

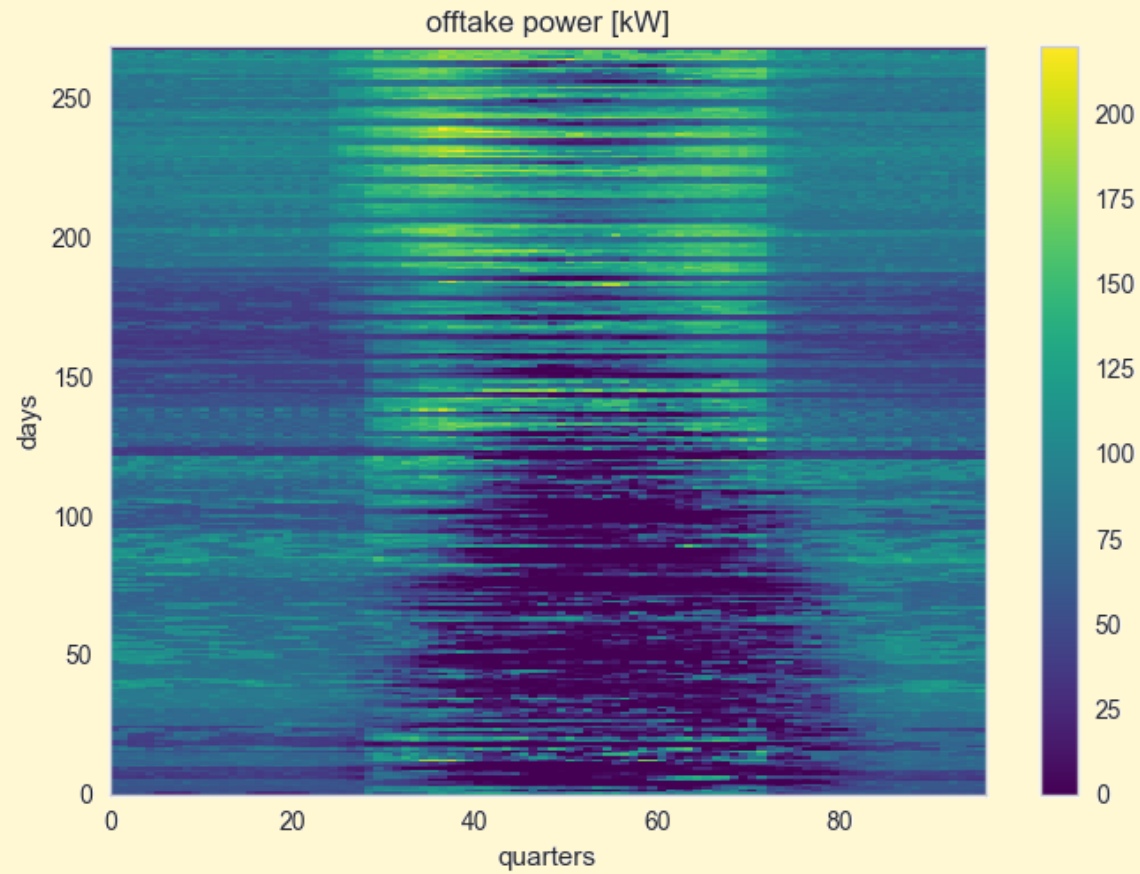


EnergyVille

Decision Support for the Low Voltage Distribution Grid *The Role of Electricity Consumption Time Series*

Koen Vanthournout





Ceci n'est pas une présentation de A.I.

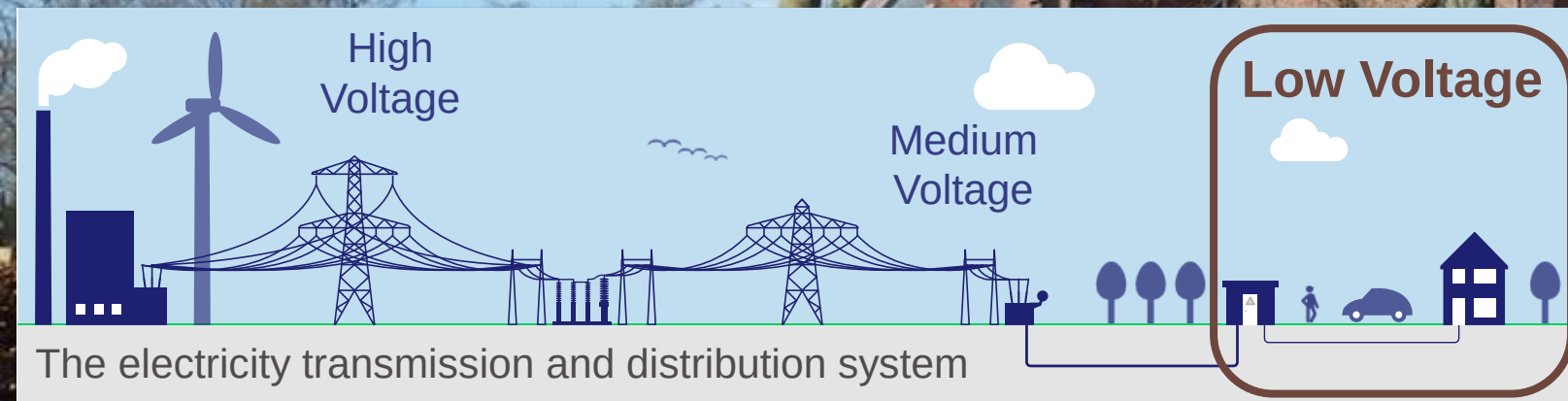
Agenda

- Introduction to the Low Voltage grid
- Timeseries in the LV grid: on electricity profiles
- The AI.Flanders research



