**Derivation of Supply Curve of PV ~**

**Impact of Setback regulation ~**

Seungho Jeona, Gildong Hongb, Gyeonggi Dob,[[1]](#footnote-2)\*

a *Climate & Environment Data Center, Gyeonggi Research Institute, South Korea*

b *Climate & Environment Data Center, Gyeonggi Research Institute, South Korea*

**Abstract**

This is an abstract.

**Keywords:** Keword1, Keword-2, Keyword-3

1. Introduction

As the 13th largest greenhouse gas emitting country, South Korea accounted for 1.3% of the global GHG emissions [1]. South Korea pledged to achieve the nationally determined contribution (NDC), and carbon neutrality by 2030 and 2050 respectively [2,3]. Obviously, utilization of renewable energy is a primary strategy over the world. Total renewable energy generation was 7,857TWh in the world, which includes 4,400TWh of hydro power,

Hydro: 4,400 TWh

Renewable Hydropower: 4,275 TWh

Pure pumped storage: 125TWh

Marine energy: 0.97TWh

Wind: 1,838 TWh

Onshore wind: 1700TWh

Offshore wind: 137TWh

Solar: 1,033TWh

Solar PV: 1,020TWh

Solar CSP: 13TWh

Bioenergy: 0.614TWh

Solid biofuels and renewable waste: 0.5TWh

Renewable municipal waste: 0.08TWh

Bagasse: 0.05TWh

Other solid biofuel: 0.37TWh

Liquidbio fuel: 0.007TWh

Biogas: 0.091TWh

Geothermal energy: 0.095TWh

Renewable energy includes solar, wind, geothermal, hydro and others.

Globally the renewable energy share of electricity generation was 27.8% in 2021, while in South Korea the one of electricity generation was 6.1% [5].

The shapes of the renewable portfolio and energy mix determined by many factors such as natural environment, energy security, economy, politics and others [4].

2021년 전세계 평균 renewable energy share of electricity generation은 27.8% 였고, 대한민국은 6.1%으로 재생에너지 활용 비중이 매우 낮은 국가 중 하나이다.

For example, South Korea made a decision to lower the renewable energy target for 2030 from 30% to 22% [XX]. The decision is based on the current government’s determination to enlarge the role of nuclear power in the middle of energy transition. 경기도얘기?

For instance, Denmark, with abundant wind energy sources, heavily invests in wind energy, while Kenya, rich in geothermal energy, capitalizes on that resource. Similarly, some countries have significant solar energy potential. However, even in nations with abundant solar resources, the choice between using Concentrated Solar Power (CSP), which converts solar heat into electricity, and Photovoltaic (PV) systems, which convert sunlight directly into electricity, can differ depending on various factors.

As all countries’ common strategy, renewable energy

large deployment of PV systems is a primary strategy to reduce GHGs in South Korea as well.

plans to achieve carbon neutrality by 2050

전세계 속에서 우리나라 특성 온실가스, (신재생)에너지 등

우리나라에서 경기도 특성: 온실가스, (신재생)에너지

신재생 도입을 방해하는 요소: 1.2.3….Setback

Setback에 대한 전세계 현황

Setback에 대한 우리나라 현황: Setback 규제가 생겨난 이유, Setback의 종류 등등

한국은 왜 풍력을 못하나?

해상풍력: <https://news.kbs.co.kr/news/pc/view/view.do?ncd=7956867>

<https://tbs.seoul.kr/news/newsView.do?typ_800=2&idx_800=3506163&seq_800=20498842>

지열:

<https://www.kharn.kr/news/article.html?no=23099>

Objective:

1) explore suitable sites for PV deployment. (GIS-based approach)

2) scenario analysis (No Setback vs. Setback)

3) Supply curve

Comparison of PV energy potential

4) Compare supply curve of PV (LCOE assumption)

4)

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텍스트, 전자제품, 스크린샷, 웹사이트이(가) 표시된 사진

자동 생성된 설명

Fig. 1. Study Design

1. Methodology
   1. GIS-based approaches

Land-use types are categorized.

# 9가지 유형별 대표 사진

|  |  |  |
| --- | --- | --- |
| 스크린샷, 태양광 발전, 태양 에너지, 태양 전지 패널이(가) 표시된 사진  자동 생성된 설명 | 스크린샷, 태양광 발전, 태양 에너지, 태양 전지 패널이(가) 표시된 사진  자동 생성된 설명 | 스크린샷, 태양광 발전, 태양 에너지, 태양 전지 패널이(가) 표시된 사진  자동 생성된 설명 |
| 스크린샷, 태양광 발전, 태양 에너지, 태양 전지 패널이(가) 표시된 사진  자동 생성된 설명 | 스크린샷, 태양광 발전, 태양 에너지, 태양 전지 패널이(가) 표시된 사진  자동 생성된 설명 | 스크린샷, 태양광 발전, 태양 에너지, 태양 전지 패널이(가) 표시된 사진  자동 생성된 설명 |
| 스크린샷, 태양광 발전, 태양 에너지, 태양 전지 패널이(가) 표시된 사진  자동 생성된 설명 | 스크린샷, 태양광 발전, 태양 에너지, 태양 전지 패널이(가) 표시된 사진  자동 생성된 설명 | 스크린샷, 태양광 발전, 태양 에너지, 태양 전지 패널이(가) 표시된 사진  자동 생성된 설명 |

Fig. 2. Representative examples of PV installation across nine land-use types.

