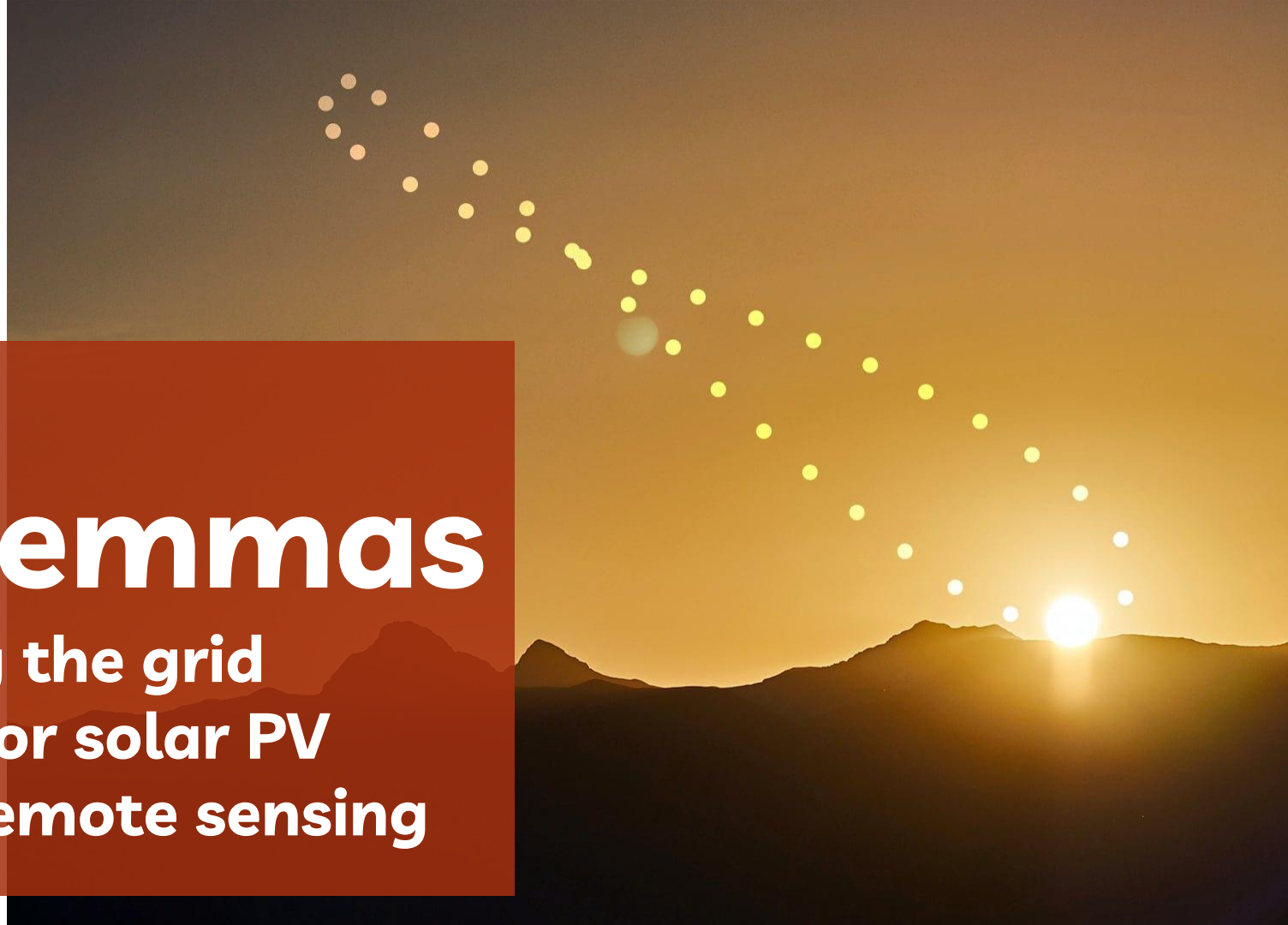
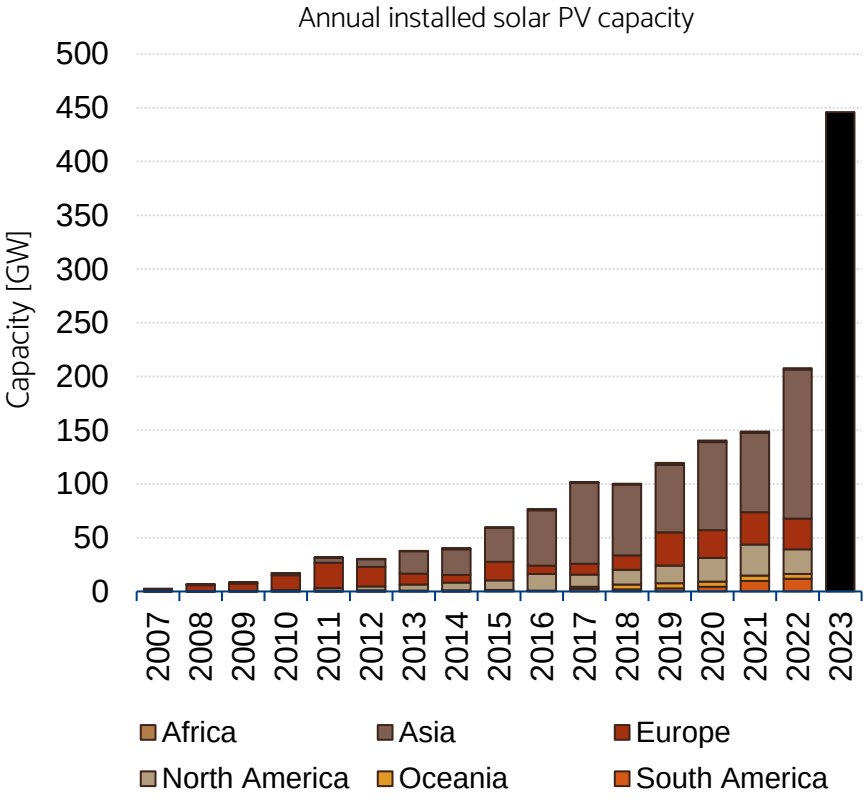


