THE FLEXNETT SIMULATOR

How can prosumers with rooftop PV panels help to reduce peak loads in the grid?

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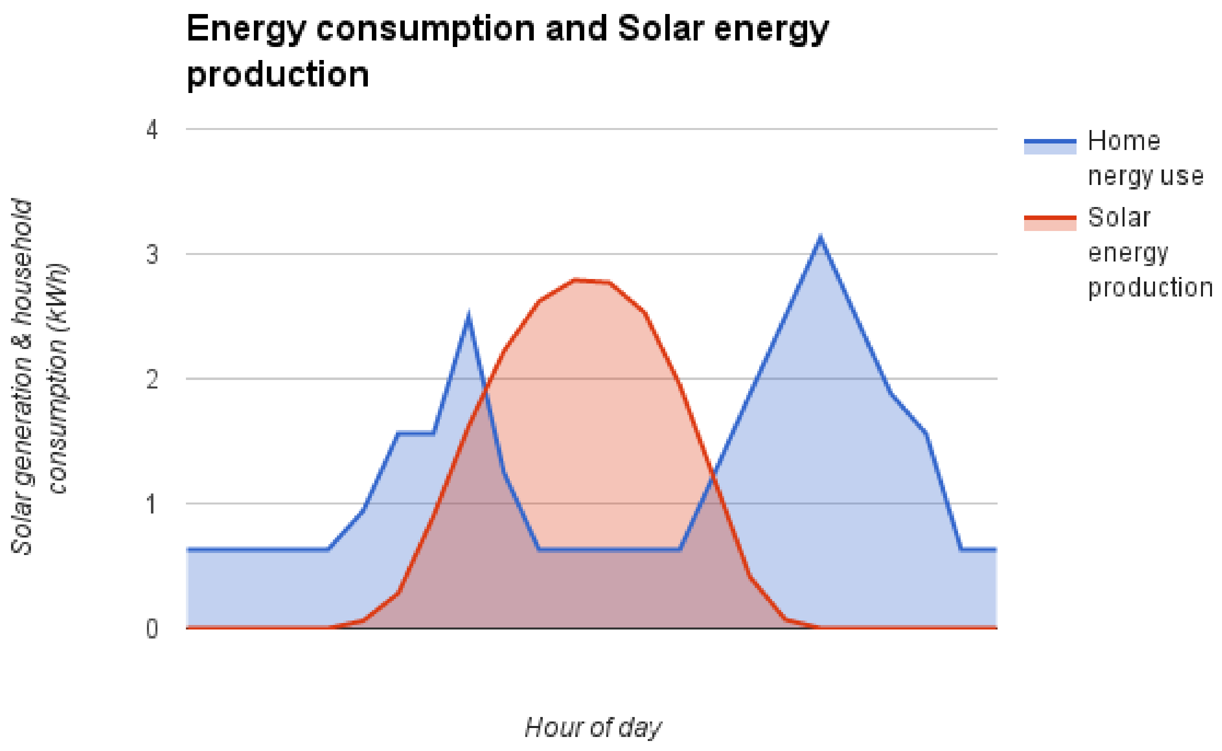
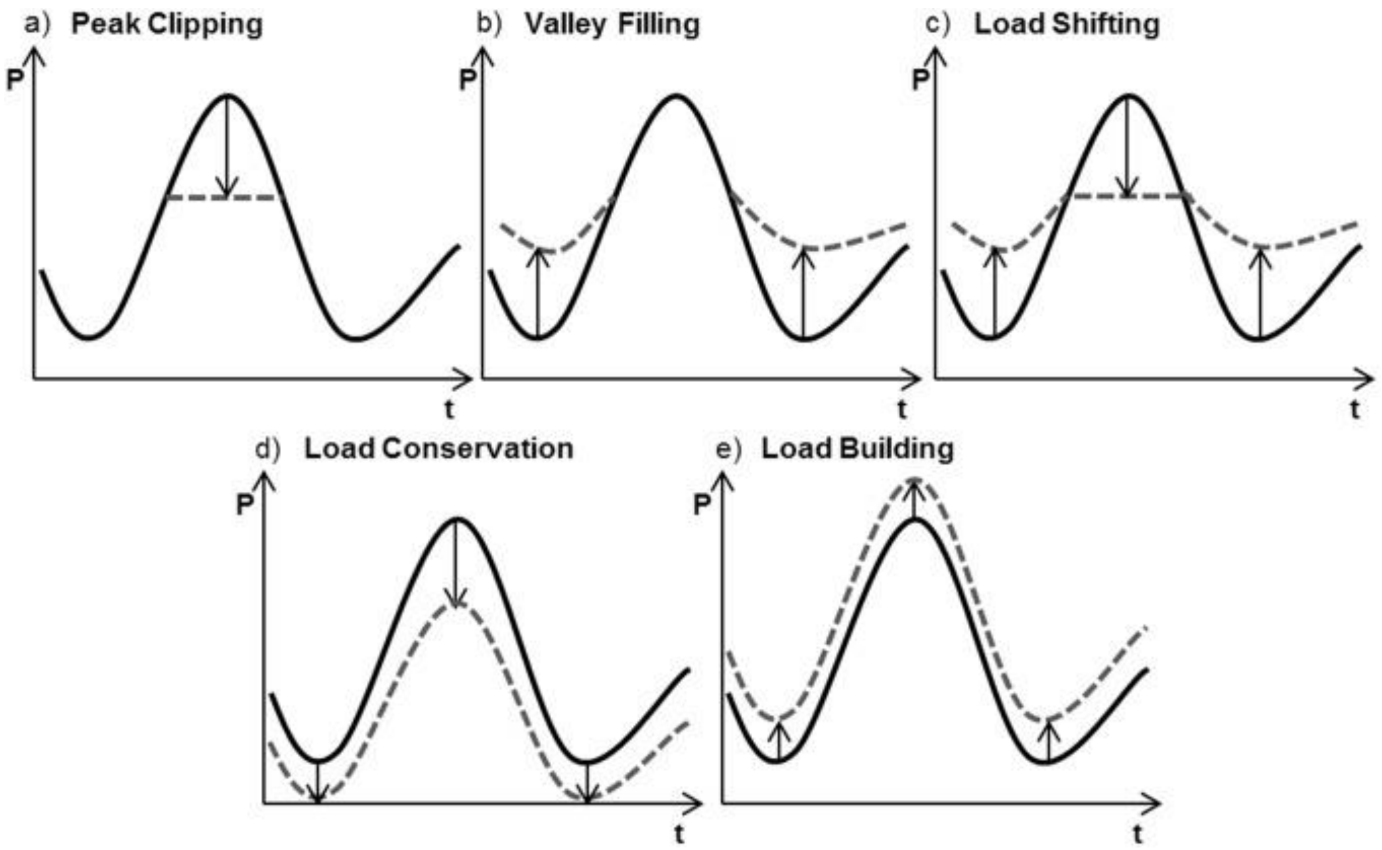
- Let by SINTEF Energi (2015 – 2018)
- Funded by Norwegian Research Council and the energy/ICT industry
- Main objectives:
  - To investigate the present and future role of prosumers in the distribution grid
  - To contribute to increased flexibility and smarter distribution networks
- UiT worked together with Smart Innovation Norway to create the FLEXNETT simulator, and has taken the simulator a few steps further as part of a PhD project

