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BOTTOM-UP GIS POTENTIAL ANALYSIS, GRID INTEGRATION IMPACTS, AND SUSTAINABILITY ASSESSMENT OF VERTICAL BIFACIAL AGRI-PHOTOVOL-TAICS

Master-Thesis at the Renewable Energies and Energy Efficiency Study Program and the Section of Agricultural and Biosystems Engineering

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Abstract

Preventing the climate catastrophe and the associated limitation of global warming to well be-low 2 °C in accordance with the Paris Climate Agreement requires a scaling of the current German ground-mounted photovoltaic system capacity by a factor of eleven to 150 GWp (Fraunhofer IEE, 2020; Luderer et al., 2021; Prognos et al., 2021; Sterchele et al., 2020). In order to make this massive expansion sustainable for society as a whole, an immense in-crease in the demand for so-called land-neutral photovoltaic technologies is expected in order to mitigate emerging land use conflicts. Agricultural dual landuse in the form of agriphotovoltaics shows the greatest potential (Wirth & Fraunhofer ISE, 2021). However, despite the great need, the expansion of ground-mounted photovoltaics lacks social acceptance, so that since then the expansion of PV-FFA has been significantly lower compared to rooftop photovoltaics. Based on this, the question of the fundamental necessity and intensity of the general ground-mounted photovoltaic expansion was discussed and answered in this study. Additionally synergy potentials of APV were identified. It was shown that an installed capacity of ground-mounted photovoltaics of at least 68 GWp is necessary to achieve climate neutrality in time. Furthermore, it was worked out that due to global and national food security as well as considering the necessary transformation of the agricultural sector, the reduction of agricultural land losses should be in the focus of renewable expansion. It could be shown that the vertical bifacial as well as the classical high elevated APV concept have the significantly lowest land losses on agricultural land with only about 7 %. In this context, the former achieves energy-specific land losses of about 2.9 m²/MWh, which is about 71 % less than classical ground-mounted pv. In addition, vertical APV has the highest light availability (85 %) and homogeneity on the agricultural land, which makes the system particularly suitable for use with standard crops in cold temperate climates. In terms of eco-nomic efficiency, the vertical APV showed significant advantages over the high stand elevated concept (8.58 ct/kWh) with an average LCOE of 6.2 ct/kWh. In addition, economic competitiveness with the classical PV FFA concept (5.76 ct/kWh) was demonstrated. With the help of the bottom-up GIS potential analysis carried out for

the state of Hessen, a sustainable potential area for vertical APV of 90,400 ha (27.7 GWp) was identified. In a nation-wide context, this would correspond to an extrapolated installable capacity of about 595 GWp. Within the framework of the grid analysis at the national level, it was shown that the expansion of vertical APV contributes to significant improvements, especially with regard to the reduction of residual load peaks and residual load gradients in orders of magnitude between 5 and 15 %. In addition, a dynamic grid simulation at the medium-voltage level resulted in significantly lower maximum loads on the network resources. Lines and transformers could be relieved by an average of 4.5 and 8.5 %, respectively. The maximum power fed back into the transmission grid was reduced by an average of 14.2 %.