and hillsides were excluded from the available land area within the industrial complexes of each city or county. Furthermore, in South Korea, land is classified into 28 categories based on its intended purpose (MOLIT, 2014). Among these categories, only those permitting the installation of power facilities or the construction of buildings were considered as available; this excluded land used for agricultural purposes such as dry paddies, rice paddies, and orchards, as well as natural areas such as forests, fields, mineral spring sites, salterns, rivers, and

Table 4
Land classification based on slope.

Land classification	Description
Lowland	Land significantly lower than the surrounding topography or arterial road
Plain	Land with a height similar to or slightly sloped compared to the surrounding topography or arterial road
Hillside	Land higher than the surrounding topography or arterial road with a slope of 15° or less
Steep slope	Land higher than the surrounding topography or arterial road with a slope exceeding 15 degrees
Upland	Land significantly higher than the surrounding topography or arterial road

marshes. The focus was placed on areas designated for building purposes, including building land, factory sites, school sites, parking lots, warehouse sites, sports facilities, and miscellaneous areas. Thus, the available land area for PV installation within an industrial complex in a specific city (A_{total_ga}) was calculated as the area where special-purpose area regulations do not apply, land type is classified as a plain or hillside, and construction is not prohibited by SRs. This calculation can be expressed as follows:

$$A_{total\_ga} = \sum \{ (A_{spa} \cap A_{slope}) - A_{sd} \} \times LBR \quad (2)$$

where A_{spa} represents the total area (including special-purpose areas) within an industrial complex where PV installation is possible, A_{slope} corresponds to the plain and hillside areas within the industrial complex where PV installation is efficient, A_{sd} corresponds to the area within the industrial complex where solar power installation is not permitted owing to SRs, and LBR denotes the land-to-building ratio of the special-purpose areas, which represents the maximum allowable ratio for the construction of PV facilities.

Calculation of solar power generation potential and GHG emissions reduction

We referred to relevant literature to calculate the solar power generation potential and GHG emissions reduction associated with PV installations within the industrial complexes of Gyeonggi Province (Wang et al., 2022). According to the New and Renewable Energy White Paper (Korea Energy Agency, 2023), 1 kWp requires a rooftop site area of 19.8 m^2 or a general land site area of 14.9 m^2. The solar power generation potential (SP_{rt}) for the rooftop sites within an industrial complex in a given city can be calculated as follows:

$$SP_{rt} = (A_{total\_rt} \times CF/19.8)*10^{-6} \quad (3)$$

where CF represents the annual conversion factor for the specific city, the value of which is based on the long-term power generation (in kWh) per unit of installed PV capacity (kWp), which the Global Solar Atlas defines as the global photovoltaic power output (PV_{out}) and refers to as the specific yield (ESMAP, 2019), and 10^{-6} represents the unit conversion factor. The equation for calculating the solar power generation potential (SP_{ga}) of available land sites within an industrial complex in a specific city is given by:

$$SP_{ga} = (A_{total\_ga} \times CF/14.9)*10^{-6} \quad (4)$$

The GHG emissions reduction owing to PV installation were determined according to the equation provided by the KEA (Korea Energy Agency, 2019), which calculates the change in emissions before and after installing a PV system assuming that emissions are reduced to zero after installation. In other words, the reduction in GHG emissions is considered equivalent to the installed PV capacity. This equation is given by:

$$GHG\ emissions\ reduction = IC \times 8,760 \times 0.15 \times 0.459411 \times 10^{-3} \quad (5)$$

where the factor 8760 represents the hours of PV operation in a year, 0.15 represents the average solar power generation facility utilization rate in South Korea, 0.459411 represents the emission factor for power generation (in tCO_2eq/MWh), 10^{-3} represents the unit conversion factor, and IC is the installed PV capacity (in kW), calculated by dividing the available PV installation area by the required area depending on the installation location (19.8 m^2 for building rooftop sites and 14.9 m^2 for general land sites) as follows:

$$IC_{rt} = A_{total\_rt}/19.8 \quad (6)$$

$$IC_{ga} = A_{total\_ga}/14.9 \quad (7)$$

Results and discussion

Available area for PV installation in the industrial complexes of Gyeonggi Province

There are 193 industrial complexes in Gyeonggi Province, the majority of which are concentrated in the northwest and southwest, as shown in Fig. 3. The detailed analysis results for each city are presented in Table 5, Table 6, and Fig. 4 shows the total areas available for PV installation on rooftop and general land sites within the industrial complexes.

The total area of industrial complexes in Gyeonggi Province is approximately 154.1 km^2. Owing to the municipal ordinances governing urban planning and SRs, solar installations are prohibited in a 99.7 km^2 area, accounting for 64.7 % of the total; thus, the area available for PV installation was determined to be 47.3 km^2, or 30.7 % of the total area. Pyeongtaek, where industrial complexes are the most abundant, has the largest area available for PV installation, accounting for 22.9 % of its total available area. Furthermore, the area lost owing to SRs in all 12 regions with such restrictions was determined to be 7.1 km^2, representing a total loss of 4.6 %.

