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Development of SEED (solar energy estimator for Daejeon) using chollian satellite imagery

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Abstract. Daejeon Metropolitan City and the Korea Institute of Energy Research (KIER) have developed a platform with the Solar Energy Estimator for Daejeon (SEED) for Daejeon citizens and solar power generation companies according to the government plan to expand new and renewable energy. Developed through four phases, the platform can calculate the solar irradiance by reflecting the shading variation of urban buildings and compute the power generation considering the module performance. The estimated power generation by the platform exhibited high accuracy of $R^2 = 0.89$ compared with the ground power generation amount. The SEED was developed to satisfy both accuracy and convenience requirements, and it is expected to meet the purpose of solar energy expansion and promotion.

1. Introduction

The government of South Korea has recently established the “Renewable Energy 3020 Implementation Plan” to have new and renewable energy sources account for 20% of the total power generation by 2030. This plan includes the goals of easing the dependence on nuclear power and coal power generation in the total power generation sources and increasing the proportion of eco-friendly renewable energy (Figure 1). The government has high expectations particularly for solar photovoltaic (PV) power generation, and it has established and implemented a number of subsidy supports and Renewable Energy Certificates (RECs) policies. The government policies focused on the propagation of new and renewable energy sources prompt many private companies and ordinary citizens to consider solar PV power generation projects. To keep pace with this, local governments have also made all-out efforts to promote solar PV projects.

Despite its high energy consumption, Daejeon has lower mean production of new and renewable energy than other cities. To overcome such circumstances, the local government of Daejeon has established plans to increase solar PV energy production. One of them was the platform for solar energy estimator. As such, Daejeon City needed to develop a high-quality solar energy estimator platform, so it implemented a collaborative project with the Korea Institute of Energy Research (KIER), which possesses its own independent technologies.

The KIER owns the technology that can estimate solar energy with the world's best accuracy from satellite observations, and it has made all-out efforts to develop a platform of solar energy estimator for Daejeon (SEED), which will be used by the citizens of Daejeon and solar PV companies conveniently. There have been several programs (stand-alone type: SAM, PVWatts, PVsyst) to estimate accurate PV power. The commercial programs are useful but require too much expertise, which makes it difficult for



ordinary users to access them easily. In order to address these problems, a public service platform call as the SEED has been developed.

The platform is developed based on the geographic information system (GIS), which can determine location information easily; shading by urban buildings is implemented with high time resolution.[1,5] Moreover, the KIER has attempted to implement functional advantages in other solar energy estimator platforms (Google's "Project Sunroof", MIT's Mapdwell, Seoul's Solar Map) in the SEED. The method of estimating solar irradiation based on satellite observations have the advantages of high spatial and temporal resolution and accuracy, and therefore many platforms are using satellite-based solar irradiation. [6, 7]

This study aims to disclose the technical items in various phases considered in the SEED platform and evaluate the accuracy of solar energy estimated by the platform.

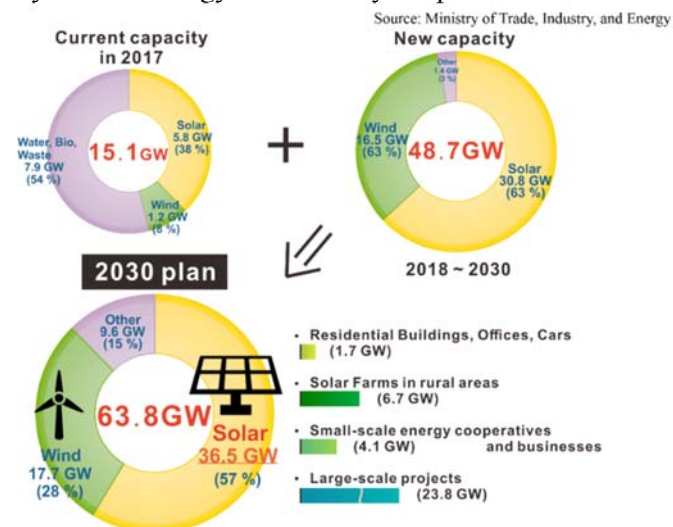


Figure 1. Renewable Energy 2020 Implementation Plan.

