Energy Policy 193 (2024) 114272

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Local versus outsider developers: Impact on development duration and its' implications for community acceptance of solar PV plants in South Korea

Jaehong Ki [a,#], Sun-Jin Yun [b,*]

[a] Department of Urban Planning and Engineering, Yonsei University, 50 Yonsei-ro, Seodaemun-gu, Seoul, 03722, South Korea
[b] Department of Environmental Planning, Graduate School of Environmental Studies, Seoul National University, Gwanak-ro 1, Gwanak-gu, Seoul, 08826, South Korea

ARTICLE INFO

Keywords:
Community acceptance
Solar PV
Community renewable energy
Censored regression model

ABSTRACT

This study focused on community acceptance of small to medium solar PV plant projects in South Korea, which has rarely been the subject of research despite reports of disputes. It set out to determine whether there is a difference in community acceptance based on a project being developed by local residents or by outsiders. We used the duration of development for each plant as a proxy variable for the level of acceptance. We interpreted longer development duration as corresponding to a lower level of community acceptance when other characteristics of solar PV plants were controlled for. Analyses using a censored regression model indicated that the development duration was shorter (with statistical significance) when plants were developed by local residents rather than by outsiders. Further investigation revealed local resident involvement had more effect on reducing the development duration for plants exploiting forested land, the type for which community acceptance was known to be low. The effect was not evident when the plants were developed using existing buildings.

1. Introduction

1.1. Background

With climate change being regarded as one of the most severe threats the planet is facing, pressure on countries to deploy more renewable energy is increasing. The proportion of primary energy supplied from renewables in OECD countries was 11.6% in 2021, almost double that of the 1st year of the 21st century (5.9%). South Korea has the lowest contribution of renewables to the primary energy supply among OECD countries: 2.1% in 2021 (OECD, 2023). Although it lags, the deployed capacity of renewables has greatly increased in South Korea in last decade. The total capacity of renewables deployed in 2021 was 29.1 GW, which was more than an eightfold increase from 2012, when it was 3.4 GW[1] (Lee, 2022). After being criticized as leading the list of "climate villains" (Mathiesen, 2016), the South Korean Ministry of Trade, Industry, and Energy (MOTIE) announced a plan in December 2017 to increase the share of renewable sources among total electricity production from 7.0% in 2016 to 20.0% by 2030 (MOTIE, 2017). In October 2021, a more ambitious target was announced as part of the nationally determined contribution enhancement plan: increasing the share to 30.2% by 2030. This target fell back to 21.4% in the 10th Basic Plan on Electricity Supply (MOTIE, 2023), issued after the 2022 change in government. Despite the lesser ambition, the latest South Korean target still requires increasing the deployed capacity of renewable sources by about 250% (to 72.7 GW) from the 2021 level of 29.1 GW (MOTIE, 2023).

Solar photovoltaics (PV) is the most prominent renewable energy source in South Korea, with a total capacity of 21.2 GW in 2021. This was more than 70% of the deployed capacity of all renewable sources. In 2012, solar PV had only 1.1 GW total capacity and was around 25% of the total deployed capacity of renewables (Lee, 2022). The growth of solar PV in South Korea is significant, accounting for approximately 80% of all growth in renewables since 2012. The deployed capacity of solar PV is planned to more than double by 2030 (to 46.5 GW) from 2021 to meet the national target (MOTIE, 2023). According to the South Korean governmental agencies, the deployment potential of solar PV was estimated to be 369 GW, which could provide electricity of 495 TWh/year (MOTIE and Korea Energy Agency, 2020). In contrast, the estimated potential of wind energy, from both on-shore and off-shore applications,

* Corresponding author.
E-mail addresses: marchsixth@naver.com (J. Ki), ecodemo@snu.ac.kr (S.-J. Yun).
Present affiliation/address: Researcher, Busan Development Institute, 955 Jungang-daero, Busanjin-gu, Busan, 47210, South Korea.

[1] We selected 2012 as the base year for comparisons because that is when the renewable energy portfolio standard scheme, still the major policy framework for renewable energy promotion in South Korea, was initiated.

https://doi.org/10.1016/j.enpol.2024.114272
Received 31 March 2024; Received in revised form 9 July 2024; Accepted 23 July 2024
Available online 1 August 2024
0301-4215/

was only 65 GW, capable of providing 171 TWh/year of electricity. Therefore, solar PV has been and is projected to continue to be at the core of South Korean renewables deployment.

For extensive solar PV deployment to be realized, the technology should be accepted by members of society. Many studies have reported that renewable energy projects have been opposed rather than welcomed by the local communities where they took place. Wind energy projects have been the subject of most such studies. Most studies of solar energy projects have focused on large applications (Carlisle et al., 2014, Carlisle et al., 2015; Cousse, 2021; Vuichard et al., 2021). However, in South Korea, small to medium solar PV projects also have received local opposition. For example, Park and Yun (2018) reported a case in which the development of a 60 kW solar PV plant was opposed by neighbors. Studies that measured South Koreans' acceptance of solar PV in financial terms indicate the general public is more accepting of new projects or investments in solar PV projects than those living close to such plants (Lee et al., 2020; Woo et al., 2019). The widespread practice of South Korean local governments enacting ordinances that regulate setback distance for solar PV plants from dwellings or roads is more evidence that disputes over the development of solar PV occur throughout the nation (Im and Yun, 2019; Ko, 2023; Park et al., 2020).