the Low Voltage Distribution Grid

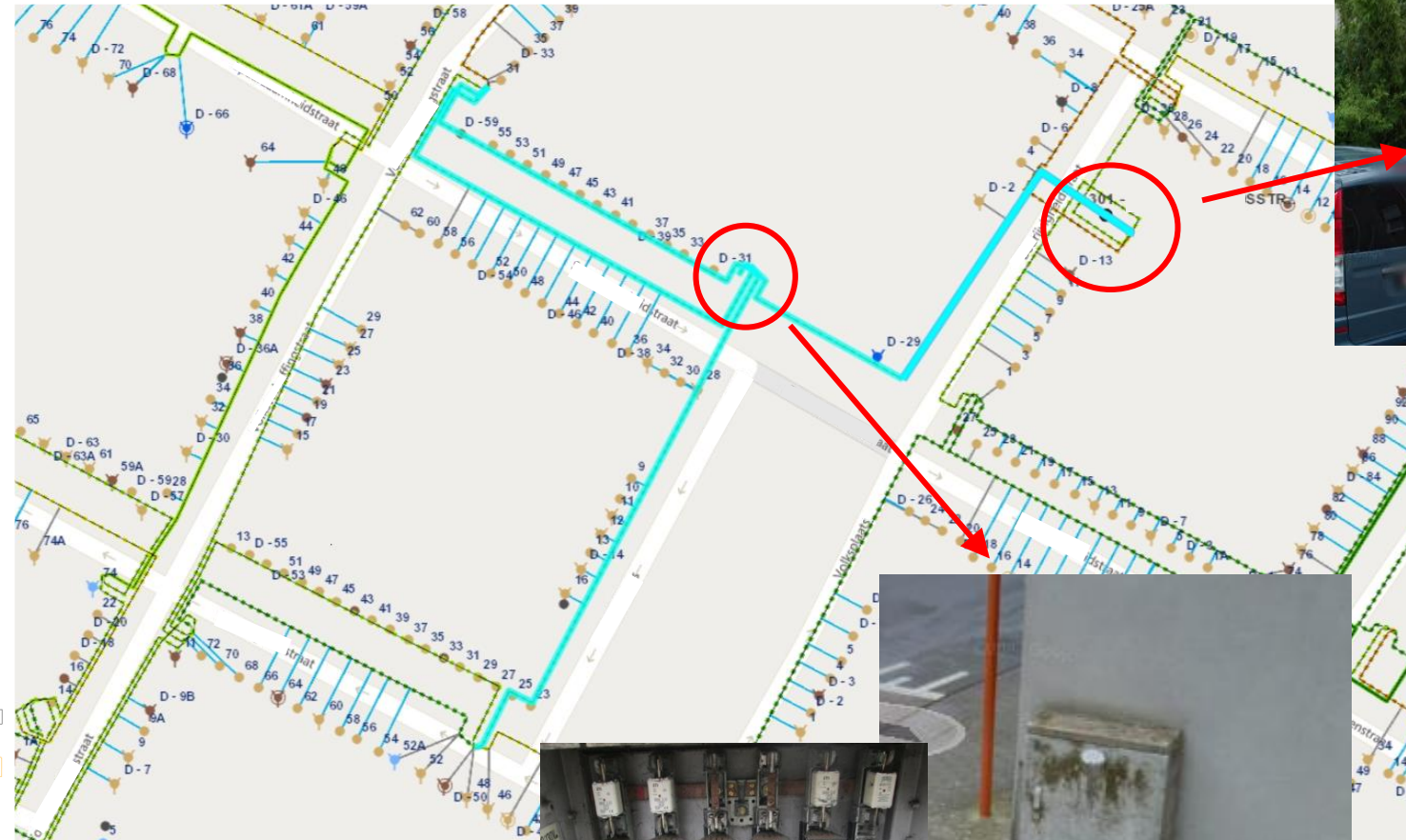
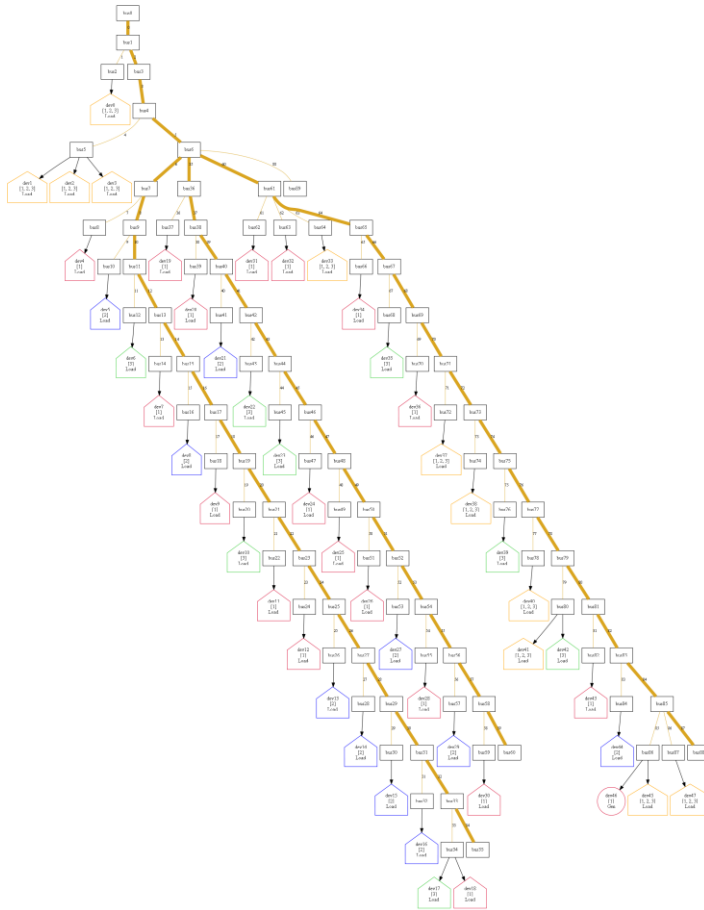
- Consists of
 - MV/LV transformers
 - Cables bringing 230V/400V to households and SME's
- A natural regulated monopoly
- Managed and operated by the Distribution System Operator
- A critical infrastructure
- A key component for the energy transition





Collection of independent small tree-shaped systems

1 transfo → 4-6 branched feeders → 30'ish connections





Massive scale

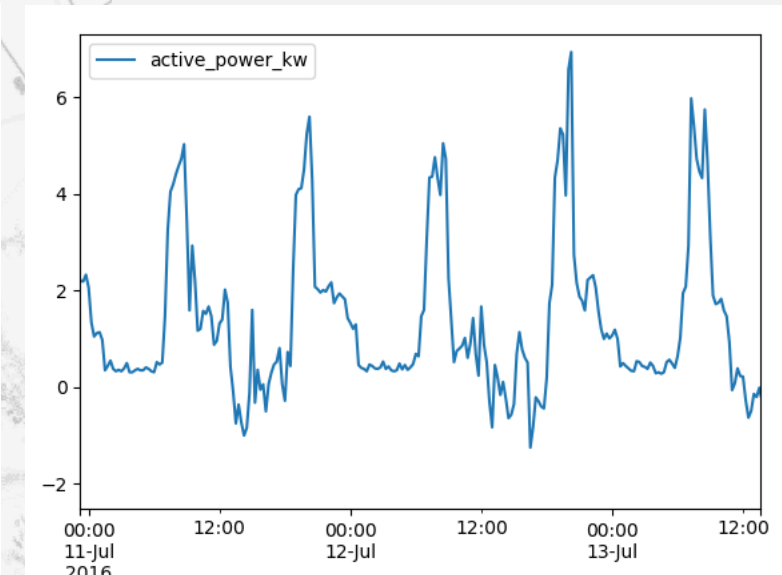
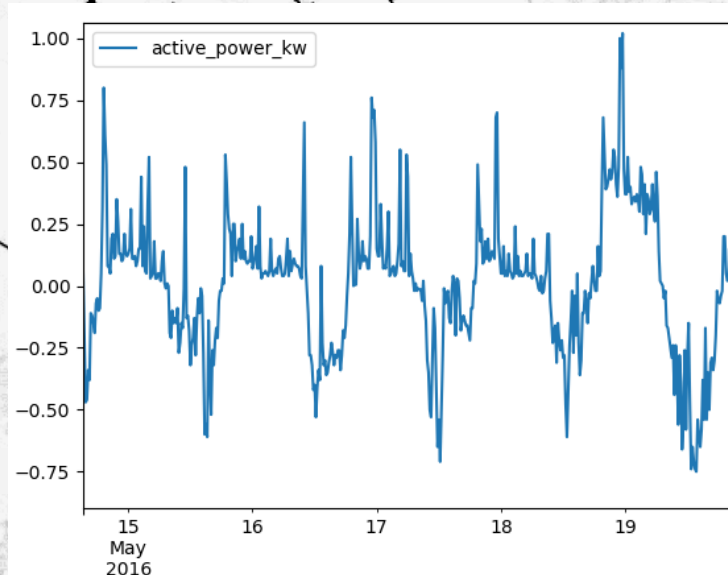
Flanders: 3,5M connections, 200k LV feeders, 40k LV transfo's
84000km cable, total asset value of 11B€