The total rooftop area for all industrial complexes was 30.7 km^2; however, because PV installations are practically limited to concrete structures, the rooftop area corresponding to concrete buildings is only 10 km^2, accounting for only 35.5 % of the total. Ansan was determined to provide the largest rooftop area, accounting for 56.2 % of its available area for PV installation. The overall results indicate that the total area available for PV facility installation, including rooftop and general land sites, in the industrial complexes of Gyeonggi Province is 78 km^2.

Contributions of PV facilities installed in the industrial complexes of Gyeonggi Province

Table 5 and Table 6 show the solar power generation potential of the PV facilities that can be installed in the industrial complexes of Gyeonggi Province by city and county. Ansan has the highest rooftop solar power generation potential of 435.68 GWh/y, leading to a GHG emissions reduction of 186,503.55 tCO_2eq/y despite that fact that Ansan has the third-largest site area among considered industrial complexes; this occurred because its concrete building area is higher than that in most areas. The total PV capacity that can be installed on rooftops in Gyeonggi Province's industrial complexes is approximately 0.55 GW, securing a solar power generation potential of 774.39 GWh/y and an annual GHG emissions reduction of 331,932.53 tCO_2eq/y. Thus, to meet the target capacity of 3.8 GW for the power supply plan in Gyeonggi Province's industrial complexes, a 3.25 GW capacity must be secured on general land sites.

In contrast to the results for the available rooftop area, the solar power generation potential and GHG emissions reduction for general land sites were the highest in Pyeongtaek, which has the largest land

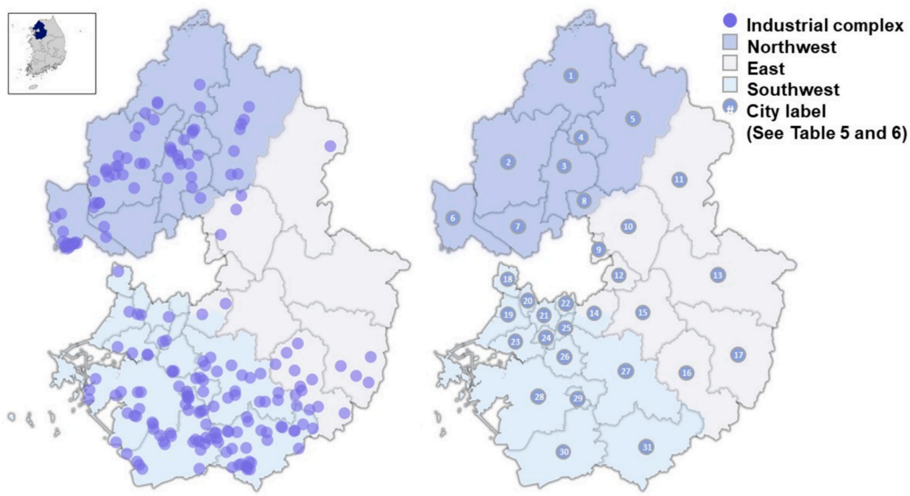

Fig. 3. Distribution of industrial complexes in Gyeonggi Province.

Table 5
Installed capacity, solar power generation potential, and greenhouse gas emissions reduction according to the available area for photovoltaic installation on the rooftop within industrial complexes.

Region	No.	Name of city	Building area (m^2)	Available area, A_{total_rt} (m^2)	Installed capacity, *IC* (kW)	PV potential, SP_{rt} (GWh/y)	GHG emissions reduction (tCO_2eq/y)
North-west	1	Yeoncheon	68,297.42	5632.10	284.45	0.40	171.71
	2	Paju	2,484,383.88	1,189,386.49	60,070.02	84.85	36,262.23
	3	Yangju	736,328.99	76,603.91	3868.88	5.39	2335.51
	4	Dongducheon	339,034.10	29,679.27	1498.95	2.04	904.87
	5	Pocheon	254,048.38	71,726.75	3622.56	4.82	2186.82
	6	Gimpo	712,826.59	122,001.13	6161.67	8.83	3719.59
	7	Goyang	6283.24	–	–	–	–
	8	Uijeongbu	240,340.93	43,633.19	2203.70	3.06	1330.30
East	9	Guri	–	–	–	–	–
	10	Namyangju	73,332.89	49,445.08	2497.23	3.44	1507.49
	11	Gapyeong	24,946.04	1298.83	65.60	0.09	39.60
	12	Hanam	–	–	–	–	–
	13	Yangpyeong	–	–	–	–	–
	14	Seongnam	343,559.08	228,177.23	11,524.10	16.12	6956.71
	15	Gwangju	–	–	–	–	–
	16	Icheon	101,690.87	31,795.65	1605.84	2.26	969.39
	17	Yeoju	12,713.97	154.80	7.82	0.01	4.72
South-west	18	Bucheon	105,231.87	71,618.92	3617.12	5.11	2183.53
	19	Siheung	5,375,745.78	791,705.55	39,985.13	56.10	24,137.67
	20	Gwang-myeong	23,729.30	1272.50	64.27	0.09	38.80
	21	Anyang	44,833.71	40,806.68	2060.94	2.85	1244.12
	22	Gwacheon	–	–	–	–	–
	23	Ansan	10,519,936.32	6,117,240.21	308,951.53	435.68	186,503.55
	24	Gunpo	–	–	–	–	–
	25	Uiwang	27,086.56	3029.00	152.98	0.21	92.35
	26	Suwon	121,374.53	9035.36	456.33	0.65	275.47
	27	Yongin	115,228.52	55,927.18	2824.61	3.95	1705.12
	28	Hwaseong	2,159,591.19	430,493.27	21,742.08	31.16	13,124.96
	29	Osan	289,501.72	140,560.01	7098.99	9.98	4285.42
	30	Pyeongtaek	4,676,341.09	928,631.81	46,900.60	66.47	28,312.30
	31	Anseong	1,819,130.67	447,396.44	22,595.78	30.81	13,640.31
Total			30,675,517.63	10,887,251.36	549,861.18	774.39	331,932.53

