Pingtung County Recovered from Natural Disaster and Achieving the Goal of Providing Domestic Electricity 100% by Green Power

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Abstract

After the completed "Aqua Solar Farm" project (installed capacity with 23.4 MW) due to typhoon Morakot in 2009, we are on the way to 100% green power for the need of domestic electricity in Pingtung. The first "Green Energy Promotion Office" was established to promote green energy in 2016. After engaging in "100% Renewable Cities and Regional Network" organized by ICLEI, Pingtung aims to the goal of achieving domestic electricity 100% provided by green power through the strategies of "Severe Subsidence Area" (SSA) project and "Multi-function Land Use." According to the GIS tool guide issued by the U.S. Department of Energy, we selected around 3,800 from 13,164 hectares in SSA where are non-arable for installing photovoltaic (PV) power plants. Multi-function Land Use has been implemented without affecting the function of public facilities, including floating PV devices on a retention pond and ground-mounted PV panels on the dike, landfill, and court at school for green power. We provide a platform for stakeholders while adjusting regulation on the fee to attract PV investors for the SSA project could be a triple-win model for other cities to learn around the world. By the end of 2022, the installed capacity would be from 777 MW to 1 GW, satisfying the need for livelihood use powered by 100% green power.

Keywords: Non-Arable Farmland, Solar PV System, Green Power

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Introduction

Located at the southernmost tip of Taiwan, Pingtung County has a tropical monsoon climate. Spanning a total area of about 2,776 square kilometers it features a long and narrow terrain that is about 112 kilometers from south to north, with hillsides on the east and densely populated plains on the west. The main economic activities are the development of agriculture, animal husbandry and fisheries. Pingtung is struck by typhoons an average of 3–4 times a year. Among these, Typhoon Morakot brought more than 3,000 millimeters of rainfall within 72 hours in 2009, and the brunt was borne by the towns and villages of the coastal strata subsidence area to the west. In the past, large-scale aquaculture activities were carried out in this area via the pumping of groundwater. Over the years, the continuous subsidence of the strata has been unable to eliminate standing water. During this typhoon, moreover, the backflow of tides and seawater has had a disastrous effect. Half a year after the storm, less than 30% of the area was available for restoration of aquaculture and fisheries, and nearly 400 hectares of orchards had sustained damage (Lin, 2017).

In order help restore the livelihoods of farmers and fishermen, the Pingtung County Government makes full use of natural sunlight resources. According to data query results of the Global Solar Atlas geographic information system established by the Energy Sector Management Assistance Program that is managed in turn by the World Bank, if solar modules are installed at an optimal angle in Pingtung, the global tilted irradiation at optimum angle can reach 1,736 kWh/m². The converted average equivalent sunshine hours can reach up to 4.7 hours/day, which is much higher than the global average annual sunshine amount of 1,209 kWh/m² (equivalent sunshine hours is about 3.3 hours/day) (Global Solar Atlas, 2021). At the same time, we have considered multiple policy links such as the reconstruction needs of the disaster area, the restoration of state-owned land (groundwater conservation), the establishment of a complete green energy industrial chain, energy transformation and combined land utilization, and so on to promote a "Aqua Solar Farm" project. This has seen the installation of about 25MW of solar photovoltaic (PV) capacity in conjunction with abandoned farmland or fish farms, transforming it into Taiwan's first large-scale groundbased solar voltaic case (Chen, 2012). This plan lays the foundation for Pingtung's promotion of green energy and is leading Taiwan on the path of energy transition.

Furthermore, we took the lead in joining the "100% Renewables – Cities & Regions Roadmap" project of ICLEI – Local Governments for Sustainability in 2016. We therefore intend to simultaneously and comprehensively inventory the development potential of renewable energy in various townships and actively plan to promote the development of renewable energy in large volumes and set the power demand for the county's 286,000 households (approximately 1.56 billion kWh). Our current goal is to replace traditional power supply with green power produced by renewable energy facilities.

Methodology

Strategies of Achieving 100% Renewable Energy Use

Having the great potential of renewable energy, we also work on changing policies to fit the restrictions on land use, power grid infrastructure, and the electricity market to balance the green energy industry with traditional agriculture. In 2016, Taiwan's first "Renewable Energy Promotion Office" was established to effectively work the renewable energy projects and be the window for the comprehensive renewable energy business and consulting services. The

promotion of "Severe Subsidence Area" (SSA) project and "Multi-function Land Use" are prioritized, two main strategies are step by step and tend to complement each other, moving towards 100% renewable energy.

