Enhancing renewable energy production in Antarctica through design and planning

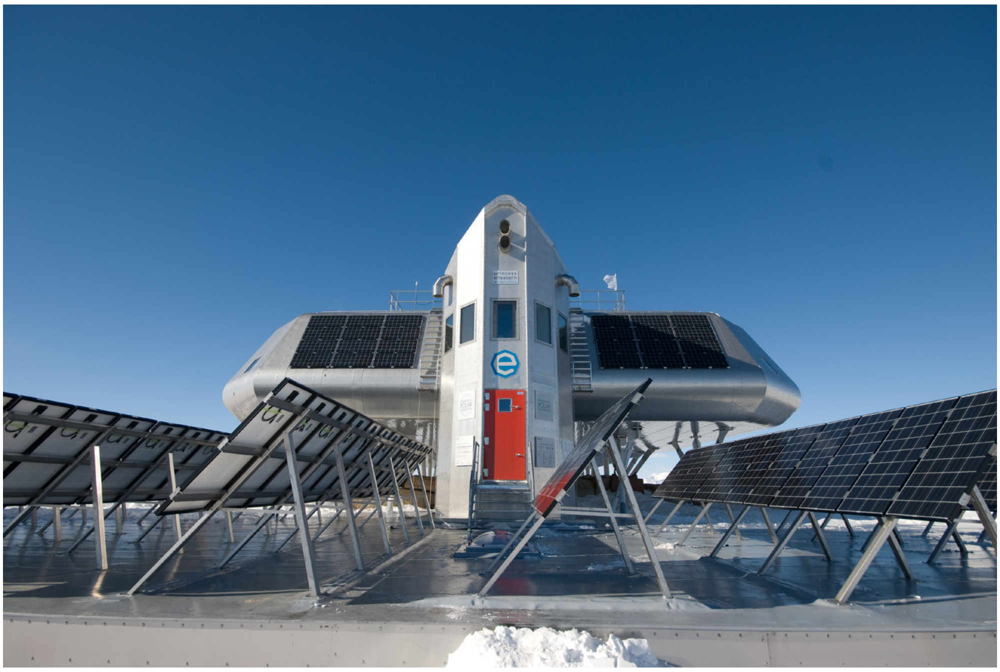
Solar in harsh climates | Antarctica is one of the harshest and most inhospitable environments for human activities due to its extreme climate. Traditionally, research stations in Antarctica were powered by fossil fuels. The comparably simple requirement of supplying a research station with electricity and heat in most other parts of the world can become much more challenging in Antarctica. The picture can be quite different when using solar power, as is the case at Belgium's Princess Elisabeth Antarctica Research Station in the continent's Queen Maud Land. PV Tech Power's Simon Yuen talks to Slovenian solar company Bisol and the International Polar Foundation about features of renewable energy production at the research station which was established in 2009.

Solar power plants have in the past been limited to climates with an abundance of irradiance, but it is getting more competitive at higher latitudes thanks to advanced technology and decreased production costs.

Characteristics of high latitude climates can affect the performance of solar power plants, according to the study 'Polar solar power plants - Investigating the potential and the design challenges' co-conducted by Iver Frimannslund and Thomas Thiis from the Norwegian University of Life Science; Arne Aalberg from the University Centre in Svalbard, and Bjørn Thorud from consulting engineers and designers Multiconsult ASA.

For example, a decrease in cell temperature increases the solar cell voltage and slightly decreases the current, but the net outcome is an increased power output of about 0.35 to 0.5%/K. Moreover, the reflected irradiance caused by the high reflectivity of snow can enhance the irradiance collected by a solar module. As a result, bifacial solar modules can produce power from the irradiance received on both sides of the modules, and can greatly increase the power output in high-reflectivity climates.

In other words, reduced solar irradiation in the polar regions, compared to areas with lower latitudes, is compensated by increased efficiency resulting from low temperatures and high reflectivity, according to the study.



Credit: René Robert, International Polar Foundation

Solar panels installed at Belgium's Princess Elisabeth Antarctica Research Station in the continent's Queen Maud Land.