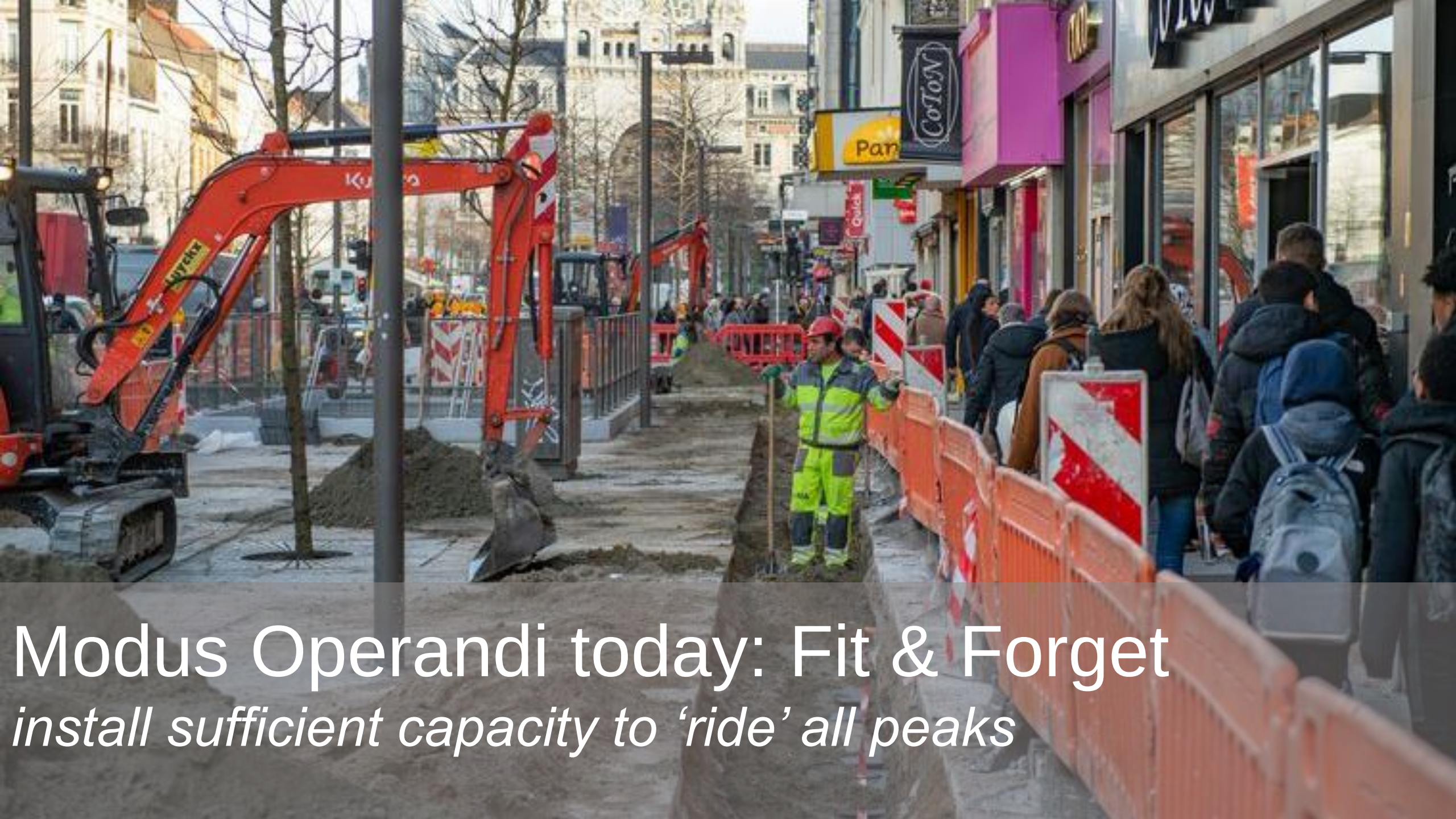
Every feeder is a unique non-linear tree shaped system
with sparse data

Behavior driven by

- Grid topology: incomplete/inaccurate data
- Offtake and injection profiles: high stochasticity, limited measurements

but increasing: digital meters ←





Modus Operandi today: Fit & Forget
install sufficient capacity to 'ride' all peaks

De Standaard

ELEKTRICITEIT

Vlaams klimaatplan vereist zwaarder elektriciteitsnet

De verplichting voor fossielvrije nieuwe wagens en verwarming zal bijkomende investeringen in het elektriciteitsnet vergen. Dat de deadline niet in 2027 maar in 2029 valt, geeft wat extra ademruimte.

Pascal Sertyn, Stijn De Cock
vrijdag 5 november 2021 om 3.25 uur

 **NWS**

Is ons elektriciteitsnet geschikt voor laadpalen van auto's? In Brussel is dat een probleem, in Vlaanderen minder

**DE
TIJD**

Rush op zonnepanelen creëert lokale overbelasting elektriciteitsnet

De Standaard

"Ons elektriciteitsnet kan dit niet aan, kabels over stoep zijn onveilig": installateurs kritisch voor "laadpalenplan"

**DE
TIJD**

Alleen nog elektrische auto's, hoe realistisch is dat?

Clean Energy Package, Electricity Directive (2019/944):

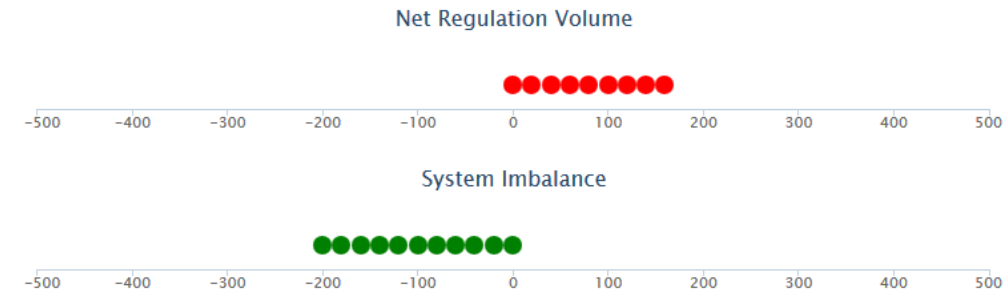
Art. 15: "final customers are entitled to act as active customers without being subject to disproportionate or discriminatory technical requirements, administrative requirements, procedures and charges"

Art. 17: "participation of demand response through aggregation should be allowed"

BUT TIMES ARE CHANGING....