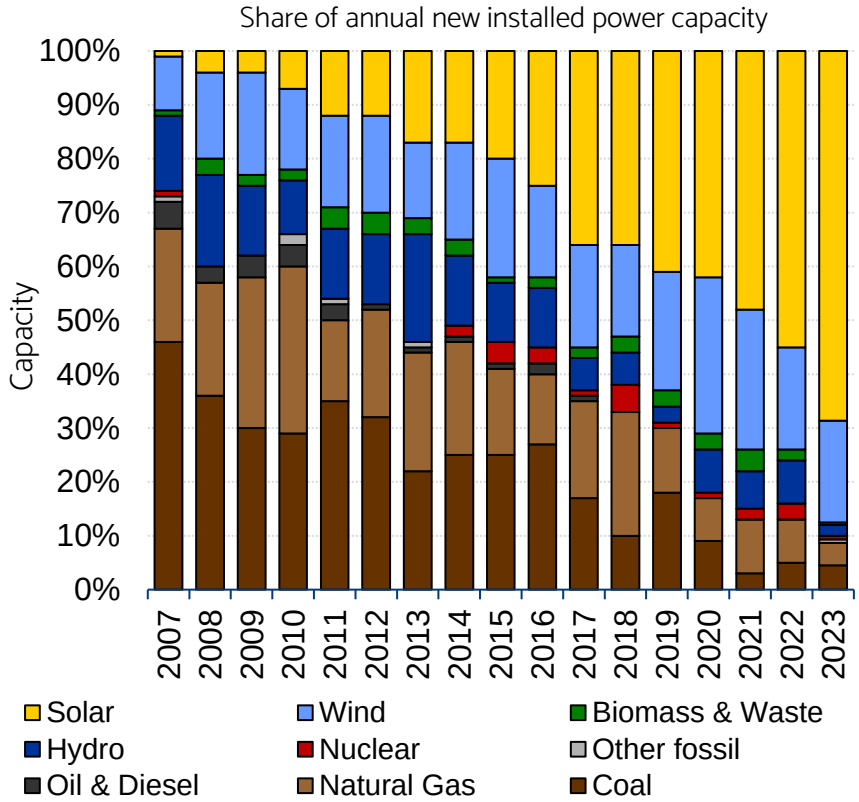
Analemmas

Increasing the grid capacity for solar PV through remote sensing

Solar PV — a game changer in the electricity sector

Solar PV is a 'granular' technology that has entered a highly centralized system dominated by 'lumpy' technologies.



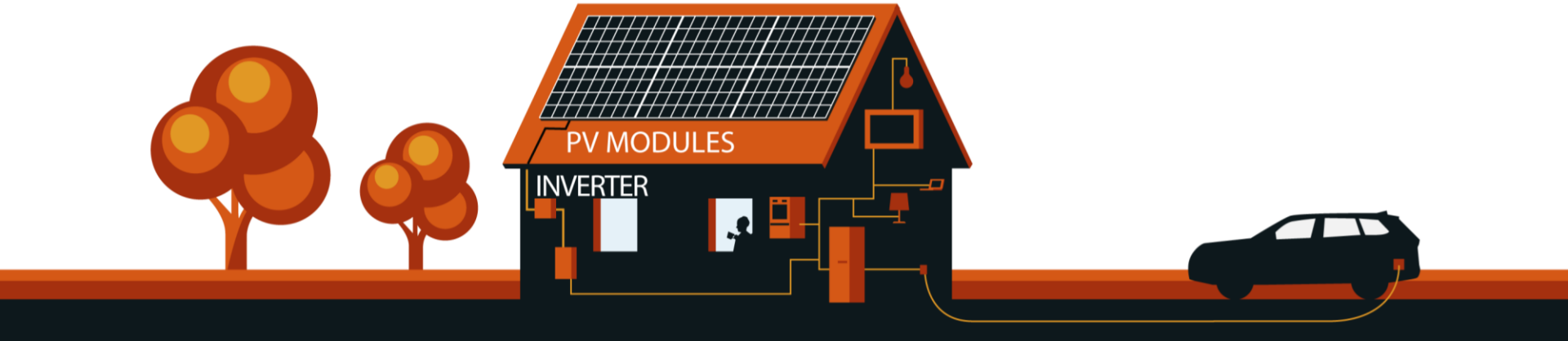


Societal challenge:

The European Commission has estimated that in a 'business-as-usual' grid scenario for 2040 up to **310 TWh of renewable energy could be curtailed** due to grid congestion, which is comparable to the current electricity usage in countries like France or Germany. The value of this wasted renewable energy are expected to rise from 26 billion euros in 2030 to a **staggering 103 billion euros by 2040.**

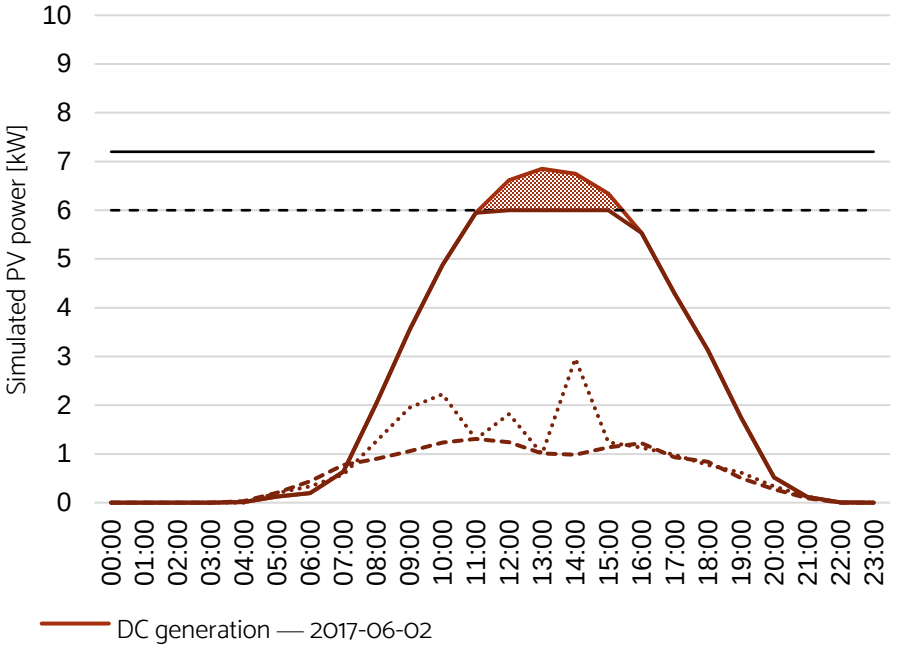
Vision:

Utilize the existing low-voltage grid infrastructure more effectively by a machine learning based remote sensing tool to facilitate a cost-efficient roll-out of solar power.



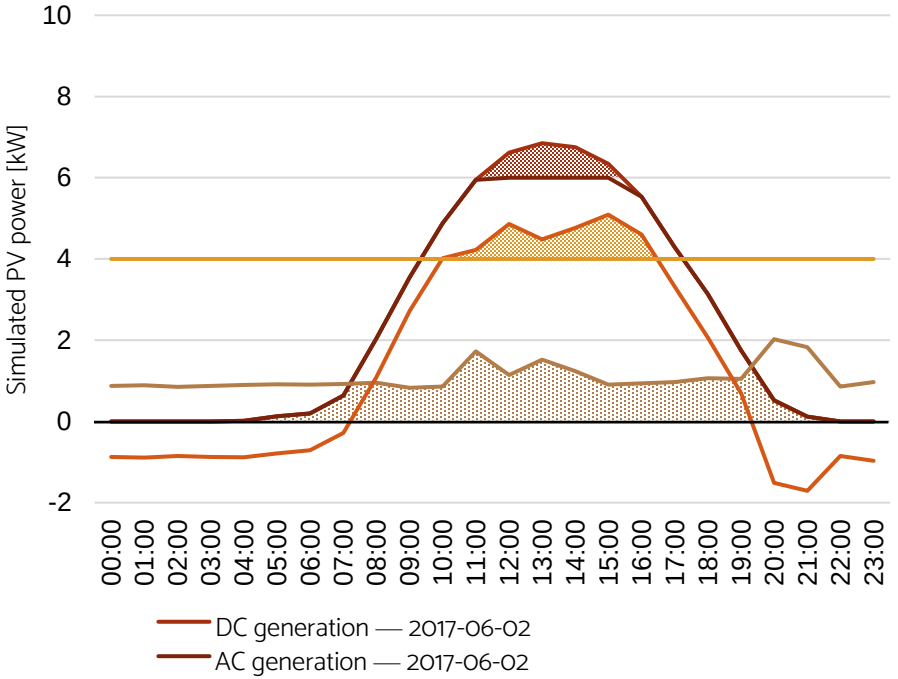
PV curtailment by the inverter

System 1 has an installed DC capacity of 7.2 kW, an AC capacity of 7.2 kW, a tilt of 26.5° and an azimuth of 15.8°.

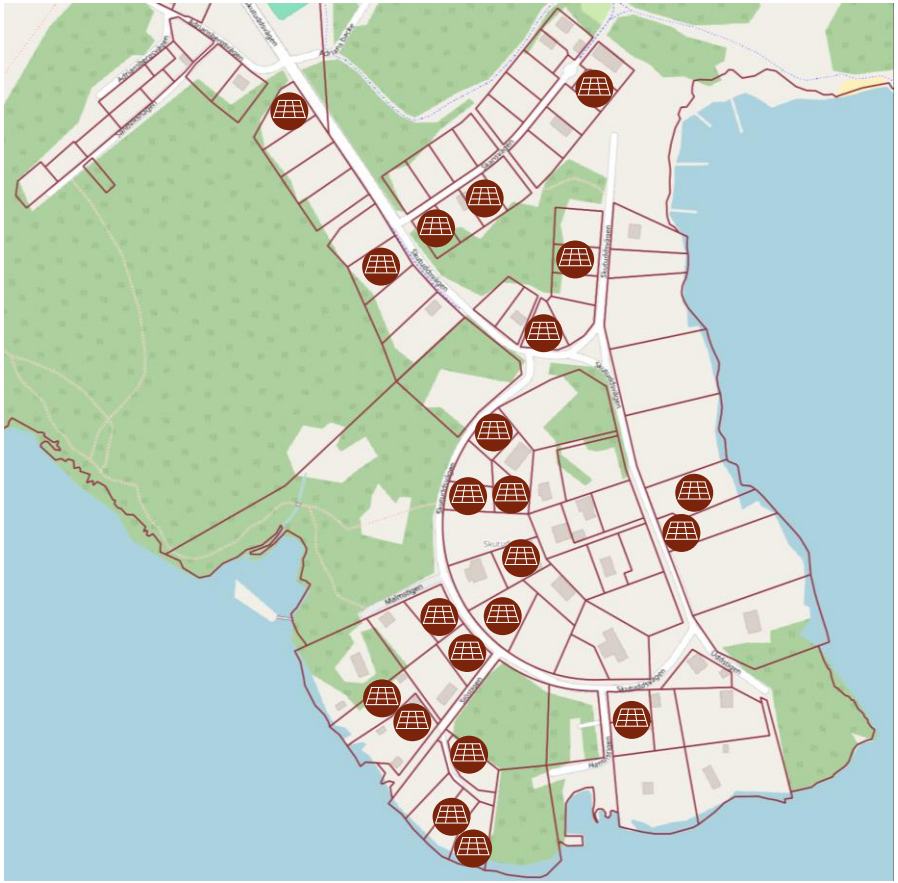


PV curtailment by grid congestions

System 1 has an installed DC capacity of 7.2 kW, an AC capacity of 7.2 kW, a tilt of 26.5° and an azimuth of 15.8°.