Apart from efficiency, settlements relying on fossil fuels as the main energy supply need to pay higher fuel costs due to the transportation of the fuel because of remoteness. Research stations in Antarctica also rely on fossil fuels which faces two challenges. First, fuel needs to be shipped by boats from settlements or ports in other continents; second, the fuel needs to be transferred to inland stations by overland vehicles.

Considering the limitations of using fossil fuels, solar PV's competitiveness, such as on-site power production, can outweighs the high fuel costs of the existing solutions.

Despite the fact that there is potential for solar PV in polar regions, the extreme climate is one of the major problems in building solar power plants. The study highlights that the implementation of solar power systems must confront the climate effects caused by snow. Snow can shade the surface of modules, resulting in a lower power generation efficiency. Moreover, the development of snowdrifts in a solar power plant can also impose a mechanical load on the PV arrays.

Installing solar in Antarctica

In the same study, the authors detail how to build a sustainable solar power plant in polar regions.

The authors use a solar power plant in Adventdalen, on Norway's Svalbard, as an example. The weather there is characterised by significant horizontal redistribution of snow due to little shelter and strong winds, causing snowdrifts to develop in the aerodynamic shade of the PV arrays.

The study also indicates that PV array snowdrifts exhibit a similarity with snow fence snowdrifts, so the snow fence theory can be used to minimise the accumulation from the PV arrays. Snow fences can cause turbulence in the wind so that it drops much of its snow load on the lee side of the fences.

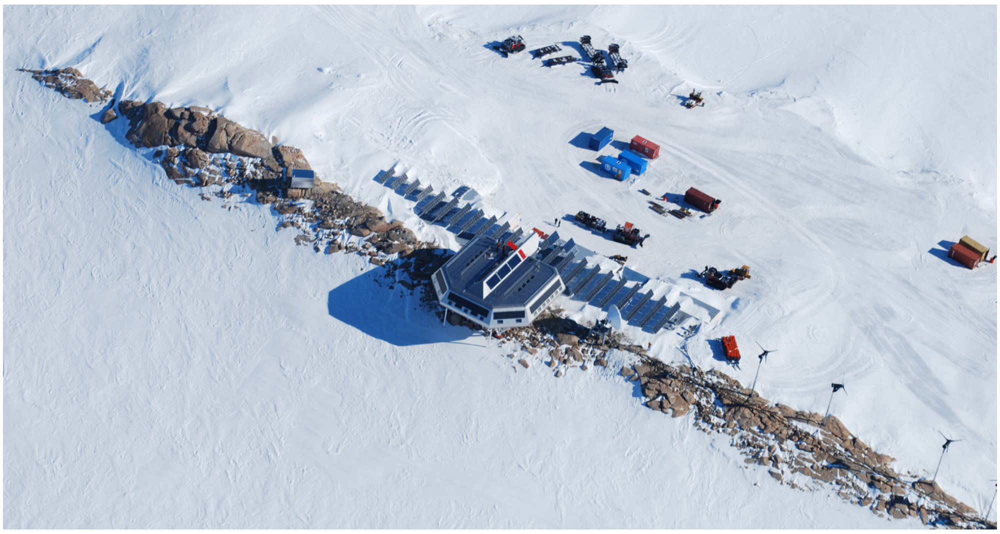
By using the snow fence theory, developers can consider the adjustment of azimuth, array tile and bottom gap of PV arrays to minimise snow accumulation in the plant.

A strong inclination for snow fences can reduce the net height of the fence and the subsequent snow storage capacity. Therefore, inclining the PV arrays significantly while maintaining a bottom gap is likely to reduce the storage capacity of the PV produced snow drifts.

Another key area developers need to take note of is that the plant should be resilient against snowdrifts, which are a direct consequence of the aerodynamic shade from objects and terrain. The authors suggest that a modification of the design of the solar power plant can be used to control snow accumulation and erosion in the plant.