area, at 1315.39 GWh/y and 560,298.87 tCO_2eq/y, respectively. When installing PV facilities according to special-purpose area designation and corresponding SRs, the total installed capacity that can be secured at all general land sites is approximately 3.17 GW, resulting in a solar power generation potential of 4494.81 GWh/y and a GHG emissions reduction effect of 1,917,632.58 tCO_2eq/y.

Fig. 5 shows a breakdown of the installed PV capacity for each city according to site type. Ultimately, the installed PV capacity within the industrial complexes of Gyeonggi Province is 3.72 GW, corresponding to a solar power generation potential of 5269.20 GWh/y and a GHG emissions reduction of 2,249,565.11 tCO_2eq/y. This installed capacity falls short of the original plan for PV installations in the industrial complexes of Gyeonggi Province, and the actual installed capacity could be even smaller. Therefore, securing the originally planned 3.8 GW of installed PV capacity is impossible given the present regulatory environment. To achieve the planned capacity, the installed capacity lost owing to SRs, which amounts to 0.47 GW, must be recovered. If SRs were relaxed, the total installed PV capacity would reach 4.19 GW, allowing an additional solar power generation potential of 655.11 GWh/y and a GHG emissions reduction of 286,078.84 tCO_2eq/y more than

Table 6
Installed capacity, solar power generation potential, and greenhouse gas emissions reduction according to the available area for photovoltaic installation on the general land sites within industrial complexes.

No.	Site area (m^2)	Available area, A_{total_ga} (m^2)	Available area excluding SD (m^2)	Installed capacity, *IC* (kW)	Installed capacity excluding SD (kW)	PV potential, SP_{ga} (GWh/y)	PV potential excluding SD (GWh/y)	GHG emissions reduction (tCO_2eq/y)	GHG emissions reduction excluding SD (tCO_2eq/y)
1	2,051,377.10	452,182.85	43,232.63	30,347.84	2901.52	42.86	4.10	18,319.96	1751.55
2	11,302,017.20	3,782,126.04	1,711,814.39	253,833.96	114,886.87	358.57	162.29	153,230.95	69,353.30
3	3,606,767.60	745,794.38	3819.06	50,053.31	256.31	69.70	0.36	30,215.49	154.73
4	794,387.80	267,571.49	124,893.79	17,957.82	8382.13	24.45	11.41	10,840.53	5060.01
5	3,534,695.50	989,483.84	–	66,408.31	–	88.42	–	40,088.44	–
6	7,353,953.60	2,576,187.70	2,576,187.70	172,898.50	172,898.50	247.83	247.83	104,372.96	104,372.96
7	129,211.50	12,899.40	12,899.40	865.73	865.73	1.23	1.23	522.61	522.61
8	425,623.90	183,109.75	183,109.75	12,289.24	12,289.24	17.05	17.05	7418.60	7418.60
9	–	–	–	–	–	–	–	–	–
10	927,533.30	222,656.50	222,656.50	14,943.39	14,943.39	20.56	20.56	9020.82	9020.82
11	53,623.00	37,536.10	–	2519.20	–	3.50	–	1520.76	–
12	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–
14	2,568,170.30	873,890.56	873,890.56	58,650.37	58,650.37	82.04	82.04	35,405.24	35,405.24
15	–	–	–	–	–	–	–	–	–
16	889,465.70	346,094.42	–	23,227.81	–	32.72	–	14,021.84	–
17	537,717.60	124,466.87	–	8353.48	–	11.76	–	5042.71	–
18	403,912.10	115,199.04	115,199.04	7731.48	7731.48	10.93	10.93	4667.23	4667.23
19	16,272,274.70	8,127,394.20	8,127,394.20	545,462.70	545,462.70	765.34	765.34	329,277.31	329,277.31
20	353,578.00	24,197.00	24,197.00	1623.96	1623.96	2.29	2.29	980.33	980.33
21	365,019.30	158,117.75	158,117.75	10,611.93	10,611.93	14.67	14.67	6406.06	6406.06
22	–	–	–	–	–	–	–	–	–
23	23,591,330.30	9,281,768.72	9,281,768.72	622,937.50	622,937.50	878.47	878.47	376,046.22	376,046.22
24	–	–	–	–	–	–	–	–	–
25	212,814.00	56,487.13	56,487.13	3791.08	3791.08	5.26	5.26	2288.55	2288.55
26	1,273,799.50	500,371.14	500,371.14	33,581.96	33,581.96	47.78	47.78	20,272.29	20,272.29
27	7,918,695.70	833,367.15	833,367.15	55,930.68	55,930.68	78.20	78.20	33,763.45	33,763.45
28	25,495,781.80	7,696,691.69	7,696,691.69	516,556.49	516,556.49	740.38	740.38	311,827.62	311,827.62
29	1,630,373.50	600,048.51	600,048.51	40,271.71	40,271.71	56.63	56.63	24,310.67	24,310.67
30	33,691,983.30	13,829,588.48	13,829,588.48	928,160.30	928,160.30	1315.39	1315.39	560,298.87	560,298.87
31	8,689,477.10	2,555,924.85	356,271.72	171,538.58	23,910.85	233.89	32.60	103,552.02	14,434.17
Total	154,073,583.40	54,393,155.56	47,332,006.31	3,650,547.33	3,176,644.72	5149.92	4494.81	2203,711.52	1,917,632.58

