University of Stuttgart
IER Institute of Energy Economics and Rational Energy Use

Contact
Dimitrij Chudinzow, M. Sc.
Institute for Energy Economics and Rational Energy Use (IER), University of Stuttgart
Heßbrühlstraße 49a, 70565 Stuttgart, Germany
Phone: +49 711 685 87870 E-Mail: dimitrij.chudinzow@ier.uni-stuttgart.de

Dimitrij Chudinzow
Joshua Güsewell
Sylvio Nagel
Dr. Ludger Eltrop

Vertical bifacial PV

A complementary technology for European electricity markets?

Background

East-west oriented vertical bifacial PV power plants (VBPV) have a diurnal generation profile with two peaks: One peak in the morning and one in the afternoon. Such a profile may be advantageous from a business perspective, since it may increase revenues at electricity markets. Also, from an electricity system perspective, VBPV could lead to overall system costs' savings.

Research questions from a...

Business perspective

1. Which benefits offers VBPV in terms of the electricity production and revenues as compared to south-oriented monofacial PV (Conventional PV, C-PV)?
2. How big is the location's impact?

Electricity system perspective

3. Does VBPV's unique generation profile allow to reduce overall system costs of the German electricity system?

Methodology

- 12 investigated locations; electricity production of VBPV and C-PV simulated according to [1]. The bifaciality ($\eta_{PV,\,rear}/\eta_{PV,\,front}$) has been set to 85%.
- For analysing the revenues, the metric „value factor" (VF) was used: $VF = Specific\ revenues\ [\frac{€}{MWh}] / Average\ spot\ price\ [\frac{€}{MWh}]$
- For analysing VBPV's impact on Germany's electricity system, the linear optimization model „E2M2" was used, following a „greenfield" approach [2]. The objective function was to minimize overall system costs, while achieving given targets of renewably generated electricity (RE) and CO_2 reduction as compared to 1990. In all scenarios, the ratio of investment costs for VBPV and C-PV was varied.