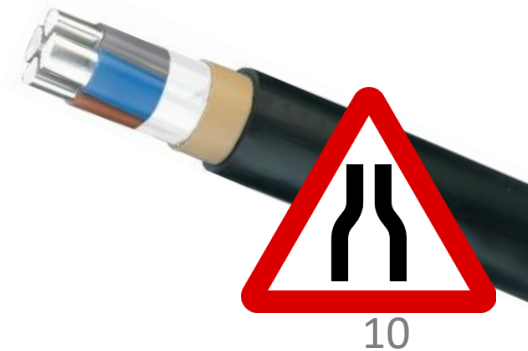


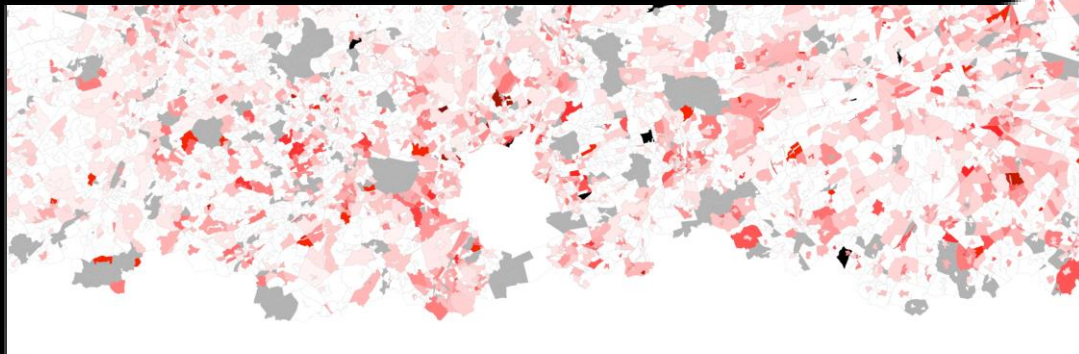
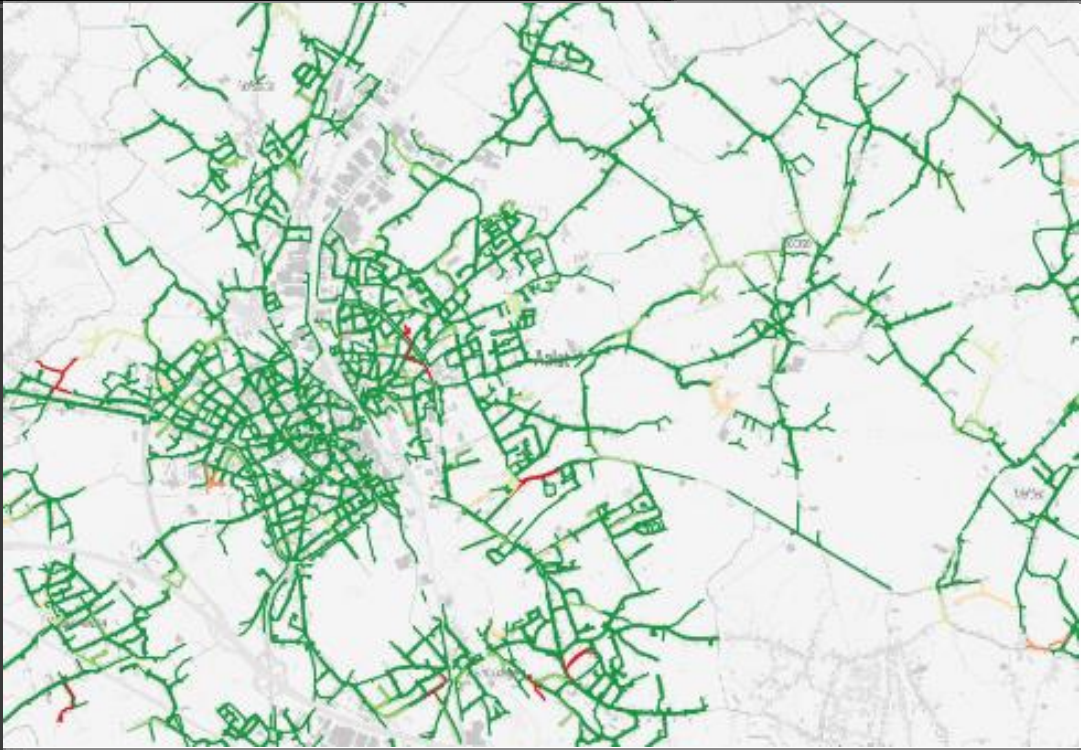
New/more loads & production



Demand response

Larger currents, more concurrency, more synchronization





Digital Twin Capabilities for the LV Grid

Combine
A.I. and Power Systems Engineering

A detailed statistical view on the LV grid
Based on sparse measurement and grid data

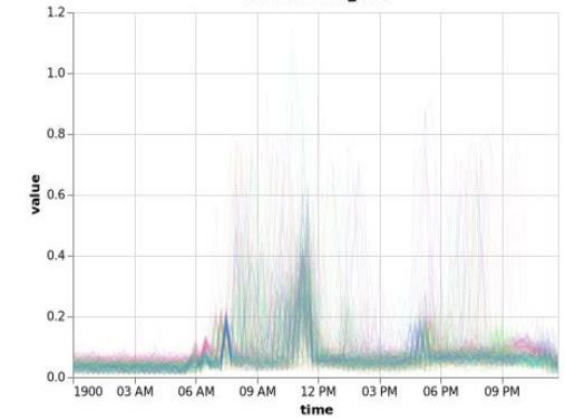
Optimized asset use
Targeted investments
Steer connected loads/production

