Applied Photovoltaic Research
Swiss Solar Competence

Highest energy yields per area for PV systems on flat roofs

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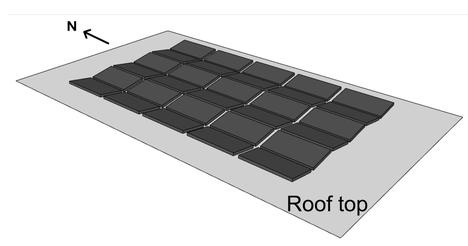
Motivation and objectives

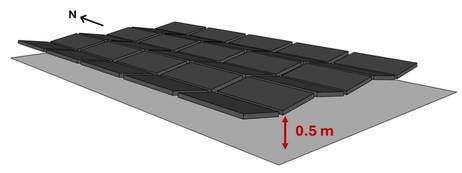
- Swiss potential for PV energy on flat roofs ~15 TWh/a [1]
- Maximizing the annual energy yield per roof area helps to realise the potential
- In the medium term, the use of cost-effective electricity storage systems could shift the focus in system design back to maximising the annual amount, even with hourly time-dependent feed-in tariffs
- The aim is to optimise the PV system economically with low module costs, high installation costs and taking into account the limited space available.

Approaches

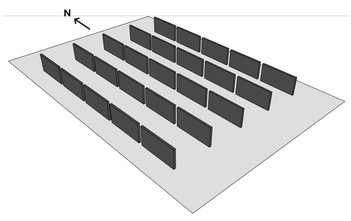
Reference
East/West orientation, tilt angle 10°
monofacial, height 0m
Ground cover ratio GCR = 100%
(without space for maintenance)



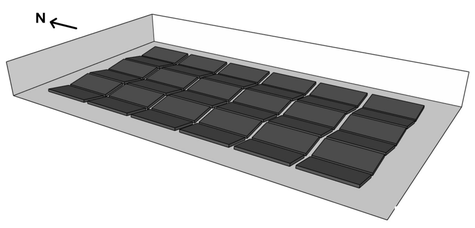
Bifacial east/west
tilt angle 10° , bifacial, height ~0.5 m
Ground cover ratio GCR = 100%,
Utilisation of light from peripheral areas



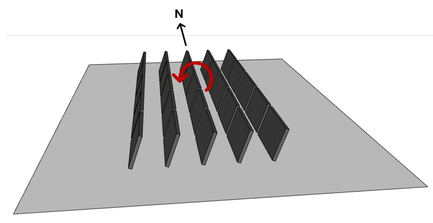
Vertical bifacial
East/West orientation, **bifacial**
Ground cover ratio GCR = 90-100%
With/without ground sculptures



Dynamic Reflectors
Reflective building elements or reflectors outside collector field
Depending on the weather conditions, the reflector extends with the aid of a motor.
=> Increase of irradiation on the module surfaces depending on the size of the module field and the reflector



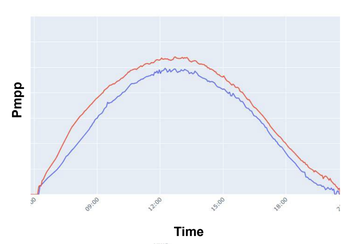
HSAT with backtracking
Horizontal axis tracking, East/West orientation, tilt angle range 5° , bifacial, elevation 0.5m
Ground cover ratio GCR = 90-100%

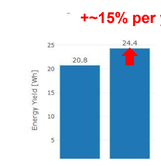


Results

Bifacial east/west

- Measured +15% yield gain compared to “Reference”
- Bifacial gain depends strongly on albedo and dimension of the collector field
- Energy yield simulations reveal only a yearly yield gain of 3.4%



