

MEDPOWER 2014



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A novel approach for electric load curve holistic modelling and simulation

Thibaut Barbier, R. Girard, F-P. Neirac, N. Kong, G. Kariniotakis

MINES ParisTech –PERSEE Centre
Ph. D. student - Renewable Energies & Smartgrids Group
thibaut.barbier@mines-paristech.fr

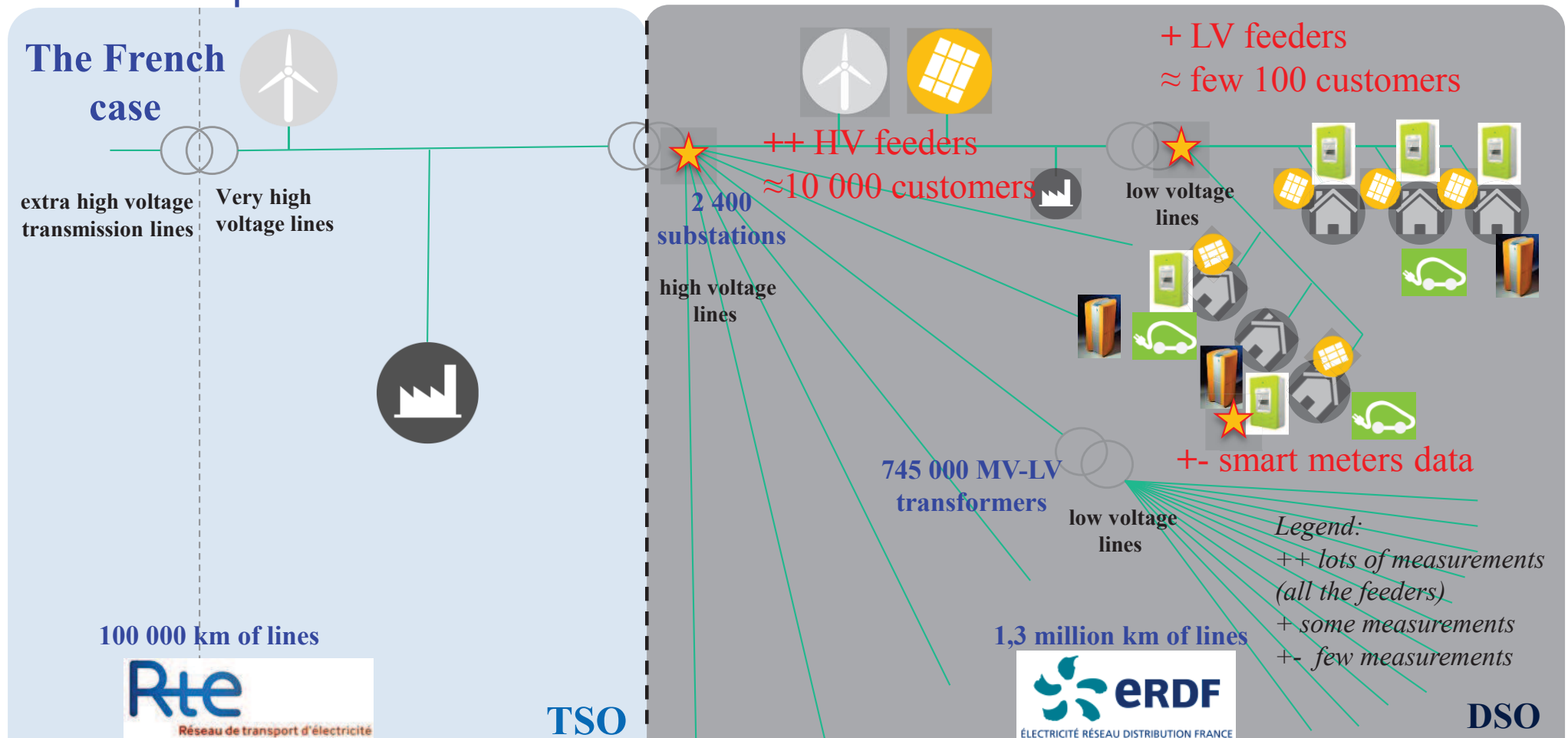


ÉLECTRICITÉ RÉSEAU DISTRIBUTION FRANCE

I. Introduction and context

Changes in electric load in the distribution network

- ❑ decentralized production
- ❑ new uses, technical innovation, renovation...
- ❑ new possibilities of smart load control



I. Introduction and context

Issues about distribution network planning and future operation

- Technical innovation
- Active and smart devices

- Accurate power equilibrium

- More and more data available

Objectives for an electricity consumption modelling

- Physical modeling of consumption devices and buildings
- Generic and easily modifiable implementation

- Simulation of individual electricity consumption of thousands of consumers at a variable time step

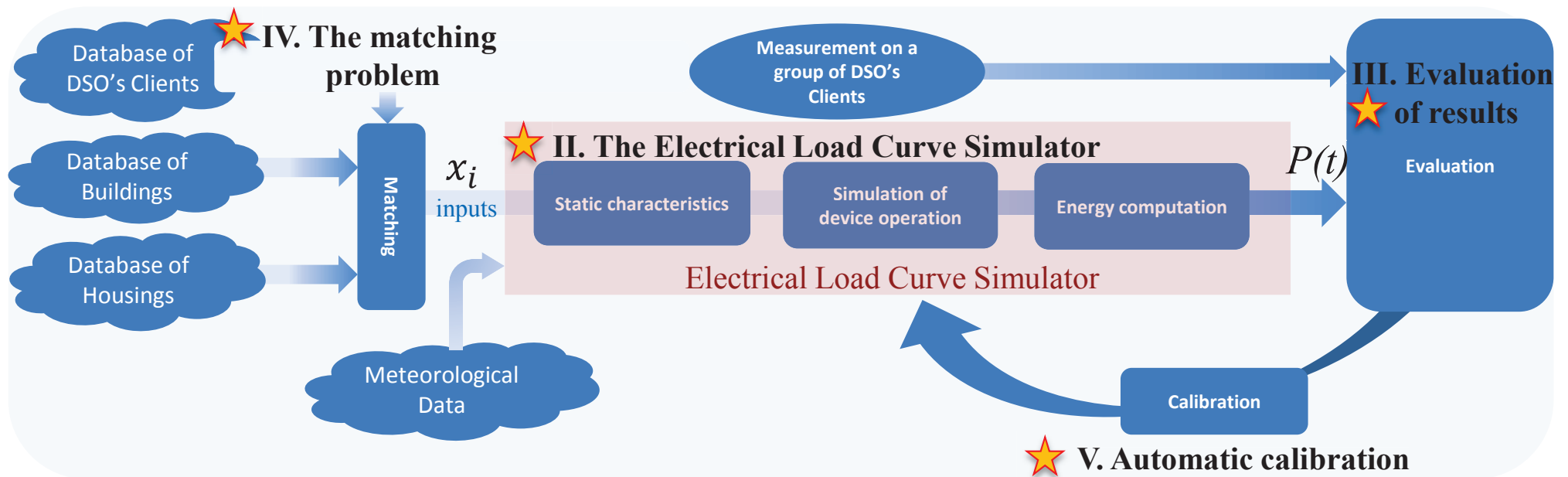
- Both macroscopic and microscopic inputs
- Rapidity of simulation to benefit automatically from large databases