Issues

- Maintain best possible balance between loads and production at terminal points
- Low solar altitude -> frequent and significant change in shadows
- Azimuth angle can impact self-consumption
- Rapid shifts in positive and negative loads
- People don't consume when the sun shines

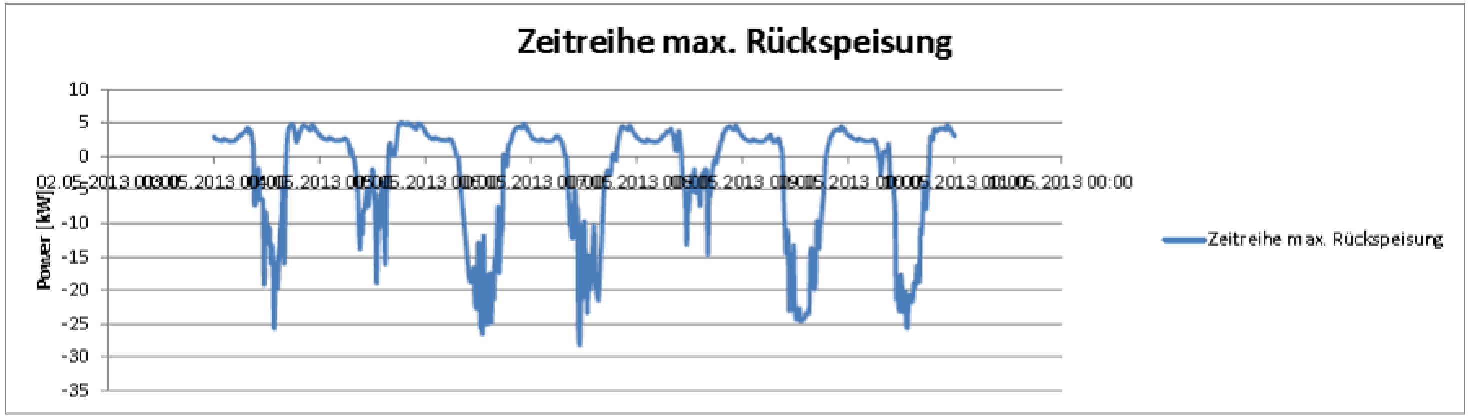


Load management

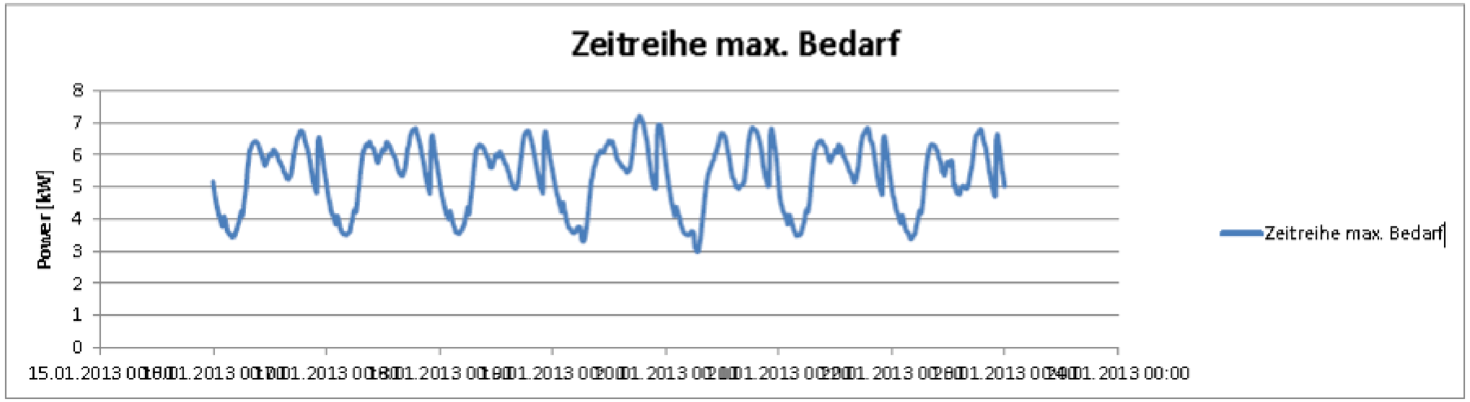


Experiences from Southern Germany

One week example of maximum feed of solar energy in a grid (3 May to 10 May 2013)



One week example of maximum consumption in a grid in wintertime without solar energy (16 to 23 January 2013)



(Courtesy of Stadtwerke Rosenheim)

Hvaler Municipality (Norway) as a case

- Smart meters/AMS data made available from the DSO
- 2015: 100 roof top PV panels in one year
- What would happen if the number of PV panels increased by 10,100, 1000?
- Energy and Power tariffs introduced by DSO in 2015

Fixed fee(NOK/year)	Period	Energy part NOK/100*kWh	Power part NOK pr. max hour per month [NOK/[illegible]*kW]
625	May-Oct	26.36	61.25
0	Nov-April	28.23	61.25

Norgesnett:
Power tariff part 61,25 NOK/kW for average of the 3 highest peaks per month

Empirical Studies

Demographic and geographic differences had to be taken into account – impacted energy profile

Older residential areas – retired couples: Spend day at home longer

- Higher base load

Newer – families with children: Work and commute

- Lower base load

Performance of same PV system across a neighborhood varied

Roof design

Roof orientation

Topography

Vegetation

Local meteorological conditions (i.e. fog) and weather change

Time series harvest:

Consumption (per hour)

Inverters (per 10 minutes)

Non-immediate history may influence forecasts and nowcasts

Tool making and modelling (1)

- Determine impact of PV size on the grid and the potential role of battery
- GIS system — A graphical interface for selection of area of study (i.e. single household, neighborhood, transformer area etc.)
- Meter data for consumption
- Gross and net load estimation (continuous time series)
- Analyses with and without household batteries
- Economic estimates for different tariffs

Tool making and modelling (2)

- Battery has priority to PV surplus when fully or partly discharged.
- Degradation of battery based on the rainfall method
- Battery: Simple Coulomb Counting to determine SOC
- PV panels where varied to determine criticalities
- Coldest day in January/February used as benchmark for negative and positive loads
- Deep Learning by means of LSTM – Not Monte Carlo. 20 training cases

Area of interest: Norderhaugsveien, Hvaler

PV-System 2
- 3.1 kWp
- Orientation SW
- Little shading

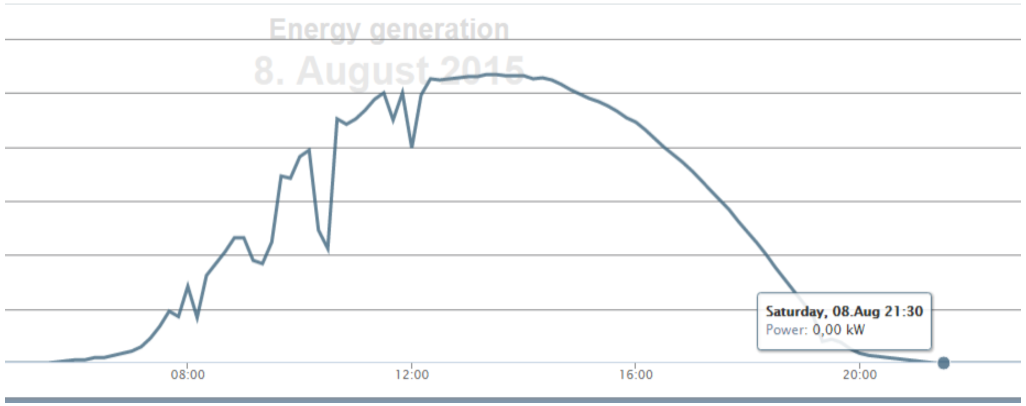
in the morning (roof)

PV-System 3
- 3.1 kWp
- Orientation SSW
- Shading

in the morning (trees)

PV-System 4
- 3.1 kWp
- Orientation SW
- No shading

LSTM



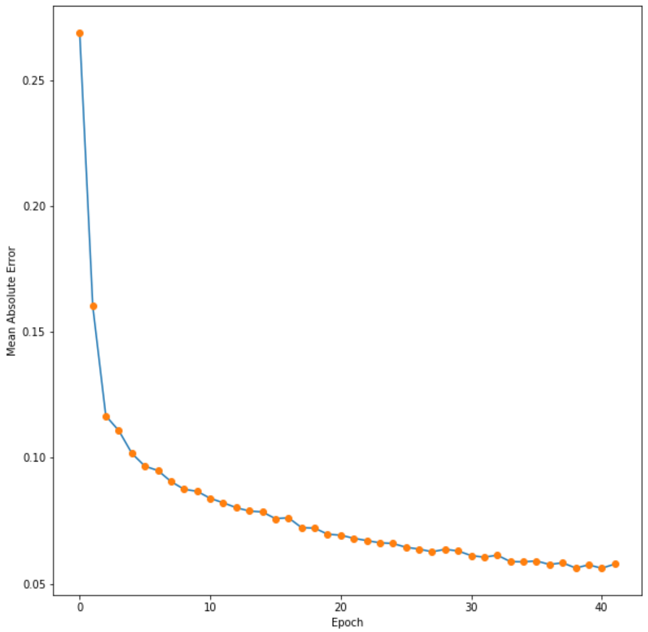
- Long Short Term Model Neural Network
- Non-Markovian condition (POMDP approach)
- Sine form timeseries without disturbance/shadows
- Irregular shape due to local conditions (i.e. topography, foliage, fog)
- Batch size 36, the first 35 input
- Now cast of 10 minutes
- Input array of 6 hours x 6 values per hour)

$$y(t,R) \sim f\left(P_{1,}, P_{2,}, P_{3,}, P_{4,}, \ldots, P_{n,}\right), R(PV, x1, x2, x3, x4, \ldots, Xn))$$