Wüstenhagen et al. (2007) conceptualized social acceptance of renewable energy into three dimensions: sociopolitical, market, and community acceptance. In South Korea, solar PV has increased based on government policy to expand renewables and active participation from investors. This is evidence for high acceptance in the sociopolitical and market dimensions. However, the development of solar PV plants is negatively perceived by community members who do not participate in the businesses, which has led local governments to restrict the siting of solar PV plants. Because of this, the Korean government has pushed for a policy that allows higher renewable energy certificate (REC) weights for projects involving residents. The additional REC weighting shows local residents had not been active in these projects. Low community acceptance of solar PV affects sociopolitical acceptance at local levels. This research focused on the community dimension of social acceptance, which could delay the expansion of solar PV in South Korea. Although community acceptance of the development of renewables has been studied, acceptance of the development of small to medium solar PV plants in South Korea offers an opportunity for new research.

According to Lee (2022), as of 2021, plants with a capacity of 50–100 kW were the most common size of deployed solar PV (29.11%) in South Korea, followed by plants with capacity of 100–500 kW (21.10%). By the end of 2021, 63.34% and 82.95% of the total deployed capacity of solar PV was from plants smaller than 500 kW and 1,000 kW, respectively (Lee, 2022). Thus, South Korean solar PV development is dominated by small to medium applications. This trend is consistent with a desirable feature of sustainable energy development: small-scale, decentralized development of renewable energy (Lovins, 1976; Strachan et al., 2015). Therefore, focusing on community acceptance of small to medium solar PV applications is crucial to the pursuit of a sustainable energy transition in South Korea. Solar PV developments of this scale are the focus of this study. Most solar PV plants in South Korea have been installed for an electricity generation business—86.5% of the total deployed capacity of solar PV as of 2021—rather than for individual consumption because of low electricity prices, so such commercial solar PV plants were the target of this study.

1.2. Participation of local residents in the development of renewable energy

One frequently suggested explanation for low community acceptance of solar PV developments in South Korea is that a relatively high proportion of solar PV business owners are outsiders, people who do not live in the region where the development takes place. For instance, Kang and Yoo (2020) reported that 87.6% of 2,356 permits for solar PV plants issued in 2018–2020 in one county in South Korea were owned by entities whose address was not in that county. It has long been argued that policy measures that could help local people develop their own solar PV projects should be introduced so the technology would be locally accepted. As a result, some programs that support projects driven by residents, especially rural ones, have been adopted and implemented since 2017. The programs that apply to individual or collective developers of projects smaller than 500 kW are low-interest loans for renewables development; preferential treatment in contracting long-term, fixed-price electricity sales; and exemption from grid connection costs.

South Korea's policy measures to encourage local residents to participate in solar PV businesses are based on the empirical findings of previous studies, which highlight the importance of involving local residents to shape their attitude toward renewable energy projects and achieve a high level of community acceptance. Consulting local residents in decision-making processes, such as for siting and layout design, could relieve their concerns related to visual impacts or place attachment (Firestone et al., 2018; Hoen et al., 2019; Ki et al., 2022; Kim and Chung, 2019). Along with such procedural involvement, distribution of benefits is also important. Sharing benefits from the operation of renewables with local communities is reported to improve residents' attitude toward projects (Hogan et al., 2022; Musall and Kuik, 2011; Warren and McFadyen, 2010). This is why the Korean government has weighted RECs for community residents' engagement projects in its renewable portfolio standards (RPS) design.

The business model for projects tagged as "community renewable energy" varies depending on their purpose, deployed technologies and scale, ownership structures, and degree of local participation in development decisions (Berka and Creamer, 2018). Walker and Devine-Wright (2008) suggested the ideal form of community involvement in renewable energy projects occurs when it is "entirely driven and carried through by a group of local people and … brings collective benefits to the local community" (p.498). This is at the top right corner in their two-dimensional framework (hatched area A in Fig. 1). Baxter et al. (2020) suggest that even if projects labeled as 'community renewable energy' may fail to gain local approval or acceptance if they do not adhere to the ideal model proposed by Walker and Devine-Wright (2008), which emphasizes high local involvement and the generation of collective community benefits.

The solar PV development types we focus on—small to medium projects that export electricity to the grid—have different process and outcome characteristics than community renewable energy projects. Solar PV projects of this scale are generally owned by individual businesses. Accordingly, their benefits are likely to accrue to a single owner or a limited number of investors. In South Korea, solar PV business that

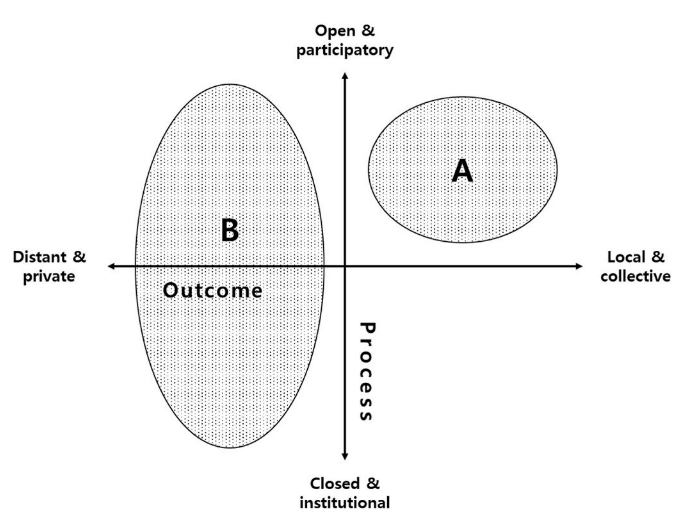

Fig. 1. Process and outcome dimensions (source: Walker and Devine-Wright (2008), redrawn by authors).

more than five local residents (those whose registered address was in the administrative district—eup, myeon, or dong—and within 1 km of the solar PV plant), invested at a certain level could get incentives in the form of additional REC weight (0.1–0.2). However, according to a MOTIE press release,[2] only 185 solar PV projects benefitted from this policy by the end of 2022. Therefore, we assumed revenues from most projects included in this study were shared by fewer than five entities. In terms of outcome, the projects of interest in this study could be driven by local residents, but the benefits would mostly be private, not fulfilling the requirements of the ideal community renewable energy.