I. Introduction and context

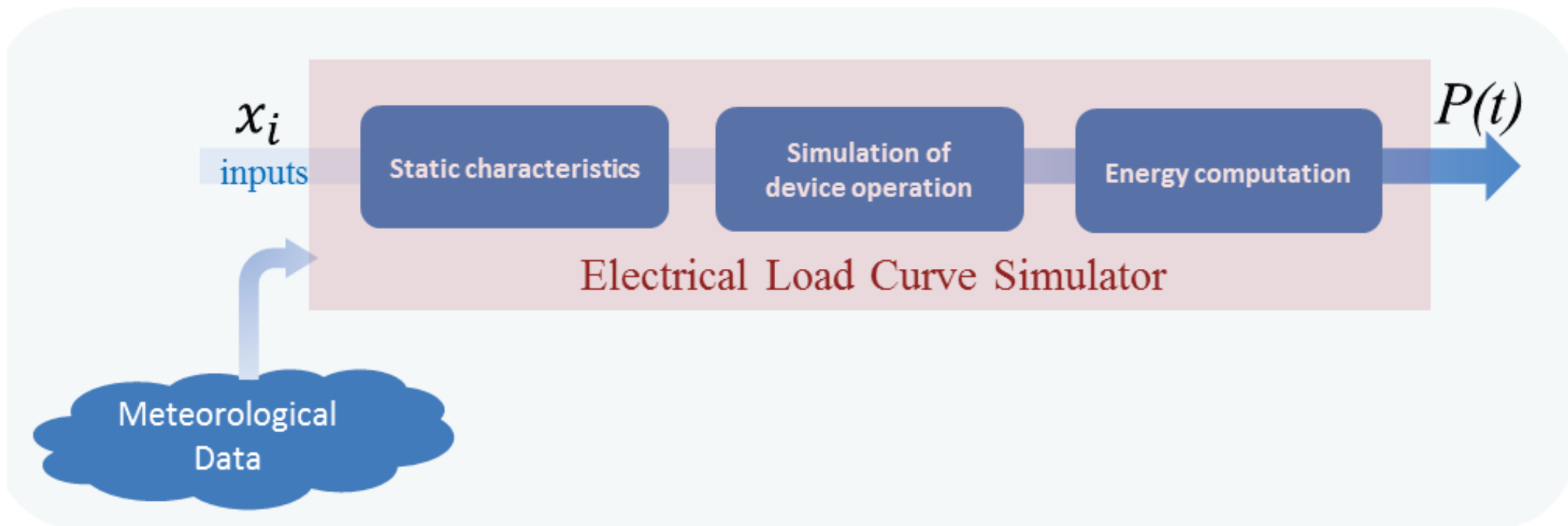
Structure of the electricity load curve simulator

Estimated electricity consumption $P(t) = f(x_i)_{i \in [1:N]}$

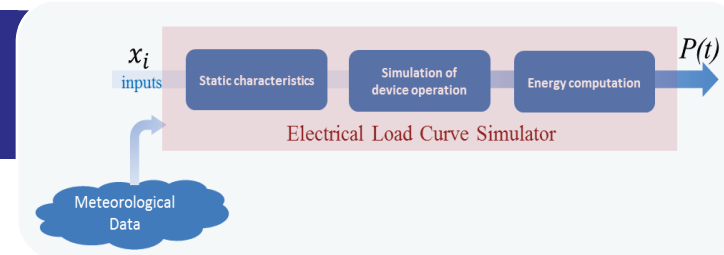
- x_i input parameters, $N \approx 1000!$