* + 1. Industrial complex

- 산업단지 정의 및 유형 설명.

- 산업단지를 골라낸 방법

* + 1. Logistics complex

- 물류단지 정의 및 유형 설명.

- 물류단지를 골라낸 방법

* + 1. Residential complex
    2. Public buildings
    3. Mountainous area
    4. Farmland
    5. Parking lot
    6. Roadside land
    7. Water

Table. 1. Summary of land-use types

|  |  |  |
| --- | --- | --- |
| Land-use type | Description | Data source |
| Industrial complex |  |  |
| Logistics complex |  |  |
| Residential complex |  |  |
| Public buildings |  |  |
| Mountainous area |  |  |
| Farmland |  |  |
| Parking lot |  |  |
| Roadside land |  |  |
| Water |  |  |

* + 1. Geographical constraint

법적, 지형적 규제를 검토한 사항들에 대한 설명.

- (농지) 농업보호구역, 농업진흥지역

- (산지) 보전산지, 경사 15도.

- (전체) 이격거리

* 1. Calculation of PV potential

Annual (8,760 hours) theoretical potential generation ( in kWh) of PV in the given area ( in m2) is calculated as the global horizontal irradiation ( in kW/m2) as followings.

The theoretical potential is limited to deliver meaningful information to policy makers. Geographical and technical constraints would be taken into account when we try to find more realistic estimation for the PV potential. The geographical and technical potential would be calculated as followings. [5–10]

Here, (in kWh/m2) is geographical and technical generation potential under geographical (ex. protected area) and technical constraints (ex. PV module efficiency). (unitless) is generator-to-system area ratio, which is the ratio of the area occupied by the PV generator (including PV arrays and the spaces between them) to the total suitable area available for the PV system. It indicates how efficiently the available area is utilized for placing PV systems. (unitless) is the packing factor, the ratio of the total PV array area to the land area PV arrays occupy. It measures how densely the PV arrays are packed within the occupied space. (unitless) is the performance ratio, the ratio of the actual generation achievable in practice to the ideal generation under no-losses conditions. Regardless of module efficiency and shading effect, it measures PV system losses from array temperature, surface soiling, panel degradation etc.[[2]](#footnote-3) is the module efficiency. is the shading factor.

In this study, instead, the reduced formula is applied as followings.

Here, (in kWh) is annual geographical and technical potential at an individual site (), located within a city& county (), classified as land-use type () and PV technology type (). (in m2) is the area of the individual site. (unitless) is the area factor, which represents the proportion of the area occupied by PV systems to the total area. It has the exact same meaning of in (eqn#). (in m2/kW) is the density factor, which represents the area required per 1kW of PV capacity. It indicates how densely PV systems are installed in a given area based on their capacity. (unitless) is the capacity factor of a PV system, defined by the ratio of the actual power generation to theoretical power generation if the PV system has generated at its maximum power output during same period [11,12]. The differences between the formula in the previous studies and the formula (# Eqn) in this study are i) measurement of PV installation size (PV module area in m2 vs. PV capacity in kW), and ii) measurement of PV system’s efficiency (disaggregation into performance ratio, module efficiency, and shading effect vs. capacity factor as integrated efficiency). In previous studies [sources], solar radiation that could be utilized by a PV system is measured, which is represented as in eqn#, while in this study, PV capacity that could be installed in the individual site is measured, which is represented as in eqn#. And in previous studies, energy losses associated with solar-to-electric power conversion, including shading losses are represented into three parts, which is represented as in eqn#, while in this study, the capacity factor, represented as in eqn#, the definition-based parameter, includes technical efficiency, shading effects, surface soiling etc.

* + 1. Total area

Data for the area of individual site is obtained from GIS-based approach as previous section describes. XX% (XXm2) of the total Gyeonggi province area (XXm2) is explored which counts totally 100,000 individual sites.

* + 1. Area factor: total area to PV system area

Fig. 3 (c) shows the graphical concept of the area factor (). 100% of the total area cannot be utilized for PV system installation, since facilities that have nothing to do with PV operation or unsuitable terrain for placing PV systems in its shape and size or other reasons may be included in the total area. Such surrounding environment varies in all shapes for each individual site, making it unfeasible to investigate every sites. Previous studies, instead, assumes that 70% of the total area could be utilized for PV system installation, which called generator to system ratio or area factor [5,13,14].

In this study, data for the area factor is calculated using actual PV installation cases data, or in some cases, is assumed, depending on the land-use types. As a result of the review on the actual cases data, for the industrial complex, logistics complex, residential complex and public building case, 54.5% of the total area is being utilized for a PV system on average. In parking lot and roadside land, 18.9% and 28.4 % of the individual site area is being utilized for a PV system respectively. The observed area factors are applied in this study. In the cases of the mountainous area and farmland, the data-absent cases, their area factors are assumed to be 40% and 5% respectively.