In terms of process, the mere fact that some community members participate in a development does not guarantee its procedures will include the wider community (Walsh, 2018). In the framework used by Walker and Devine-Wright (2008), a small to medium solar PV project driven by one or a small group of local residents is in the area to the left of the process axis (hatched area B in Fig. 1). Such a development would not be much more accepted than one driven by outsiders. Previous studies showed that renewable energy projects owned or controlled by a small number of local residents were not perceived as community development projects by other community members (Walker et al., 2010; Walsh, 2018). Therefore, we needed to estimate whether the acceptance of small to medium solar PV plants developed by local residents is different from their acceptance of those developed by outsiders. This effort expands knowledge about local acceptance of renewable energy projects in understudied cases. Moreover, although South Korean government policy measures were aimed at achieving higher community acceptance of solar energy developments, we are aware of no previous attempts to estimate the effect of the policies. Thus, this research provides empirical evidence of the legitimacy of policy measures that promote local resident ownership of solar PV.

1.3. Measurements of local acceptance

Given increasing concern about local acceptance of renewable energy developments, many empirical studies have been carried out during the last couple of decades. Most of those studies targeted wind energy developments, were conducted to identify factors associated with the level of acceptance or attitude toward renewable energy projects, and adopted quantitative surveys to measure the level of acceptance or used proxy measures such as monetary values. These surveys were generally conducted for a limited number of cases (Rand and Hoen, 2017), though a few exceptions exist. For example, Hoen et al. (2019) used a nationwide random sample for a survey. Rand and Hoen (2017), in their review of studies conducted in North America, recommended more geographically representative and random surveys be conducted to address the limitations of previous studies.

To overcome the limitations of using a few cases to estimate local acceptance, we included solar PV development cases from across the nation. However, it is extremely difficult to conduct surveys of residents near existing plants because such plants are too numerous. According to the Electricity Power Statistics Information System[3] managed by Korea Power Exchange, 95,666 solar PV plants for electricity generation were deployed by the end of 2021. The proportion of plants with capacity less than 1,000 kW and 500 kW were 98.63% and 93.83%, respectively, indicating most plants are small to medium applications. Unlike wind farm cases, which generally have capacity of several tens of megawatts and local residents defined by several kilometers of radius, the survey area around solar PVs of these scales would be smaller and difficult to quantify.

Therefore, we adopted a different approach to measure the level of local acceptance. We posited that the duration of development for a solar PV plant reflects the level of local acceptance. When local residents oppose a project, they may complain to the authorities or organize protests, which could delay the development of the plants. Such conflicts could also lead authorities to delay the issuance of required permits. Consequently, the duration of development would be a proxy for the level of acceptance—longer for less accepted projects. Anecdotal reports issued by governmental research institutes, Korea Environment Institute, and Korea Energy Agency refer to complaints filed by residents with local governments that have delayed the development of solar PV plants, and they note the need to improve community acceptance to resolve the issue (Lee, 2017; Noh, 2020). Moreover, legal disputes have resulted from a local government's cautious approval process after receiving such complaints (Leem, 2020). Some local governments have required developers to get written consent from residents as a condition for approving development plans (Park and Yun, 2018; Im and Yun, 2019). Moreover, there are few cases of participation-based cooperative solar power projects that could have benefitted from the additional REC weight described in Section 1.2, in which a delay results from the time required to form a cooperative and promote the project even among receptive residents. Therefore, we used the duration of development for solar PV projects as a proxy variable for the level of local acceptance. This approach has not been adopted in studies focused on social acceptance of renewable energy projects. Harper et al. (2019) investigated the institutional acceptance rate of wind energy projects' planning applications in the United Kingdom to highlight the importance of social and political parameters to the successful implementation of projects. Inspired by that study, we devised this approach and applied it to South Korean solar PV projects.

In summary, the aim of this study was to estimate whether the location of the owners of small to medium solar PV plants influences the level of local acceptance. Our estimation strategy was to statistically compare the duration of solar PV plant development across cases where the owners of the project are local residents and those where they are outsiders.

2. South Korean policy environment regarding solar PV projects

2.1. Renewable portfolio standards and renewable energy certificates

This section summarizes South Korea's renewable energy policy framework, focusing on solar PV, and discusses some adjustments made to enhance social acceptance. In 2012, South Korea adopted RPS as the main framework for promoting renewable energy in the nation, replacing the feed-in tariff scheme that had been in effect since 2002. Under the RPS scheme, power suppliers that have generators larger than 500 MW capacity (hereafter called obliged suppliers) are obliged to provide a certain portion of their electricity from renewable sources. If they cannot supply the obliged amount through their own generation, they can fill the gap by buying RECs from designated trading markets. RECs are the main component that subsidizes renewable energy producers. One REC is granted for every 1 MWh of produced electricity. Renewable energy suppliers benefit by selling their products to the electricity market and their RECs to obliged suppliers.

When RECs are issued, a weight is applied based on the capacity and installation location. Business holders gain RECs in the amount of the electricity produced multiplied by that weight. Table 1 presents the REC weights for solar PV plants that were in effect when we collected data. The legislation stipulates that REC weights are determined by the minister of trade, industry, and energy. In determining the REC weights, the acceptance level of local residents must be considered along with other factors, including impact on the environment and industry, power

[2] https://www.korea.kr/briefing/pressReleaseView.do?newsId=156549354#pressRelease.

[3] http://epsis.kpx.or.kr/(Accessed on 28 June 2023). The webpage supports English service, but the information on the details of the plants is available only in the Korean version.

Table 1
REC weights for solar PV (applied from June 2018 to June 2021).