**Avoid that the LV grid becomes a
bottleneck to the energy transition**

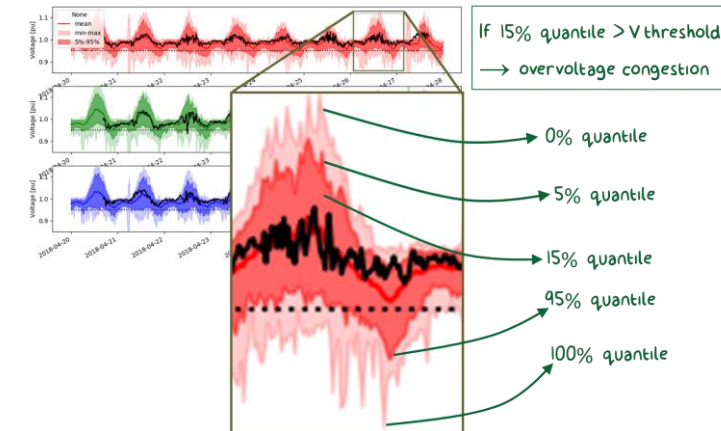
Grid Model



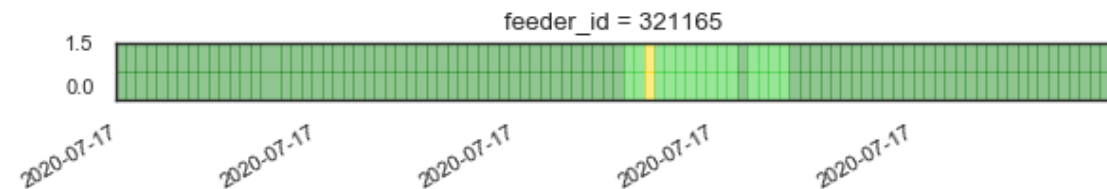
Connection Model/Forecast



Voltage/Current probability distribution



Congestion Probability



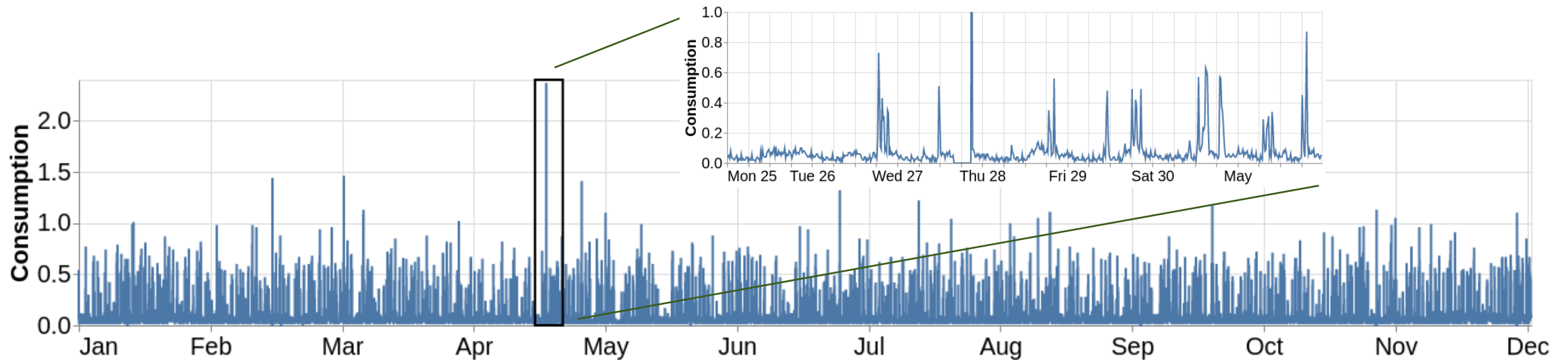
1. Enhance the knowledge on the topology and use of the grid
2. Accurate view on grid state: what are the voltages and currents in the grids today, and predict on the long term
3. Forecast and communicate the state and capacity of the grid to other energy actors

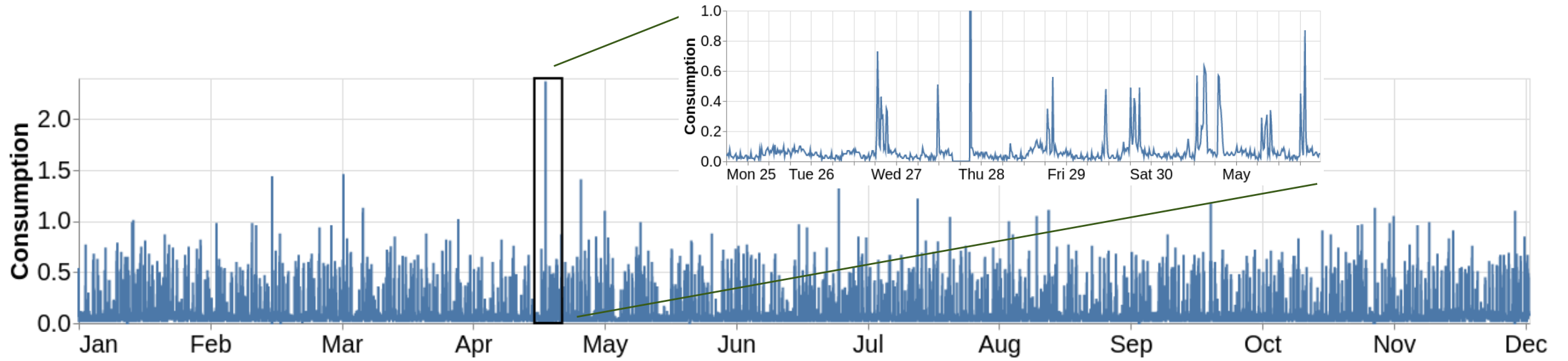
TIMESERIES IN THE LOW VOLTAGE GRID

- Are everywhere: P, Q, V, I, congestion probabilities, ...
→ any electrical properties at a node in the grid
- Typically, quarter hour data



Most important & challenging:
Offtake/injection at individual connections





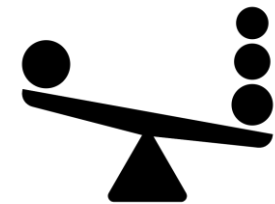
Quasy periodic



Highly volatile and stochastic

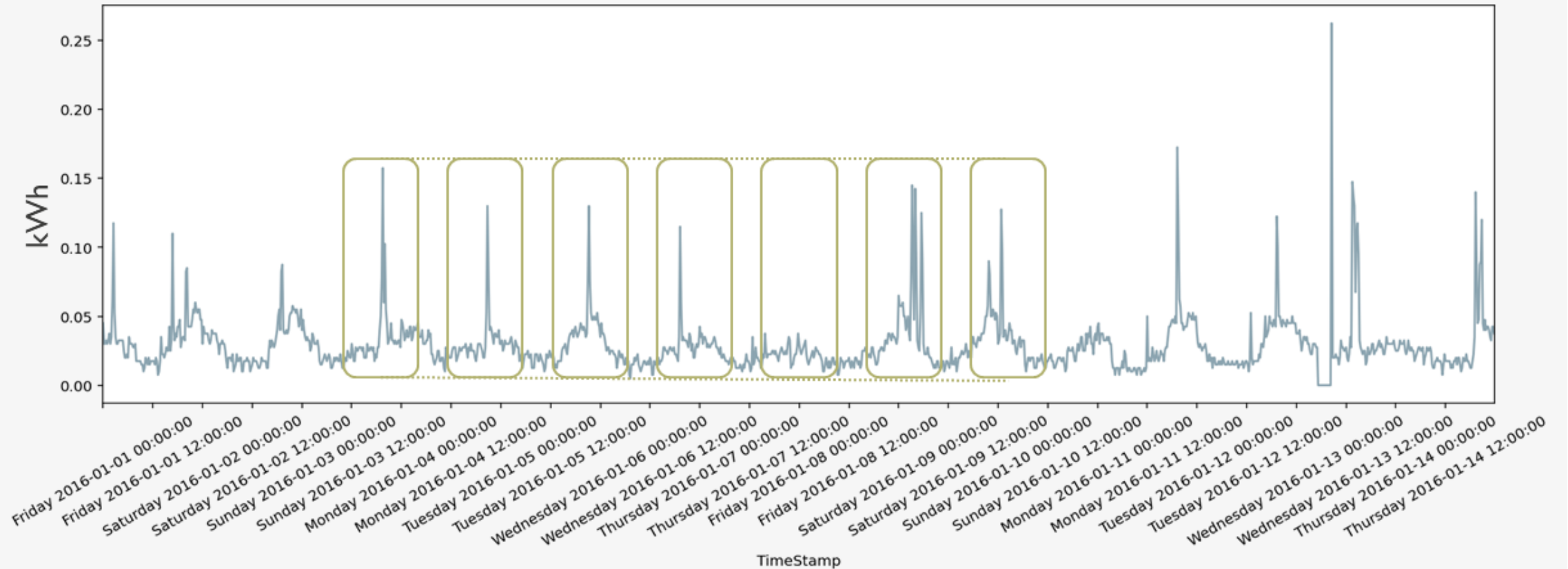


Unbalanced



(yet when aggregated in large numbers,
very predictable)