* + 1. Density factor: PV system area to PV capacity

Fig. 3 (d) shows the graphical concept of the density factor (). As a roof-top PV for three building types, single-family, multi-family and apartment complex, the density factors were assumed to be 11.7, 4.7, 4.7 (kW/m2) respectively in previous studies [15]. As a conventional ground-mounted PV, the density factor was 9.57, 13.16 (kW/m2) in previous studies [16,17]. For more efficient land-use, new types of PV technologies such as PV tree [16–18] and agroPV [19–21] would be considered.

In this study, the data for the density factor is calculated using the actual PV installation cases data as well. Unlike the area factor, the density factor is applied depending on the PV technology types. For the cases of roof-top and ground-mounted PV, the area of 7.23m2 and 11.50m2 is being utilized for a PV system of 1kW capacity on average respectively. The observed density factors are applied in this study.

* + 1. Capacity factor: PV capacity to PV generation

Data for capacity factor is obtained from XX, which is calculated based on the actual power market data, where XX. Capacity factor includes all types of losses

The capacity factor is applied differently depending on the city& county where the individual sites are located.

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자동 생성된 설명

Fig. 3.

PF (Apv/Agen)

Ground Cover Ratio or (Spacing factor): Elkadeem et al. (2022) : the ratio of total land requirements compared to the actual surface area of PV panels: 20%

Ouchani et al. (2021): Ground Coverage Ratio: 20%

IRENA (2014): Ground Coverage Ratio: 20%

Land Occupancy Factor (LOF) : 1.4: Yushcenko et al. (2018) : ratio of total land requirements to the surface of PV panels.

()

Vyas et al. (2022), Land Cover Ratio (LCR) : 13.16(m2/kW) : Land Coverage Ratio, which is the ratio of land area occupied by the structures (which becomes unusable for any other purpose) to the total land area available at the project site(area occupied by structure/foundation of SPV tree can be seen in graphical representation in Fig3.))

오명찬 (PhDThesis) Table5.2

태양 전지, 태양광 발전, 태양 에너지, 태양의이(가) 표시된 사진

자동 생성된 설명

* 1. Assumption of LCOE

LCOE assumption from KEEI. Draw a graph.

* 1. Scenario

지도, 텍스트, 아틀라스이(가) 표시된 사진

자동 생성된 설명

|  |  |
| --- | --- |
| Scenario | Description |
| No Setback | PV generation potential without Setback regulation |
| Setback | PV generation potential under Setback regulation |

Coefficient >> LCR (Land Coverage Ratio)

Power-based direct land use : Martin-Chivelet (2016)

Ground Cover Ratio or (Spacing factor): Elkadeem et al. (2022) :20%: the ratio of total land requirements compared to the actual surface area of PV panels.

Ratio >> ELR이라고 명명하자. (Effective Land Ratio)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Explored suitable sites for PV | | | Applied parameters | | | | LCOE |
| Land-use type | Area (m2) | Number of sites | PV type | Area factor  (unitless) | Density factor (m2/kW) | Capacity factor |
| Industrial complex | 25,293,157 | 25,128 | Roof-top PV | 54.5 | 7.23 | Applied geographically\* | Applied geographically\* |
| Logistics complex | 5,450,717 | 1,848 |
| Residential complex | 44,657,356 | 132,000 |
| Public buildings | 5,618,738 | 12,810 |
| Mountainous area |  |  | Ground-mounted PV | 40 | 11.50 | Applied geographically\* |
| Farmland |  |  | 5 |
| Parking lot |  |  | 18.9 |
| Roadside land |  |  | 28.4 |
| Water | 56,372,992 | 446 | Floating PV |  |  |

\* It is applied differently depending on the city & county where the individual site is located.

1. Results
   1. Geographical potential of PV

GIS

s

|  |  |
| --- | --- |
| No Setback | Setback |
| Total | Total |
| 텍스트, 지도, 도표, 폰트이(가) 표시된 사진  자동 생성된 설명 |  |
| 지도, 텍스트, 아틀라스, 폰트이(가) 표시된 사진  자동 생성된 설명 |  |
| Industrial complex |  |
| Logistic complex |  |
| Residential complex |  |
| Public buildings |  |
| Parking lot |  |
| Roadside |  |
| Water |  |

Fig. 4. Geographical potential of PV generation

* 1. Supply curve of PV

스크린샷, 다채로움, 도표, 그래프이(가) 표시된 사진

자동 생성된 설명

* 1. CO2 mitigation potential of PV

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1. Conclusions

Electrification

**CRediT authorship contribution statement**

**Seungho Jeon:** ABC. **Gildong Hong:** ABC. **Gyeonggi Do:** AB

**Declaration of competing interest**

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

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1. \* Corresponding author.

   *E-mail addresses:* [shjeon@gri.re.kr](mailto:shjeon@gri.re.kr) (S. Jeon), [email@gri.re.kr](mailto:email@gri.re.kr) (G. Hong), [email@gri.re.kr](mailto:email@gri.re.kr) (G. Do) [↑](#footnote-ref-2)
2. Definition of PR depends on researchers. [↑](#footnote-ref-3)