II. Structure of the simulator

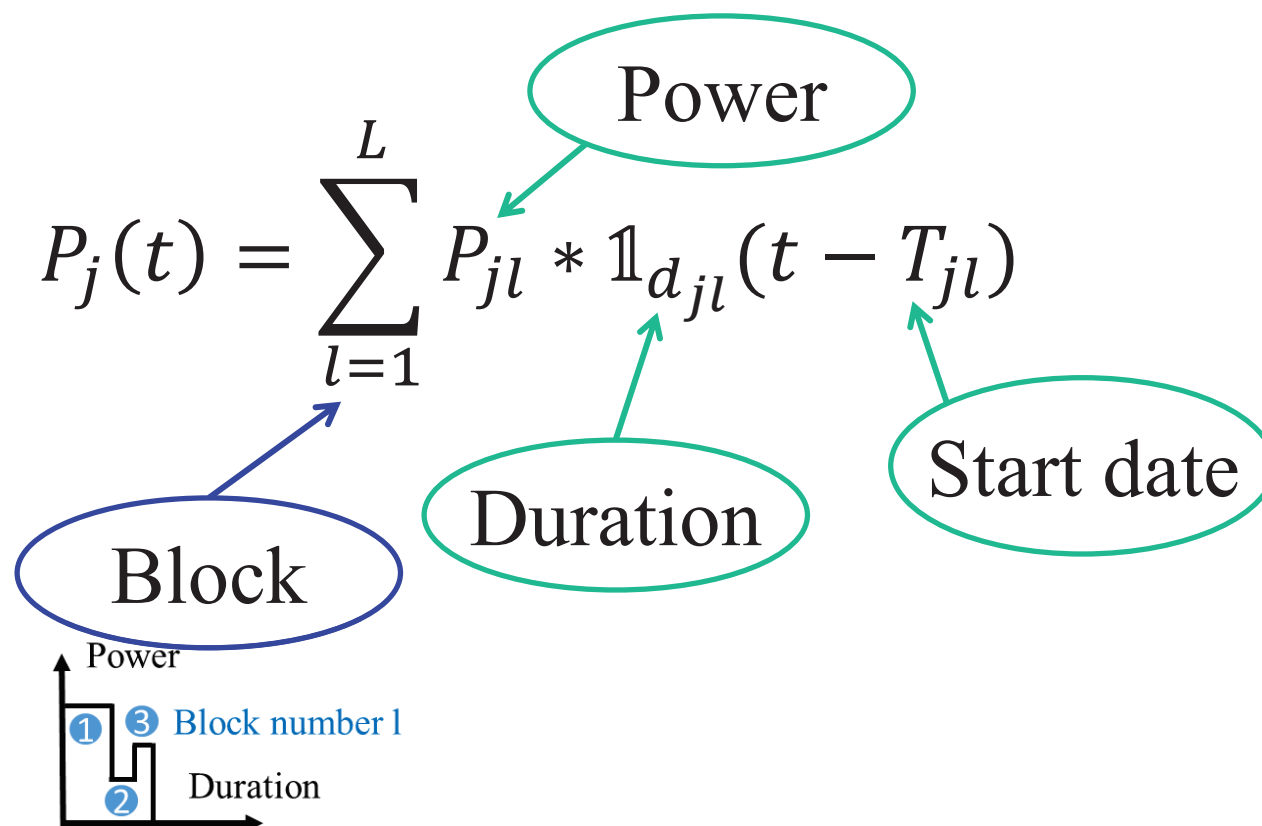


II. Structure of the simulator

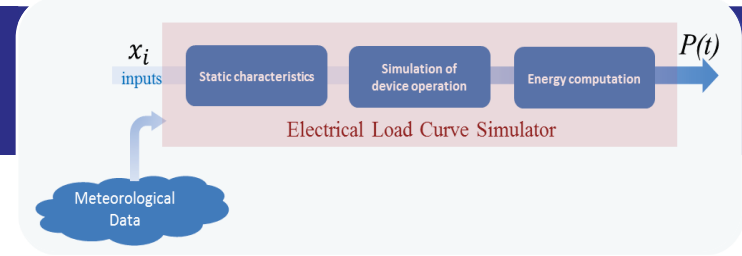


Formal description of the simulator

- Each device j is modeled by blocks of constant power

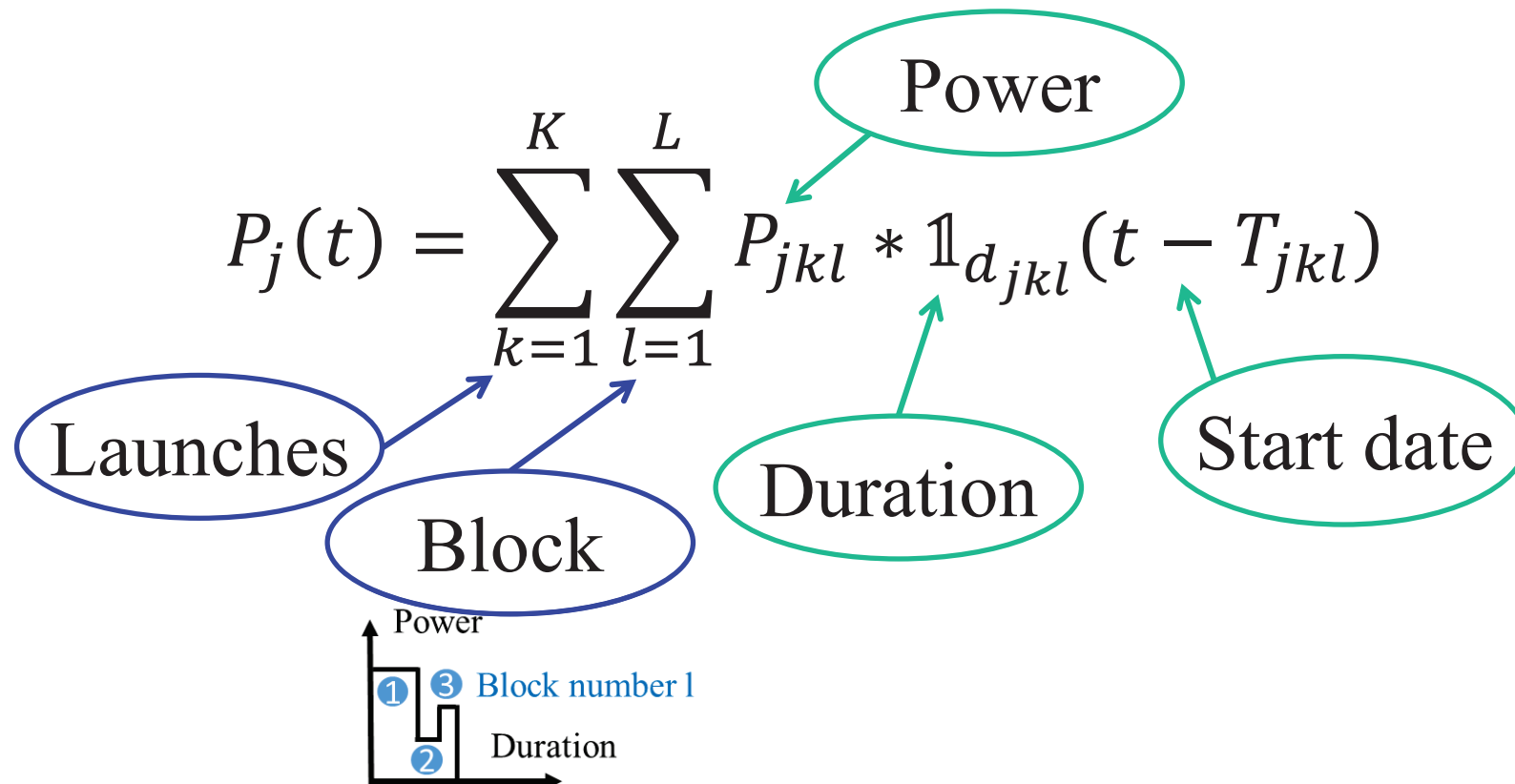


II. Structure of the simulator

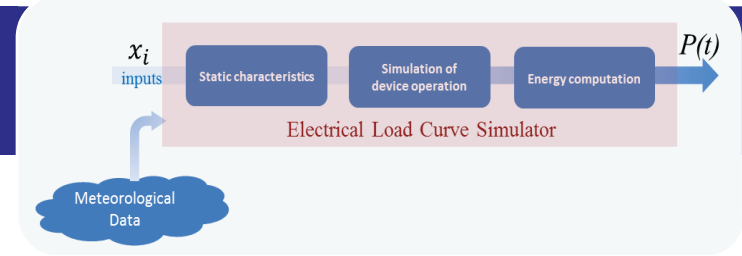


Formal description of the simulator

- ❑ Each device j is modeled by blocks of constant power
- ❑ Each device is launched



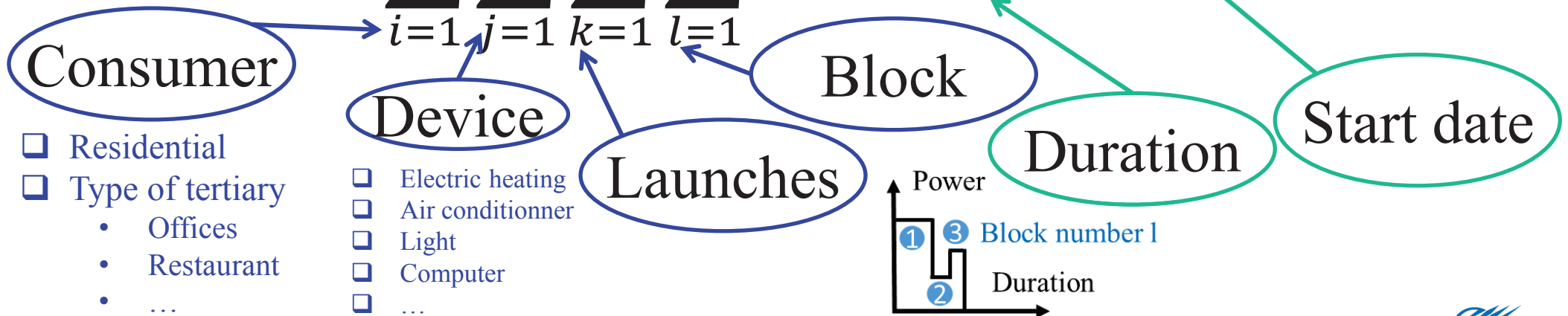
II. Structure of the simulator



Formal description of the simulator

- ❑ Each device j is modeled by blocks of constant power
- ❑ Each device is launched
- ❑ The total power is the sum on each device and each electricity consumer

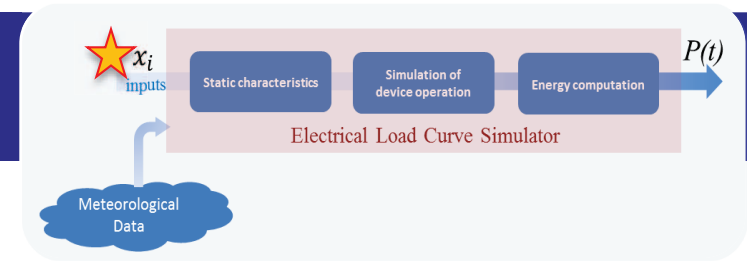
$$P(t) = \sum_{i=1}^I \sum_{j=1}^J \sum_{k=1}^K \sum_{l=1}^L P_{ijkl} * \mathbb{1}_{d_{ijkl}}(t - T_{ijkl})$$



- ❑ Residential
- ❑ Type of tertiary
 - Offices
 - Restaurant
 - ...

- ❑ Electric heating
- ❑ Air conditioner
- ❑ Light
- ❑ Computer
- ❑ ...

II. Structure of the simulator



The inputs

- List of different inputs depending on the consumer type

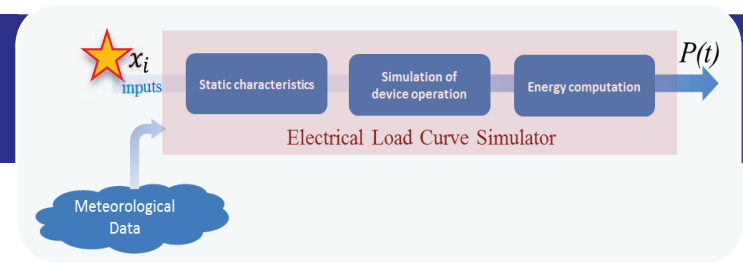
Deterministic
inputs

- Geometrical characteristics
- Assembly characteristics
- Number of people
- ...

Statistical
inputs

- Ownership rate of appliances
- Power distribution of appliances
- ...