that provided by the original plan.

Discussion

This study presents the development of a GIS-based method to determine optimal sites for PV installation by considering various complex factors, including legal regulations and topographic features. The research specifically focused on the industrial complexes within Gyeonggi Province, evaluating the available areas for PV installations, the potential installed capacity, solar power generation potential, and the associated reductions in GHG emissions. The study aimed to identify the advantages and limitations of a proposed plan to install 3.8 GW of PV capacity. The findings revealed that under the current regulatory framework, the available area within the industrial complexes allows for an installed capacity of 3.72 GW. However, to achieve the originally planned 3.8 GW capacity, a relaxation of SR is necessary. This point is illustrated through an example within the study.

Fig. 6 depicts an industrial complex in Paju and the current status of the surrounding roads and houses showing the relevant SR offsets. As shown in Fig. 6(b), the area around this industrial complex is densely populated with roads and numerous houses, from which any PV installation must be set back 100 m. As a result, most (54.7 %) of the industrial complex area cannot host a PV facility, as illustrated by the example in Fig. 6(c). Thus, it can be argued that the relaxation of SR is essential to realize sufficient activation of PV electricity generation in South Korea as the country focuses on promoting RE100 goals.

Supporting literature emphasizes the negative impact of setback regulations on solar power generation potential. According to Lopez et al. (2023), who analyzed the regulations and potential for PV installations in the United States, if the 90th percentile level of identified setback distances were applied nationwide, the potential for solar power would decrease to 62 % of its original capacity. This trend aligns with recent patterns in the expansion of PV installations in South Korea. According to annual statistics on the new installed capacity of renewable energy supplied by the KEA (Korea Energy Agency, 2024), the new PV installed capacity at 4 GW in 2020 and has gradually decreased (with the new PV installed capacity in 2022 being 3.3 GW). Considering a lag of 1–2 years before the effects of these regulations are reflected in the market, this trend suggests that the setback regulations, which sharply increased from 2018, have indirectly impacted the deployment of solar power. While the primary consideration is that setback regulations reduce the area available for potential solar installations, thereby directly decreasing potential capacity, they can also indirectly impact the levelized cost of energy (LCOE) (Chang, 2024). PV project developers aim to generate profit through cost-minimization strategies, but with fewer potential project sites due to these regulations, they may be forced to select relatively inefficient locations in terms of cost. This could result in an increase in the average LCOE of the remaining options, adversely affecting the overall market. The findings of this study, along with these issues, suggest that SRs are a significant obstacle to achieving the desired production levels through solar installations. Therefore, discussions on efficiently improving the current setback regulations are necessary. However, the high level of domestic regulations is closely tied to issues of public acceptance, often manifested through complaints, so identifying the root causes is essential. Moreover, rather than simply advocating for the removal of regulations, it would be more effective to avoid disputes and encourage voluntary relaxation of regulations by local governments, which requires consideration of effective incentives for municipalities (Chang, 2024; Ko, 2023).