Technical challenge — the grid operator information gap



The grid operator generally collects the following information about each PV installation through the pre-notification and final registration processes:

- The connection point (real property designation)
- The DC capacity of the modules
- The AC capacity of the inverter

What they know since before:

- Cable dimensions and length

What they need to fulfil:

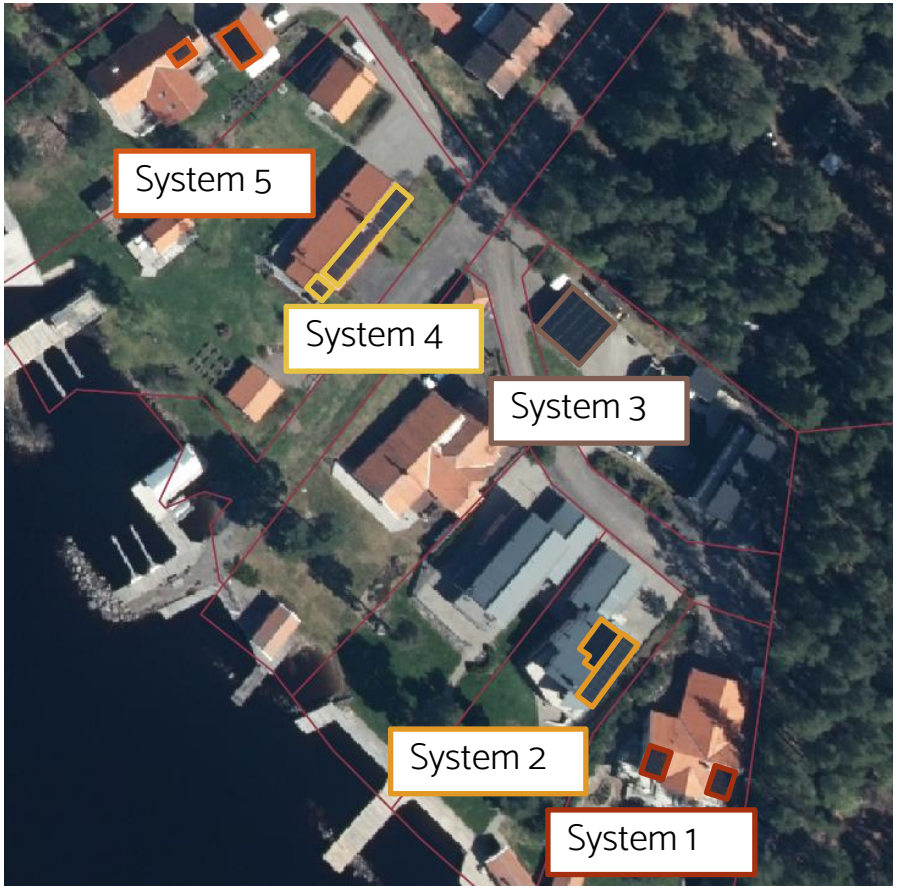
- The voltage and frequency variations

What they lack:

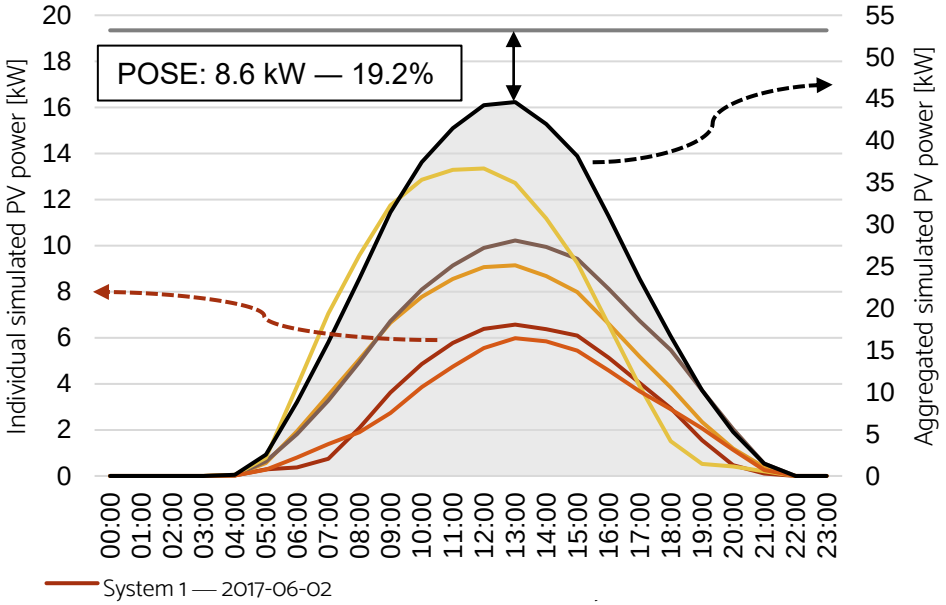
- The orientation PV systems

What they do:
Make a worst-case scenario assumption which is that all systems can produce at their maximum capacity at any given time.

The PV orientation smoothing effect — “POSE”



