# BI-FACE
# High-Efficiency Bifacial PV Modules and Systems for Flat Roof Applications

*Project duration: from 03.2018 to 09.2020*
*Report submitted: 10.2021*

## Publishable Summary

### Initial situation

Although bifacial cells need some additional manufacturing steps, from an economical point of view the production costs are comparable and the yield increase can be between 5 and 30% yield [1], [2]. This depends on the solar cell technology used, the location and system design. Today one of the most effective ways to include PV is the usage of solar panels on manufacturing sites and public buildings, where the generated power is used immediately. In many of these buildings, flat roofs are state of the art. Therefore, the BI-FACE project focused on optimized light weight bifacial PV systems for flat roofs.

The first main challenge at the beginning of the project was optimization of the module itself, e.g. the used components and design rules. Novel materials for i.e. encapsulation and glass / foil had to be evaluated with regards to costs as well as reliability. Furthermore, the manufacturing process was not well analyzed and needed optimization. Besides that, also the characterization of the built modules was still challenging. At that time the characterization of bifacial modules was not well defined, labelling was therefore unprecise and unsatisfactory for customers as well as for manufacturers. Especially there was a big gap between laboratory and manufacturer characterization and measurements.

Parallel to these module aspects the second main challenge was the optimization of the overall system design, where layout and mounting design of the system had to be optimized for energy performance. Energy performance of a system is critically influenced by structure and albedo of the roof surrounding modules and shape of the modules and should be thus evaluated and optimized to achieve maximum performance. The system design needs to take into account different (ballast) load profiles, due to added wind load, which can influence ground reflection and irradiation. Heavy ballast contradicts the requirements of many flat roofs, as many cannot handle heavy weights. This combined optimization of module, system and construction needed to be combined with the economic needs to have high energy yield at low costs.

[1] https://www.solarpowereurope.org/blog-solar-technology-update/ September 17, 2019
[2] G. Janssen et al., "Outdoor performance of bifacial modules by measurements and modelling", Energy Procedia 77, pp. 364-373, 2015

BI-FACE project aimed the following objectives:
(1) New validated simulation tools for bifacial modules and systems, including simulation of the wind load
(2) Modeled and validated standardization advice for characterization of bifacial modules
(3) New high efficiency bifacial modules and system
(4) Outdoor performance qualification of the bifacial system in different European climate zones and wind and snow load conditions
(5) Guidelines for flash tester upgrade at the module manufacturer's site

**Project methods and results**

The scope of the project BI-FACE was to develop innovative bifacial modules and systems for flat roofs to exploit the enormous potential of this technology. The results included three novel variations for bifacial modules and systems which were tested in three different climate zones: subtropical (Cyprus), temperate (Austria, 2 sites) and maritime temperate (The Netherlands, 2 sites). The ultimate design of these systems was challenging due to the large number of parameters that influence the energy yield (tilt and distance between modules, reflecting surfaces, shading, cell spacing, materials used and weather conditions).

Within the project five bifacial PV systems were realized and monitored (one system at each site). The setups each featured 3 different types of modules (mono-facial, bifacial n-type (bifaciality ~90%), bifacial p-type (bifaciality ~70%)). So bifacial energy gain on yield could be assessed, as function of module bifaciality, openness of the support structure, as well as the dependence on ground albedo. The monitoring campaign took place over the summer of 2020, putting the extension of the project end-date to good use. The data were evaluated and analyzed with the tools and knowledge developed for bifacial PV within the project.

A holistic approach to energy performance took the aspect of standardization into account. This standardization was not available at the beginning of the project for bifacial modules, hindering rapid market introduction. Therefore, critical efforts were put in to harmonize performance characterization of bifacial PV modules in a factory and laboratory setting and correlate this with the outdoor performance. The results were communicated with the standardization committees.

The layout and mounting design of a bifacial system was critical to obtain the maximum possible performance on flat roofs. The construction demands with respect to wind load, stability, total weight (incl. ballast) and maximum allowed weight on a roof were directly influenced by ballast design and needed to be critically examined in parallel. The intended approach compared theoretical investigations with tests in the laboratory and in the field.

Performance simulations of bifacial modules and systems were developed and compared to laboratory and in field test results. Finally, all innovations were collected, synthesized and validated on a flat roof where the need for lightweight was an additional challenge.