According to the study 'Renewables in Antarctica: An assessment of progress to decarbonise the energy matrix of research facilities', solar energy became prevalent in Antarctic operations in the last decade. It was mainly introduced either to complement wind energy or in summer bases, summer shelters and on expedition equipment powered by solar energy such as radios and very-high-frequency repeaters.

The study listed four main reasons for using renewables in Antarctica based on interviews with personnel in charge of energy operation and contractors responsible for installing renewables systems, namely fuel cost reduction or avoidance,



Credit: René Robert, International Polar Foundation

Aerial view of Princess Elisabeth Antarctica Research Station.

reduction of greenhouse gas emissions, a secure electricity supply for the operations of scientific equipment during the winter when fuel deliveries are very difficult, and the development or testing of new technologies.

However, several obstacles and constraints hamper the use of renewables in Antarctica, with the main one being technical challenges.

For example, the authors said panels at the Princess Elisabeth Station were initially installed too close to the station which created extra work for the team when snow accumulated. In response to this problem, new installations, including cylinders with 360-degree PV cells and bifacial panels, were added to double their capacity and allow for heating of the annexe buildings.

Other challenges include the comfort of the staff as diesel generation is still required as backup, and logistics. In addition to difficulties in delivering renewables systems components, any missing components or tools can postpone projects for months or even a year as these items would have to be shipped in the next expedition or supply mission.

How can the Princess Elisabeth Antarctica Research Station tackle the problems and thrive in Antarctica?

Antarctica has been the home of scientific research for decades, with multiple research stations operated by different countries on the continent. Located on Queen Maud Land, a region of Antarctica claimed by Norway as a dependent territory, the Princess Elisabeth Antarctica Research Station was designed as a prototype that can continually be improved over time, according to the International Polar Foundation, administrator of the station.

The research station can access two of the most omnipresent features of the Antarctic weather: the wind and the sun. They are renewable sources that provide energy to the research station which claims to be running with zero emissions.

According to the International Polar Foundation, the Princess Elisabeth Antarctica Research Station has 284 solar PV panels that produce an average of 420kWh per day. In addition, to better leverage solar irradiance, the station has 96 bi-facial modules that can benefit from snow-reflected irradiance.

In addition to solar panels, nine wind turbines that can produce 6kW each are installed at the research station. The solar modules and wind turbines supply 76% of the energy required by the station. The energy produced by these two sources are stored by 192 lead-acid batteries.

A total of 30 solar thermal panels are included in the station, providing 21% of the energy with the remaining 3% of energy being provided by a generator set.

Intelligent systems

As renewable energy production is variable, an intelligent system is installed to balance available energy and energy demand through a system of dynamic prioritisation. Generated energy will be transferred to a battery storage system with a total capacity of 438kWh before being transferred to a programmable logic controller.

The station consumes between 10 and 20kW on-season, so storage lasts for 13 to 26 hours if there is no sun or wind. The demand for energy can be divided into five categories, including safety, scientific research, daily usage from stationed researchers and staff, leisure and operations consisting of water treatment and distribution, snow melter, ventilation and heating.

Additionally, there are mobile solar-powered energy field units producing up to 25kWh per day so that scientists can use them while on extended research missions in the field.

The Princess Elisabeth Antarctica Research Station has a smart microgrid designed by research centre and technical service provider Laborelec, and an automated energy management system designed by Schneider Electric.

David Orgaz, CEO of Schneider Electric Belgium and the Netherlands, said that ensuring smart energy management is crucial to the polar station, adding that energy produced by solar modules and wind turbines is either stored in batteries or used immediately. Therefore, maintaining a balance between what is produced and what is consumed is critical, minimising the station's energy usage and eliminating energy waste.

Bisol's role in the station

Recently, Slovenian solar company Bisol has installed more solar modules to power the research station.

Bisol says its 22kW project aims to meet the increasing energy needs of the Princess Elisabeth Antarctica Research Station. In February this year, the containers with the company's 60 solar modules arrived in Antarctica, and installation is nearly complete.