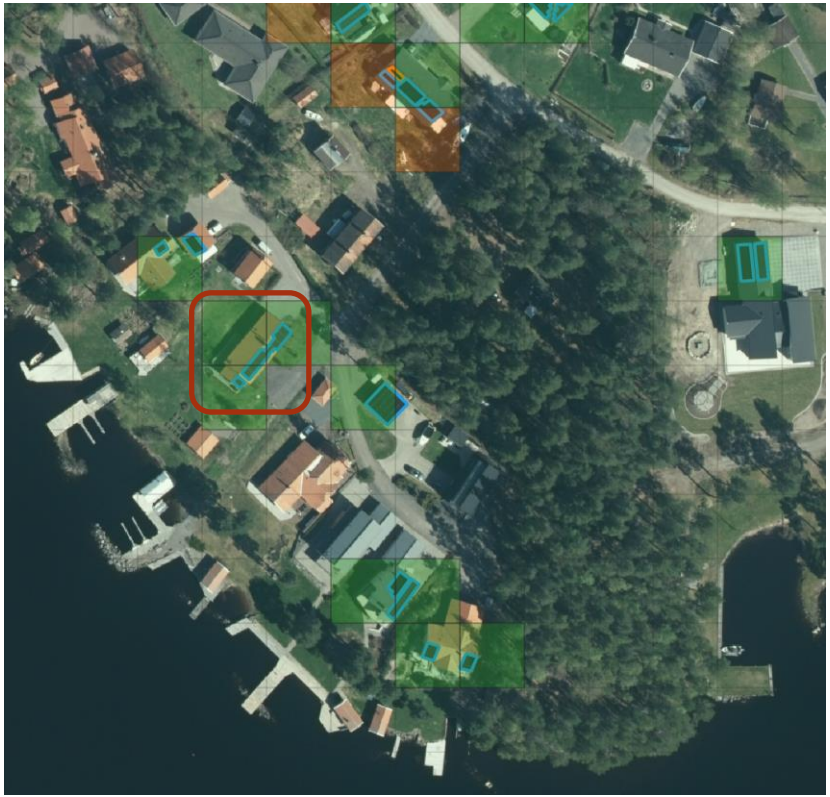
The five systems has a total installed AC capacity of 53.2 kW.
Simulation of all hours between 2017-05-01 and 2024-09-01
(64 329 hours) revealed these peaks:



The Analemma technology

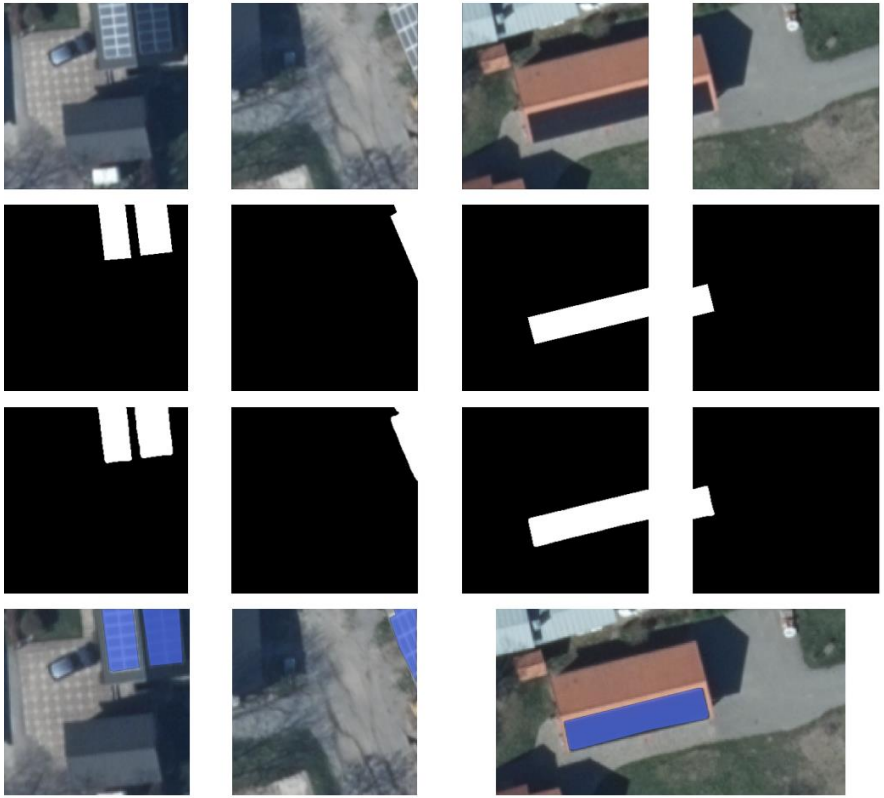
Aerial orthophotos taken every second year

Current accuracy: >95% of all systems identified, F1-score of 0.89



A U-net segmentation machine learning algorithm

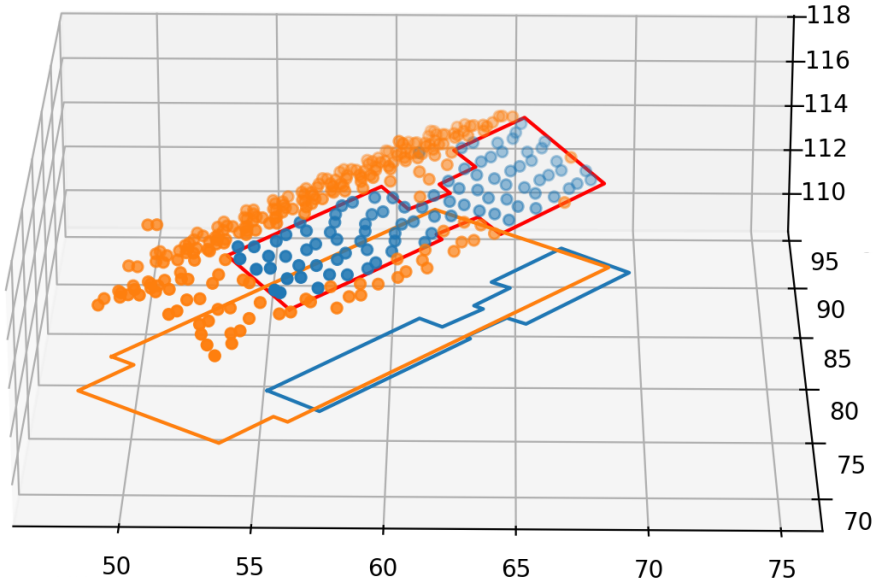
Current accuracy: A Mean Intersection over Union (mIoU) of 0.89