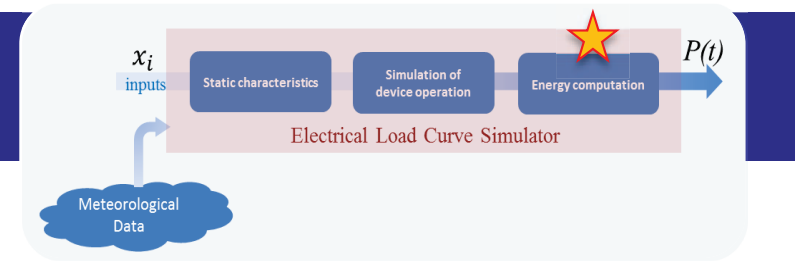
II. Structure of the simulator



Example of uses of the inputs in the first steps of the simulation

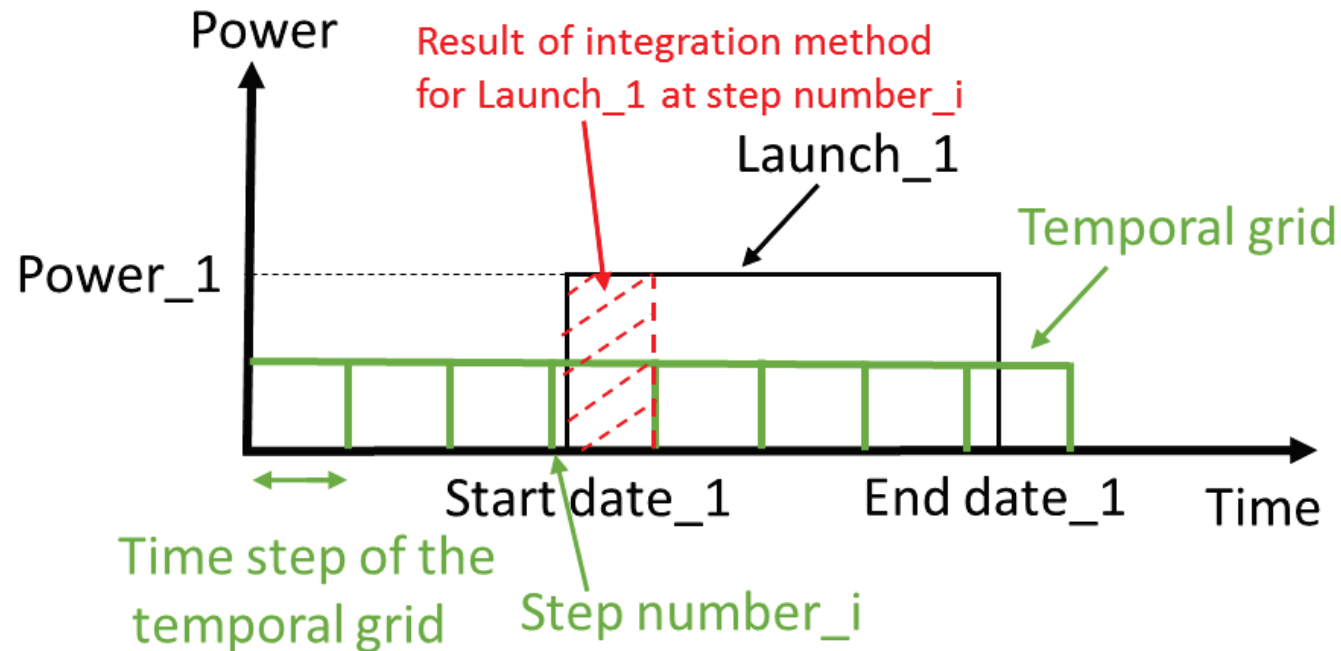
Kind of inputs / Step of simulation	Statistical inputs (Sample)	Deterministic inputs (Assignment)
Static characteristics	<ul style="list-style-type: none"> • Ownership rate of appliance • Number of bulb per surface • Power of TV • 	<ul style="list-style-type: none"> • Type of consumer • Geometry of building • Thermal assembly characteristics • Power of the electric heater • ...
Simulation of device operation	<ul style="list-style-type: none"> • Density of probability of uses • Duration of TV • ... 	<ul style="list-style-type: none"> • Number of launch of consumption device • Target temperature for electric heaters • ...

II. Structure of the simulator

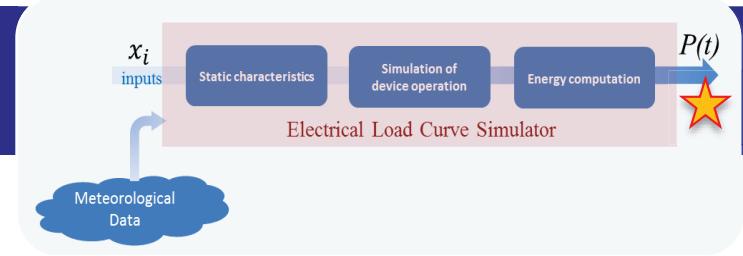


Energy computation

- The vector of launches is crossed by applying the chosen temporal grid (not necessarily regular)

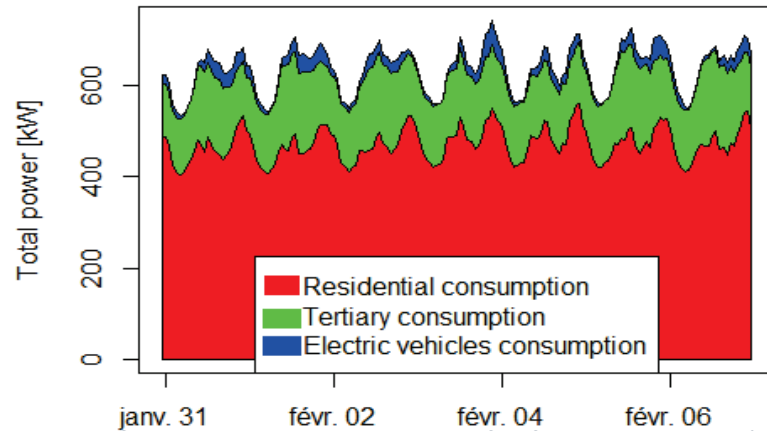


II. Structure of the simulator

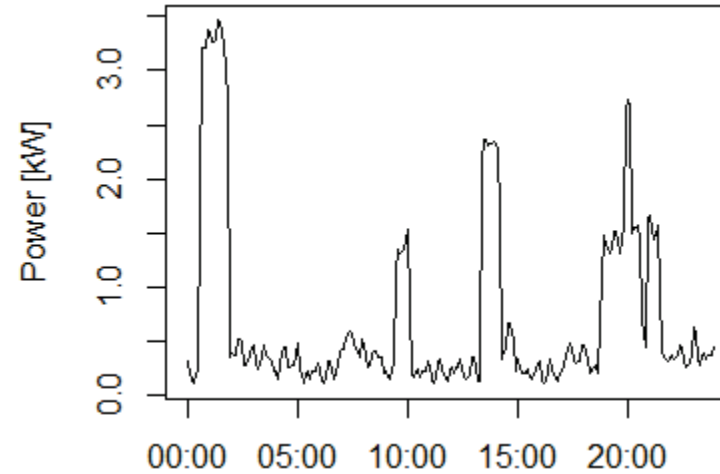


Outputs of the simulator

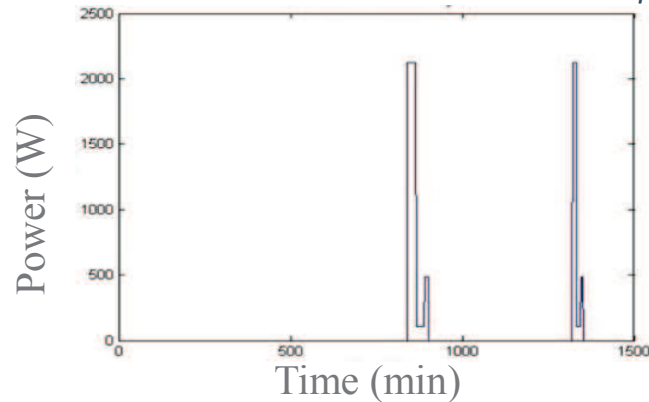
- Possibility to display a global load curve, per appliance, per consumer, at different time steps...