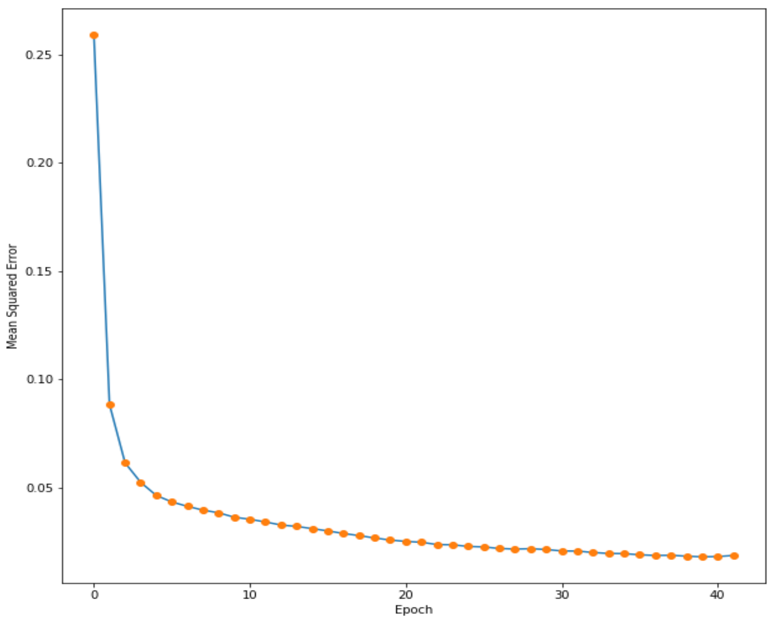
$P_{i,} = historic\ production$

$PV = peak\ production\ of\ panel$

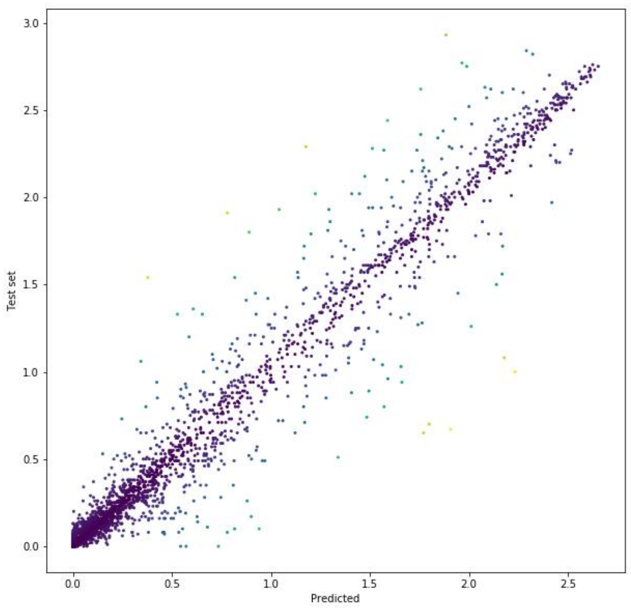
$x_i = geographical\ ,\ meteorological\ \ parameters$