On the other hand, the contribution assessment method developed in this study can be applied to any renewable energy facility, including wind power or geothermal energy installations, allowing for the

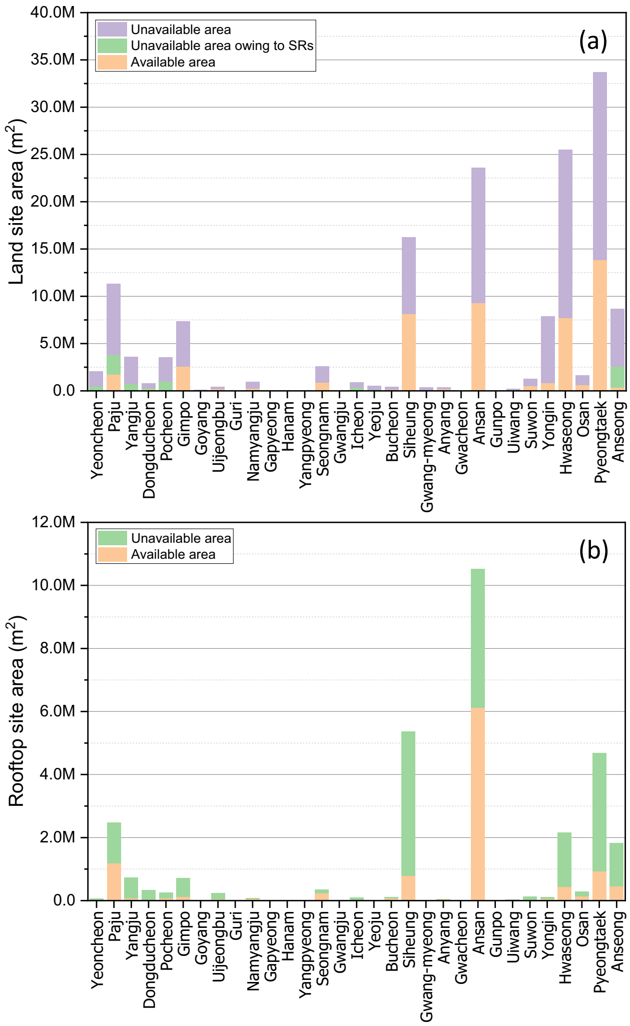

Fig. 4. Area available for photovoltaic installation on the rooftops and sites within industrial complexes.

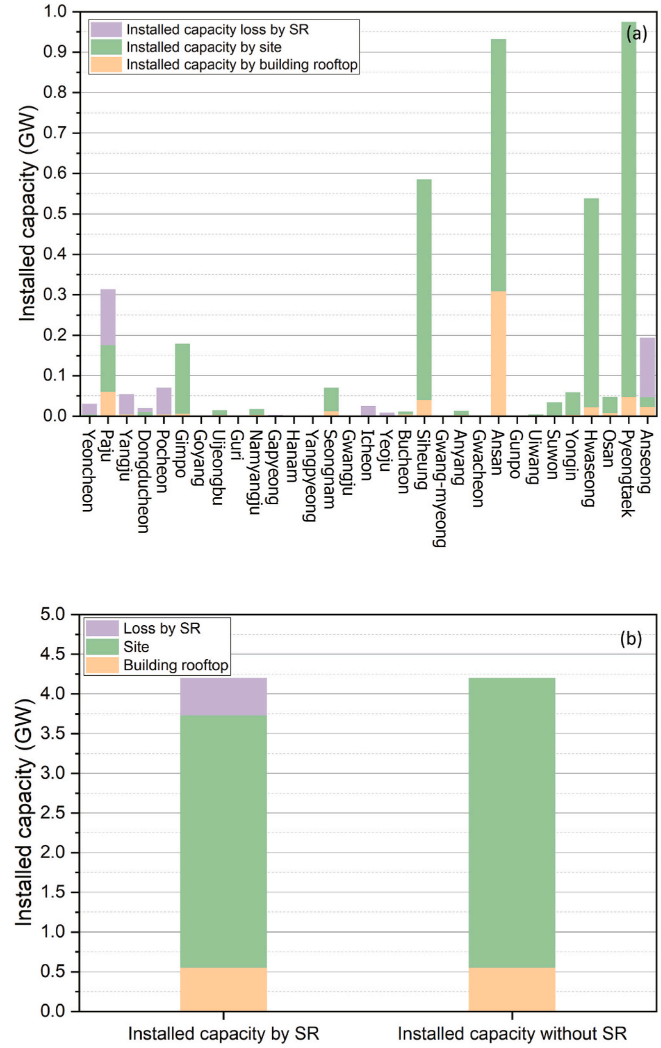

Fig. 5. (a) Installed capacity by cities (b) Installed capacity depending on setback regulation.

anticipation of benefits and limitations in the early planning stages. However, a critical limitation of this study is the possibility of errors. Indeed, previous research has focused on reducing accuracy and error rates of similar analyses by considering detailed factors, such as solar radiation and shading caused by buildings, to assess PV power generation potential more precisely. As this study focused on evaluating PV power contributions using a simple method to consider the effects of legal regulations, building type, and topography, future research should consider detailed factors such as shading owing to the height of surrounding buildings for rooftop installations in industrial complexes as well as the local solar radiation to reduce the potential for error when assessing installed capacities and GHG emissions reductions.