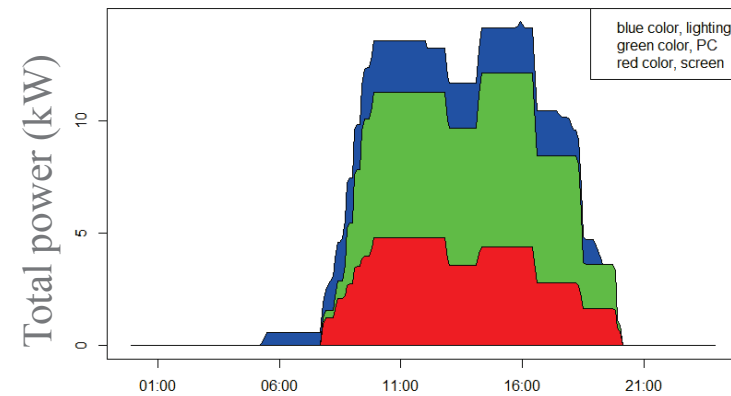
Example of a load curve simulated of a futurist district (2030) : 500 apartments, 6000m² tertiary, 1 EV charging station of 25 terminals
Around 10 seconds to simulate at 1 hour time step one year



Example of a simulated load curve for a residential customer



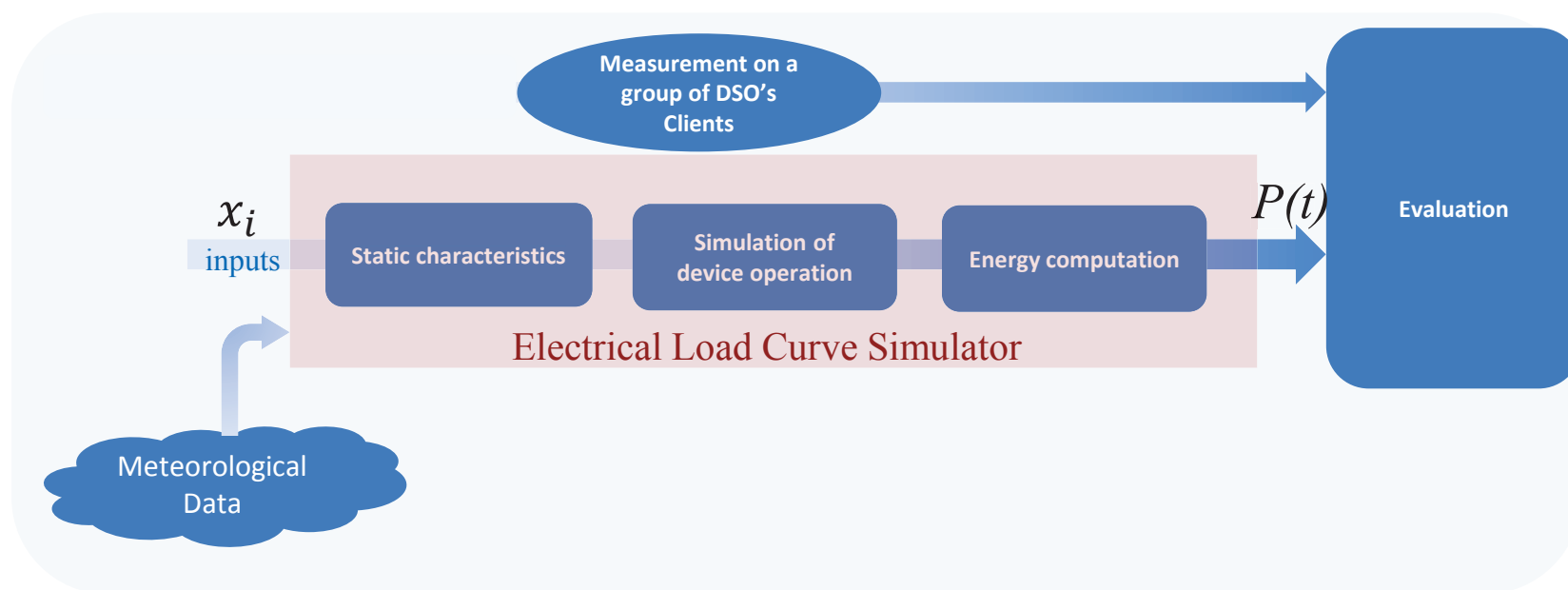
Load curve of a laundry machine modeled by
Constant block of power



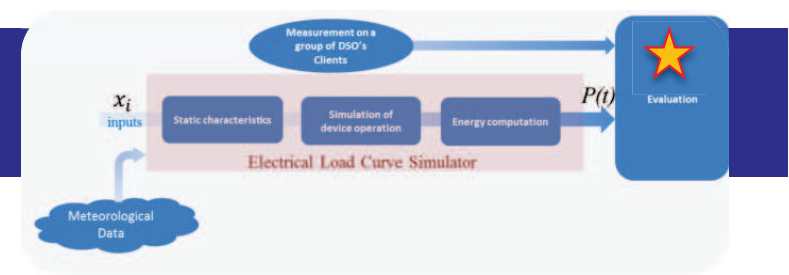
Simulation of a 1000m² office without standby

III. Evaluation of results

Compare the results to a reference



III. Evaluation of results



Methodology for evaluation on the whole curve

❑ Statistical indicators

- Mean, min, max, RMS value etc.

❑ Temporal aspect

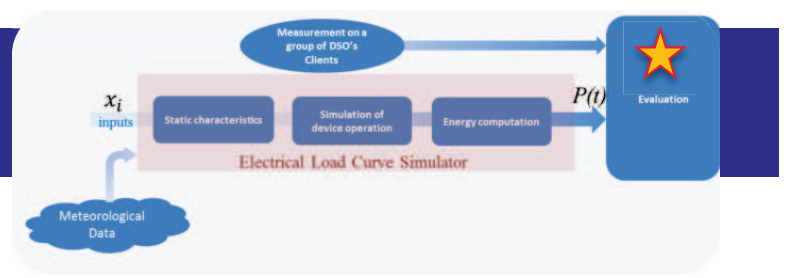
- Peak correlation, frequency spectrum etc.

❑ Both spatial and temporal comparison

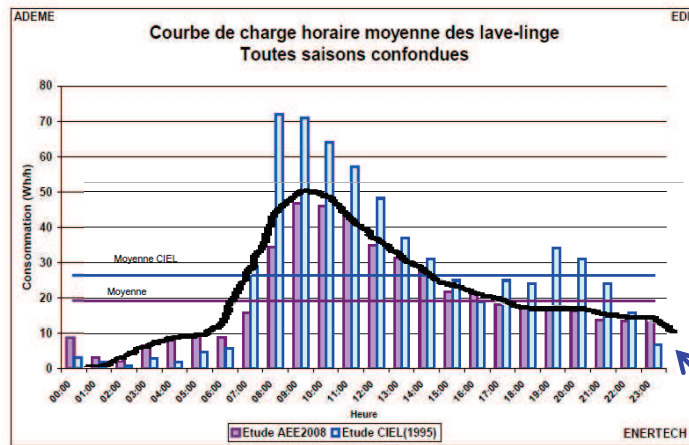
- Dynamic Time Warping [1]

[1] A. Grandjean. “Introduction de non linéarités et non stationnarités dans les modèles de représentation de la demande électrique résidentielle“. Ph. D. Thesis. January 2013.

