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Welcome to Singapore

We are pleased to welcome you to Singapore as a participant participate at the 40th Annual IAEE International Conference, organised by the Energy Studies Institute (ESI) of the National University of Singapore.

Singapore's name is derived from 'Singa Pura' which means Lion City in Sanskrit. According to legend, a 13th century prince, Sang Nila Utama, was shipwrecked on the island and saw a creature that he thought was a lion, so he named the island accordingly. Lions have never existed in Singapore (with the exception of the zoo).

The origins of modern Singapore are generally traced back to 1819 when Sir Stamford Raffles purchased it as a British outpost because of its excellent harbour located on the international spice route. Five years later it became a British "possession". However, its written history dates back to the third century and it appears to have been a thriving trading post for some centuries after that.

With the advent of the steamship and the opening of the Suez Canal, in the second half of the 19th century Singapore thrived as a trading port linking Europe with the Far East. Today, it is the world's busiest trans-shipment port and the world's second busiest port in terms of total tonnage, whilst half of the world's annual seaborne movements of oil are trans-shipped through Singapore.

SHARING DECENTRALIZED PHOTOVOLTAIC SYSTEMS: TECHNICAL AND ECONOMICAL EFFECTS OF COLLABORATION CONCEPTS

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Overview

Increasing photovoltaic distribution has led to high social and economic acceptance in recent years. Decreasing costs for photovoltaic systems let it become a competitive energy source for decentralized as well as centralized use. While there may be limited space for large centralized photovoltaic systems, the potential for decentralized systems as roof- or façade integrated systems is enormous. In the last years, one can observe increasing self-consumption of photovoltaic electricity. Responsible for this trend is the increasing spread of retail electricity prices and feed-in remuneration. Therefore, the profitability of decentralized photovoltaic systems mainly depends on self consumed PV-electricity. As there are some regulatory issues which should be solved soon, it will also become more popular to install photovoltaic systems in cities and to provide the electricity produced on rooftops or fassades to the tenants of one or more buildings in the next few years. Cities are predestined for PV sharing concepts because of the small distances between neighboring houses.

This paper focuses on the techno-economic impacts of sharing photovoltaic systems throughout buildings and different load profiles in the EU28 with a time horizon until 2030. We therefore consider different scenarios of electricity tariffs and feed-in remunerations and also consider technological learning.

Methods

Based on measured data of horizontal irradiation and ambient temperature, the PV-output is calculated following the approach suggested by Huld (Huld et al., 2010). The electricity consumption of households and industries are implemented as standardized load profiles. The PV-output and the load profiles are input parameters for the linear optimization model. The optimization model, which is based on the YALMIP toolbox and the GUROBI solver, decides when to purchase electricity from the electricity grid and when to feed in the PV-surplus, depending on the (time variable) tariff and the composition of the different load profiles. The objective function of the model is to minimize the costs of electricity purchase and the calculation is conducted for different PV capacities. The potential of battery storage for sharing electricity throughout different load profiles can also be considered. The battery is modelled as lithium battery with typical parameters regarding loading gauge, efficiency and load cycles. With assumptions on the future developement of retail electricity prices, feed-in tariffs and investement costs, the internal rate of return (IRR) is calculated.

The economic calculation is done by

$$NPV = -(I_{PV}) + \sum_{t=1}^{25} \frac{C_t}{(1+IRR)^t} = 0$$

where the cash-flow (C_t) is mainly affected by self-consumption, electricity tariffs and feed-in remuneration.

The benchmark for the economic performance of the PV-Systems is the WACC (wheighted average cost of capital), which is an output from the Green-X Model. This is a well known model for the calculation of cost effective pathways of renewable generation in EU Countries and beyond (www.green-x.at) and it is used in many EU projects and is well proven. If the IRR is higher than the WACC means, that this PV system is profitable from an investors point of view. If the IRR is below the WACC, this PV system is not profitable from an economic point of view and will probably not be built except it is subsidized. This methodology is applied for two scenarios and for all scenarios it is assumed, that there are no subsidies implemented for decentralized PV systems.

Regarding electricity tariffs, we split actual retail electricity prices in the EU28 into its different parts like “Energy Price and Supply”, “Network costs”, “VAT” and “other Taxes”. We then vary in one scenario the share of fixed and capacity costs of “Network costs” to see how a cost reflective network tariff affects the profitability of decentralized PV-Systems, because only kilowatthourly based parts are responsible for cost savings due to self consumed PV-electricity. In an other scenario we replace the fixed “Energy Price and Supply” with wholesale market prices to see how this time variable component will affect the profitability of these shared PV-systems. Therefore we use the electricity price scenarios “NoPol” which calculates the wholesale electricity prices at current market designs and regulations, “Trend” scenario which considers actual discussed regulations and market designs and “Optimal” scenario, which considers optimal regulations and market function until 2030.