I. Planning of "SSA" Project

In order to effectively plan for Pingtung's suitable promotion of PV facilities and its complete program, Taiwan's first "renewable energy database" was established in 2018 through use of the geographic information system (GIS). In the first step, we undertook a three-dimensional spatial layout of points, lines, and polygon to obtain information on different land use category and power system feeders. Furthermore, we adopted a strategy of "following the lines to find the land" as we screened land for the sake of promoting of ground-based solar PV targets. By using factors such as land that was non-arable, avoiding ecologically sensitive locations, and the availability of land acquisition. Meanwhile, we concurrently checked the status of adjacent transmission lines and power substations, used the "circumferential analysis" function in the Geographic Information System (GIS) to overlay land and feeder information, and filtered out land within a distance of 1 kilometer from transmission lines. This ensured that future cases can be connected to the grid within a certain distance to reduce power conversion and return process losses. The structure of database construction is shown below in Figure 1. This method of selecting the potential locations of renewable energy development is in line with the four aspects of "resource feasibility," "technical feasibility," "economic feasibility," and "market feasibility" that are considered by the evaluation system used in the Renewable Energy GIS Tool Guide -Informing Choice of Tools to Support Decisions, published by the National Renewable Energy Laboratory of the U.S. Department of Energy in 2019.



Figure 1. Geographic Information System tool guide for selecting potential locations of renewable energy development

(I) Non-Arable Land – Location Selection for Installing PV in SSA

The "Renewable Energy Database" overlaps the results of the 1996 survey of agricultural land productivity and importance by the Council of Agriculture of the Executive Yuan, and also overlaps the 2005 announcement of "SSA" by the Water Resources Agency (WRA) of the Ministry of Economic Affairs. The results show that 4 townships on the western side of Pingtung County, Donggang, Linbian, Jiadong, and Fangliao, are less suitable for agricultural operations in the coastal area (Figure 2), and 3/4 of the aforementioned areas are not suitable for agricultural development. Furthermore, all are encompassed by SSA.

We have divided them into the following 3 aspects for a total of 10 factors: (1) regulations and policies, such as the scope of policy plans, land use laws, and environmentally sensitive areas; (2) distribution of power equipment, such as the distribution of substations and power grids; (3) other social aspects, such as land ownership and property rights. We will exclude factors one after another in the subsequent site selection process (Figure 3) (Ou, 2019).



Figure 3. The criteria of selecting potential sites for GIS tool

II. Site Selection and Evaluation Method of Combined PV Facilities

Without changing the origin function of existing facilities, we consider how to develop various PV facilities within the concept of combined use of available space. First, we have prioritized the inventory of idle existing public facilities and space use functions. Through the integration of the public and private sectors, a demonstration case will be built for the emulation of other counties and cities in Taiwan for the sake of stimulating private participation. Through inter-office meetings, we have inventoried locations where PV capacity may be installed, such as detention ponds, dikes, landfills, and roofs of public buildings. In addition, the Green Energy Promotion Office shall further evaluate the feasibility, benefits and costs of the installation from the perspective of power equipment distribution, regulations and policies, and other social factors, while improving economic incentives and encouraging private industry to participate.

Result

I. Application of Pingtung Renewable Energy Database

We follow the subsidence area issued by WRA in 2005 including the four townships of Donggang, Linbian, Jiadong, and Fangliao in the western of Pingtung. We then further excluded conditions such as environmentally sensitive areas, special areas for cultivation and production, densely populated areas, and so on (**Figure 4**). From a total of 13,164 hectares of land, we thus determined a priority promotion range of about 3,800 hectares; and within 1 km from the grid, grid-connected ranges that are suitable for installation of booster stations (Figure 5).

After establishing the priority promotion range, we announced in 2018 the "Pingtung County Comprehensive Planning Review and Counseling Management Measures for the Solar PV Power Generation Industry in SSA" and officially launched the "SSA Project". Furthermore, as of September 2021, all cases of field booster stations have been built within the recommended grid connection range, and the field of the solar PV case has been built outwards with the booster stations as the center.



Figure 4. Pingtung County SSA project exclusion conditions



Figure 5. Solar PV project scope in SSA.

II. Implementation of the SSA Project

After the official launch of the SSA project, we also carefully executed overall planning in consideration of the fact that the plan is a project for collective private land development. This was in view of the past promotional experience of "Aqua Solar Farm" project to set up green energy on private lands, where a lack of relevant specification limits resulted in land and PV industry participants developing under a free market mechanism. This in turn led land development participants to collude with industry operators to falsely occupy feeder lines. All sorts of chaos occurred as participants did not install PV capacity yet were driving up the value of land and of feeders, or landholders would not obtain the protection of rights and obligations after leasing their properties. In order to effectively integrate and solve various problems, we officially implemented the SSA project in 2019 without preparing any budget. Through economic incentives, we selected qualified and competent investors to participate in this project, established a communication platform (Figure 6) between investors and landholders with administrative contracts to ensure the rights and obligations of both landholders and PV investors. This enabled landholders and PV investors to pursue private interests while also cooperating with the promotion of Pingtung's green energy policy and pursuing comprehensive social interests.