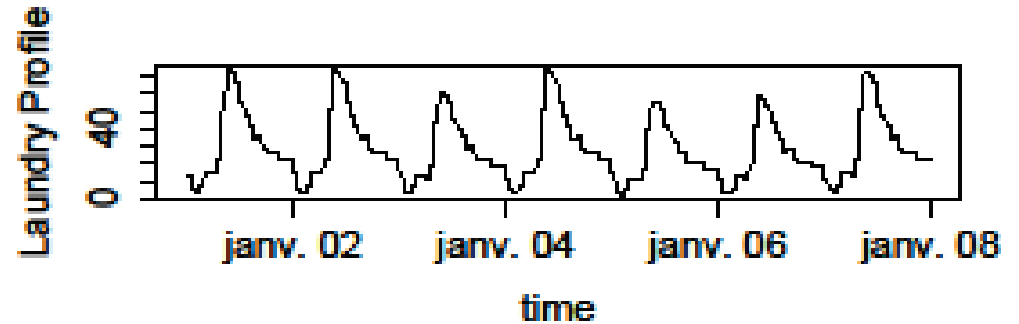
III. Evaluation of results



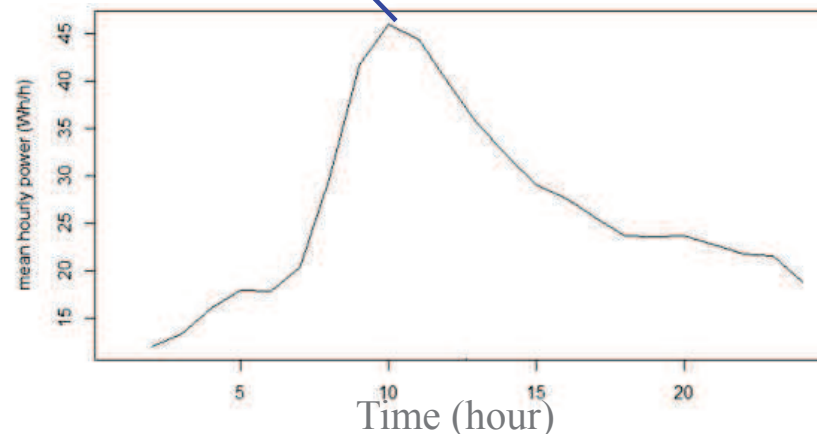
Case study: the hourly load curve of an average day



Hourly load curve of an average day for a washing machine from campaign measurement [ENERTECH]

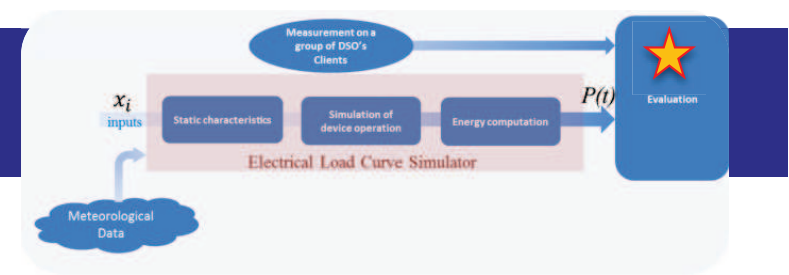


Target function for the launch of the consumption device « washing machine »

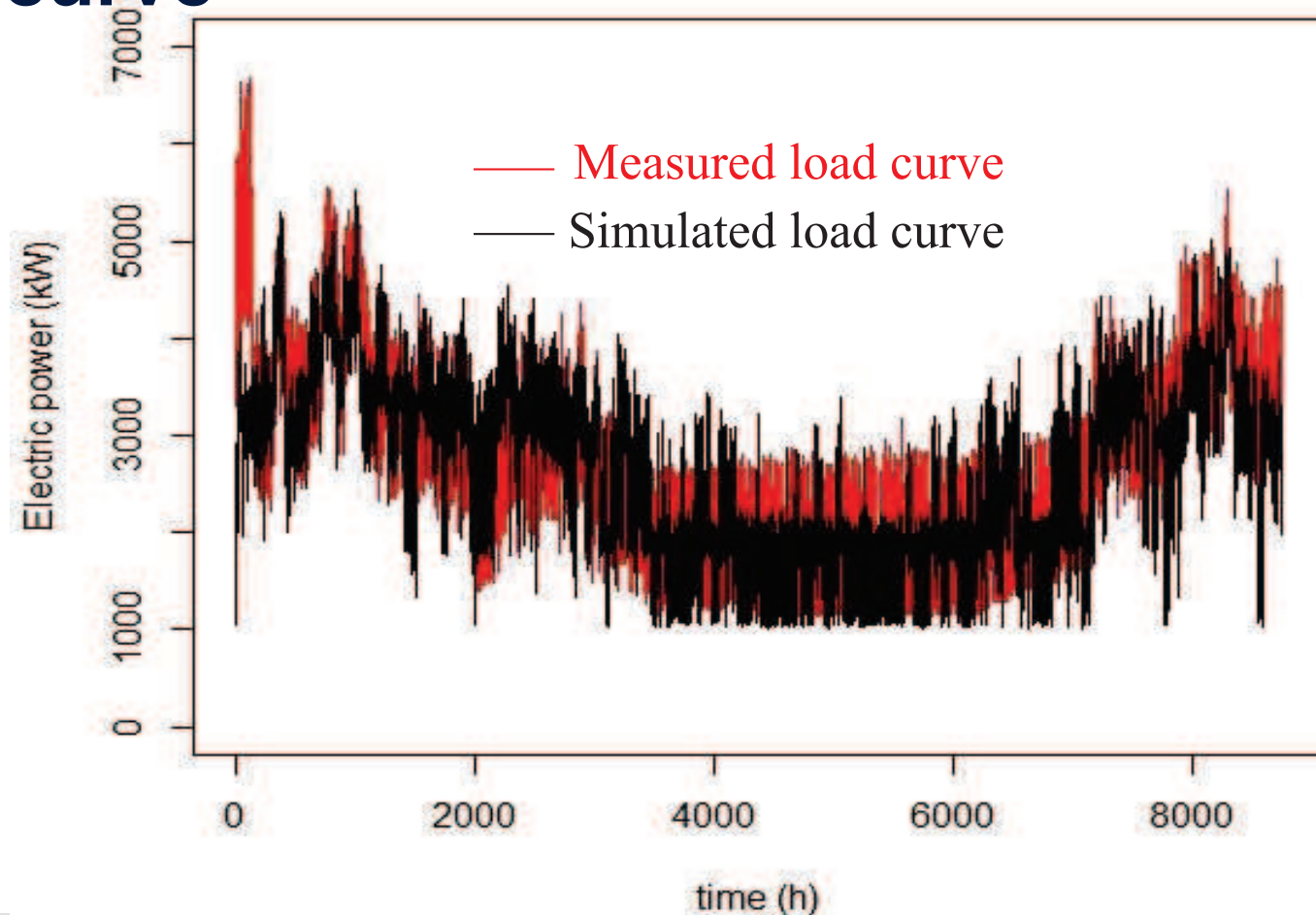


Mean hourly load curve obtained with 1000 simulations during 1 year

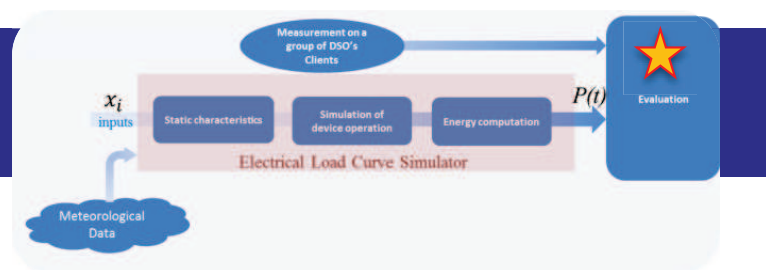
III. Evaluation of results



Case study: comparison between a HV feeder of 2500 residential customers and the simulated load curve