MAE -> 0,055



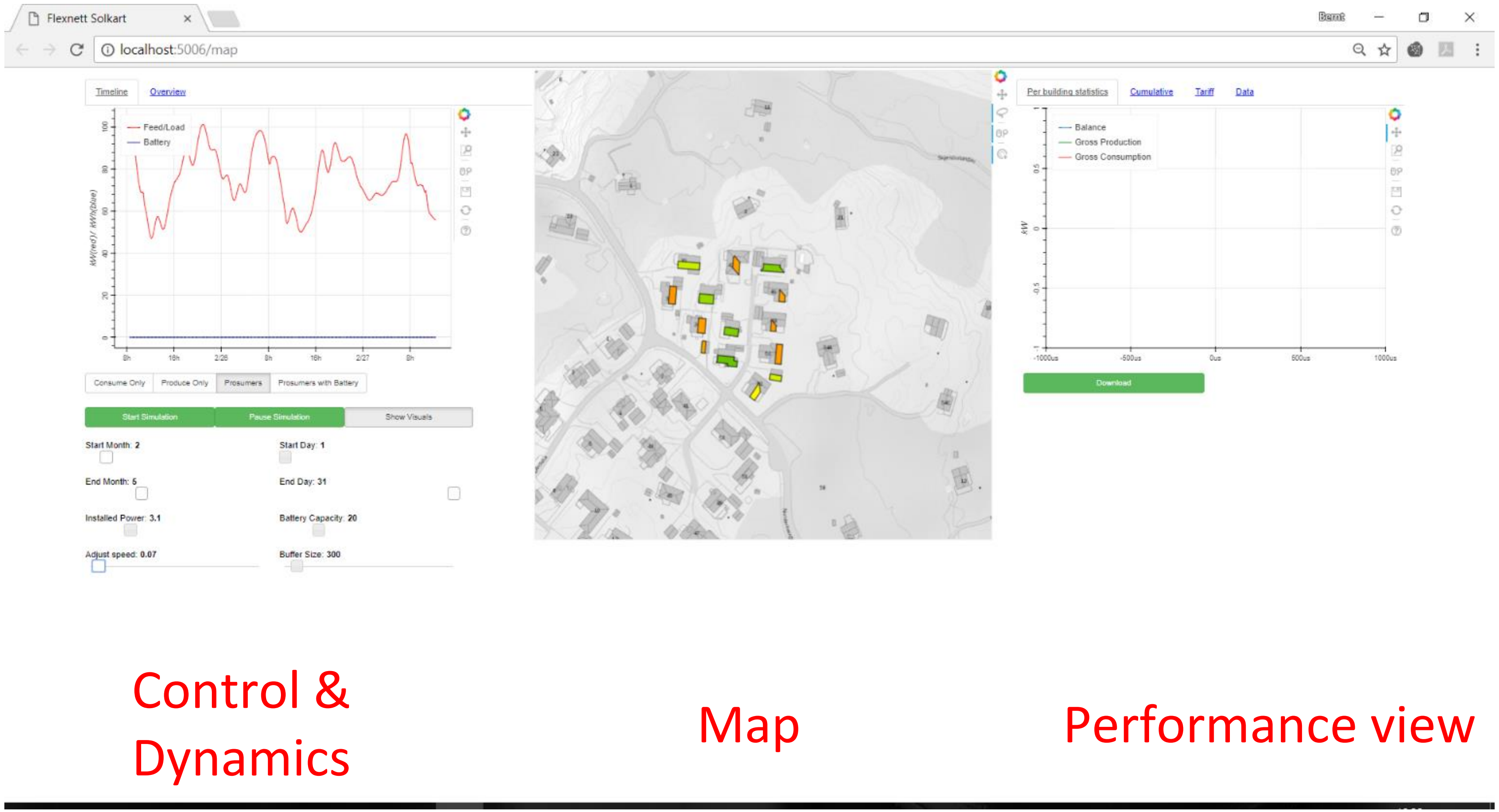
MSE -> 0,015



3-stack sequence (8,128,128,128,1)
Activation: ReLu
Optimizer: ADAM
Dropout: 0,2

LSTM Model

Simulation Dashboard

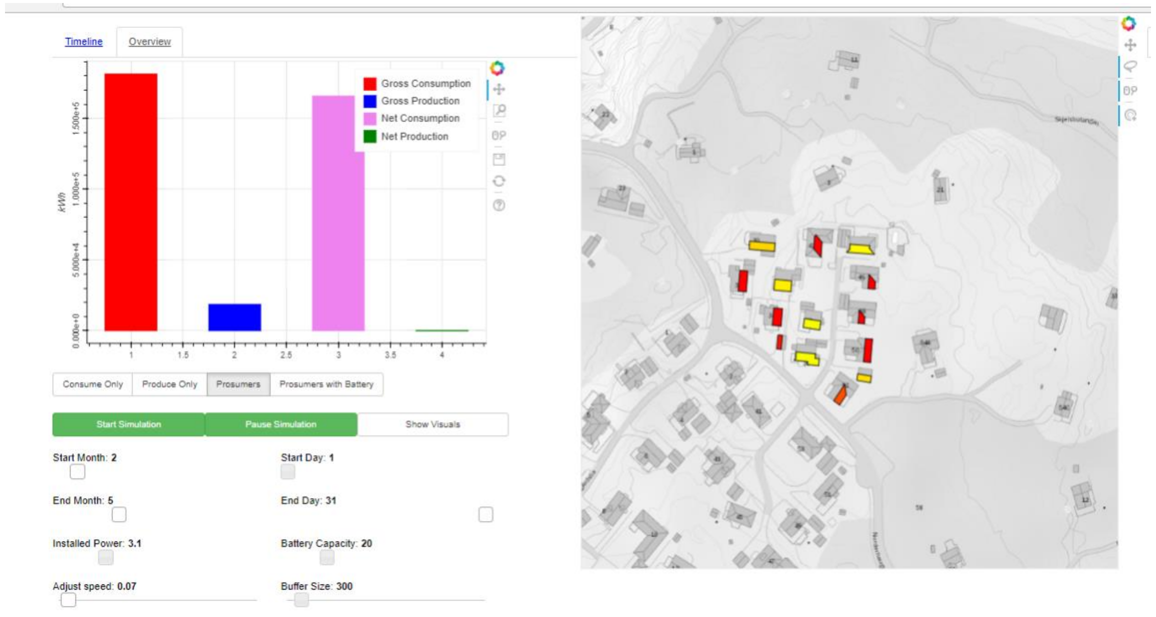


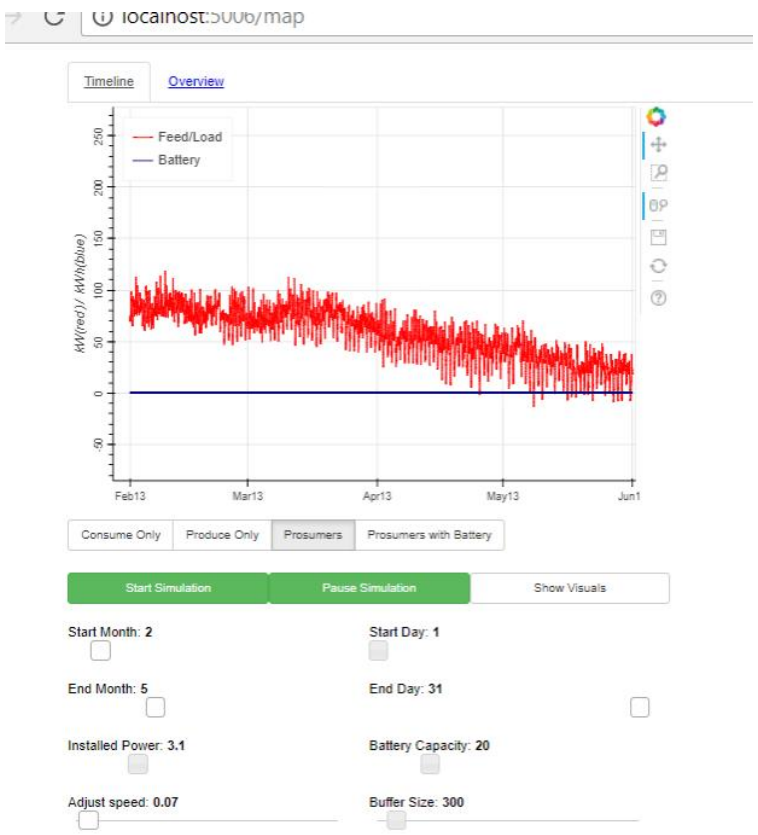
Control & Dynamics