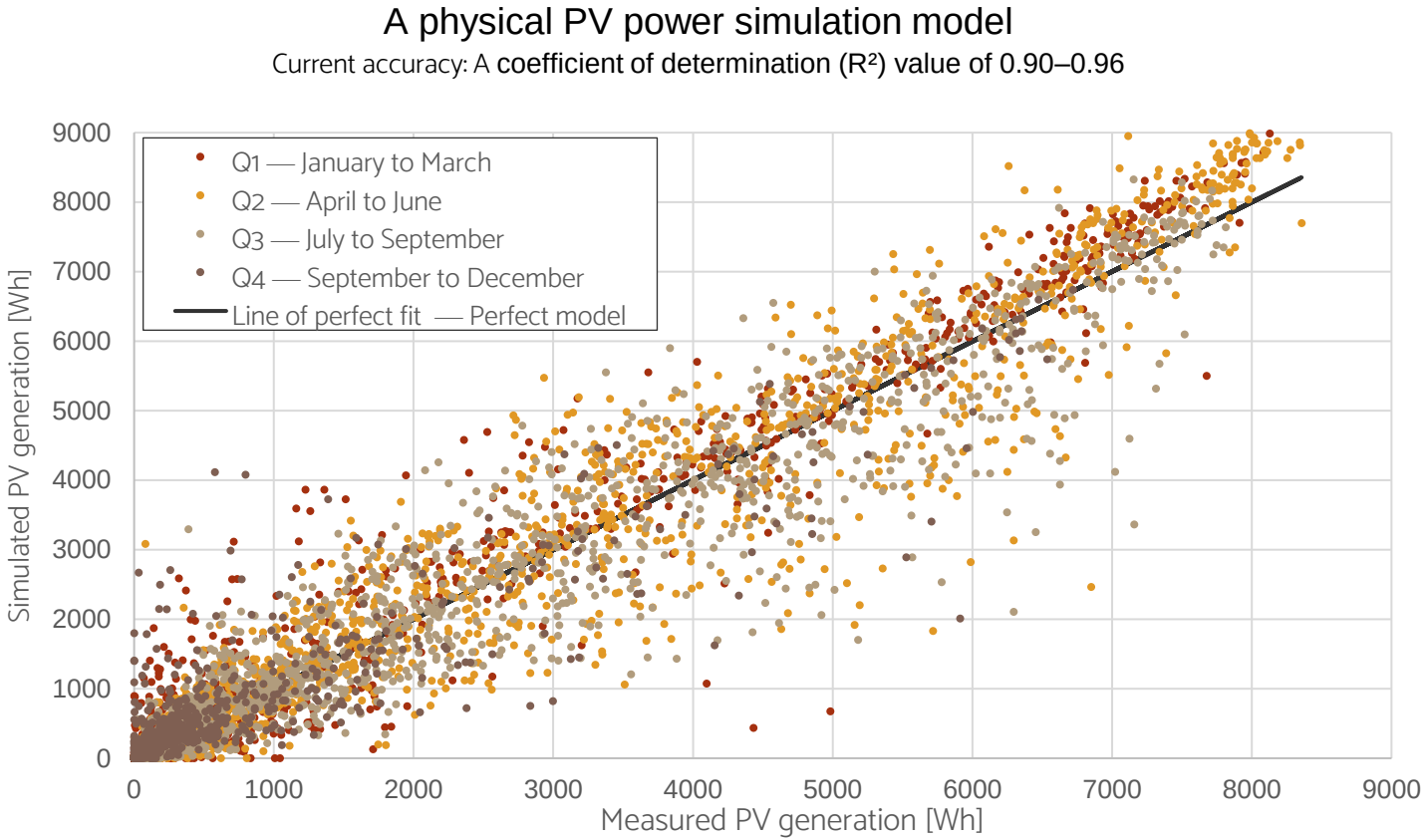
The Analemma technology

Light Detection and Ranging (LiDAR) data is downloaded and processed through geometrical calculations

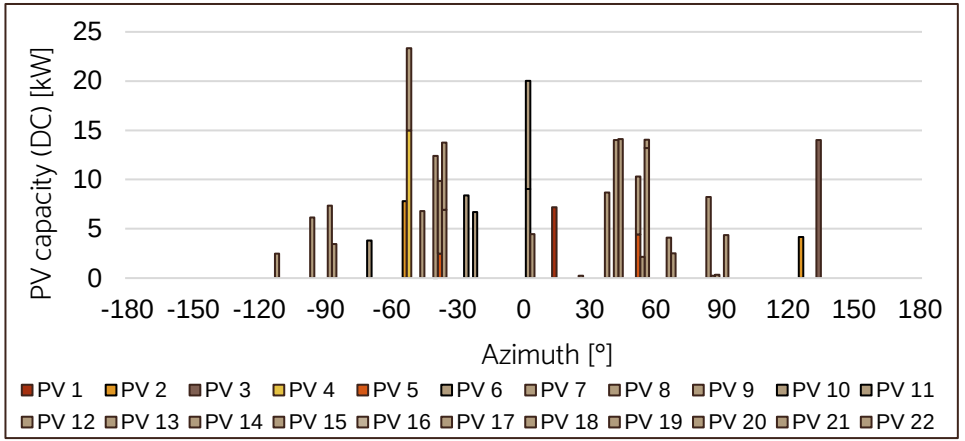
Current accuracy: >95% of PV systems get the right orientation