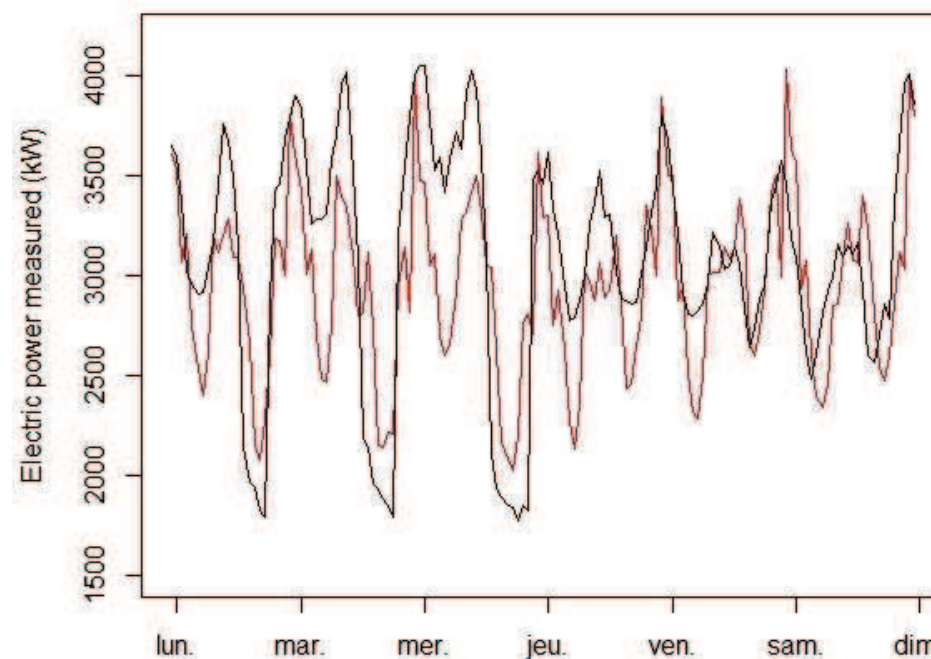
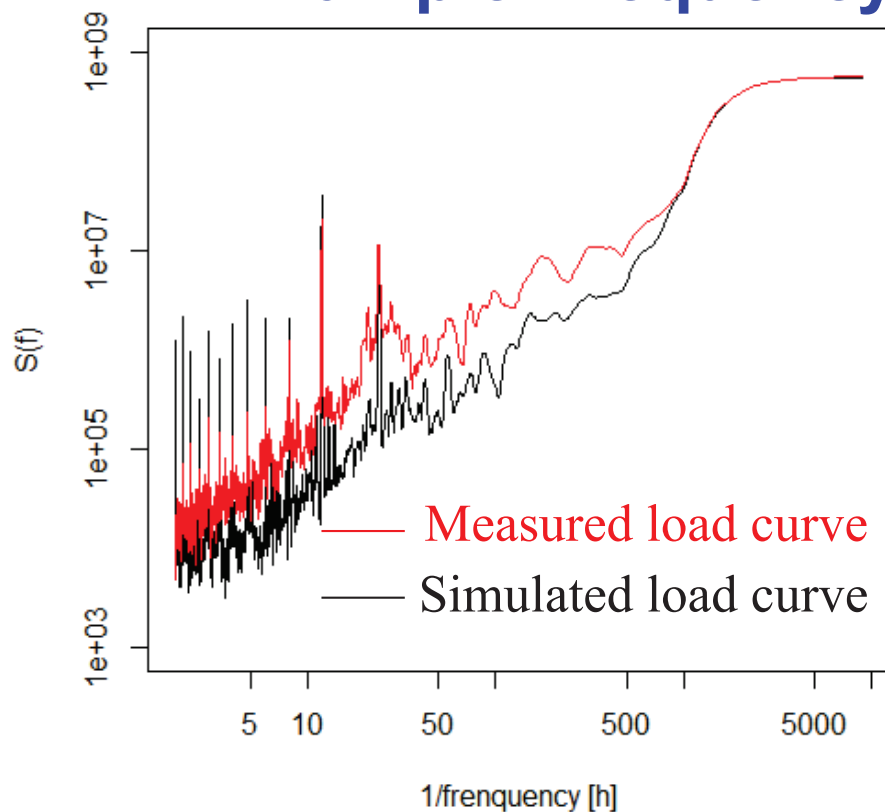


III. Evaluation of results



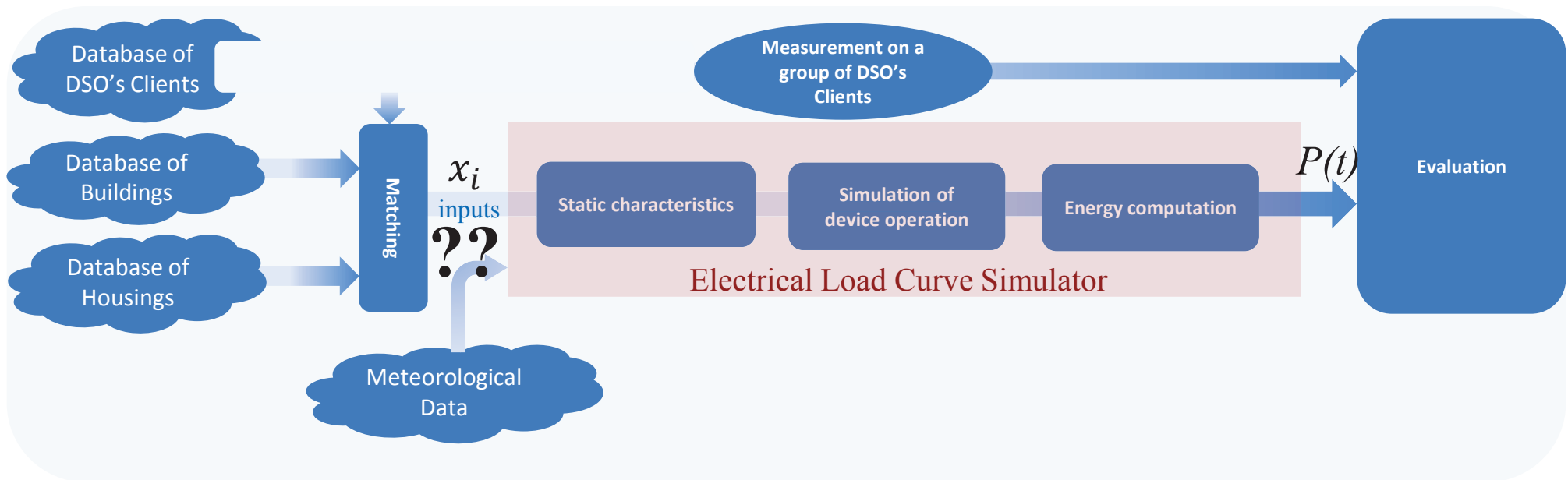
Case study: comparison between a HTA feeder of 2500 residential customers and the simulated load curve