The project BI-FACE aimed to develop technically as well as economically novel bifacial PV systems to exploit the enormous potential of this technology.

## Main results achieved

- Novel lightweight bifacial modules and systems for flat roofs for representative climates in Europe
- Innovative, comprehensive models for design and installation of bifacial modules and systems including construction requirements
- Novel manufacturing strategies
- New performance and characterization measurements
- Innovative mounting structures

## Highlights of the project

- New validated simulation tools for bifacial modules and systems, including simulation of the wind load. (See Figure 1)
- Modeled and validated standardization advice for characterization of bifacial modules
- New high efficiency bifacial modules and systems. Energy yield increase in comparison to mono-facial systems by up to 20% were achieved according to the results. LCOE decrease of 11.4% were achieved. The decrease is in comparison to LCOE of monofacial modules with black non-transparent backsheet.
- The gain of bifacial PV panels with p-PERC technology and 70 % bifaciality, compared to monofacial ones, were in the range of 15-20 %. Bifacial modules with n-PERT solar cells having a bifaciality of 92% showed an up to 3 % higher yield than bifacial modules with bifacial p-PERC cells. https://doi.org/10.1016/j.renene.2021.02.015 (See Figure 2)
- Outdoor performance qualification of the bifacial system in different European climate zones and wind and snow load conditions
- Guidelines for flash tester upgrade at the module manufacturer's site

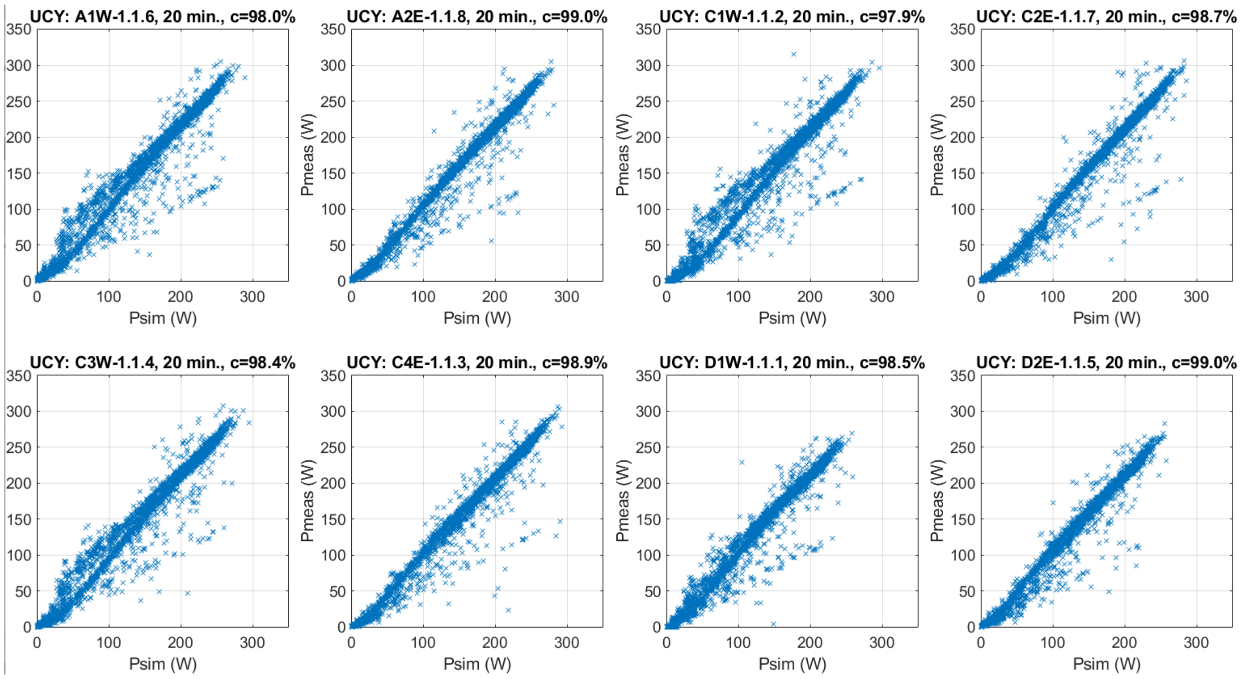


Figure 1: UCY: correlation between measured and simulated module powers.