REC weight	Installation location	Capacity
1.2	on land, excluding forests	<100 kW
1.0		≥100 kW and <3,000 kW
0.7		≥3,000 kW
0.7	in forests	–
1.5	on existing structures, including buildings	≤3,000 kW
1.0		>3,000 kW
1.5	on the water surface (floating)	–

generation cost, resource potential, capability of reducing greenhouse gas, and effects of the technology on power supply stability.[4]

The criteria and amounts of REC weights have been changed several times since the adoption of the RPS scheme. The most significant change was made for projects using sites that had been forested. When the REC weights were introduced in 2012, forest sites had a weight of 0.7, regardless of capacity, just like installations that used agricultural land. The criterion concerning land type was abolished in 2015, after which installations using forested land would get the same REC weight as plants installed on other types of land: 1.2 for capacity <100 kW, 1.0 for capacity ≥100 kW and ≤3,000 kW, and 0.7 for capacity >3,000 kW. This change led developers to install small to medium solar PV plants on mountainous forest sites where the land was cheaper so they could maximize their profits (Um, 2022). However, the use of mountainous forests as solar PV sites raised public and local concerns regarding environmental degradation (e.g., deforestation), landscape disruption, and increased risk of landslides (Kim and Park, 2021; Ko, 2023; Um, 2022). Thus, the weight for solar PV plants using forest sites, regardless of capacity, was reset to 0.7 in 2018 and to 0.5 in 2021 to obstruct this type of project. The weight for projects using existing structures (e.g., buildings) has been consistently the largest among all types of projects except floating ones. These changes in REC weights indirectly indicate the level of social acceptance for types of solar PV.

2.2. Administrative obligations for development of solar PV plants

In South Korea, for an entity to participate in the electricity generation business, it must obtain an electric utility business license (EBL) from authorities designated in the Electric Utility Act.[5] Obtaining an EBL is the first administrative work required of developers who wish to install solar PV plants for businesses. According to the legislation, Si, Gun, and Gu—the smallest autonomous local governmental units in South Korea—have the authority to issue EBLs for small to medium solar PV plants. The capacity under which these local governments are authorized to issue an EBL ranges from 500 kW to 1,500 kW. When a developer starts to operate the business after obtaining permission, constructing a plant, having it inspected, and contracting for electricity transmission, it must submit a commencement of business report (CBR) to the same authority that issued the EBL. Submission of a CBR indicates the development of the solar PV plant is complete. We used information on when these two administrative actions occurred—EBL issuance and CBR submission—to compute the duration of a solar PV plant's development.

[4] The legislation is available in English at https://elaw.klri.re.kr/kor_service/lawView.do?hseq=57299&lang=Eng (Accessed on 28 June 2023).

[5] The legislation is available in English at https://elaw.klri.re.kr/kor_service/lawView.do?hseq=61392&lang=Eng (Accessed on 28 June 2023).

3. Methods

3.1. Data acquisition

This study estimated the effects of project ownership on local acceptance by comparing the duration of development of solar PV power plants. Factors other than ownership classification that could influence duration were also considered. Therefore, information regarding the characteristics of solar PV plants in South Korea was required.

To acquire the data, we asked local governments (i.e., Si, Gun, and Gu) to disclose official information. South Korea's official information disclosure act obliges public institutions to disclose information they possess upon request unless it falls into a category designated for nondisclosure (e.g., information that identifies an individual).[6] For each plant granted an EBL by the end of 2019, we requested the date of EBL, the date of CBR, the address of the solar PV plant, the address of the business owner,[7] plant capacity, and installation location (i.e., the categories in the second column of Table 1). The requests were submitted in March and April 2020 and the responses were gathered in April 2020. The requests were sent to 159 local governments in the eight provinces where solar PV plants that account for 90% of national capacity were installed as of 2019. We received responses from 125 of them. We gathered information for 91,801 projects that obtained EBLs; however, the information for many projects was incomplete. Local governments selectively maintain information for issued EBLs based upon their own need, so some of the information we requested was missing from their electronically recorded data. Therefore, information for only 24,084 projects could be used for the analyses. Because of this missing information, rigorously assessing whether the analytic sample was systematically biased was not possible. Alternatively, we compared descriptive statistics of variables representing development characteristics calculated from the analytic sample and all available sample, the number of which is differ by variables, and found they were not much different (see Appendix A). Therefore, although the number in our sample is less than the initial amount, we believe it is sufficient to represent small to medium solar PV projects in South Korea. These criteria were considered when selecting projects to be analyzed: gained EBL in 2012–2019, had capacity less than 500 kW, and had full information on the variables introduced in the next subsection.

3.2. Variables

The duration of the project development, the proxy dependent variable used to measure the level of acceptance, was calculated by counting the days between the date the developer obtained the EBL and the date they filed the CBR.

A major independent variable is ownership location, which is divided into two categories: local residents and outsiders. South Korea's policies to promote local ownership of solar PV businesses regard a person as a local resident when their address is in the administrative district (eup, myeon, or dong) where the plant is installed or in an adjacent one. We used a stricter definition and considered the project to be owned by local residents only when the address of the solar PV plant was in the same administrative district as where the developer was registered; otherwise, we tagged the ownership as an outsider. This variable is binary. We hypothesize that developers who are local residents will more likely to engage with local stakeholders, and that local ownership may contribute to shorter development durations for solar PV

[6] The legislation is available in English at https://elaw.klri.re.kr/kor_service/lawView.do?hseq=55667&lang=Eng (Accessed on 28 June 2023).

[7] To the minimum administrative district level. The PV plants of interest were owned mostly by individuals and local governments were reluctant to provide full address of them. Therefore, we only could get information on the business owners' district.

projects.