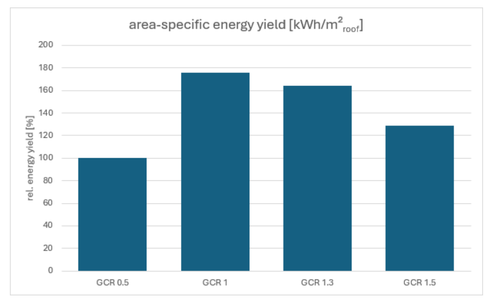


Energy yield/year
Left: “Reference”,
Right: bifacial

Power of “Reference” blue compared to system with bifacial modules in red

Vertical bifacial

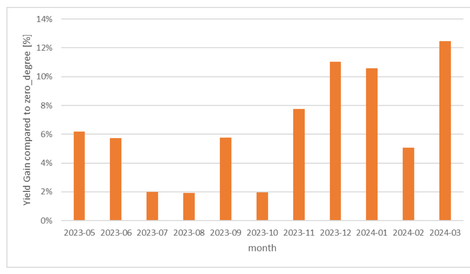
- No gain compared to Reference even with ground sculptures
- Grid-compatible power generation profile
- Maximum GCR 100% for highest area specific yield
- Interesting applications: PV&green roof and alpine regions



Area specific yearly energy yield of east/west-orientated vertically installed bifacial modules as a function of GCR

HSAT with backtracking

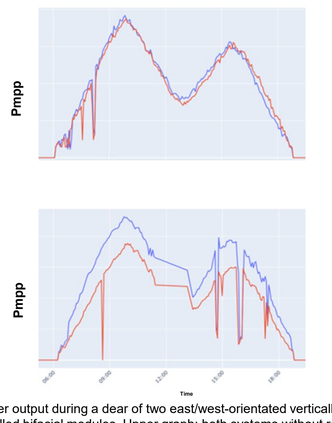
- ~5% yield gain compared to Reference through tracking only
- Bifacial gain outweights the gain from tracking
- Highest energy yield per area in combination with bifacial modules
- Not economically interesting on the Swiss Plateau
- Niche applications: PV&green roof and alpine regions



Monthly yield gain in percent compared to horizonal position (Reference)

Dynamic Reflectors

- Substantial yield gain depending on the size of the reflector and the dimension of the collector field.
- Daily gains of up to 30% measured
- Perhaps of practical interest as a retrofit kit
- Economic feasibility must be proven



Power output during a dear of two east/west-orientated vertically installed bifacial modules. Upper graph: both systems without reflector Lower graph: in blue with reflector, in red without reflector

Conclusions and Outlook

- Depending on the albedo of the roof and the dimensions of the collector field, energy yields can be increased at little extra cost compared to the reference system with bifacial modules mounted higher up. The yield gain is strongly depending on the size of the collector field and the albedo of the roof
- Vertically mounted bifacial modules are not suitable for increasing the energy yield per area. Due to their generation profile, their snow-free properties and the good accessibility in between rows, they have advantages when used in combination with green roofs or in alpine regions.
- Horizontally single-axis tracked modules can achieve a higher yield compared to the reference, but do not promise any economic advantage with small row spacing. Niche applications could be found in combination with green roofs or in alpine areas.
- Reflectors at the edge of the collector array can significantly increase the irradiation on the collector array and thus the energy yield. Yearly energy yield gains requires longer measurements on a practical scale. The economic viability of such systems, for example as retrofit kits, has yet to be analysed.

Acknowledgement

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[1] D. Anderegg, S. Strebel, und J. Rohrer, „Photovoltaik Potenzial auf Dachflächen in der Schweiz“, ZHAW Zürcher Hochschule für Angewandte Wissenschaften, Juli 2022. doi: 10.21256/zhaw-2425.
[2] H. Nussbaumer, R. Hiltebrand, S. Pfyffer, L. Tulinski, J. Preisig, und M. Klenk, „Highest Energy Yields per Area for PV Systems on Flat Roofs“, 41st Eur. Photovolt. Sol. Energy Conf. Exhib., S. 020459-001-020459–005, 2024, doi: 10.4229/EUPVSEC2024/4DV.4.10