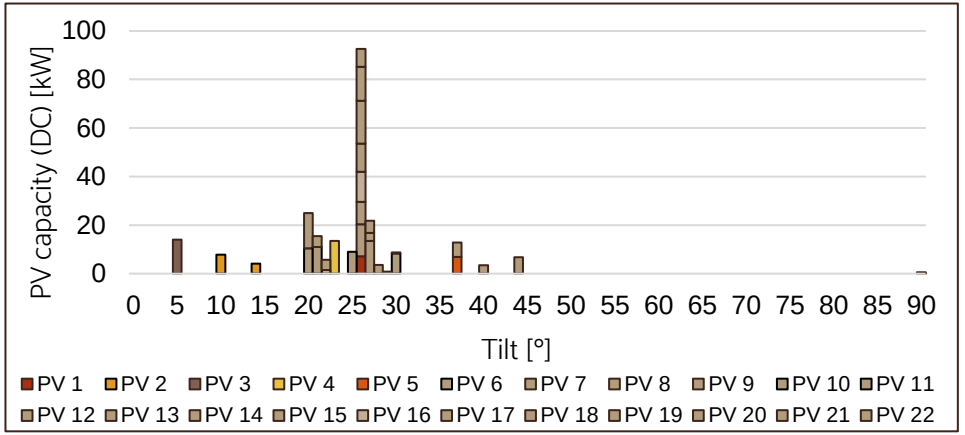


The Analemma technology

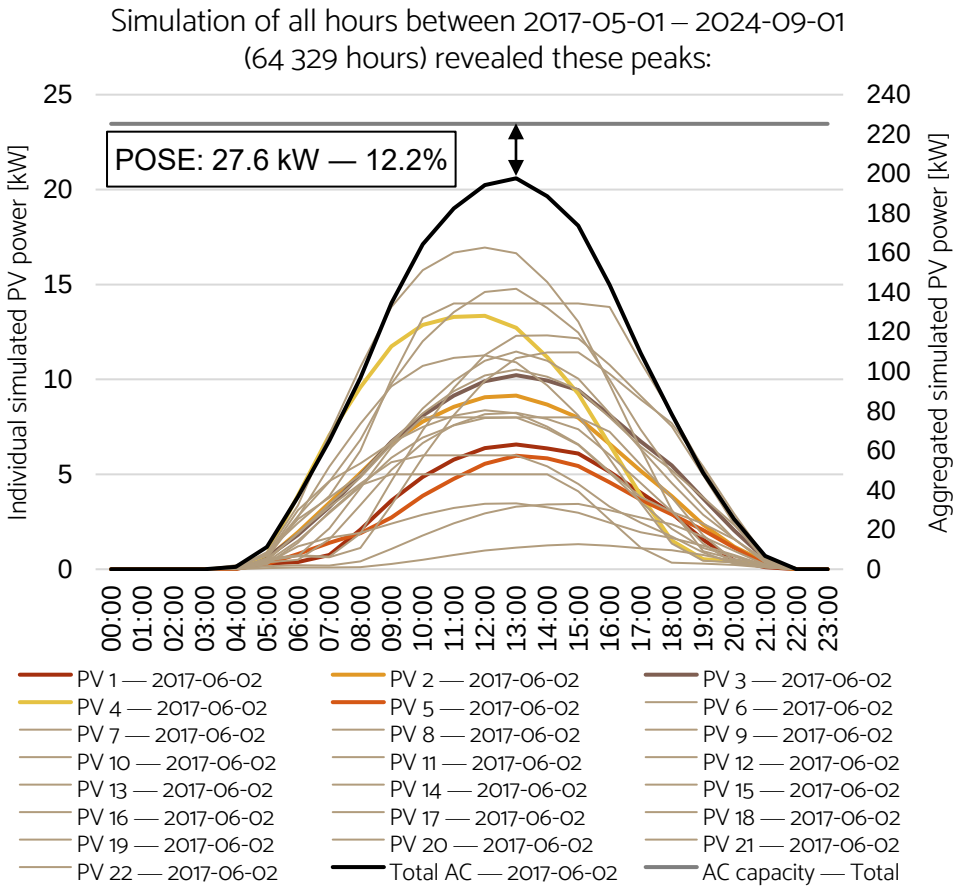


The orientation of PV systems within substation T0188





The “POSE” for substation T0188



The value creation

Between mid-2022 and mid-2024 19 new residential PV systems was installed within substation T0188.

According to the grid operation calculations, voltage levels in certain cables would increase with more than 5% as compared to the nominal voltage under normal operating conditions if all of these PV systems were to inject their maximum AC capacity simultaneously.

To address the issue, the grid operator has concluded that it is necessary to reinforce the grid within this substation. This will involve increasing the capacity of a few of the cables connected to the most distant connection points from the substation, at an estimated **cost of 40,000 €**.

Generally, the costs for reinforcing a smaller grid area or upgrading an individual transformer are **30,000 to 300,000 €.**

With the remote sensing approach we can assess the "POSE" within a substation at a cost of less than 4 000 €.