Results for the business perspective

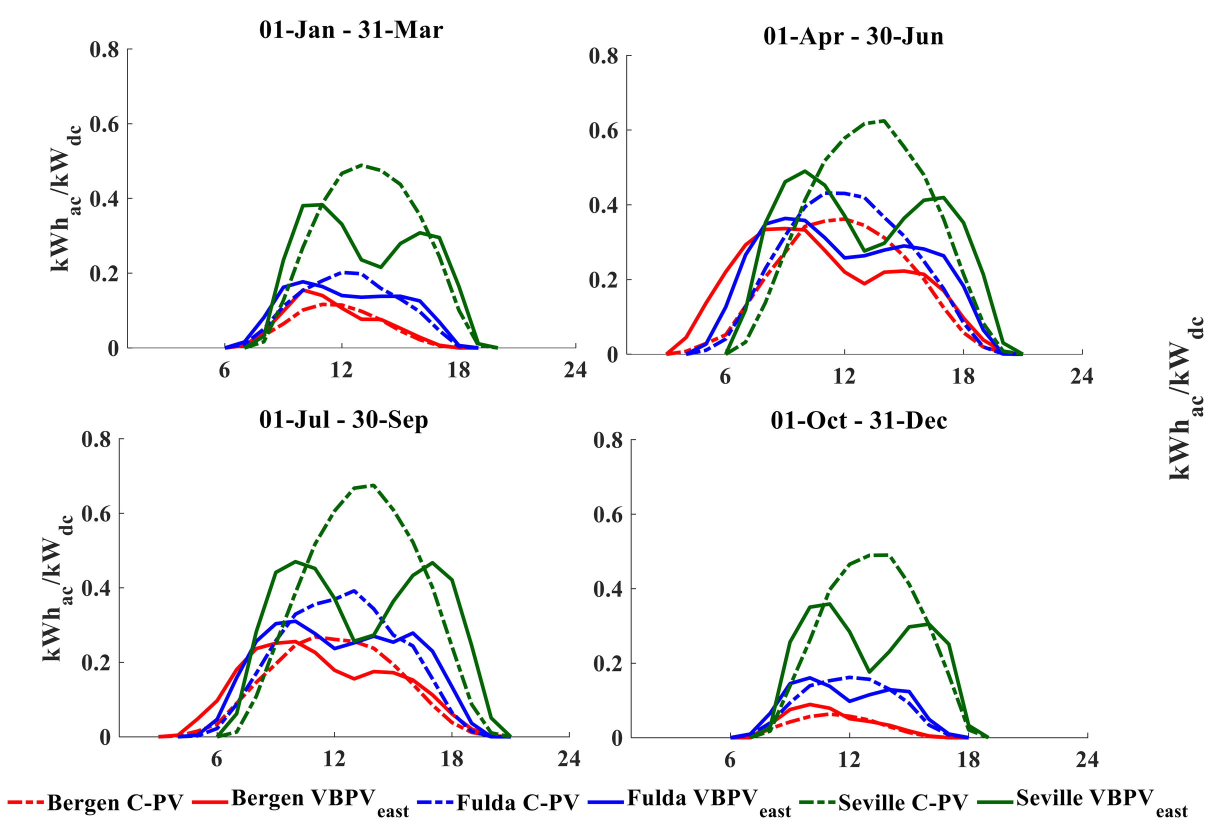

Figure 1
Hourly averaged specific electricity production of four quarters of a year for the northernmost investigated location Bergen, central location Fulda and southernmost location Seville. The index (east/west) indicates the configuration of VBPV (e.g. „$VBPV_{east}$": the more efficient front side is facing east).