Conclusion

The deployment of PV systems in Gyeonggi Province's industrial complexes offers great potential to contribute to South Korea's renewable energy goals, but it also faces significant challenges. This study evaluated the feasibility of installing 3.8 GW of PV capacity across 193 industrial complexes in the region using GIS-based methods. Results showed that 47.3 km^2 of land—30.7 % of the total industrial complex area—could be used for PV installations, split between rooftops and general land sites. However, practical limitations, such as building structural concerns and shading, reduce the usable rooftop area to approximately 10 km^2.

General land sites within these complexes also provide significant potential, with an estimated 16.6 km^2 available for PV installations. These areas could support 3.17 GW of PV capacity. Nevertheless, stringent SRs pose a critical barrier, significantly limiting available installation space, as seen in Paju, where SRs made 54.7 % of potential areas unusable for PV deployment.

To overcome these regulatory hurdles, the study recommends revising SRs to align with renewable energy targets. Collaborative policy efforts, enhanced data transparency, and public engagement are essential to streamline PV installations and address conflicts. Moreover, integrating advanced factors like solar radiation and shading into assessments would improve accuracy in capacity estimates.

In conclusion, while Gyeonggi Province holds substantial potential for PV energy generation, addressing regulatory and structural challenges is crucial to achieving the region's full capacity and contributing to South Korea's broader renewable energy goals.

CRediT authorship contribution statement

Ji Hun Park: Writing – original draft, Conceptualization. **Sungwoong Yang:** Visualization, Resources. **Sumin Kim:** Supervision, Funding acquisition.

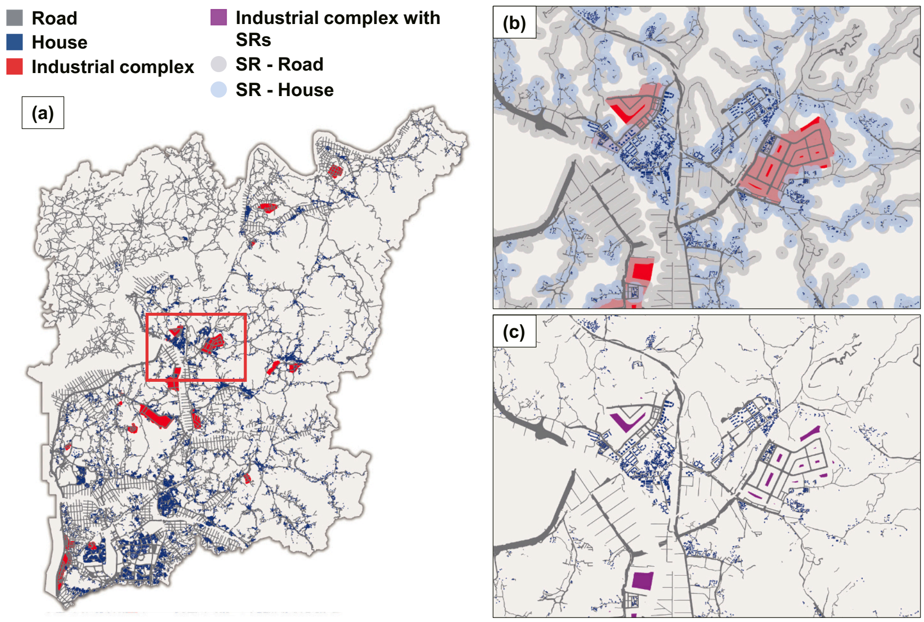

Fig. 6. (a) Industrial complexes in Paju (b) area excluded according to setback regulations from houses and roads (c) available area for photovoltaic installation according to applied setback regulations.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This study was carried out with the support of 'R&D Program for Forest Science Technology (Project No. "RS-2024-00400730")' provided by Korea Forest Service (Korea Forestry Promotion Institute).

References

Abdel-Aziz, N. M., Eldrandaly, K. A., Abdel-Fatah, L., & Abdel-Basset, M. (2023). Enhanced multiobjective optimizer for GIS-based siting of solar PV plants in Red Sea Governorate, Egypt. *Egyptian Journal of Remote Sensing and Space Science, 26*(1), 161–172. https://doi.org/10.1016/j.ejrs.2023.01.001

Abdel-Basset, M., Gamal, A., & ELkomy, O. M.. (2021). Hybrid multi-criteria decision making approach for the evaluation of sustainable photovoltaic farms locations. *Journal of Cleaner Production, 328*. https://doi.org/10.1016/j.jclepro.2021.129526

Agnoletti, M. (2014). Rural landscape, nature conservation and culture: Some notes on research trends and management approaches from a (southern) European perspective. *Landscape and Urban Planning, 126*, 66–73. https://doi.org/10.1016/j.landurbplan.2014.02.012

Agyekum, E. B., Amjad, F., Shah, L., & Velkin, V. I. (2021). Optimizing photovoltaic power plant site selection using analytical hierarchy process and density-based clustering – Policy implications for transmission network expansion, Ghana. *Sustainable Energy Technologies and Assessments, 47*. https://doi.org/10.1016/j.seta.2021.101521