Substations have individual characteristics

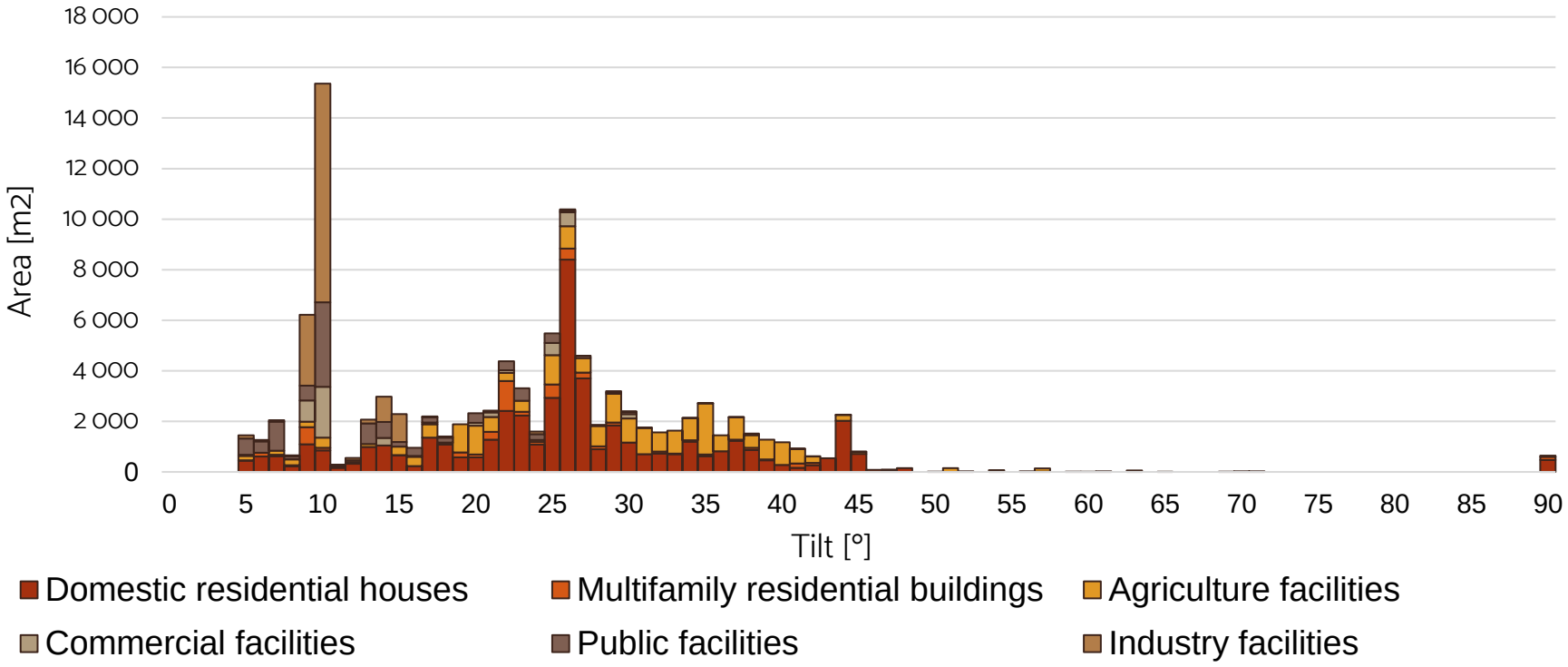
DC capacity: 291.0 kW
AC capacity: 261.3 kW
DC/AC ratio: 1.11
Max generation: 238.3 kW
Time: 2017-06-02 12:00:00
POSE: 23.1 kW — 8.8%

DC capacity: 160.3 kW
AC capacity: 148.7 kW
DC/AC ratio: 1.08
Max generation: 131.0 kW
Time: 2017-06-02 12:00:00
POSE: 17.6 kW — 11.9%

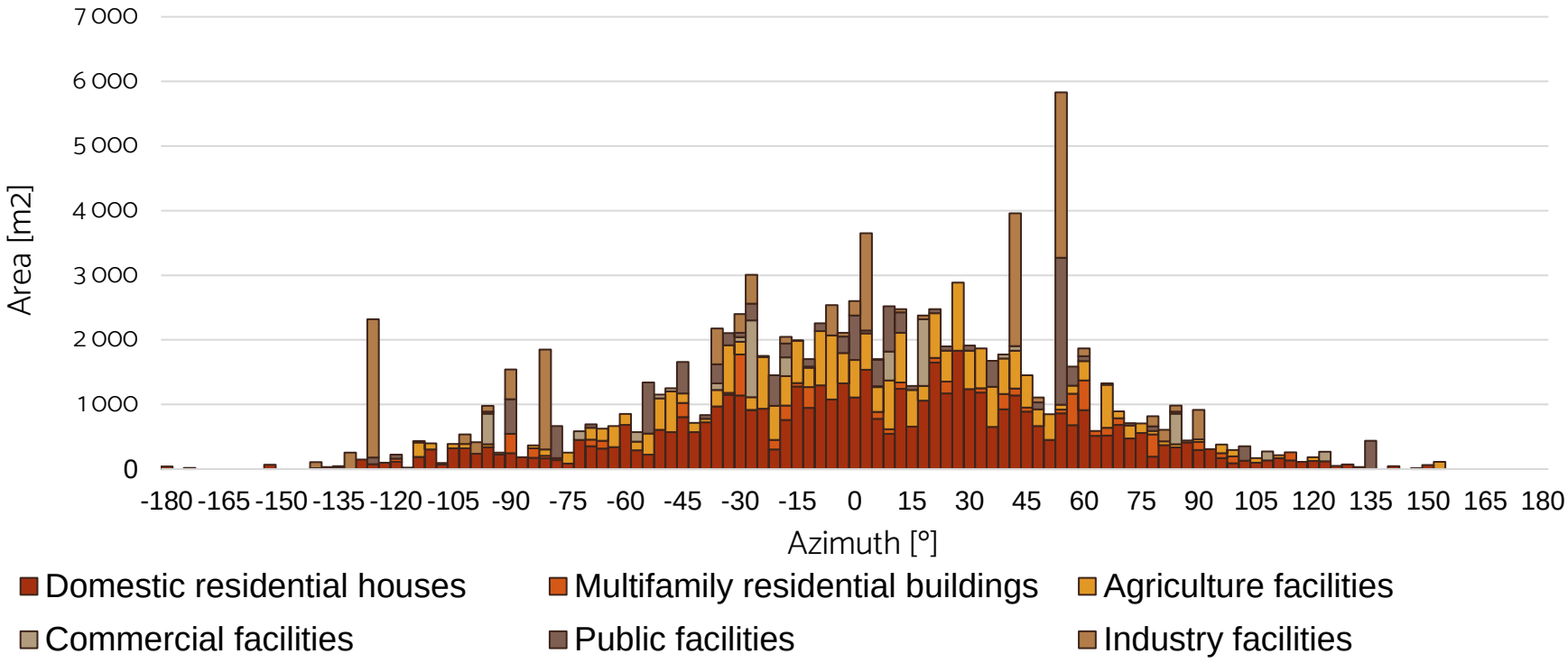
DC capacity: 213.0 kW
AC capacity: 187.5 kW
DC/AC ratio: 1.14
Max generation: 171.8 kW
Time: 2017-06-02 12:00:00
POSE: 15.7 kW — 8.4%

DC capacity: 163.3 kW
AC capacity: 151.2 kW
DC/AC ratio: 1.08
Max generation: 130.1 kW
Time: 2017-06-02 12:00:00
POSE: 21.1 kW — 14.0%

The tilt of 3498 systems in three municipalities



The azimuth of 3498 systems in three municipalities



Thank you for your attention!