Figure 6. Zero budget promoting model in SSA project

(I) Regulating Investors to Fulfill Their Rights and Obligations

This plan adopts an open tendering procedure in order to strengthen the process and scale of solar PV capacity in SSA, and to prevent inferior investors from unscrupulously attempting to sign an administrative contract and seriously damaging the rights and interests of the landholders. The contract formulates autonomous rules: in regulating project counseling participants when changing category of land for setting up solar energy, although 50% of the current value of the land announcement fee is waived (rebate fee), it must be paid in installments to the green energy fund in accordance with the commitment to the administrative contract. With regard to the application procedures of investors, we will conduct simultaneous examinations in conjunction with relevant departments. The land category change process, which took more than 12 months in the past, has been shortened to less than half a year, and this has greatly reduced the time cost of investors' applications.

(II) Method of Protecting the Rights of Landowners

Private land shall be given priority for promotion in this SSA. Due to the large number of landowners in the SSA, they do not have a complete understanding of the background knowledge of PV installations on leased land and we have collected the relevant problems of PV installations on farmland in practice (including land category change procedures, taxation, agricultural insurance qualifications, and solar PV recycling). By building a digital platform, we have disclosed relevant information on the Internet. However, most local residents fall under the classification of digitally challenged senior citizens. Therefore, while in the early stages of plan implementation, we go to township offices to handle SSA project briefings with on-site explanations and answer to resolve public doubts. In addition, we also

use administrative contracts to require investors to set up special accounts for performance management trusts for landholders in order to protect their rights.

(III) Regulating Land Use Methods of Investors

Through the constraints of our "administrative contract," the land leasing price can be maintained within a reasonable range. Moreover, before signing a land contract with the landholders, the investor must first explain to the landholders the method of land use, such as whether the land needs to be backfilled, and the source of the backfilled earth, so as to avoid illegal dumping and backfilling of the land without the government's permit. After the investor's acquisition of the land is completed, it can only be used to build PV facilities. In addition, after the 20-year feed-in tariff contract with Tai-power Company has expired, the landholder can also choose whether to continue to rent out the solar PV system according to the current setup or ask the investor to remove the solar PV facility and restore it to agricultural land.

I. Promotion of Benefits of SSA Project

(I) Centralized PV Facilities in SSA

Since our implementation of the "SSA Project" in 2019, 4 Ultra High Voltage (UHV) booster stations have been completed, with a total capacity of 140MW officially generating electricity. According to the current transmission line usage in this area, it is estimated that there will be a potential of 1GW that can be connected to the grid in the future. Taking "Operator A" in Jiadong Township with the greatest volume currently as an example: at present, 99MW has been connected to the grid for power generation, and it can be seen from the distribution block of the investor's solar PV capacity (Figure 7) that the case is concentrated in the area within 3 kilometers from the booster station. Thus, through centralized development, land fragmentation can be effectively avoided in other townships in Pingtung County.



Figure 7. Schematic diagram of the distribution of land and grid-connected lines for the case of "Operator A" in Jiadong Township

(II) Extra Advantage for Environment from SSA Project

As of October 2021, about 140 hectares of non-arable farmlands or fish farms in SSA have been replaced to solar PV power plants. While expanding the green energy industry, we can also reduce the situation in which farmland and fish farms extract groundwater for cultivation or irrigation. Currently, the scope of the Multi-function Land Use project covers about 110 hectares of subsidence land with solar PV power plants. By letting the land lie fallow for 20 years and reducing the extraction of groundwater to irrigate crops, land subsidence can be slowed down. According to WRA (2021(a)), the conversion can reduce extraction by 2.97 million metric tons of groundwater annually. Similarly, in referring to the "Statistics on Aquaculture Area and Aquaculture Water Consumption" (WRA, 2021(b)), because there are also about 30 hectares of fish farms with PV, environmental benefits are seen as the conversion can reduce the extraction of 960,000 metric tons of groundwater for use as aquaculture fisheries every year. The calculation methods are as in Eq. (1) and Eq. (2).

Water savings from installed solar power in irrigation area (10,000 metric tons/year) =(1)Total water consumption for irrigation (10,000 metric tons/year)(1)Total irrigated area (hectares)Water savings from installed solar power in breeding area (10,000 metric tons/year) =Total water consumption for breeding (10,000 metric tons/year)Total water consumption for breeding (10,000 metric tons/year)Total breeding (10,000 metric tons/year)Total breeding area (hectares)

(III) Adapting to Local Conditions and a Friendly Environment

Since the SSA has continuously sunk at the rate of 2 to 3cm every year, PV power plants are designed in a way that is adapted to local conditions and that is environmentally friendly (Figure 8), explained as follows:

1. From **Figure 8-A.** As this project adopts the principle of not changing the original topography to install solar equipment, therefore, for some subsidence areas that are prone to flooding, a design of elevated solar equipment is adopted. For example, see the highest booster station in the country (4 meters).