Almasad, A., Pavlak, G., Alquthami, T., & Kumara, S. (2023). Site suitability analysis for implementing solar PV power plants using GIS and fuzzy MCDM based approach. *Solar Energy, 249*, 642–650. https://doi.org/10.1016/j.solener.2022.11.046

Asrami, R. F., Sohani, A., Sayyaadi, H., & Moradi, M. H. (2023). Geographical information system as an approach for PV power plants allocation with 3E criteria. *Solar Energy, 264*. https://doi.org/10.1016/j.solener.2023.111966

Bae, J. H., Rishi, M., & Li, D. (2021). Consumer preferences for a green certificate program in South Korea. *Energy, 230*. https://doi.org/10.1016/j.energy.2021.120726

Bawazir, R. O., Çetin, N. S., & Fadel, W. (2023). Optimum PV distributed generation based on grid and geographical area: A case study of Aden governorate, Yemen. *Energy Conversion and Management, 297*. https://doi.org/10.1016/j.enconman.2023.117703

Benalcazar, P., Komorowska, A., & Kamiński, J. (2024). A GIS-based method for assessing the economics of utility-scale photovoltaic systems. *Applied Energy, 353*. https://doi.org/10.1016/j.apenergy.2023.122044

Chang, Y. (2024). Setback regulation in solar photovoltaic deployment: A comparative analysis involving international cases for policy insights. *New & Renewable Energy, 20* (1), 2–14. https://doi.org/10.7849/ksnre.2024.2028

Colak, H. E., Memisoglu, T., & Gercek, Y. (2020). Optimal site selection for solar photovoltaic (PV) power plants using GIS and AHP: A case study of Malatya Province, Turkey. *Renewable Energy, 149*, 565–576. https://doi.org/10.1016/j.renene.2019.12.078

Demir, A., Dinçer, A. E., & Yılmaz, K. (2023). A novel method for the site selection of large-scale PV farms by using AHP and GIS: A case study in İzmir, Türkiye. *Solar Energy, 259*, 235–245. https://doi.org/10.1016/j.solener.2023.05.031

Enerdata. (2023). Share of renewables in electricity production. https://yearbook.enerdata.net/renewables/renewable-in-electricity-production-share.html.

Enserink, M., Van Etteger, R., Van den Brink, A., & Stremke, S. (2022). To support or oppose renewable energy projects? A systematic literature review on the factors influencing landscape design and social acceptance. *Energy Research and Social Science, 91*. https://doi.org/10.1016/j.erss.2022.102740

ESMAP, D. (2019). *Validation Report: Global Solar Atlas 2.0 Validation Report*. Washington, DC: World Bank.

Fakharizadehshirazi, E., & Rösch, C. (2024). A novel socio-techno-environmental GIS approach to assess the contribution of ground-mounted photovoltaics to achieve climate neutrality in Germany. *Renewable Energy, 227*. https://doi.org/10.1016/j.renene.2024.120117

Finn, T., & McKenzie, P. (2020). A high-resolution suitability index for solar farm location in complex landscapes. *Renewable Energy, 158*, 520–533. https://doi.org/10.1016/j.renene.2020.05.121

Hasan, A. S. M. M., Kesapabutr, P., & Möller, B. (2024). Bangladesh's pathways to net-zero transition: Reassessing country's solar PV potential with high-resolution GIS data. *Energy for Sustainable Development, 81*. https://doi.org/10.1016/j.esd.2024.101511

Im, H., & Yun, S.-J. (2019). Analysis of the policy process of the separation distance regulation of local governments concerning the location conflicts of photovoltaics facilities. *New & Renewable Energy, 15*(2), 61–73. https://doi.org/10.7849/ksnre.2019.6.15.2.061

Ioannidis, R., & Koutsoyiannis, D. (2020). A review of land use, visibility and public perception of renewable energy in the context of landscape impact. *Applied Energy, 276*. https://doi.org/10.1016/j.apenergy.2020.115367

Kannan, D., Moazzeni, S., Darmian, S. mostafayi, & Afrasiabi, A. (2021). A hybrid approach based on MCDM methods and Monte Carlo simulation for sustainable evaluation of potential solar sites in east of Iran. *Journal of Cleaner Production, 279*. https://doi.org/10.1016/j.jclepro.2020.122368

Ko, I. (2023). Rural opposition to landscape change from solar energy: Explaining the diffusion of setback restrictions on solar farms across South Korean counties. In *, Vol. 99. Energy research and social science*. Elsevier Ltd.. https://doi.org/10.1016/j.erss.2023.103073

Koh, J., Kim, D. Y., Lee, J.-I., & Ye, M. (2022). *Measures to manage excessive energy-consuming business entities for carbon neutrality in Gyeonggi-do*. 정책연구. Gyeonggi Research Institute. http://www.dbpia.co.kr/journal/articleDetail?nodeId=NODE11228556.