Map

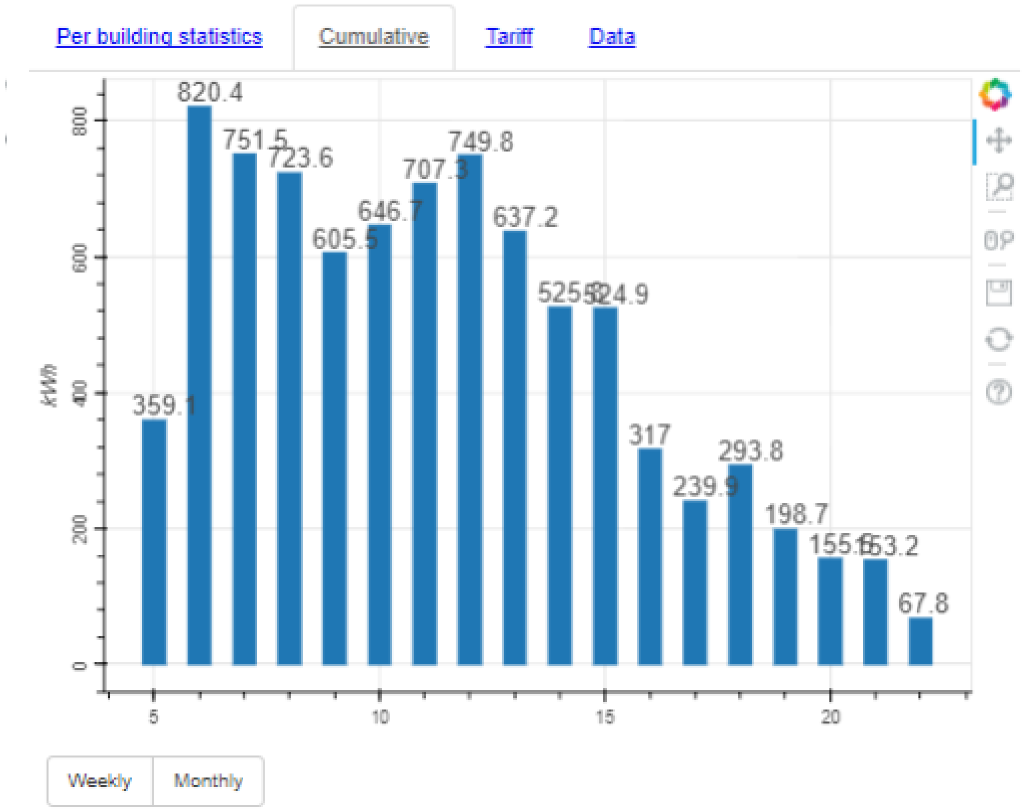
Performance view

Can study the load dynamics for a neigborhood

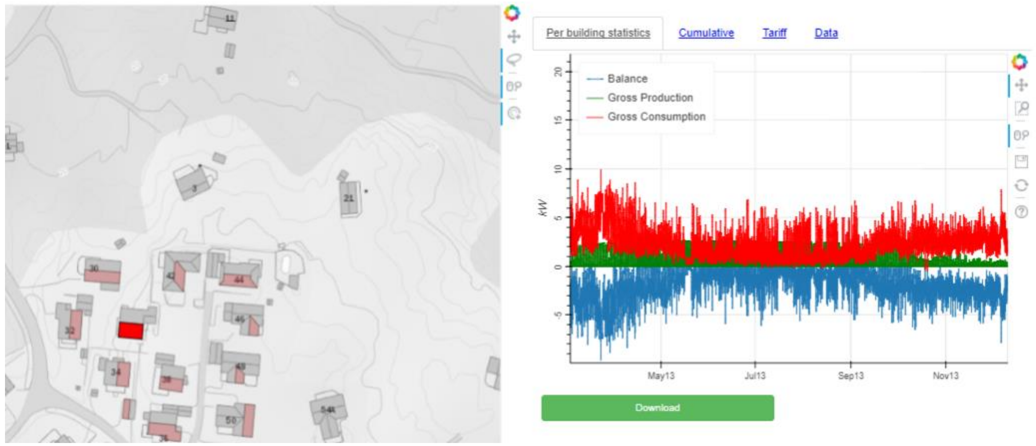


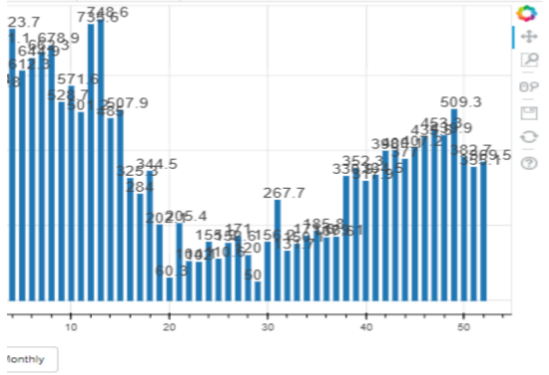


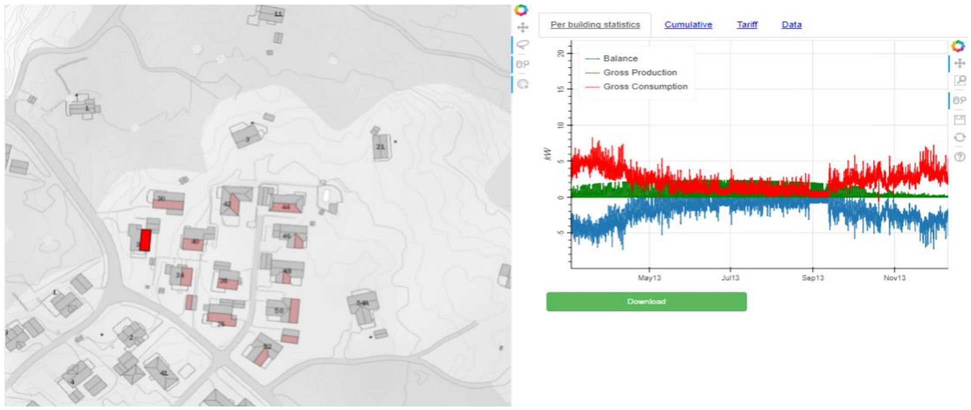
Possible to extract impact of individual households

