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Analysis of socioeconomic determinants of implementing Photovoltaics into island electricity systems

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I. Introduction and Research Objectives

Islands are typical mini-grids by geographic isolation. On a global scale, the vast majority of small islands rely on diesel power plants for their electricity supply [1]. These islands are characterized by high energy costs, caused by increasing fuel prices, high transportation costs and limited scaling effects, as well as by high specific greenhouse gas emissions. At the same time many islands have promising natural conditions to use solar energy for power generation. The integration of photovoltaic (PV) power capacity on these islands can reduce energy costs and environmental impact. Though the integration of high shares of PV into island grids is often economically viable, some decision makers still hesitate to switch to PV [2], while the installed PV capacity continuously increases on other islands [3]. To understand the different levels of implementation, it is important to analyze different socioeconomic factors of these islands. The main purpose of this paper is to identify main drivers and to show their importance. Additionally a global market potential is derived. Islands with the most attractive investment conditions can be determined in a next step.

II. Approach & Methods

Within this work, the relation between the percent installed PV power plant capacity in relation to the total installed power capacity and selected socioeconomic and natural factors is analyzed for 63 autonomous and semi-autonomous island regions with dominating island grid characteristics. The sample has been defined by the absence of large coal and nuclear power plants and a maximum population size of three million on any island. Additionally, extremely discordant cases are filtered (> factor 3 of standard deviation). A simple linear regression analysis is used to determine possible relevant socioeconomic determinants for the share of installed PV capacity. Data for the dependent variable of installed PV capacity in relation to total power plant capacity are based on the UDI World Electric Power Plants data base [1], which is extended and updated for the emerging wind [4] and PV capacity [2]. For the identification of the socioeconomic independent variables, high emphasis has been put on the global availability of statistics. The following socioeconomic, natural and demographic variables are researched: GDP per capita, population density [5], energy vision, regulatory framework [6], utility ownership, market structure [7] and population weighted irradiation [8]. Furthermore the global market potential for small island grids is identified via GIS analysis, first locating global islands with a significant size of >0.0238 km² and combining them with a population density raster from 2000 [9].

III. Results

Tab. 1 shows the results of the simple regression analysis, comparing the correlation coefficient r and the coefficient of determination r^2 for the relation of the aforementioned determinants to the share of installed PV capacity. The indicators with the highest explained variation (r^2) are socioeconomic values: regulatory framework (0.07) and GDP/capita (0.06). The existence of a feed-in tariff (FIT) or increasing wealth of a region potentially enlarges the percent installed PV capacity. The existence of an energy vision, market structure (monopoly/ market) and utility ownership (public/ private) seem to have no or little influence on the success of PV implementation. In addition the analysis reveals that the success of increasing PV share in small island grids is not dependent on natural conditions, i.e. incoming global radiation, or population density, which is used to represent the influence of land shortage for free field PV power plants. The concurrent GIS analysis shows an enormous amount of small offshore islands, which can be considered as promising market area for PV (see Tab. 2). Globally, 26,213 of more than 80,000 islands of relevant size are inhabited (32 %) with a population of 666 million. Islands with up to 100,000 inhabitants can be considered as mini-grids, which are especially interesting for the implementation of PV and other renewable energies. The GIS analysis reveals an overall market potential of 26,027 islands with less than 100,000 inhabitants, accumulating to 30.5 million inhabitants (4.6 % of global island population).

IV. CONCLUSION

The analysis underlines the hypothesis that socioeconomic factors such as an existing regulatory framework and high GDP determine to a significant degree the success of PV system integration in small island grids. This leads to the conclusion that a stable renewable energy friendly regulatory framework attracts investments in large-scale PV capacities. Data indicate that low GDP has the potential to block investments in large-scale PV capacities. According to the results investors should focus on countries with existent FITs and high GDP. However, the importance of FITs is expected to decline, as an increasing number of islands are reaching grid parity. Hence, data depicts especially past determinants of PV implementation. The current huge dynamics in PV technology and capacity adding has to be covered by further research. Even though the solar irradiation shows no direct correlation with the share of installed PV, most of the islands with PV have an annual irradiation higher than 2,000 kWh/(m^2*year). This seems to be a well enough condition for the implementation of PV. Overcoming socioeconomic barriers for PV implementation can contribute tapping the huge market potential of small island grids for PV capacity integration. Meanwhile, the analysis of socioeconomic factors can help increasing the success rate of PV system implementation attempts by identifying islands with high irradiation and supporting socioeconomic factors. Developing a multivariate statistical regression accompanied by including more factors in the model can help validating the key findings of this paper. A market analysis based on these determinants enables investors to identify most promising investment regions and helps governments to create attractive investment conditions. Globally, 1/3 of the global islands are inhabited and hence can be considered as potential markets for PV capacity adding. Islands with less than 100,000 inhabitants are numerous and possess a huge market potential of up to 30 million inhabitants. Most of them live on few islands with 10,000 - 100,000 inhabitants, while a small fraction is living very scattered on more than 20,000 islands. These island characteristics illustrate the different markets ranging from extreme micro-grids over mini-grids up to larger grid entities.

	Installed PV capacity in relation to total electricity generation capacity	
Factors	Correlation, r	Coefficient of determination, r²
Regulatory framework	0.26	0.07
GDP/capita	-0.25	0.06
Energy vision	-0.13	0.02
Market structure	-0.08	0.01
Utility ownership	-0.07	0.00
Population density	-0.03	0.00
Pop. weighted irradiation	0.01	0.00

Table 1: Results of simple regression analysis

Population size class	Islands	Inhabitants
<1	54,614	0
1-100	18,154	352,866
100-1,000	4,944	1,716,699
1,000-10,000	2,233	7,326,098
10,000-100,000	696	21,130,544
100,000-1,000,000	140	39,899,243
1,000,000-10,000,000	32	95,787,982
>10,000,000	14	499,424,286
Total	80,827	665,637,719

Table 2: Number of islands and total inhabitants of islands worldwide, representing the maximum market potential for renewable energy supply on small islands; listed by population size class

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