The duration of solar PV project development could be influenced by factors other than ownership. Accordingly, we included variables to control their impact. We created two binary variables to indicate the location of the project. One classifies whether the plant was installed or planned on forested land or not. As explained in Section 2.1, due to the relatively low land price, exploiting forested land to install solar PV plants had been an economically attractive option for developers when the REC weight for that type of development was the same as for other types of land. However, using forested land for a solar PV plant results in environmental degradation and ecosystem destruction, such as deforestation, which has been one of the most common reasons local residents oppose solar PV projects in South Korea (Kim, Kim, et al., 2018; Lee et al., 2020). Concerns about visual intrusion and heightened risk of landslides are also present when development occurs on forested land (Kim and Park, 2021; Ko, 2023; Um, 2022). Moreover, developing forested land requires additional construction processes that extend the installation time, including logging, site clearing and grubbing, and construction of access roads. Therefore, solar plants installed in forested areas are expected to have longer development duration than installations on other locations.

Another variable indicates whether the plant was installed using existing structures, mostly buildings. South Korean studies have reported citizens' positive attitudes toward solar PV plants installed on existing buildings (Kim et al., 2020; Park and Yun, 2018). Installing solar PV plants using existing structures requires few preliminary processes such as site clearing. Thus, this type of installation is expected to have a shorter development duration than others.

A project's installation capacity is another variable that could influence the duration of development. Construction time is expected to be longer if a project has a larger capacity. In addition, people prefer smaller projects over larger ones (Kim et al., 2020). Therefore, this variable is expected to have a positive relationship with the dependent variable.

A solar PV project could be affected by the other projects in the region. In a region where many solar PV plants are already installed, local residents and authorities could have an attitude toward the project based on previous experiences. While empirical literature finds that people living near renewable energy plants have been more positive toward them than those living further away, South Korean literature and practices indicate local people and governments are more likely to be negative about developing solar PV plants in their region (see Section 1.1.). Ko (2023) indicated that South Korean local governments with more solar PV plants were more likely to adopt setback restrictions for them. When the attitude is generally negative, the development duration could be prolonged due to local opposition or delayed issuance of required permission. Congested solar PV development also raises concerns regarding the plants' connection to the power grid. Problems with delayed business commencement due to lack of local grid capacity have been reported in South Korea (Kim, Lee, et al., 2018). This is likely to occur where many other projects already exist or are underway. These factors may contribute to longer project development duration. On the other hand, locally accumulated knowledge or skills acquired by past experiences with solar PV development could smooth the planning process and reduce the duration. Therefore, a variable that represents previous solar projects' density could have a positive, negative, or neutral effect on the dependent variable. The value of this variable for a project was calculated as the sum of the capacity of the projects that had gained EBL from the same local government before the date of its own EBL.[8]

Finally, characteristics of local governments, such as administrative performance and regulatory requirements, could influence the duration of solar PV plant development. Nationwide changes in related policies and citizens' general attitudes toward solar PV generation also could have an impact. Therefore, the characteristics of local government and time effects were controlled by adding dummy variables to the analysis model. Variables used for the analyses and their hypothesized relationships with the dependent variable appear in Table 2.

3.3. Empirical strategy

We estimated the impact of the characteristics of solar PV projects on development duration using a linear regression model. However, there was an issue regarding the value of duration, a dependent variable in the regression model. When we collected the information for projects that had obtained EBLs, not all observations in the dataset had records for date of CBR. We could not determine the duration of projects that were in the middle of the development process at the time of data acquisition. As shown in Table 3, the duration of development could be calculated only for about 40% of projects in the dataset. For the other projects, we could only know that the duration was longer than a certain amount, as estimated by counting the number of days from the date of EBL to the date of data acquisition. Therefore, the dependent variable contains right-censored observations with varying censoring values.

If we estimated the regression model using only observations with uncensored duration values, we could have a problem with selection bias. Therefore, tests to check a dependent variable's censoring (i.e., the status of project completion) relative to the explanatory variables were conducted. When an explanatory variable had continuous values, Welch's *t*-test was used to compare the variable's mean value for censored and uncensored dependent variable groups. The relationship between binary explanatory variables and the censoring status was checked by a chi-square test. These tests indicated the censoring of the dependent variable was related to explanatory variables, so a censored regression model was employed. The estimation with a censored regression model was conducted using STATA 17's interval regression command.

4. Results

4.1. Descriptive statistics

Table 4 presents descriptive statistics of the variables employed in the analyses. It took an average of 11 months (337.4 days) for a project to complete development (duration). However, considering that value was calculated only with uncensored observations, the actual duration

Table 2
Variables used for the analyses.

Variable	Unit/Type	Description	Hypothesized direction of effect
Duration	Days	Days from issuance of EBL to CBR	Dependent variable
Local	Binary	Whether the developer is a local resident (1) or not (0).	–
Forest	Binary	Whether the installed or planned location is forested land (1) or not (0).	+
Building	Binary	Whether the installed or planned location is an existing structure (1) or not (0).	–
Capacity	100 kW	Capacity of the solar PV plant	+
Previous capacity	MW	Sum of the capacity of projects that had gained EBLs from the same local government	+/-/neutral
County	Categorical	The local government that issued the EBL	N/A
Year	Categorical	The year the EBL was issued	N/A

[8] The calculation of this value requires information only for capacity and the date of EBL issue, which was available for almost all projects that were initially gathered (see Section 3.1). Therefore, information from 91,534 projects, which is 99.7% of total projects, was used for the calculation.

Table 3
The status of EBLs and CBRs by year.

	2012	2013	2014	2015	2016	2017	2018	2019	Total
EBLs	69	199	1,305	959	1,595	5,753	9,830	4,374	24,084
CBRs	65	173	1,188	853	1,144	2,713	2,248	1,122	9,506
% CBR	94.20	86.93	91.03	88.95	71.72	47.16	22.87	25.65	39.47

Table 4
Descriptive statistics for variables.

Variable	Obs.	Mean	Std. Dev.
Duration	9,506	337.4	260.0
Local	24,084	0.318	0.466
Forest	24,084	0.287	0.452
Building	24,084	0.234	0.423
Capacity	24,084	1.421	1.215
Prev. capacity	24,084	141.6	165.4

would be longer.