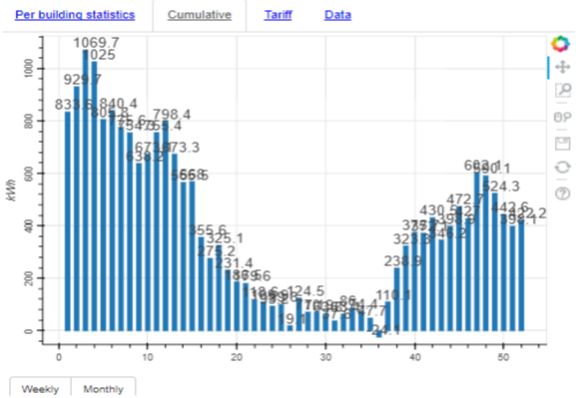


Compare individual performance within same neighbourhood

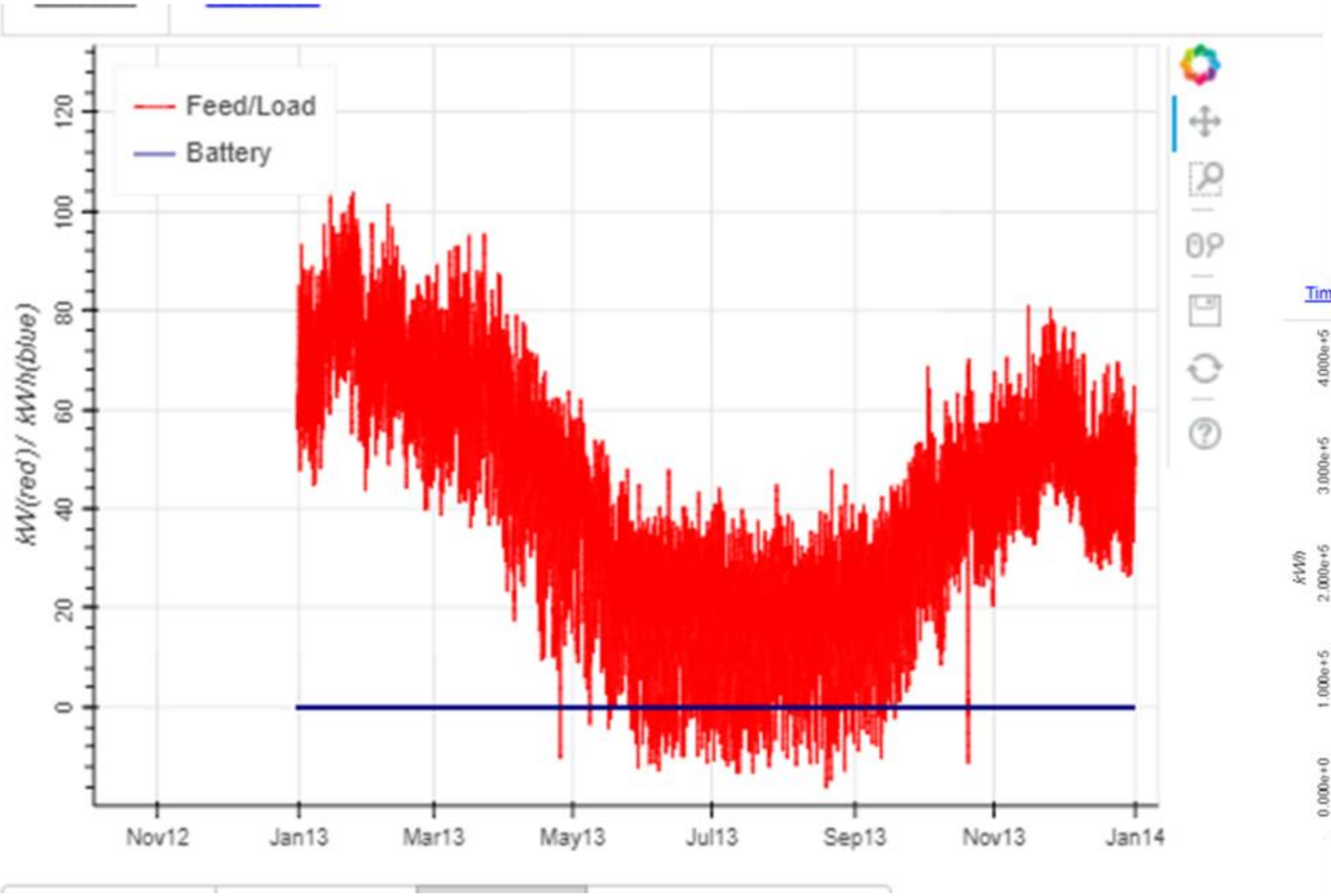


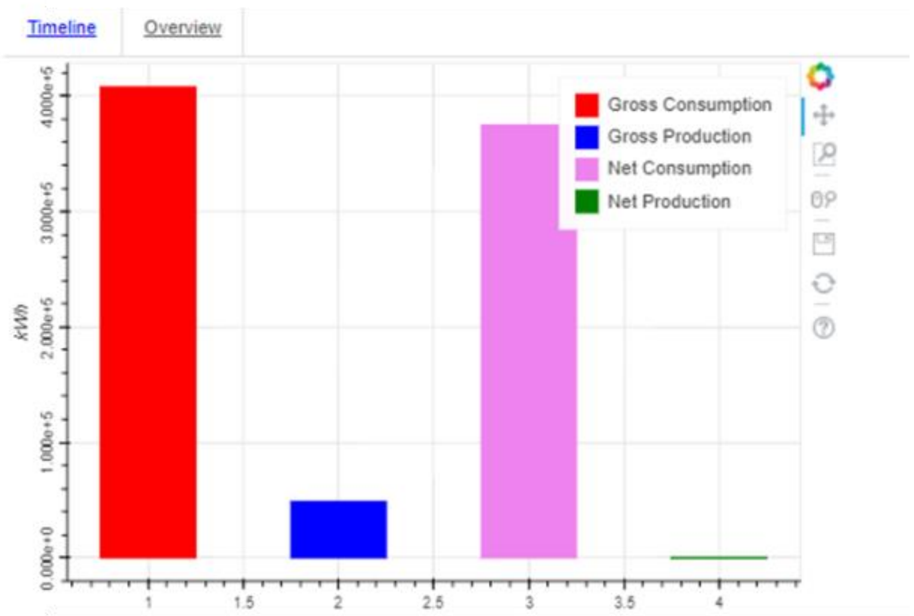




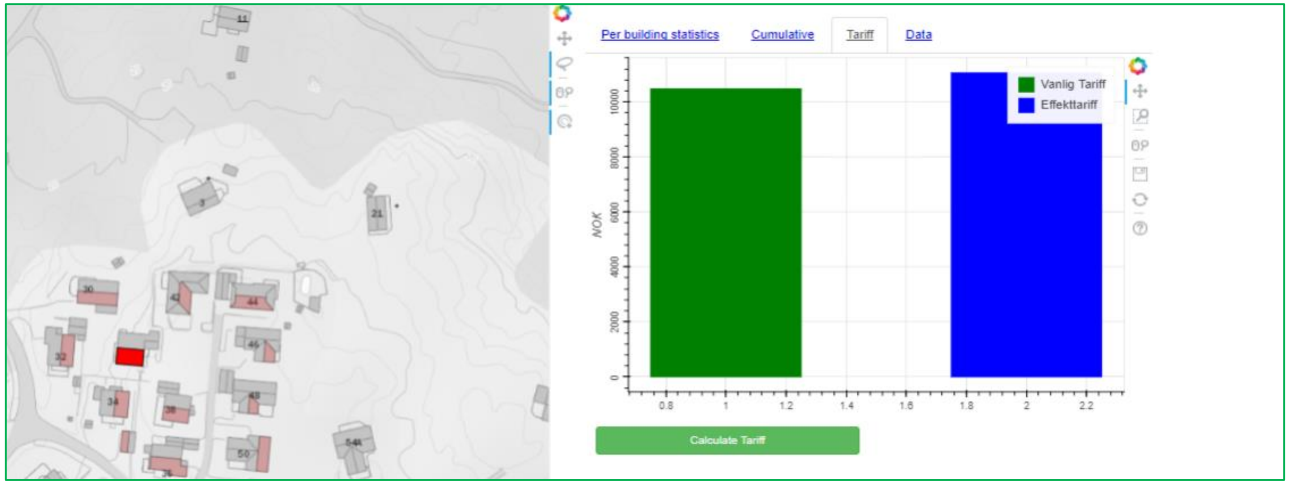


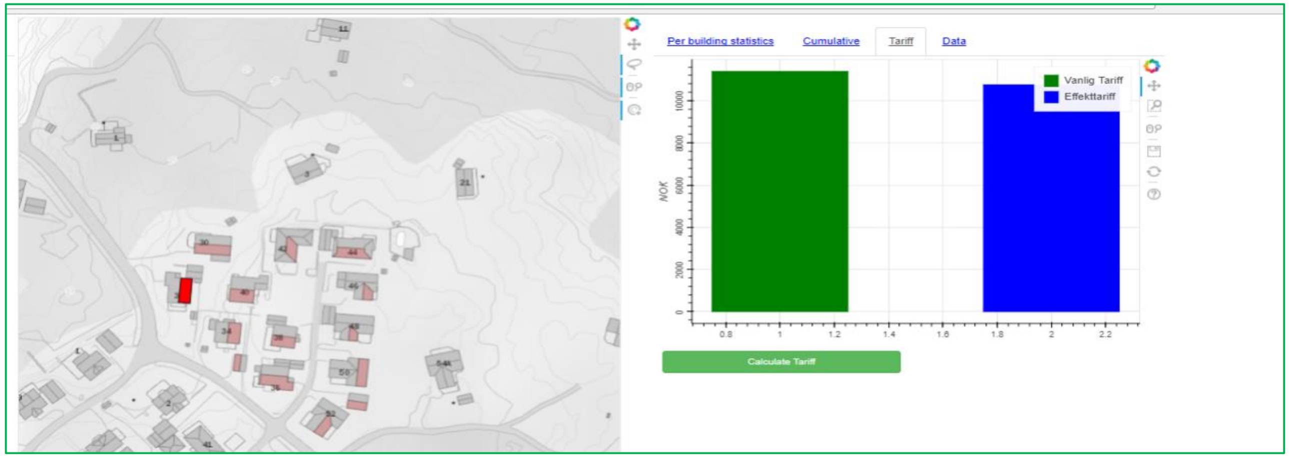
Max og Min loads studies





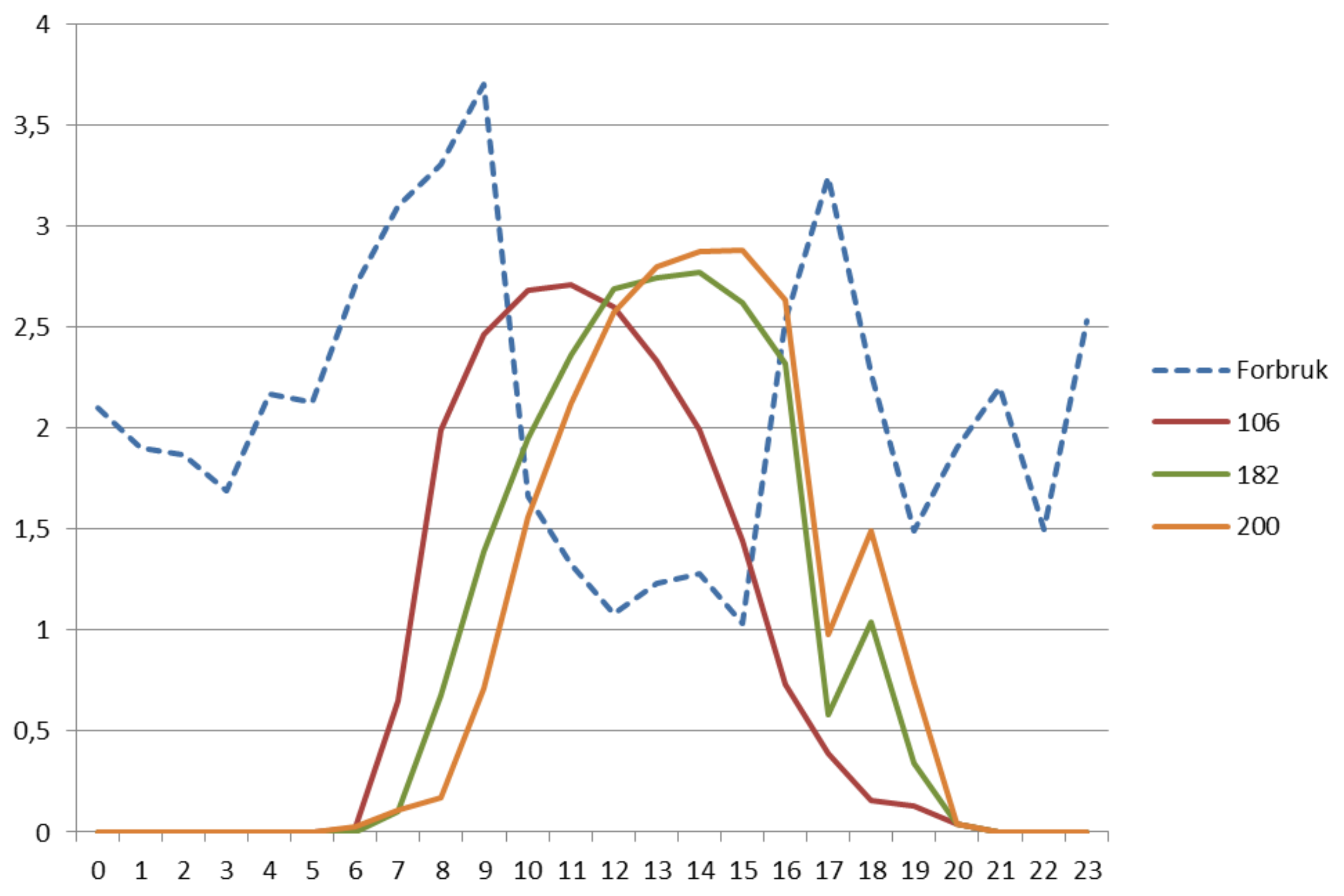
Economic considerations with different tariffs





The impact of power tariffs at Hvaler

Hvaler case: The impact of roof top orientation



Hvaler case

Max and Min power [kWh/h] for the average household with 3.1kWp panel (winter and summer)

Compass direction of PV	Max power consumption[kW]	Month	Min power (feed-in) [kW]	Month
South	-12.82	january	2.41	june
East	-12.82	january	2.06	june
Southeast	-12.82	january	1.99	june
West	-12.82	january	1.91	june

Azimuth angle matters to curb peaks in summer

Conclusion

- Local geography and demography can impact the aggregated load on the grid
- The FlexNett Simulator is a prototype tool for investigating impact of high-density deployment of solar panels
- The tool useful to determine the magnitude of peaks caused by local feeds and consumption
- Helps to determine the degree of dynamics and flexibility potential
- Helps to determine the benefit of batteries
- Can help analyses related to self-consumption
- Local load-balancing “by design”
- Economic studies show the benefit of PVs under a power tariff regime
- Productive machine learning techniques (LSTM) can cater for realistic simulations where local variations and past history matters.