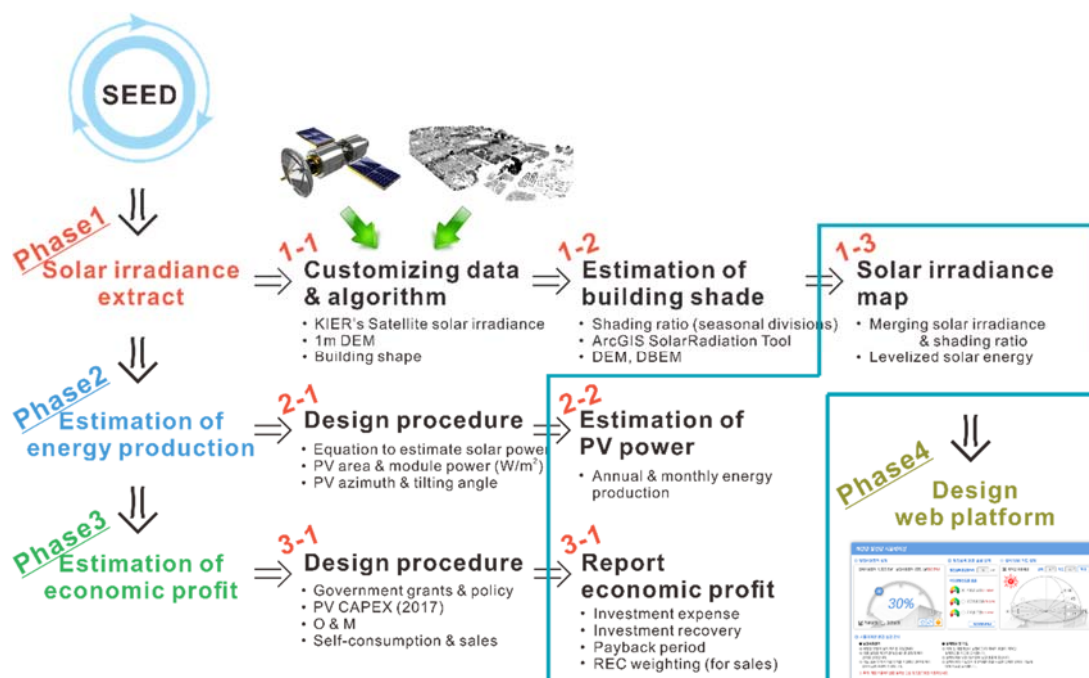


Figure 2. Tasks by phase in the development of the SEED platform.

2. Method

2.1. Solar energy estimator for Daejeon

The SEED platform that estimates power generation by the photovoltaic PV facilities in Daejeon was developed according to a four-phase procedure (Figure 2).

Phase 1: Calculation of solar irradiance map

Phase 2: Development of power estimation algorithm

Phase 3: Development of economic profit estimation algorithm

2.2. Phase 1: Creation of solar irradiance map

The SEED platform estimates PV power generation using ground solar irradiance calculated via UASIBS-KIER, the calculation model of solar energy developed by the KIER [2, 3, 4] UASIBS-KIER (Figure 3) calculates the global horizontal irradiance (GHI) and direct normal irradiance (DNI) of sunny and cloudy skies with 1 km resolution. The DNI and diffuse solar irradiance are calculated from the brightness temperature and reflectance obtained through the Communication, Ocean, and Meteorological Satellite (COMS), a geostationary satellite of Korea characterized by high accuracy.

Urban areas such as Daejeon have many spots of DNI block due to building shades (Figure 4). Thus, the platform should consider the variation of shading according to the change in the sun's position. The SEED platform is equipped with a database that calculates the daily (24 hrs.) and annual (365 days; Figure 5) shading variances by building in Daejeon, and it includes an algorithm that calculates power generation based on the shade database

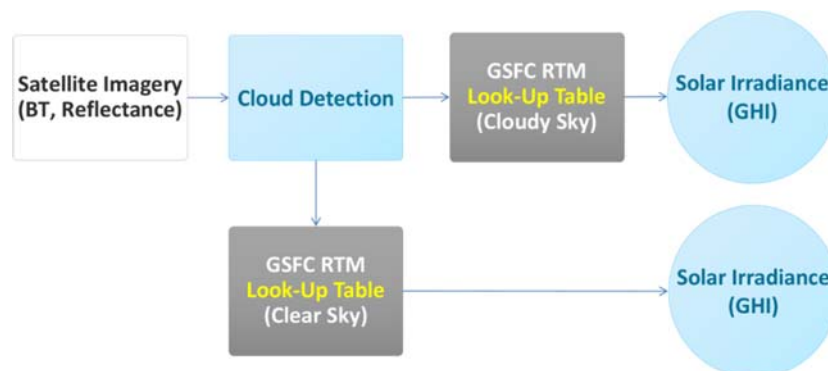


Figure 3. Flow chart of the UASIBS-KIER algorithm.