The mean value of the binary variables—local, forest, and building—indicates the proportion of observations that had a value of 1. Local people owned 31.8% of projects in the dataset. This means there were more than twice as many outsider-owned projects as local-owned ones among South Korean solar PV projects. It has been widely said outsider-driven solar PV penetration was problematic in South Korea; however, to the best of our knowledge, no quantitative evidence had been provided at a national scale.

Regarding the location of installations, 28.7% of the projects were developed or planned on forested land. As depicted in Fig. 2, that proportion changed greatly over the years: only 5.8% in 2012, a peak of 39.6% in 2016 that remained above 34% to 2018, and an abrupt drop to 3.4% in 2019. We interpret this variation as a consequence of the adjusted REC weights for projects using forested land, as explained in Section 2.1. The increase of REC weight (0.7–1.0) in 2015 incentivized developers to exploit more forested land for developments; the weight decrease in 2018 (1.0–0.7) made this type of development economically less attractive.

Meanwhile, 23.4% of the projects were installed or planned on buildings. This proportion also showed yearly variation: above 40% from 2012 to 2014, down to around 15% in 2016, and back up to 47.2% in 2019. The yearly proportion of proposals using buildings mirrored the proportion using forested land, especially since 2014, as shown in Fig. 2. We interpret this trend as reflecting the relative profitability of project types based on changes to the subsidizing policy measure, the REC weight.

The mean capacity of the proposed projects was about 142 kW. One

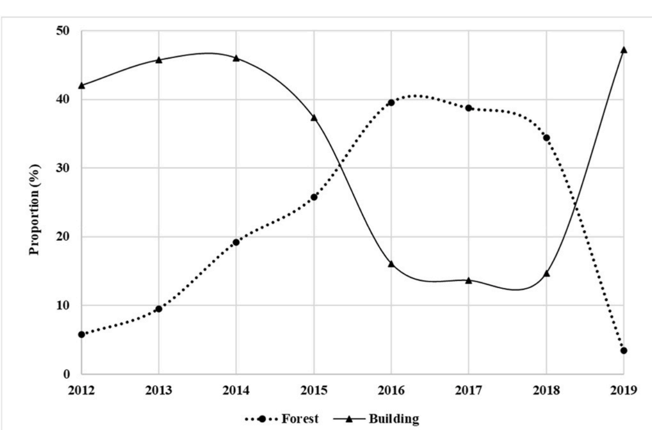

Fig. 2. The proportion of solar PV development proposals using forested land and buildings.

distinct characteristic in the distribution of capacity was that most projects, approximately 85%, had capacity between 90 and 100 kW. Given that REC weights were based on whether a plant's capacity was smaller (1.2) or greater (1.0) than 100 kW (see Table 1), we think this distribution reflects developers' strategic behavior to maximize profit from their project.

4.2. Relationships between variables

This subsection describes our test of the significance of the relationship between a single explanatory variable and the dependent variable. First, the mean value of the projects' development duration, using only uncensored observations ($N = 9{,}506$), was compared for the three binary variables (local, forest, and building) using Welch's *t*-test. Table 5 shows a statistically significant different duration for these variables. When the projects were owned by local people, the average development duration was about 116 days shorter. Installing a plant on forested land required about 220 more days on average than other types of installation, while using existing buildings reduced the average development by about 242 days. Two continuous variables, capacity and previous capacity, had statistically significant Pearson's correlation coefficients ($p < .000$) of .259 and .118, respectively. Because all explanatory variables had a statistically significant relationship with the dependent variable, they were included in the regression models.

Tables 6 and 7 present the results of statistical tests to check whether the status of a development's completion (business commencement) is related to the factors that affect the duration of project development. Table 6 shows cross-tabulations of the categorical explanatory variables (local, forest, and building) with the completion status, which is called "CBR categories" in the row name. Among projects owned by local residents, 51.71% had reported the commencement of business by the end of 2019, but only 33.76% of projects owned by outsiders had done so. The proportion of projects that had commenced business was significantly lower for projects developed on forested land (27.93%) than for those on other types of land (44.12%). Conversely, projects that used buildings as installation sites were more likely to commence business (65.61%) than other sites (31.48%). A chi-square test indicated the observed frequencies of categories were significantly different from the expected frequencies for all pairs of variables at $p < .000$. Table 7 shows differences between the mean values of continuous explanatory variables by category of CBR. Projects that had commenced business by the time of data acquisition had smaller average capacity (114.4 kW) than ones that had not (160.2 kW). In addition, the capacity of projects that had previously gained EBLs from the local government had a significantly smaller mean value for the group that had commenced business (61.9 MW) than for the other group (193.6 MW). The results of a *t*-test indicated such differences were significant at $p < .000$.

The results shown in Tables 6 and 7 clearly indicate that the observation groups divided by the censoring status of the dependent variable

Table 5
Mean (Std. Dev.) Duration by Binary Independent Variables and *t*-Test Results.

Variable	Categories		Mean difference (A – B)	*t*-test $p > \|t\|$
	Yes (A)	No (B)		
Local	269.6 (221.7)	385.8 (274.2)	−116.2	<0.0000
Forest	513.4 (257.7)	292.6 (240.9)	220.8	<0.0000
Building	189.6 (180.2)	431.6 (259.2)	−242.0	<0.0000

Table 6
Frequencies by binary explanatory variables and CBR.

Variable		CBR categories		Total (% row)
		Yes (% row)	No (% row)	
Local	Yes	3,961 (51.71)	3,699 (48.29)	7,660 (100)
	No	5,545 (33.76)	10,879 (66.24)	16,424 (100)
Forest	Yes	1,930 (27.93)	4,981 (72.07)	6,911 (100)
	No	7,576 (44.12)	9,597 (55.88)	17,173 (100)
Building	Yes	3,698 (65.61)	1,938 (34.39)	5,636 (100)
	No	5,808 (31.48)	12,640 (68.52)	18,448 (100)
Total		9,506 (39.47)	14,578 (60.53)	24,084 (100)

Table 7
Mean (Std. Dev.) by CBR categories and *t*-Test Results.