"Adding the new Bisol PV panels is not just about having more energy available. The panels are facing east because we want to harvest the morning sun," says Guus Luppens, renewable energy system engineer of the International Polar Foundation.

The research station used to have a production gap between midnight and morning, but this is now covered by the new Bisol PV modules once they are all installed.

In the 'Polar solar power plants - Investigating the potential and the design challenges' study, the authors highlight that the redistribution of snow is "caused by snow eroding from exposed areas and accumulating in sheltered areas, creating snowdrifts". To reduce snowdrifts in unwanted areas, the design of infrastructure in polar regions needs to control where snow is deposited and eroded.

To ensure the resilience of solar power plants in snowdrift climates, the design should be adapted to snowdrift development. This can be performed by adapting the configuration of the PV arrays so that snow is deposited in designated areas or so that the deposition is minimised.

Luppens says due to the strong katabatic wind – a wind carrying high-density air from a higher elevation down a slope under the force of gravity – and the acceleration of the wind on the ridge, almost no snow is accumulating on this PV array.

But some special designs are adopted in such an extreme environment. "We learned to never underestimate the power of the katabatic winds in Antarctica. The mounting system has been carefully designed to withstand the high winds," says Luppens, adding that the PV modules did not receive any adjustments as they are -40°C-rated.

For wind turbines, they are designed for harsh conditions, according to Luppens. The blades tilt when the wind speed is too high, causing them to catch less wind and preventing the blades from overspeeding. The company also installs a dumpload system to ensure enough braking power by consuming all produced energy.

Operation and maintenance

The operation and maintenance of the solar modules could be a problem due to the extreme weather. To prevent the solar modules and wind turbines from being damaged by any external factors, the systems are designed to be firmly fixed to minimise vibration. However, Luppens admits that the solar power systems and wind turbines are more prone to damage due to the extreme weather they are deployed in.

For the wind turbines, Luppens says they need yearly maintenance, while the PV modules – lacking the moving parts – do not need any maintenance.

Speaking of the design of the systems, there were some difficulties during the construction process. According to Luppens, the ridge on which the Princess Elisabeth Antarctica Research Station is built can be a very windy place. What makes the installation process more difficult is that the winds accelerate in the area close to the station. To successfully install the systems and modules, the process needs to be done on days with low wind speed.

The research station is designed to operate without any people on site, and it can remain unstaffed for up to eight months. By using programmable logic controllers and supervisory control and data acquisition systems, operators can monitor and control light, switches, valves, and thermostats from a remote place.

"Excluding all possible failures is, of course, not possible, but we do try to make sure all scientific instruments stay operational during the whole winter until the first crew member arrives again," Luppens says.

What made Bisol start working on this project in Antarctica?

The Princess Elisabeth Antarctica Research Station was established in 2009. Bisol first contacted Brussels-based International Polar Foundation in January 2022 to plan the project.

The company said that the design and clean energy concept of the research station integrates passive building technologies, renewable wind and solar installations, together with power electronics in a micro smart grid that delivers maximum energy efficiency.

The quality, reliability and low degradation of solar modules are areas that are particularly important in the severe weather conditions in Antarctica. Bisol says it only uses top quality EVA foil and longer lamination. Additionally, the company invests in its own climate chamber, performs peel tests on every module and also develops tailor-made BISOL tracking systems.

Asked by PV Tech Power about the reasons for working on this project, the spokesperson of Bisol says that the project's zero-emissions goal aligns with the company's values and missions, which involve energy solutions that are being commercialised in mainstream applications. Second, Bisol hopes to use this project, located at an unusual location, as an opportunity to showcase its products as the company's presence spans more than 100 countries at present.

"We believe that companies can play a key role in building a sustainable economy and society, which is why we take our responsibility towards the environment and the community around us very seriously," the company says.

Bisol started manufacturing solar PV modules in 2004, and expanded its business to PV mounting solutions and investments in solar power plants in 2009. Currently, with an annual capacity of 750MW, the company's products are sold in more than 100 countries. ■