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Next – generation interdigitated back-contacted silicon heterojunction solar cells and modules by design and process innovations

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D8.4: Yearly energy yield estimation of IBC-SHJ-based full-size PV modules in both mono-and bi-facial configurations

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Publishable summary

Society faces an enormous challenge supplying sustainable energy. Installing large PV installation in Mediterranean areas, MENA and Northern -Africa, provides an interesting opportunity to tackle this ever-growing challenge thanks to the high irradiance and abundance of land. However, PV modules face various difficulties when installed in the harsh desert conditions or at tropical climates. Amongst dust accumulation, moisture ingress, and other effects, PV module temperature strongly affects the operation of PV systems. The temperature effects influence the PV module reliability and strongly reduce the energy product due to a reduced conversion efficiency.

In case of silicon-based PV modules, in origin of the reduced conversion efficiency is band gap narrowing as a result of the elevate operating temperate. This effect, however, depends on the conversion efficiency, hence the solar cell technology used for the PV modules. In general, one can state that there is an inversely proportional relation between the conversion efficiency and the temperature dependence of the same value. Hence, high-efficiency solar cells are more suitable for installation in above mentioned regions as their efficiency drops less at elevated operation temperature and less sunlight is converted into heat.

A cell technology that is known for his high conversion efficiency and thus also low temperature dependency, are the heterojunction solar cells. Especially, newly developed Interdigitated Back-Contacted Silicon Heterojunction (IBC-SHJ) PV modules are very attractive for installation in hot climates.

First the energy yield for PV modules in mono-facial configuration was calculated by the energy yield calculation framework developed at imec. Note that the optical properties were kept constant for the all the simulation cases. This means that we simulated the performance of a glass-glass module but neglected for the first analysis the light coming at the rear of the module. As final step in the process, energy yield was calculated by dividing the annual energy production by the power rating at STC. The results are shown in **Error! Reference source not found.**.

Simulations showed that the SHJ-IBC module produces 1534 kWh/kWp for the tested location for optimal inclination and orientation. Compering this result to the other technologies, the SHJ-IBC technology is the best performing module. Results indicate that this technology will produce up to 2.3% more energy compared to the full Al-BSF solar cells. As we investigated the energy yield of each technology, the improvement is mainly thanks to the lower temperature coefficient of the developed solar cell. There is also a slight improvement in performance as less heat is generated in the cell since more electrical energy is extracted thanks to the improved efficiency, however, solar cell temperature analyses showed that this only a minor effect compared to the contribution of the lower temperature coefficient.

As mentioned above, we calculated the energy yield of each solar cell technology by dividing the annual energy production of the module by its rated power. Obviously, the 60 cell PV module with SHJ-IBC cells produced more energy per module unit that the full Al-BSF PV module, but by rating it to STC power, the difference becomes smaller.

Next to the PV energy yield in case of a mono-facial setting, also bifacial module configuration was also simulated. As mentioned in the introduction, during the compilation of the weather dataset, we assumed an albedo ground reflection value of 0.3. Furthermore, a 90% bifaciality was implemented for the simulation based on indoor measurement data. The effect of the cell bifaciality will be discussed later in this section.

The bifaciality was considered by adding the rear-side irradiance, multiplied with the bifaciality factor of the PV module, to the front site irradiance. Hence, no correction for optical, thermal or electrical element was added to the PV energy yield model, only the irradiance was increased. This is certainly a correct assumption for the thermal and optical part as there no significant variations are expected. For the electrical simulation part, there is a discussion ongoing in literature about the most accurate method to simulate bifacial solar cells. However, there is (not) yet consensus amounts researcher and no significant improvement has been shown for other simulation methods (especially for solar cells with bifaciality values approaching one) , hence we are also using the normal single diode model for the electrical modelling part. The PV energy yield results are also shown in Fig. 1.

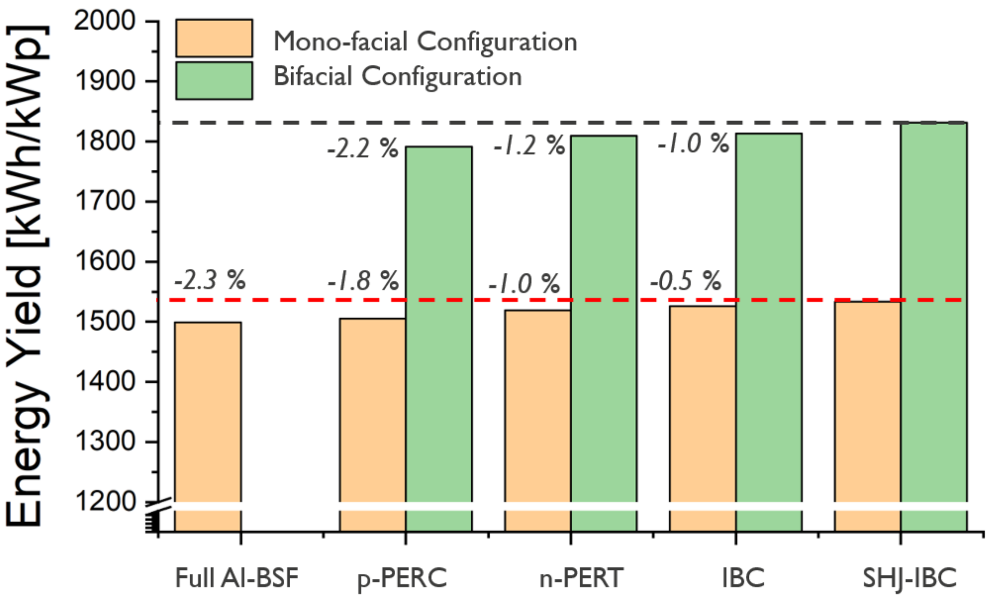

Fig.1: Annual energy yield for the different PV module technologies. Both mono-facial and bifacial configuration were tested.

For the bifacial configuration, the PV module with SHJ-IBC cells was again the best performing of all modules showing an annual energy yield of 1831 kWh/kWp (rated according to front-side STC). The bifacial energy gain for this case was 19% compared to the mono-facial case. As mentioned above, this simulation assumed uniform rear side irradiance and a free-standing PV module, hence, the actual outdoor energy yield will be slightly lower due to e.g. frame and interrow shading and due to the fact that the bottom part of the module is closer to the ground. For the bifacial case, the difference observed between the best performing (SHJ-IBC technology) and the worst performing (PERC, as full

Al-BSF does not allow any bifaciality) was -2.2 %. This difference is bigger compared to the mono-facial configuration. This can be explained as more light reaches the cell, resulting in a higher heat generation in the solar cell followed by an increased solar cell temperature. As the SHJ-IBC module performance is less sensitive to higher operating temperature, this technology showcased the highest annual energy yield.

Also in this case, the improvement in energy yield originate mostly from the reduced temperature sensitivity of the SHJ-IBC solar cell. For the climate discussed in this study, this technology was already producing +2.2% more energy per rated power than PV modules with p-PERC cells. The gains will be even higher for hotter climates with better reflective conditions like the MENA region. Previous studies showed gains up to +1.6% by comparing the n-PERT cell to the full Al-BSF technology in a monofacial configuration (see in [1]). Following that trend, one can expect +3% yield improvement for SHJ-IBC cells compared to PERC cells. Obviously, further research is required to confirm this, however, this indicates that the developed cell technology is extremely suitable for hot, high-irradiance conditions.