Variable	CBR categories		Mean difference (A – B)	*t*-test $p > \|t\|$
	Yes (A)	No (B)		
Capacity	1.144 (0.974)	1.602 (1.317)	−0.458	<0.0000
Prev. capacity	61.9 (100.0)	193.6 (178.4)	−131.7	<0.0000

are significantly related to the explanatory variables. Therefore, a linear regression model using only uncensored duration observations could produce biased estimates due to sample selection. For example, an estimation using only a group with uncensored observations could underestimate the effect of forest on duration because the group contains a smaller proportion of projects on forested land than the available dataset. Consequently, the linear model was estimated by censored regression that employed all available observations.

4.3. Linear regression estimations

Table 8 presents the results of linear regression model estimation. The second column presents the regression coefficients of an ordinary least squares (OLS) estimation. The estimation used only observations with uncensored dependent variable values ($N = 9.506$). The signs of the estimated coefficients indicate that the duration of solar PV plant developments was shorter for local residents than for outsiders, longer when using forested land than other sites, shorter when installed on existing buildings than on land, longer as the capacity of the plants increased, and longer as the region had more approved development proposals. These relationships coincide with the results presented in Section 4.2 and hypothesized directions presented in Table 2 for local, forest, building, and capacity.

The third to fifth columns of Table 8 present the estimated results of censored regression models. Unlike OLS estimation, these three models employed all available observations in the dataset (N = 24,084). In Model 1, which incorporated the same explanatory variables as the OLS model, all explanatory variables had coefficients statistically significant at $p < .000$ and had signs identical to those in the OLS model. However, the magnitude of the coefficients was different from the OLS estimation, reduced by approximately 40% for local and increased by 74–175% for others. The estimated coefficient indicates that local people completed their solar PV projects' development about a month (31.1 days) earlier than outsiders' projects. The location of an installation had a statistically significant impact on the time required for development. Projects installed on forested land required almost 250 more days than those in other locations, and projects installed on existing buildings required almost 250 fewer days for completion. An increase of 100 kW in a project's installation capacity was associated with about 45 days additional development duration. Finally, 1.1 more days were required as the capacity of projects approved by the same local government increased by 1 MW.

Although the developer type significantly influenced the development duration of solar PV plants, the impact could vary based on other characteristics of the project. Therefore, models with the interaction terms Local × Forest (Model 2) and Local × Building (Model 3) were estimated. The interaction terms comprised two binary variables, and the effects of each combination of variable categories is shown in Table 9.

In Model 2, the coefficient of local was not significant at $p < .05$. This indicates that duration between local residents and outsiders was not statistically different when the projects planned to use sites other than forested land. When projects used forested land, duration was approximately 288 days longer for outsiders and 134 days longer for local residents than when outsiders developed a solar PV plant on a site other than forested land.

In Model 3, average duration for outsiders was about 63 days longer than for local residents when solar PV plants were not installed on existing buildings. When using buildings for installation sites, outsiders and local residents completed their development about 300 days and 281 days earlier, respectively, than when outsiders did not use buildings for installations.

Analyses of the models with interaction terms showed that the effect of the variable local on duration differed depending on where a solar PV plant was planned to be installed. When a project used forested land, duration reduction for local residents was much larger (about 154 days) than the average effect of the variable local estimated in Model 1 (about 31 days). When a project was installed on existing buildings, duration for local residents was estimated to be about 19 days longer than for outsiders.

Table 8
Results of linear regression model estimations.

Variable	OLS (N = 9,506)	Censored regression (N = 24,084)		
		Model 1	Model 2	Model 3
Local	−52.7	−31.1	−5.9 (.545)	−62.7
Forest	108.4	247.8	287.7	243.8
Building	−109.4	−258.8	−263.0	−299.5
Capacity	26.0	45.3	46.4	45.6
Prev. capacity	0.4	1.1	1.1	1.1
Local × Forest	–	–	−147.4	–
Local × Building	–	–	–	81.0
Constant	248.6	321.7	308.5	336.2

Note. Significance of estimated coefficients are $p < .000$ unless notated in parentheses. In Model 2 and 3, interaction terms were incorporated in the censored regression model (Model 1). In all models, categorical variables of county and year were incorporated.

5. Discussion

In this study, the duration of solar PV plant development for projects owned by local residents and outsiders was compared using censored linear regression models. The results indicate the duration of a solar PV project's development was shorter for local residents than for outsiders when other conditions were controlled for. Longer development duration of renewable energy is associated with higher costs for installation and administrative work (Schumacher, 2019; Seel et al., 2014; Lee and Lee, 2019). This in turn affects market acceptance and could hinder or delay the deployment of renewable energy. Therefore, policy makers are required to seek measures to reduce projects' development duration.

Table 9
Calculation of relative differences in duration for values of interacted variables.

Local	Forest (Model 2)		Building (Model 3)	
	0 (No)	1 (Yes)	0 (No)	1 (Yes)
0 (No)	Datum	Datum + 287.7	Datum	Datum - 299.5
1 (Yes)	Datum - 5.9	Datum −5.9 +287.7–147.4	Datum - 62.7	Datum - 62.7 −299.5 + 81.0

This finding provides empirical evidence that South Korean governments' policies to support local residents' solar PV developments contribute to the promotion of solar energy in the nation.

Along with the finding regarding the main question of this research, other properties of projects also affected the duration of solar PV development. The location where the plant was installed or planned (forest or existing building) had a particularly large impact. Our estimation with interaction terms shows how installation location affected development duration for local residents. The effect was larger when a project used forested lands and was not found when a project used existing buildings—in that case, duration for outsiders was marginally shorter. We explain the results in terms of community acceptance. We used the duration of projects' development as a proxy for the level of community acceptance.