Korea Energy Agency. (2019). External project greenhouse gas emission reduction calculator (solar power generation - grid-connected, self-consumption). https://offset.energy.or.kr/popup/calculator08.do.

Korea Energy Agency. (2023). New and renewable energy white paper. https://www.knrec.or.kr/biz/pds/pds/view.do?no=326.
Korea Energy Agency. (2024). New installed capacity of renewable energy facilities. https://www.knrec.or.kr/biz/statistics/supply/supply04_01_list.do.
Korea Energy Economics Institute. (2022). *Analysis of international new and renewable energy policy and market*.
Lee, J. W., Choi, E. J., Jeong, M. J., Moragriega, R. C., Zaragoza, P. G., & Kim, S. W. (2022). Optimal sourcing strategy for enterprises to achieve 100% renewable energy. *Energy Reports, 8*, 14865–14874. https://doi.org/10.1016/j.egyr.2022.10.443
Li, X. Y., Dong, X. Y., Chen, S., & Ye, Y. M. (2024). The promising future of developing large-scale PV solar farms in China: A three-stage framework for site selection. *Renewable Energy, 220*. https://doi.org/10.1016/j.renene.2023.119638
Liang, H., Shen, J., Yip, H. L., Fang, M. M., & Dong, L. (2024). Unleashing the green potential: Assessing Hong Kong's building solar PV capacity. *Applied Energy, 369*. https://doi.org/10.1016/j.apenergy.2024.123567
Lindberg, O., Birging, A., Widén, J., & Lingfors, D. (2021). PV park site selection for utility-scale solar guides combining GIS and power flow analysis: A case study on a Swedish municipality. *Applied Energy, 282*. https://doi.org/10.1016/j.apenergy.2020.116086
Lopez, A., Cole, W., Sergi, B., Levine, A., Carey, J., Mangan, C., Mai, T., Williams, T., Pinchuk, P., & Gu, J. (2023). Impact of siting ordinances on land availability for wind and solar development. *Nature Energy, 8*(9), 1034–1043. https://doi.org/10.1038/s41560-023-01319-3
Marques-Perez, I., Guaita-Pradas, I., Gallego, A., & Segura, B. (2020). Territorial planning for photovoltaic power plants using an outranking approach and GIS. *Journal of Cleaner Production, 257*. https://doi.org/10.1016/j.jclepro.2020.120602
MOLIT. (2014). Act on the establishment and management of spatial data. https://elaw.klri.re.kr/kor_service/lawView.do?hseq=60991&lang=ENG.
MOLIT. (2020). Korea national spatial infrastructure portal. http://www.nsdi.go.kr/lxportal/?menuno=3085.
RE100. (2023). RE100 members. https://www.there100.org/re100-members.
Rekik, S., & El Alimi, S. (2024). A GIS based MCDM modelling approach for evaluating large-scale solar PV installation in Tunisia. *Energy Reports, 11*, 580–596. https://doi.org/10.1016/j.egyr.2023.12.018
Ruiz, H. S., Sunarso, A., Ibrahim-Bathis, K., Murti, S. A., & Budiarto, I. (2020). GIS-AHP multi criteria decision analysis for the optimal location of solar energy plants at Indonesia. *Energy Reports, 6*, 3249–3263. https://doi.org/10.1016/j.egyr.2020.11.198
Shriki, N., Rabinovici, R., Yahav, K., & Rubin, O. (2023). Prioritizing suitable locations for national-scale solar PV installations: Israel's site suitability analysis as a case study. *Renewable Energy, 205*, 105–124. https://doi.org/10.1016/j.renene.2023.01.057
Soha, T., Sugár, V., & Hartmann, B. (2024). City-scale analysis of PV potential and visibility in heritage environment using GIS and LiDAR. *Energy and Buildings, 311*. https://doi.org/10.1016/j.enbuild.2024.114124
Šťastná, M., & Vaishar, A. (2020). Values of rural landscape: The case study Chlum u Třeboně (Bohemia). *Land Use Policy, 97*. https://doi.org/10.1016/j.landusepol.2020.104699
Sun, L., Jiang, Y., Guo, Q., Ji, L., Xie, Y., Qiao, Q., Huang, G., & Xiao, K. (2021). A GIS-based multi-criteria decision making method for the potential assessment and suitable sites selection of PV and CSP plants. *Resources, Conservation and Recycling, 168*. https://doi.org/10.1016/j.resconrec.2020.105306
Wang, L., Xu, S., Gong, Y., Ning, J., Zhang, X., & Zhao, Y. (2022). High resolution photovoltaic power generation potential assessments of rooftop in China. *Energy Reports, 8*, 14545–14553. https://doi.org/10.1016/j.egyr.2022.10.396
Yum, S. G., & Das Adhikari, M. (2023). Suitable site selection for the development of solar based smart hydrogen energy plant in the Gangwon-do region, South Korea using big data: A geospatial approach. *International Journal of Hydrogen Energy, 48*(93), 36295–36313. https://doi.org/10.1016/j.ijhydene.2023.06.024