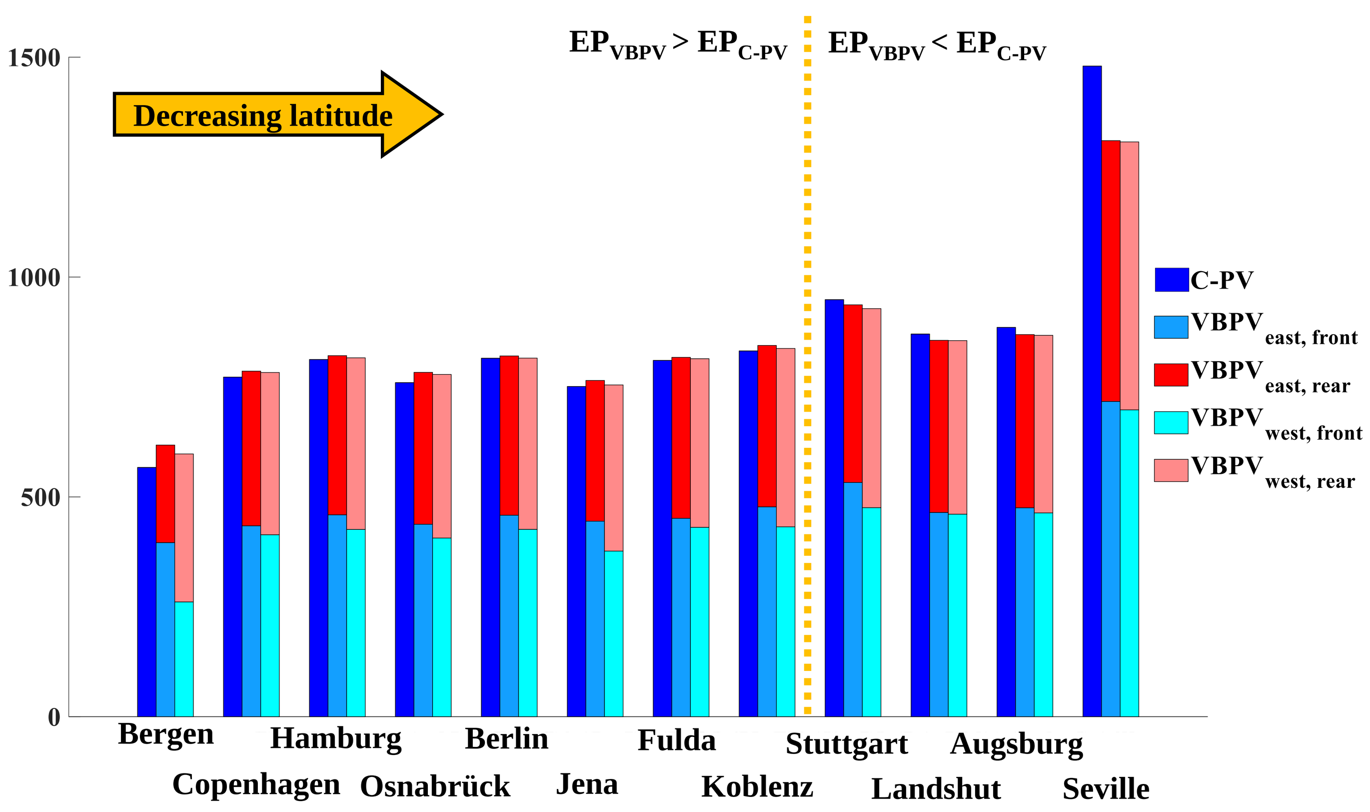

Figure 2
Simulated electricity production (EP) in investigated locations. Starting with the northernmost location Bergen, VBPV generates more electricity until reaching Stuttgart. From there, C-PV generates more electricity than VBPV.