Results

The results in this section are based on a 5 kWp PV-system with southward orientation.
There are many advantages of collaboration for investors to share their photovoltaic systems, most important:

- Due to collaboration, there may be larger areas suitable for PV systems. As the specific investment costs decrease with the size of the PV system, the economic performance is influenced in a very positive way
- As Figure 1 points out, the collaboration of different load profiles increases the rate of self consumption significantly. Therefore also the economic performance will increase.
- PV sharing concepts can be included or extend other sharing concepts. Especially an integration in space sharing concepts like roof garden can be beneficial, where PV systems can easily be integrated

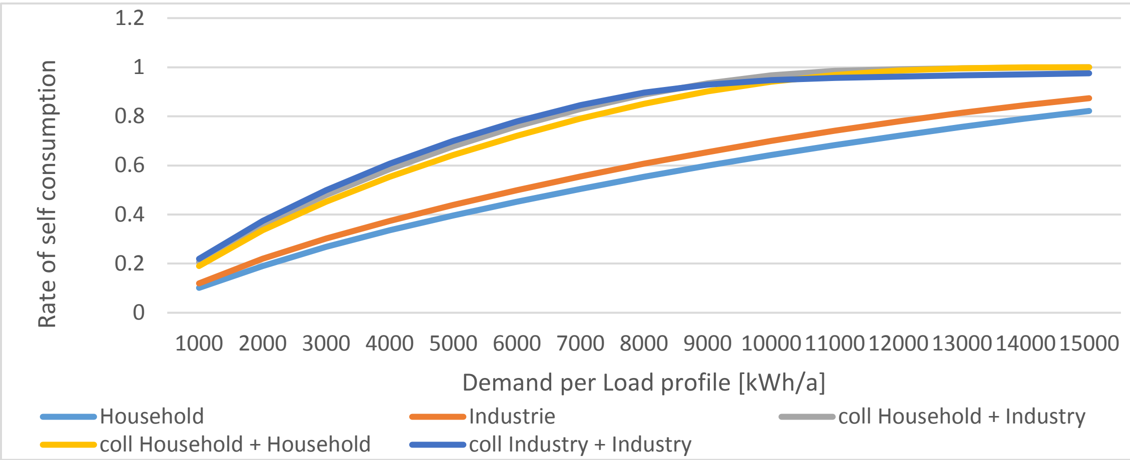

Figure 1: Self- consumption for different combinations of load profiles

When we look at the economic performance of PV systems in the EU 28, as pointed out in Figure 2, one can see, that in some countries the IRR is still negative for all electricity tariff scenarios and that the WACC is only reached

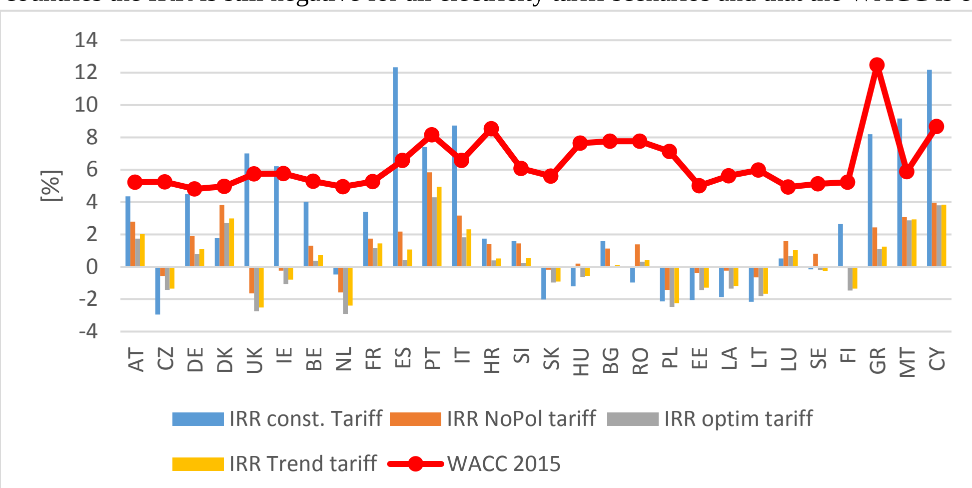

Figure 2: Economic performance of decentralized PV systems in the EU in 2015

in some countries in 2015. When we consider technological learning, then PV systems become more profitable and the WACC will be exceeded in many more countries until 2030, as we will show in the final version of the paper.

Conclusions

As shown, collaboration regarding investments in decentralized PV systems have many advantages. The economic performance is improving and the WACC as benchmark is reached earlier. Especially in cities it makes sense to share PV systems and to integrate tenants for using PV electricity on site.
As we will be shown in the final version of the paper, the influence of electricity grid designs is also significantly as the economic performance of PV systems decrease with an increase of fixed and capacity elements in the grid tariff.

References

Huld, T., Gottschalg, R., Beyer, H.G., and Topič, M. (2010). Mapping the performance of PV modules, effects of module type and data averaging. Sol. Energy *84*, 324–338.