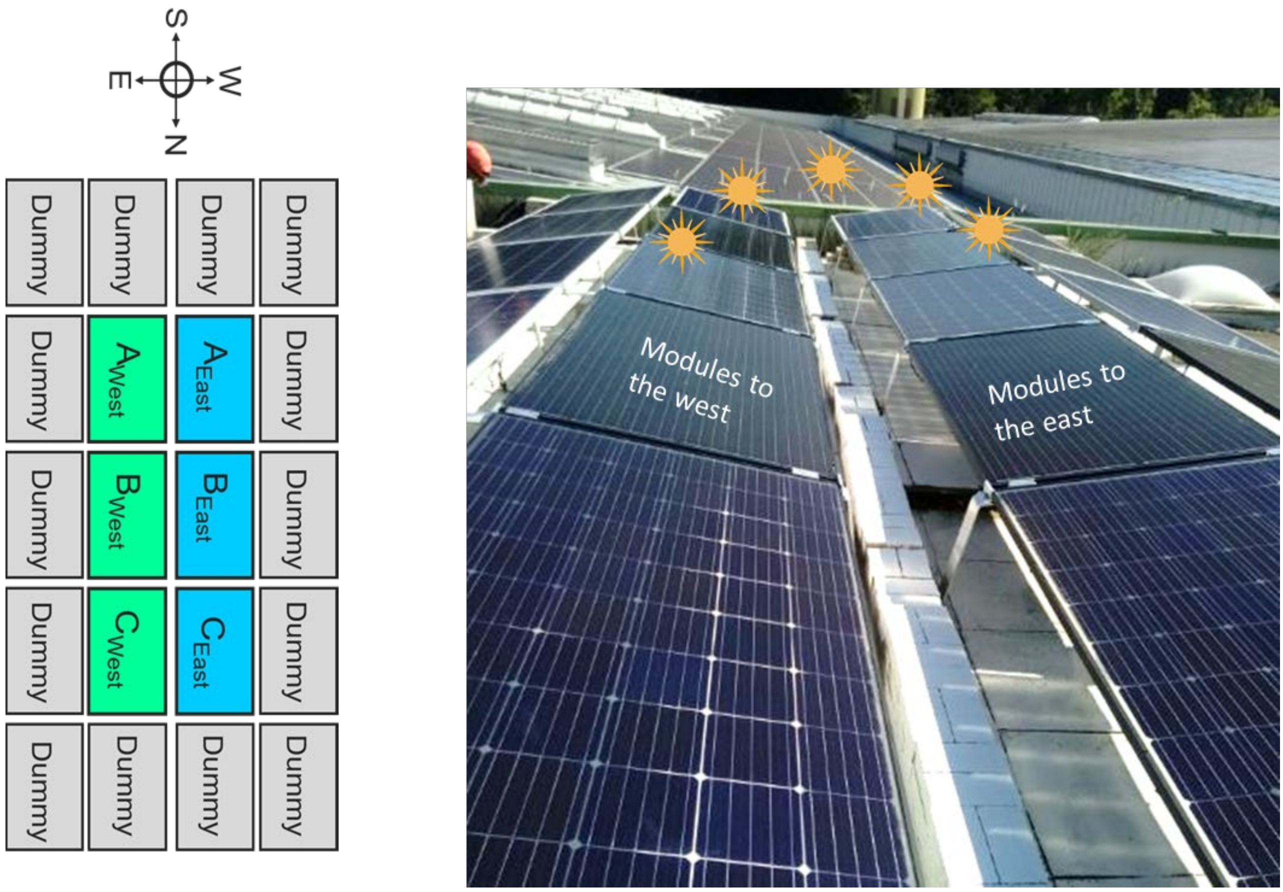


Figure 2: Monitoring site in Austria, with 3 different types of modules

**Project consortium**

Coordinator and all contact details:

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|---|---|
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Participating countries and financing:

| **Country** | **Number of organisations involved** | **Project costs in EUR** | **Public funding in EUR** |
|---|---|---|---|
| Austria | 3 | 582'424 | 465'588 |
| The Netherlands | 3 | 568'946 | 374'255 |
| *Total* | *6* | *1'151'370* | *839'843* |

**Funding agencies involved and contracts**

| **Funding Agency** | **Contract N° and Title** |
|---|---|
| FFG | Förderungsvertrag, Projektnummer: 863515 |
| RVO | Besluit tot verlening subsidie<br>Kenmerk:SOL17BUKZU |

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