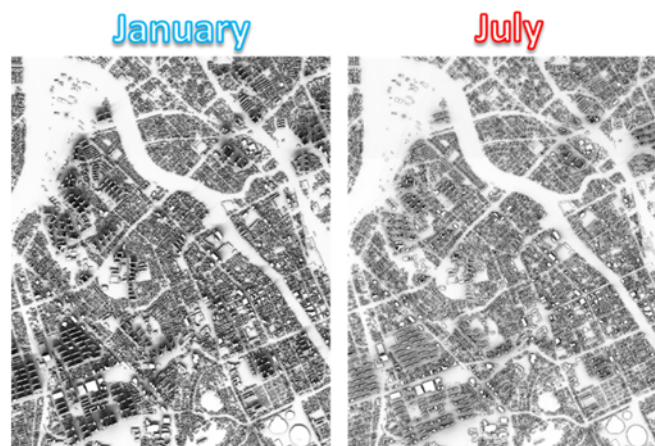


Figure 4. Distribution of power generation considering the building shade (January and July in Daejeon).

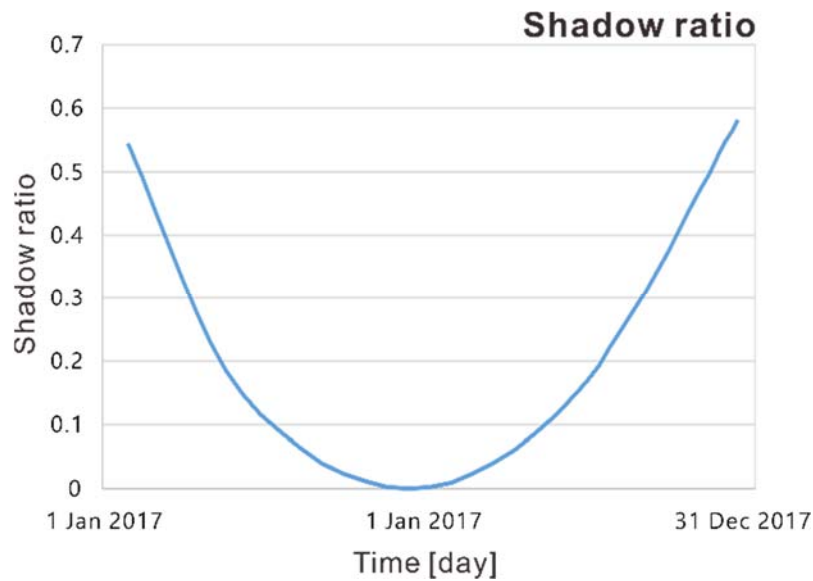


Figure 5. Shadow ratio according to changes in solar altitude at the meridian passage.

2.3. Phase 2: Development of power estimation algorithm

The estimated power generation in the SEED was calculated according to Eq. (1). The daily power generation was calculated for 365 days, and it was designed to calculate power generation according to PV performance and installation angle. The PV was divided into three modes (best, good, and average) according to the module's power performance.

$$\text{Daily power} \left[\frac{\text{Wh}}{\text{day}} \right] = \text{area}[\text{m}^2] \times \text{module power} \left[\frac{\text{W}}{\text{m}^2} \right] \times \frac{\text{m}^2}{1000[\text{W}]} \times \text{daily irradiance} \left[\frac{\text{Wh}}{\text{m}^2 \text{day}} \right] * 0.75 \quad (1)$$

Module power:

- Best: (200 W/m²)
- Good: (160 W/m²)
- Average: (130 W/m²)

2.4. Phase 3: Development of economic profit calculation algorithm

Realistic economic profit calculation results are needed for citizens who install PV panels for self-power consumption or companies for small-scale power generation. The SEED reflected the latest policies of the Korean government and subsidy information to meet such demand. It calculates the initial investment cost based on capital expenditure (CAPEX) and operation and maintenance (O&M) cost and performs economic feasibility analysis considering the recent REC price trend. The economic profit calculated in the platform is returned in the form of energy reduction for self-consumption citizens and is in the form of revenue amount for companies.

2.5. Phase 4: Development of web platform including (GIS)

It is necessary to interlink the GIS and the platform to calculate power generation easily for user-preferred buildings or areas as a function included in other previous platforms. The SEED contains the GIS database, which has the most up-to-date building data in Daejeon. The GIS database is expected to be uploaded to the location information service network in Daejeon.