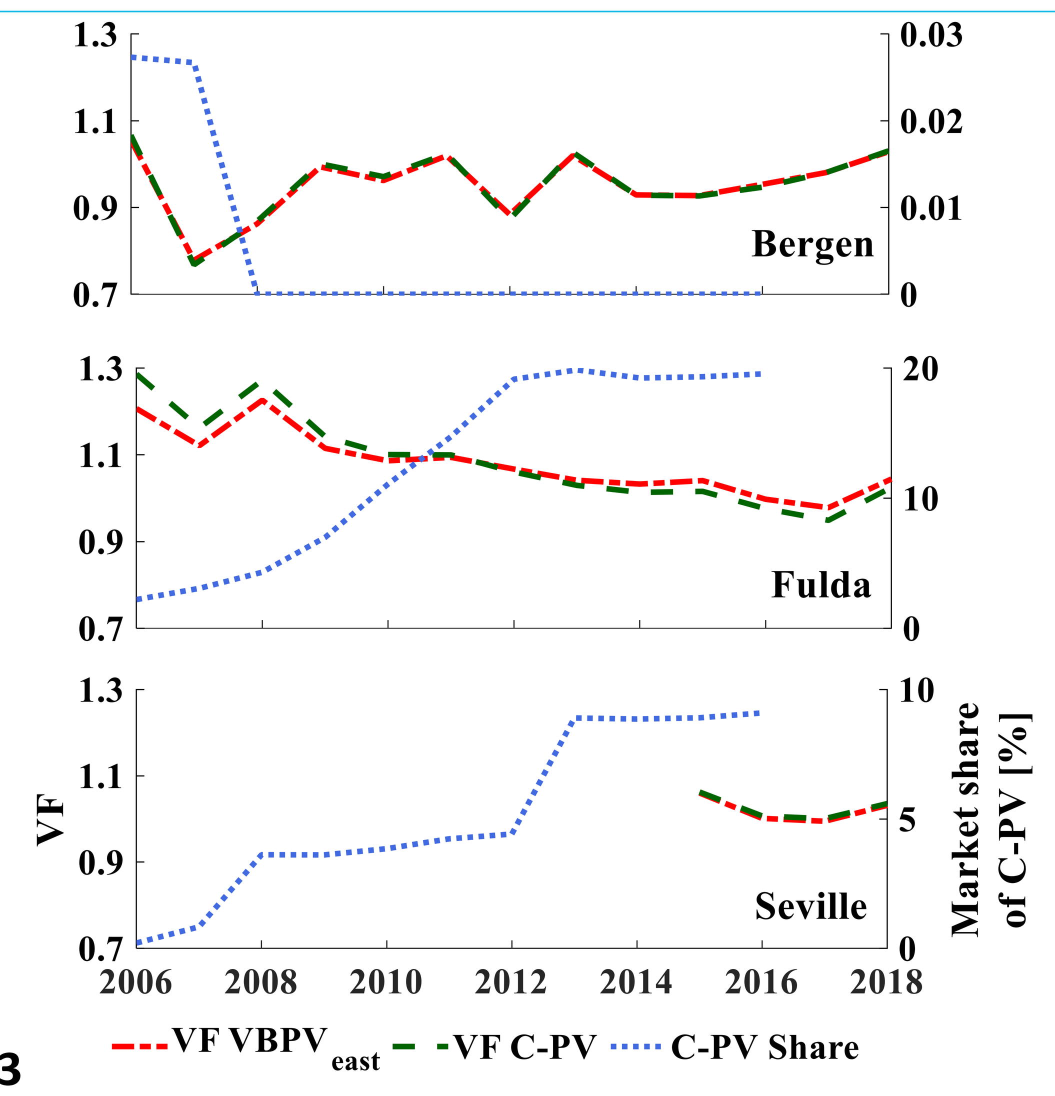

Figure 3
Calculated value factors (VF), based on historical market data. Since Norway's electricity system has almost no PV, the VF of VBPV and C-PV are roughly equal. In contrast, as Germany's PV share rose from 2011, VF_{VBPV} was always higher than $VF_{C\text{-}PV}$. In Spain, the VFs for both technologies are roughly the same.

