Spatial Analysis of Residential Combined Photovoltaic and Battery Potential: Case Study Utrecht, the Netherlands

Geert Litjens *, **Bala Bhavya Kausika** *, Ernst Worrell, Wilfried van Sark
Copernicus Institute of Sustainable Development, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands
Email: G.B.M.A.Litjens@uu.nl , B.B.Kausika@uu.nl
* The first two authors contributed equally to this work

Universiteit Utrecht

Netherlands Organisation for Scientific Research

Copernicus Institute of Sustainable Development
Faculty of Geosciences
IMEW – Energy & Resources

Introduction

This study aims to **analyse and identify the spatial potential of combined PV and battery systems** at neighbourhood level. We use the city of Utrecht in the Netherlands as case study to demonstrate the methodology. PV potential, demand data and socio-economic factors like household composition and house values were used to explore the self-sufficiency rates and power flows between different neighbourhoods. Battery potential was determined for each neighbourhood using historical data on annual demand and load patterns.

Method

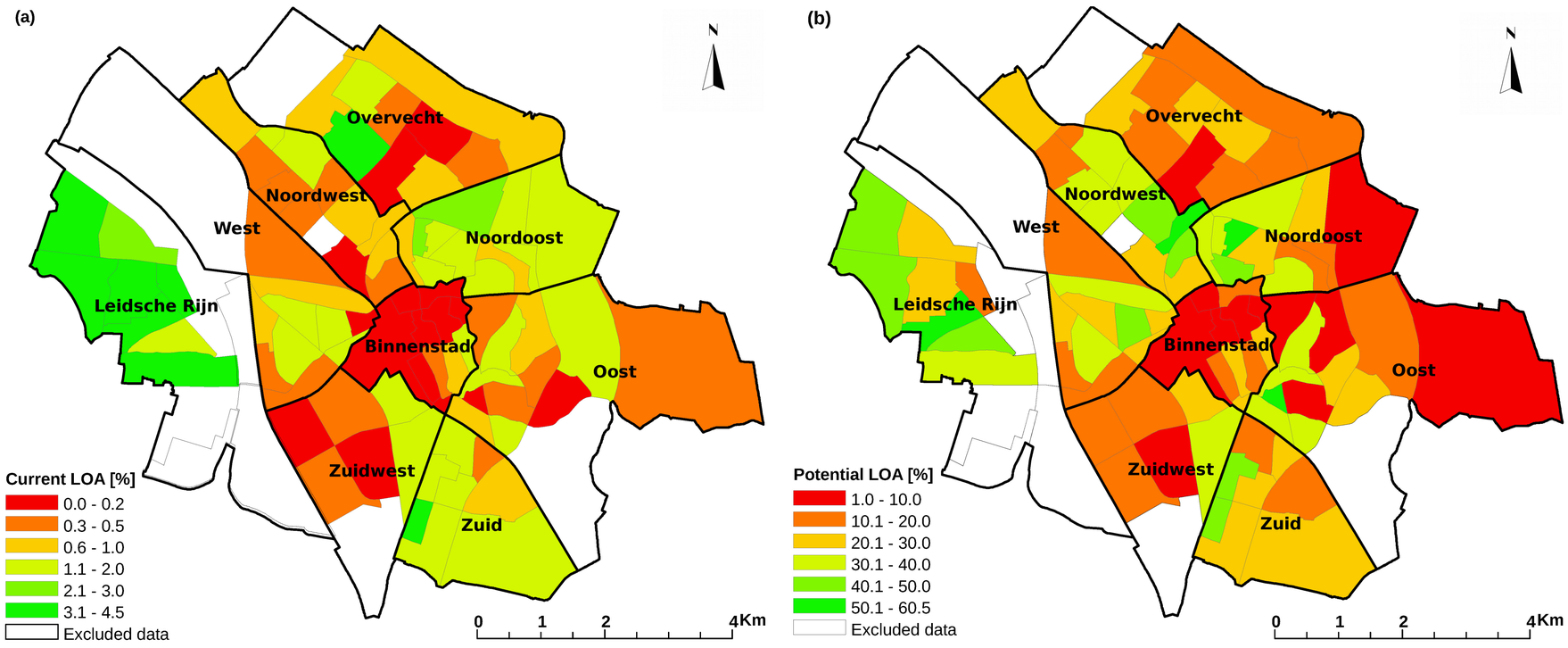
The **maximum PV capacity potential** for a total of 59,554 residential roofs was calculated using high resolution laser altimetry data [1]. **PV yield pattern** for each building was modelled using the open source package PVLIB, using local irradiation data. The PV yield patterns were aggregated to a neighbourhood level. **Residential electricity demand patterns** were taken from unique demand patterns of 60 households. The **average annual household energy demand** at postal code 6 level, coupled with the **population statistics** was used to determine demand patters for each neighbourhood.

The PV yield patterns and the demand patterns were linearly interpolated to a time interval of 5 minutes. Charging and discharging of the battery was modelled using an algorithm presented in previous research [2]. The battery state of charge range was set from 10% to 90%. Battery roundtrip efficiency of 92% and a C-rate of 0.5 was used.

Conclusions

- The final outputs show neighbourhoods which could act as potential battery sites for providing electricity to adjacent neighbourhoods.
- A large difference of current and potential level of autarky between neighbourhoods in the city Utrecht is observed.
- PV yield is currently larger in areas with relatively higher dwellings values. None of the neighbourhoods achieved a 100% level of autarky.
- High self-consumption values are indicated in most neighbourhoods, representing limited PV potential.
- The influence of the battery size shows interesting areas where self-sufficiency can be increased with relatively small battery sizes.
- The obtained knowledge is valuable for local governments and developed method can be easily adapted to other areas.