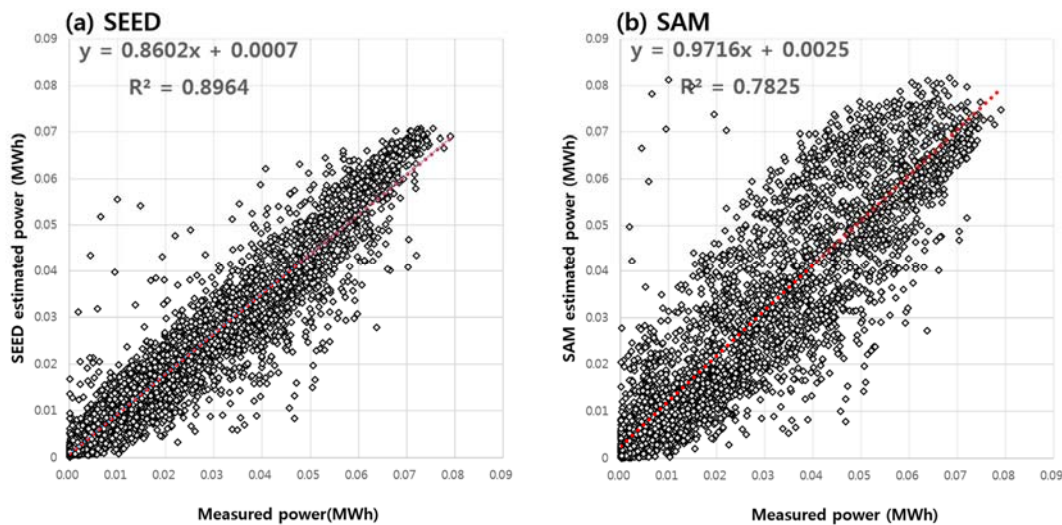


Figure 6. Verification of the power generation estimated by (a) SEED and (b) SAM (x-axis: ground power generation, y-axis: estimated power generation).

3. Verification and conclusion

The accuracy of the developed SEED platform needs to be verified. The ground PV power generation estimated by the SEED was compared with the power generation in PV power stations (100 kW, 2.4 MW, 1.4 MW, 2 MW, and 2.5 MW) operated in Daejeon. In addition, the performance of the SAM, which is commonly used, was analyzed to provide a relative standard of SEED. Figure 6 shows the scatter plot wherein the Y-axis refers to the estimated power generation by (a) SEED and (b) SAM and the X-axis pertains to the power generation measured at the ground. According to the analysis, these two variables have high correlation as $R^2 = 0.89$, which verifies the high accuracy of the SEED. On the other hand, SAM also has a linear relationship for two variables, but it shows that the correlation ($R^2 = 0.78$) is much lower than SEED.

The SEED was developed to derive the best results by fusing the advanced technical level of the KIER and GIS. The functions in the SEED reflected the feedback collected from the users as well as the requirements from administrative public servants (Figure 7). The target platform users who needed the platform were set clearly from the early phase of development. For future studies, a business model will be developed for the target users to create economic profits.

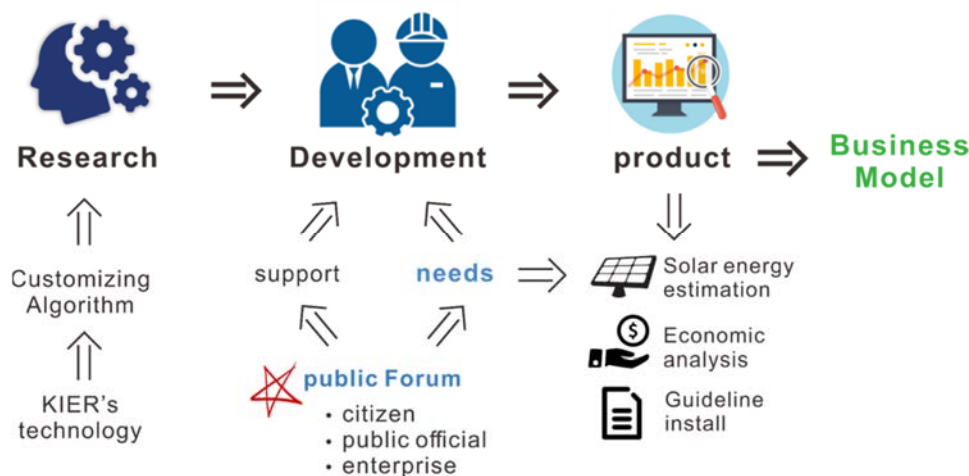


Figure 7. Project strategy for SEED.

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