Results for the electricity system perspective with Germany as a case study

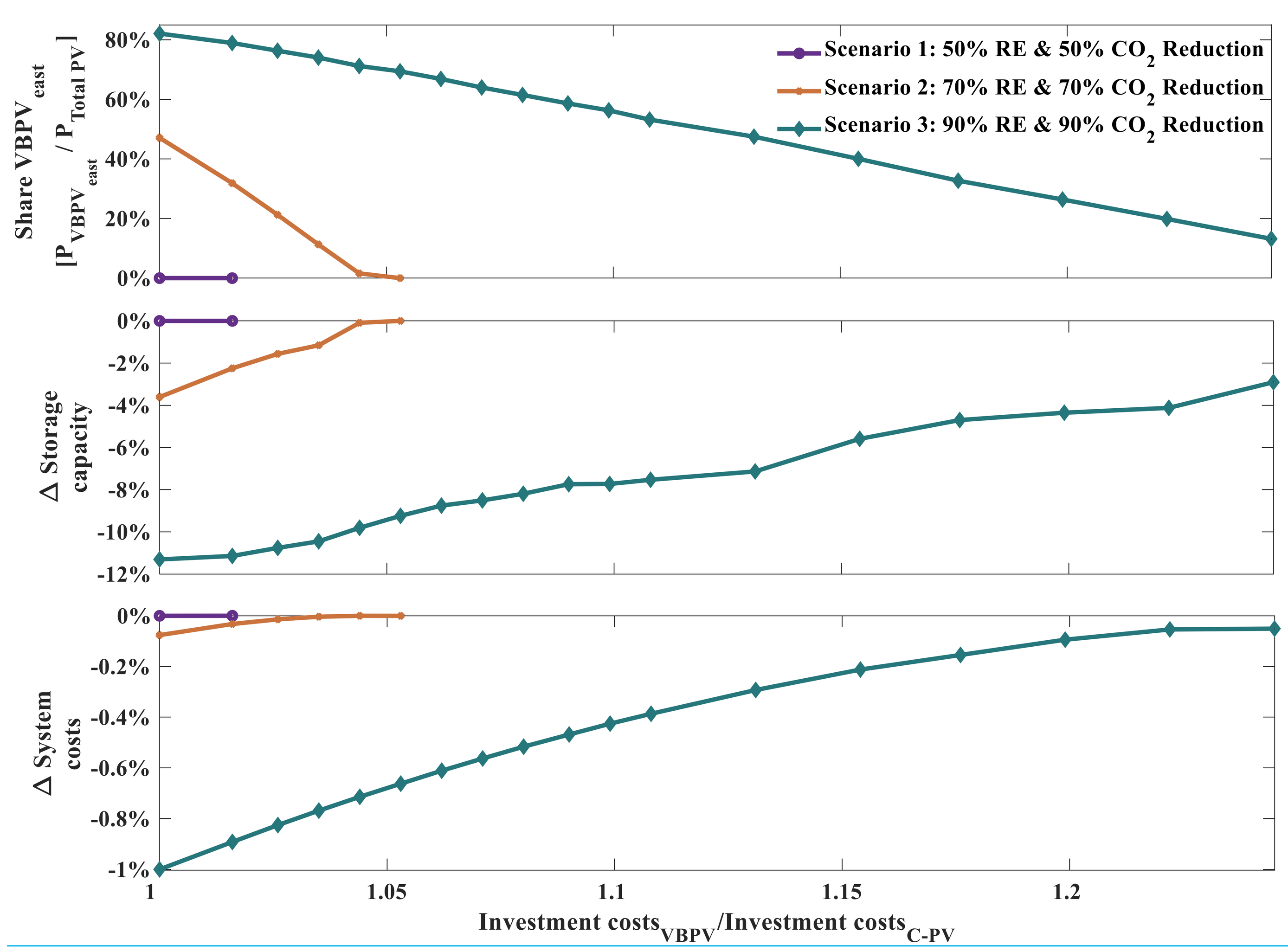

Figure 4a - Share of installed VBPV and total PV capacity
Stricter RE generation & CO_2 reduction targets lead to more installed VBPV capacity. In the first scenario, no VBPV is build at all, while in the third scenario VBPV is build for all analysed investment costs' ratios. When the investment costs for VBPV become more expensive as compared to C-PV, VBPV's share in total installed PV capacity decreases.

Figure 4b – Change in storage capacity as compared to a system without VBPV
Stricter RE generation & CO_2 reduction targets lead to less required storage capacity. The lower the investment costs' ratio for VBPV, i.e., the more VBPV is built, the less storage capacity is needed.

Figure 4c – Change in system costs as compared to a system without VBPV
Stricter RE generation & CO_2 reduction targets lead to more system costs savings. The lower the investment costs for VBPV, the higher the savings are. The more ambitious the targets are, the more important is VBPV's role in a cost-minimal electricity system.

Conclusions...

For the business perspective

1. Among the investigated locations, VBPV generated always more electricity than C-PV at higher latitudes (>50°N).
2. In Germany, whose electricity system is characterized by high shares of C-PV capacity, VBPV allows to generate higher specific revenues at electricity markets since 2011.

For the electricity system perspective

1. For the case of the German electricity system: when high shares of renewably generated electricity (RE) and high CO_2 reduction targets are to be achieved, VBPV plays a major role at equal investment costs in the two most ambitious scenarios.
2. At equal investment costs and in the most ambitious scenario, the use of VBPV reduces required storage capacity by >10% and overall system costs by 1% as compared to a system without the possibility to use VBPV.

Yes, VBPV is a complementary technology for European electricity markets with high shares of PV, because when comparing to C-PV

1. **it offers higher electricity generation at higher latitudes (>50°N) and higher value factors in the investigated German locations,**
2. **depending on the scenario, VBPV can reduce the required storage capacity and overall system costs in the German electricity system.**

References

[1] Chudinzow, Dimitrij; Haas, Jannik; Díaz-Ferrán, Gustavo; Moreno-Leiva, Simón; Eltrop, Ludger (2019): Simulating the energy yield of a bifacial photovoltaic power plant. In: Solar Energy 183, S. 812–822. DOI: 10.1016/j.solener.2019.03.071.
[2] Sun, Ninghong (2013): Modellgestützte Untersuchung des Elektrizitätsmaktes. Kraftwerkseinsatzplanung und -investitionen. Dissertation (PhD thesis). Universität Stuttgart, Stuttgart. Institut für Energiewirtschaft und Rationelle Energieanwendung.