Exploiting forested land for solar PV plants has raised concerns such as environmental degradation, visual intrusion, and risk of landslides; these could be associated with the lower level of community acceptance (Kim, Kim, et al., 2018; Kim and Park, 2021; Ko, 2023; Lee et al., 2020; Um, 2022). In our analyses, longer development duration was estimated for these projects. Of course, converting forested land into solar PV plants requires more work for site preparation and additional permit processes than installations using other sites. However, if such characteristics were the only contributor to development duration, the difference between local residents and outsiders would not have been found. Therefore, we interpret that a business owner being a local resident enhances community acceptance of developments compared to the case of outsiders.

Applying the concept suggested by Walker and Devine-Wright (2008), the outcome distribution between local ownership and outsider ownership is not different for projects of this study's interest (details in Section 1.2). Therefore, we speculate that the relatively higher level of community acceptance for local residents' developments is related to the process of the development. Previous qualitative studies conducted in South Korea reported concerns about landscape disruption as one reason local communities have a negative attitude toward solar PV plant projects (Ko, 2023; Park and Yun, 2018). Community members thought the local landscape, and the surrounding environment in a wider sense, had been historically managed by them and they should control decisions to change it (Park and Yun, 2018). They felt outsiders did not offer opportunities for them to meaningfully engage in the development process and did not seem to manage the developed sites properly because they did "not stay around the sites" after the plants were built (Ko, 2023: 5). Local residents are likely to have more chances than outsiders to consult with community members before and during the development process, so their projects could be installed in a way that could alleviate local concerns. In addition, as members of the community who are familiar with its norms, locals could preemptively plan their business in a way that other members would not be likely to oppose. This advantageous position of local residents is thought to enhance community acceptance when developing less acceptable projects—those using forested lands—so development duration could be markedly reduced. On the other hand, studies show the South Korean public prefers solar PV plants be installed on existing buildings (Kim et al., 2020) and that community members accept plants on existing buildings even when they oppose other project types (Park and Yun, 2018). That type of project has few issues with community acceptance, which may be why we did not find a shorter development duration for local residents in those cases.

Although we have provided plausible explanations for the estimated result, linking development duration with the level of community acceptance has limitations because the latter was not directly measured and incorporated in the analyses. Therefore, we recommend future research estimate differences in the level of community acceptance for solar PV projects depending on the type of business owner using directly measured terms and data that explains reasons behind them. Comparative field research targeted at communities having both local- and outsider-driven solar PV projects could be an option. Incorporating cases with collective community-driven developments such as cooperatives could provide implications to community renewable energy literature.

6. Conclusions and policy implications

This study empirically estimated that the development duration for solar PV plants is significantly shorter when they are developed by local residents rather than by outsiders. We interpret this result as indicating solar PV plants developed by local residents are more accepted by communities than those developed by outsiders. This result is meaningful in that the effect of the South Korean government's policies to help rural local residents have their own solar PV plants had not been empirically tested. Based on the findings, maintaining and improving current policies could alleviate local opposition to the projects, reduce their development duration, and help achieve renewable energy deployment goals. However, considering that more than 90% of the population is registered in urban areas and rural residents' relatively poor financial resources, outsider investment in solar energy in rural areas is still expected to be required to achieve South Korea's renewable energy development goal. Moreover, the most dominant solar PV business model in South Korea, ownership by an individual or a small number of developers, has limitations in terms of outcome distribution, even in cases driven by local residents. Therefore, measures to develop solar energy in a manner closer to the ideal community renewable energy model may be required.

Analyses using interaction terms revealed that the effect of reduced development duration for local residents was significantly larger for projects that planned to exploit forested land for installation sites, which was known to raise community concerns. We speculate that the reasons for this result are that local residents can more easily consult with community members before and during the development process and that they are familiar with community norms and can plan their development in a way that alleviates local concerns. These findings indicate that community acceptance of solar PV projects could be improved depending on how developments are conducted. In addition, we think low acceptance of solar energy development occurs when the siting process for a project is driven by individual developers. Although local residents may be more likely to adjust development plans in accordance with community concerns, they do so under the constraint of resources such as site availability. Government-led site seeking and designation of solar PV plant practices could help overcome the current status of solar energy developments. Planned siting by local governments was suggested in the early 2017 South Korean renewable energy deployment implementation plan as a strategy to develop renewables in a more acceptable form, but only limited planning exists to date. In December 2023, MOTIE, recognizing that local government-led processes have not worked well, announced the central government will lead a planned siting process as part of measures to innovate the power system. The government will consider environmental, societal, and economic aspects of the developments and communicate with communities so the development process can be more acceptable to community members. Facilitating administrative processes for projects using the planned sites could be an incentive for developers so individual siting practices would decrease. In addition, if governments mandate developers using designated sites to get investments from community members, or consult local residents to operate some solar PV businesses as cooperatives, outcome justice could be improved compared to the current practices in South Korea.

Funding

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of the Republic of Korea (NRF-2022S1A5B5A16053105 and No. 5120200113713).

CRediT authorship contribution statement

Jaehong Ki: Writing – original draft, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Sun-Jin Yun:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

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.

Data availability

Data will be made available on request.

Appendix A. Descriptive statistics of analysis sample and all available sample

Table A.1
Comparison for Descriptive Statistics for Variables

Variable	Analysis sample			All available sample		
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Duration	9,506	337.4	260.0	33,617	354.4	268.3
Local	24,084	0.318	0.466	47,970	0.305	0.460
Forest	24,084	0.287	0.452	35,309	0.316	0.465
Building	24,084	0.234	0.423	77,532	0.245	0.430
Capacity	24,084	1.421	1.215	82,496	1.367	1.152

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