2. **Figure 8-B.** This area is still in a state of continuous subsidence. According to the National Cheng Kung University's Stratigraphic Subsidence Prevention and Control Information Network (Stratigraphic Subsidence Prevention and Control Information Network, 2021), the maximum subsidence rate in this area in 2020 was 3.3 cm per year. Therefore, in the design of PV equipment, the height and angle of the frame can be adjusted manually according to the subsidence of the ground.

3. **Figure 8-C.** We can cooperate with the data monitoring plan of subsidence areas of the Water Resources Agency of the Ministry of Economic Affairs, and regularly provide microclimate monitoring data within the scope of the case, such as the amount of subsidence and flooding depth of individual cases.

4. **Figure 8-D.** Considering the field of vision of local residents, this SSA is designed with a small inclination angle (7 degrees) to prevent glare and avoid affecting the safety of passers-by.



Figure 8. Explanation of design features aligning with local conditions for solar PV capacity in SSA

II. The Multi-Function Land Use Project

(I) Diversified Solar PV Facilities

The Multi-Function Land Use project is to utilize the available space of public facilities effectively (see Figure 9). This includes 9-A Floating PV on the detention pond, 9-B PV on the dike, 9-C PV on the landfill, and 9-D PV on covered court at schools. They all adopt the practice of installing renewable energy without affecting the functions of the original facilities. For example, the floating PV device on the retention pond, ground-mounted PV panels on the dike, landfill, and court at school. The first floating PV device with an installed capacity of 499 kW was built in Taiwan in 2016. Under the consideration of the Electricity

Act, if the installed capacity of the PV plant were over 500 kW, there would become a complicated application procedure. Therefore, the floating PV device installed with a capacity of 499 kW shows that this floating PV device is the first on-water PV device in Taiwan. The promotion of floating PV power plant also drives the local investor to invent floating devices spreading worldwide.

The other benefits of floating devices are that the system is eco-friendly with animals. Birds will build their nest under solar panels and lay eggs; baby birds co-exist with the device to become new biodiversity. PV panels could reduce water evaporation by 70%, and the water cools down the system making it around 10% more efficiently. After monitoring the water quality, the retention pond has no adverse effect.

(II) Setup of Biogas Power Generation on Livestock Farms

Pingtung has the largest number of pig farms in the country (approximately 1,500), and the number of pigs raised is 1.22 million, ranking second in Taiwan (Council of Agriculture of the Executive Yuan, 2021). The livestock industry is well developed and is an important source of supply for Taiwan's pork market. In the past, however, livestock raising bore a public perception that it discharges sewage and causes environmental pollution. We give active counseling to promote the recycling and reuse of livestock wastewater and cooperates with the installation of renewable energy such as solar PV capacity and biogas power generation. In this way, it can transform traditional livestock farms into clean, economically circular green energy livestock parks that effectively reduce the output of odor and that may also enjoy additional income from electricity sales. At present, 12 livestock farms in Pingtung County have installed biogas power generation with a capacity of about 1.5MW.

The installed capacity of renewable energy in Pingtung now is 777 MW. The annual green power generates 1.28 billion (kWh/year), sufficient for 235,000 households' use. Reviewing the past ten years, we successfully created several milestones in each year, especially in 2016. The first Green Energy Promotion office was established to provide green power for the need for domestic electricity. By having Green Energy Promotion Office be the sole window to facilitate the process of administration, till now, the installed capacity of 777 MW is seven times higher than its quantity in 2016 (Figure 10).



Figure 9. Methods of combined use of solar PV capacity for various types of land



Figure 10. Installed Capacity of renewable energy in Pingtung

Conclusion

After taking the lead in considering various factors such as laws and regulations, land, and grid connection, we put forward effective methods to confirm locations for the effective development of renewable energy and adopted two strategies according to local conditions. Furthermore, we coordinated the overall planning of the grid distribution to promote the project plan, indicating the limitations of renewable energy promotion. As of the end of November 2021, the county's overall grid-connected renewable energy installed capacity has reached 777MW, of which the SSA project has been connected to the grid with approximately 140MW. The combined PV facilities include public sector and private installations. We are continuing to move towards the goal of using 100% renewable energy for people's livelihoods, to supplement the possible power supply gap after the decommissioning of Taiwan's third nuclear power plant in the future.

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