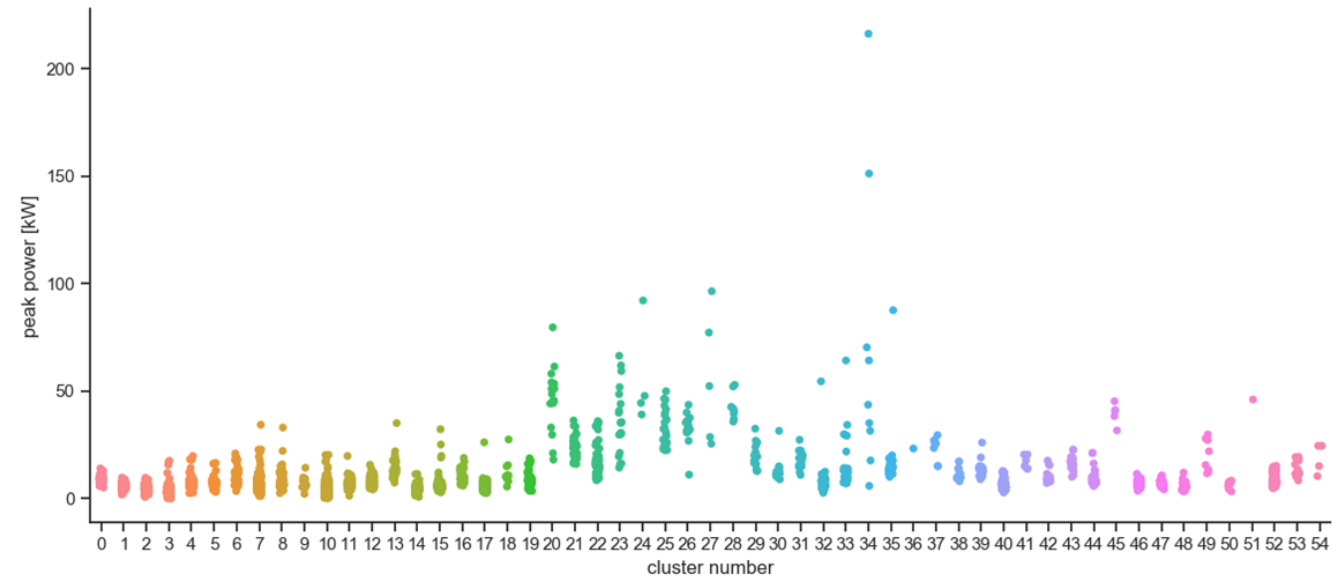
Quarter hourly consumption for one household during two weeks



HOW TO FORECAST PROFILES, OR MODEL NON-MEASURED CONNECTIONS?

Current state of the art:

M.C. sampling from historic profile dataset,
clustered with K-Means on profile meta-specs,
and day selection using temp. and solar irradiation



IMPROVING THE PROFILE CLUSTERING

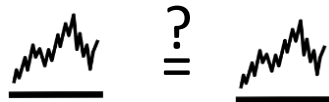
Jonas Soenen, Aras Yurtman, Wannes Meert and Hendrik Blockeel

Problem statement:

1. Cluster profiles
2. Assign non-measured connection to cluster using available meta-specs

→ Two subproblems:

Measure distance

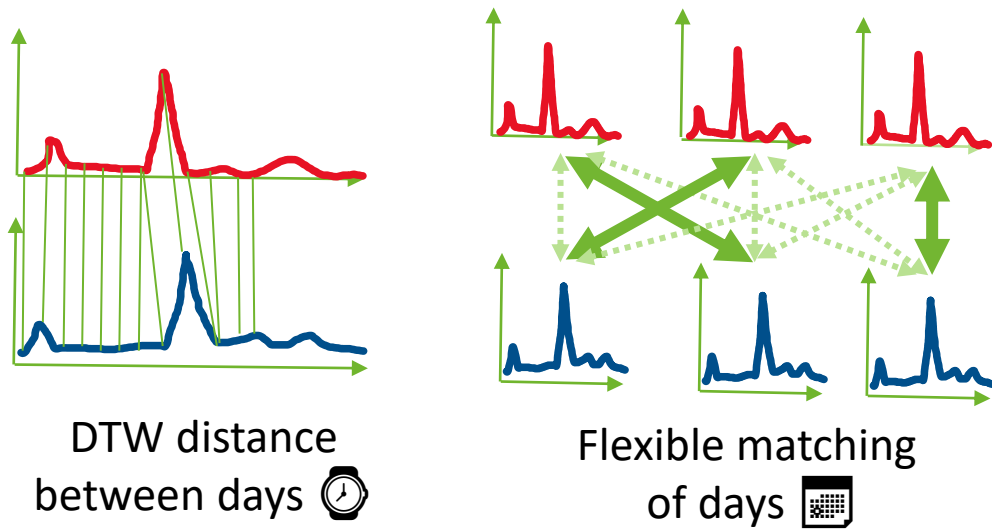


Cluster

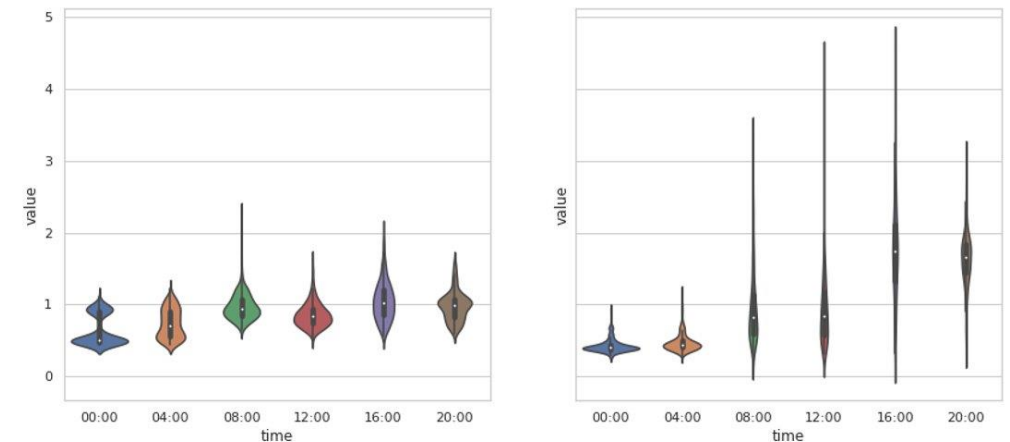


MEASURING PROFILE DISTANCE

Matching dissimilarity measure



Wasserstein-based distance metric



compare the distribution of consumption values at each timestep

CLUSTER PROFILES

1. Cluster using the distance metric
2. Improve clustering using expert feedback (COBRAS)
3. Validate and improve metric
(Rinse and repeat)