Level of autarky



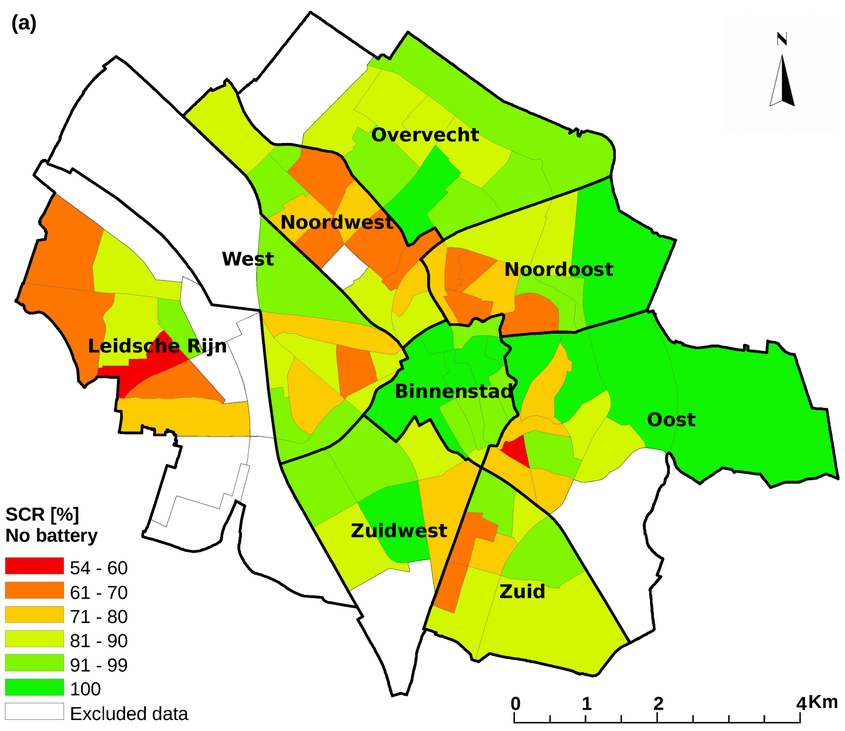
Current level of autarky **(a)** and potential level of autarky **(b)** for each neighbourhood of the city of Utrecht. The white areas are neighborhoods containing less than 100 households, and are excluded.

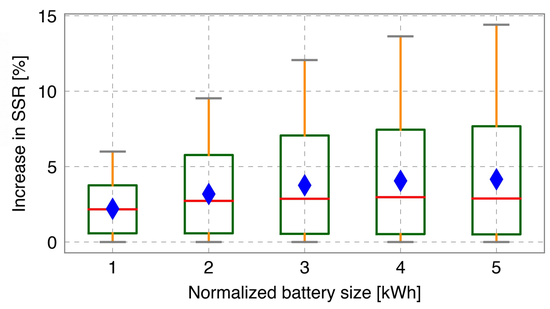
The maximum share of energy demand that can be covered with PV energy on an annual basis is defined as the level of autarky (LOA). This is the ratio between annual consumed energy and annual produced energy. It gives an indication of the maximum self-sufficiency that a neighbourhood can achieve.

The historical centre (**Binnenstad**) shows a very low level of autarky, mainly due to the large demand and the relative small PV potential. Tall residential apartment buildings are located in Overvecht, resulting in a relatively low PV potential for each resident.

On the other hand, dwellings in sub-urban areas like **Leidsche Rijn or Zuid** are one or two family terraced houses, which the roof potential could provide a substantial share of the annual energy demand. These areas also have relatively high amount of PV potential and a lower demand.

Self-consumption and self-sufficiency





Distribution of the increase in self-sufficiency for battery sizes from 1 to 5 kWh for each neighbourhood, shown using boxplots. Battery sizes were normalized with the amount of connections within a neighbourhood. Medians are indicated by the red line and means by the blue diamond.

Color-coded potential self-consumption rate (SCR) **(a)** and potential self-sufficiency rate (SSR) **(b)** for each neighborhoods of the city of Utrecht without batteries. The white areas are neighborhoods containing less than 100 households, and are excluded.

The self-consumption rate is defined as the ratio between the direct consumed electricity and the total produced electricity. The self-sufficiency rate is defined as the ratio between the direct consumed electricity and the total consumed electricity. Self-consumption rates are between 54% and 100%, indicating a wide difference between the neighbourhoods. **Noordwest** and **Leidsche Rijn** and other areas indicate low self-consumption ratios, whereas **Binnenstad, Oost** and **Overvecht** show large SCR. Self-sufficiency rates are between 1% and 35%.

[1] B. Kausika, O. Dolla, W. Folkerts, B. Siebenga, P. Hermans, and W. van Sark, "Bottom-up analysis of the solar photovoltaic potential for a city in the Netherlands - A working model for calculating the potential using high resolution LiDAR data," in 2015 International Conference on Smart Cities and Green ICT Systems (SMARTGREENS), May 2015, pp. 1–7.
[2] G. Litjens, W. van Sark, and E. Worrell, "On the influence of electricity demand patterns, battery storage and PV system design on PV self-consumption and grid interaction," in 2016 IEEE 43rd Photovoltaic Specialists Conference (PVSC), June 2016, pp. 2021– 2024.