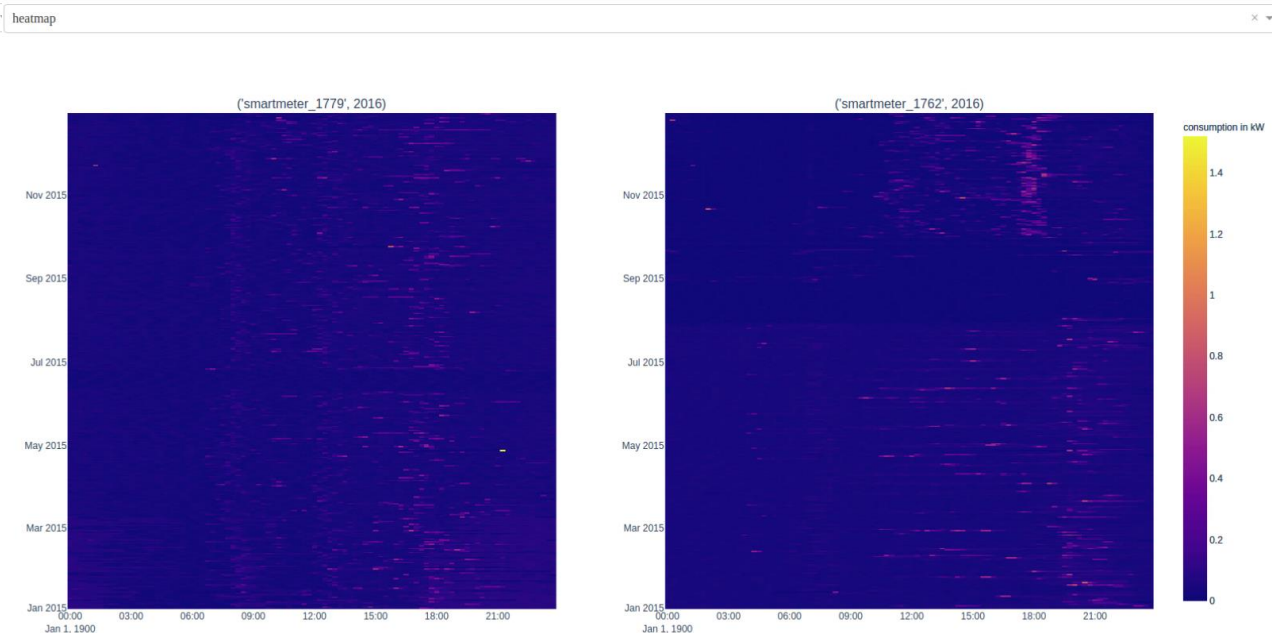
1 Queries answered



MUST-LINK

CANNOT-LINK

4 Queries answered



MUST-LINK

CANNOT-LINK

ROBUST DAYS-OF-YEAR CLUSTERING

Konstantinos Theodorakos, Mauricio Agudelo, Bart De Moor

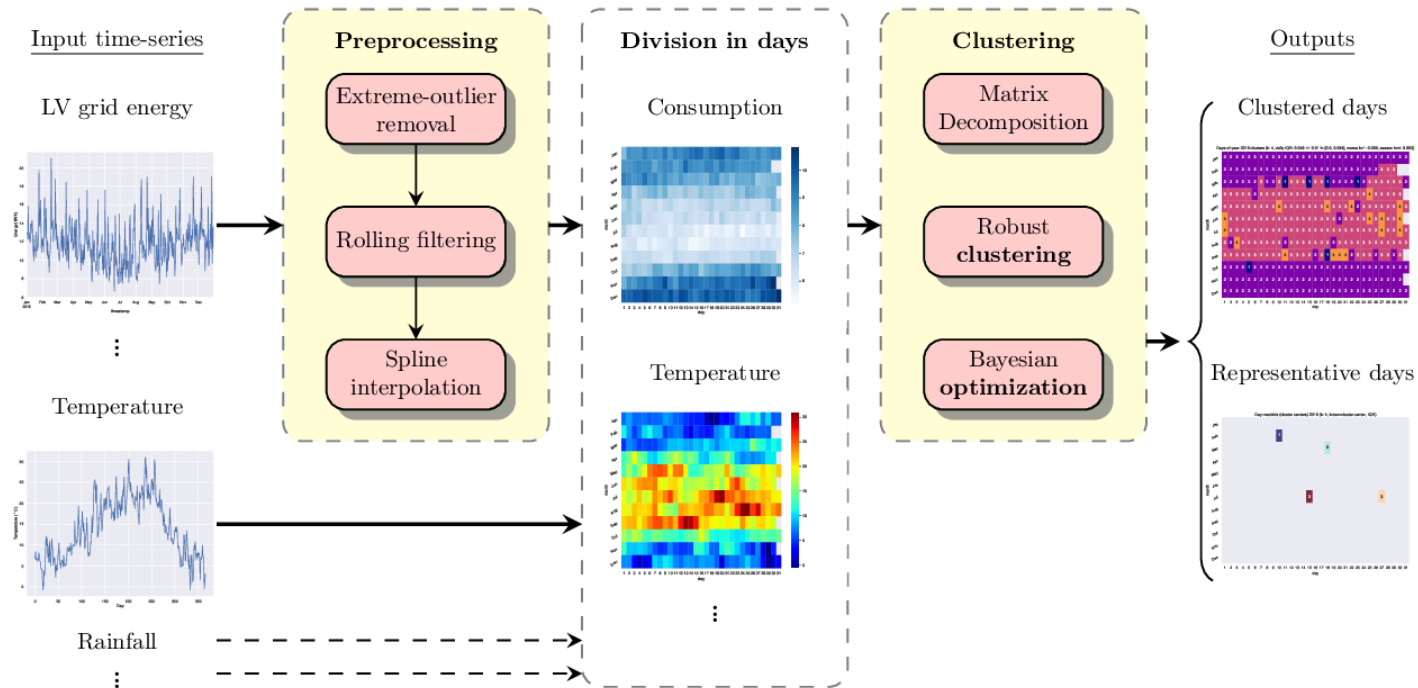
Problem statement:

The LV grid is non-linear

- Calculating currents and voltages requires iterative algorithms
- Country scale calculations for long periods of time (a year) is computationally challenging
- Instead: calculate limited set of representative days, and extrapolate

For what days are the profiles sufficiently alike, that they can be replaced by a representative day from the cluster?

Solution:



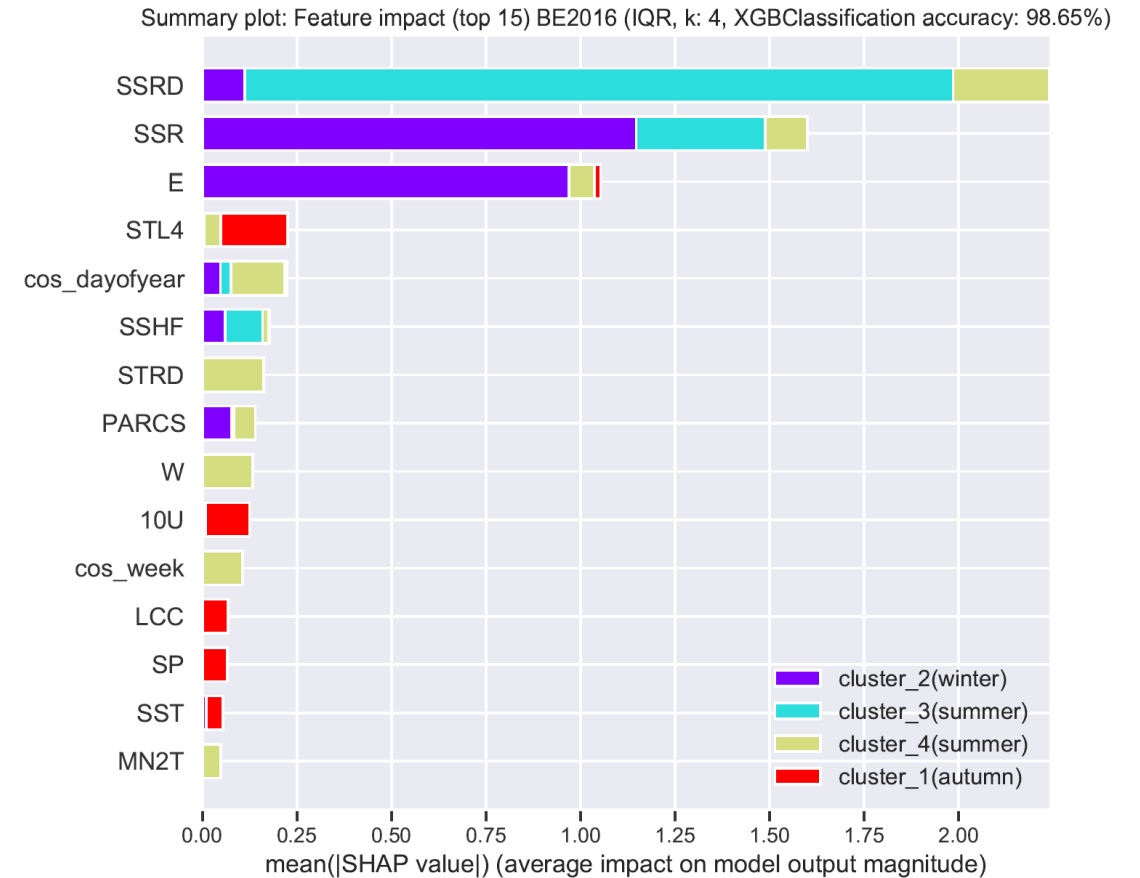
MOST INDICATIVE METEOROLOGICAL PARAMETERS

When sampling from profiles, we select days based on temperature and solar irradiation

Are there better parameters?

Ranked feature importance result

1. Surface Solar Radiation Downwards (SSRD)
2. Surface net Solar Radiation (SSR) (SSR = SSRD - earth's reflection)
3. Evaporation (E)

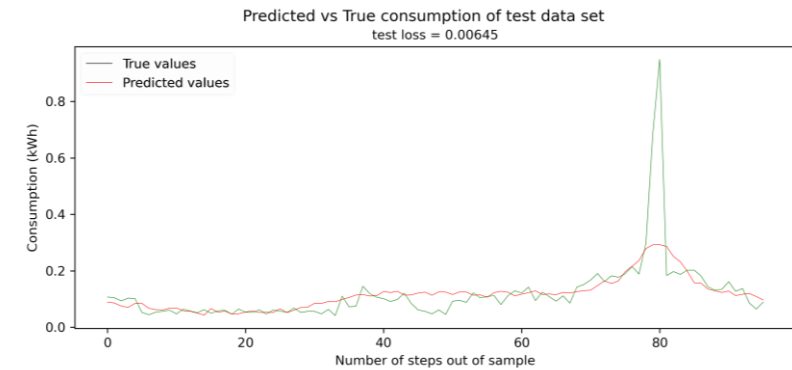
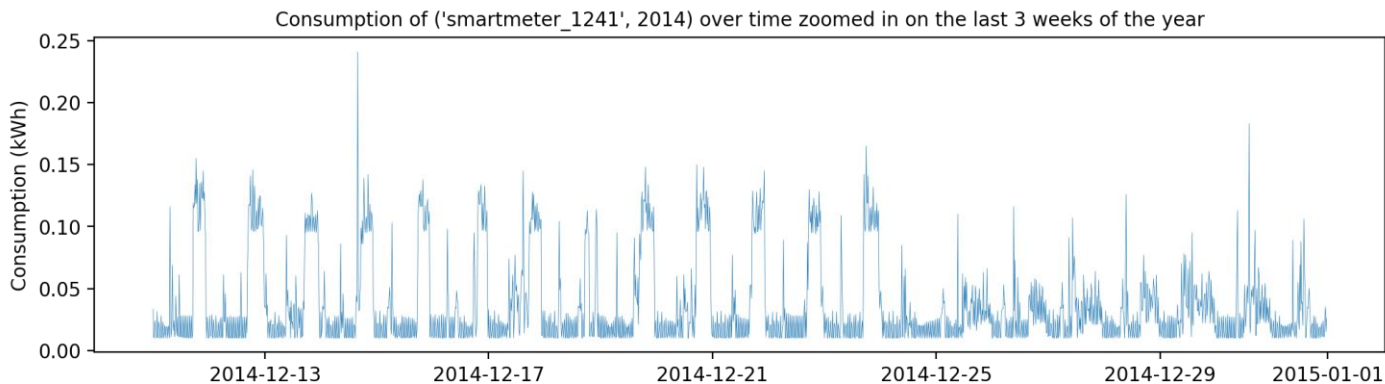
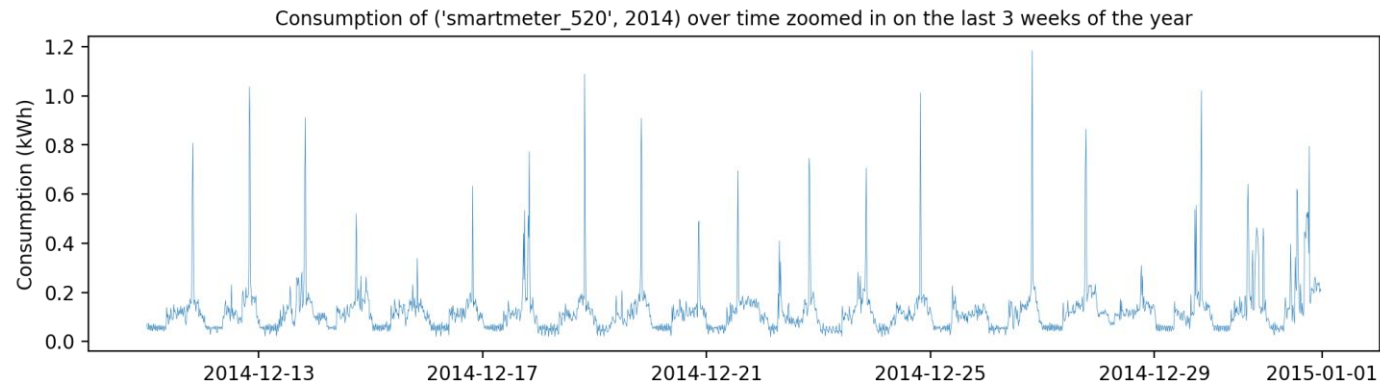


FORECAST MEASURED CONNECTIONS

Lola Botman, Mauricio Agudelo, Bart De Moor

Problem statement: Given quarter hour data till yesterday, forecast the profile of tomorrow

→ Explored various regression techniques (NN's, ...), but...



More
seasonality
↓
Better
predictions

Peaks are always under estimated. Complex problem to solve !

FORECAST MEASURED CONNECTIONS

The peaks are what we really need

→ **anomaly forecasting**

Next steps

- Reframing the problem – Regression → Classification
- Mechanisms to tackle unbalanced data sets
- New predictors: Traffic, weather,...
- Other leads: Custom loss function, Frequency domain, Log scale

BUILDING A REPRESENTATIVE DIGITAL METER DATASET



- Now: historic profile data set assembled from various ad hoc sources
- # digital meters increases, but vast majority collects no quarter hour data
- How to define a representative set of meters to model all the others?



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Questions?

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