□ Example: frequency spectrum comparison

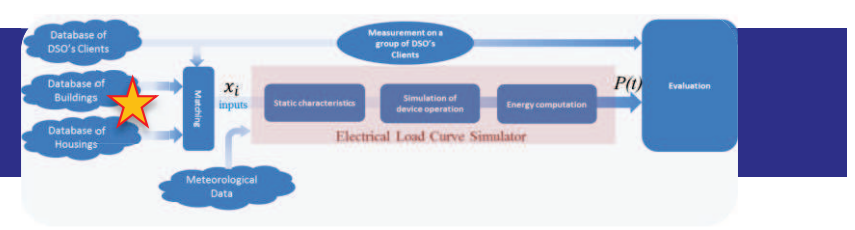


IV. The matching problem

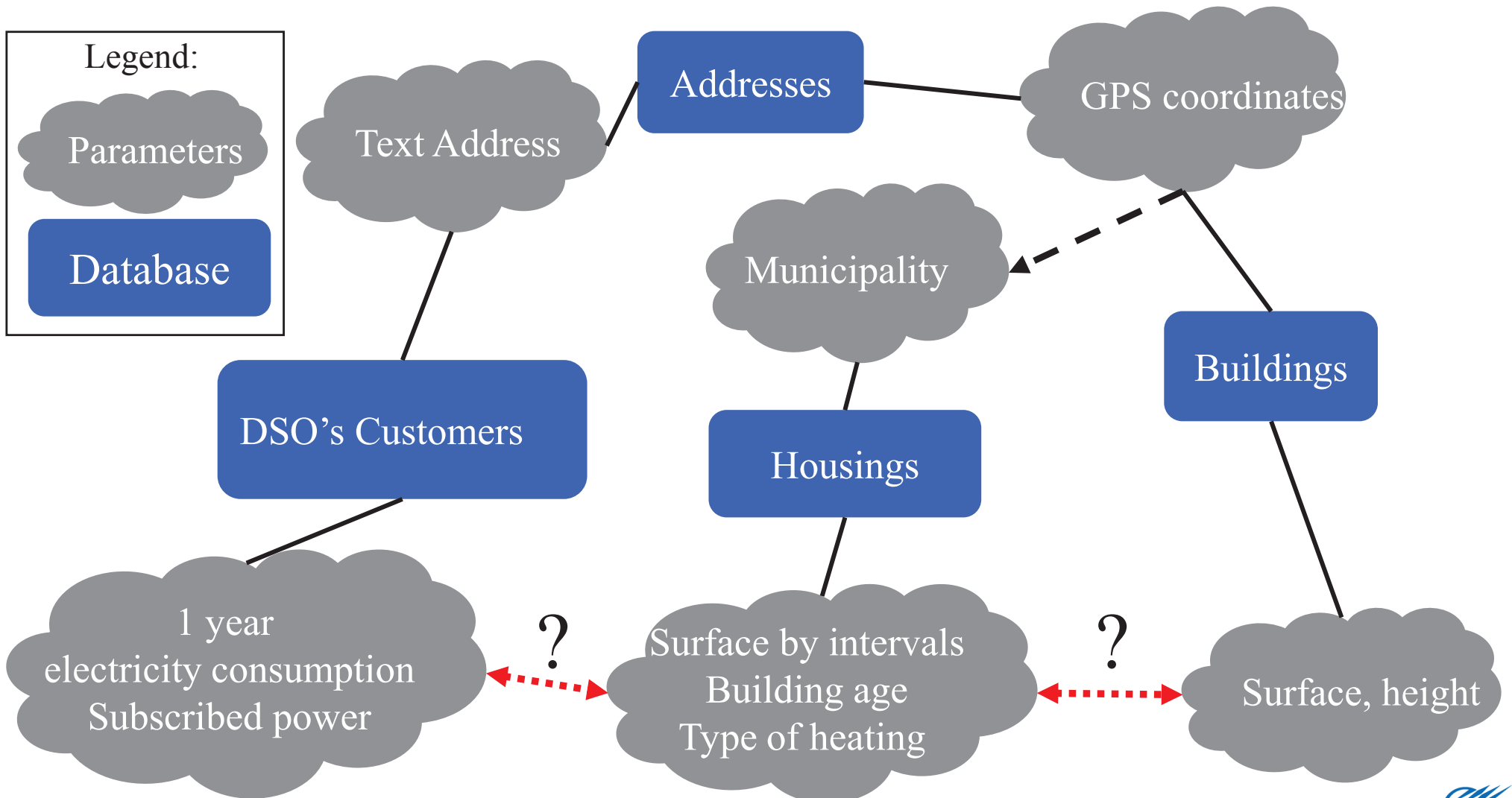
How obtain comparable load curves ?



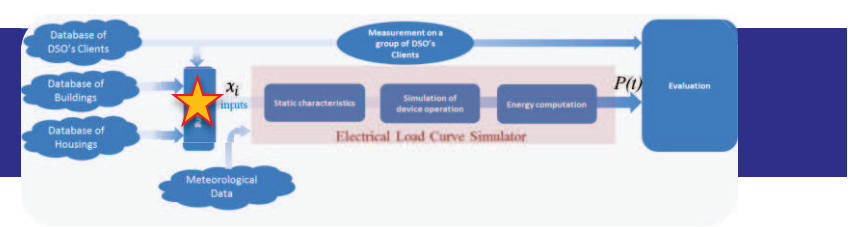
IV. The matching problem



The databases and their relationship



IV. The matching problem



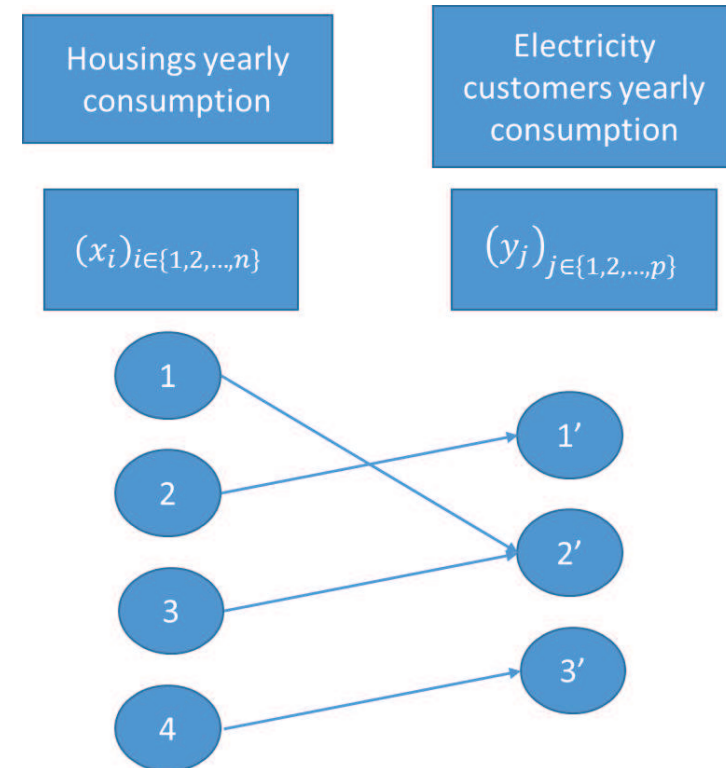
Mathematical formulation of the problem

□ Aim to match each electricity customers with one housing

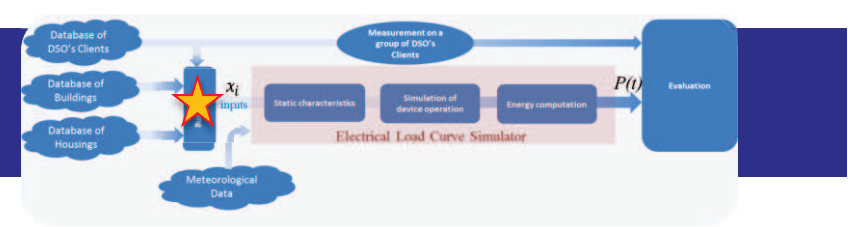
$$\min_{(\alpha_{ij})_{(i,j) \in [1:n] \times [1:p]}} \left[\sum_j^p \left| \sum_i^n \alpha_{ij} x_i - y_j \right| \right]$$

St:

- $\alpha_{ij} \in \{0,1\}, \forall (i,j) \in \{1,2, \dots, n\} \times \{1,2, \dots, p\}$ **(1)**
- $\sum_j^n \alpha_{ij} \geq 1 \forall i \in \{1,2, \dots, n\}$ **(2)**
- $\sum_i^n \alpha_{ij} = 1 \forall j \in \{1,2, \dots, p\}$ **(3)**



IV. The matching problem

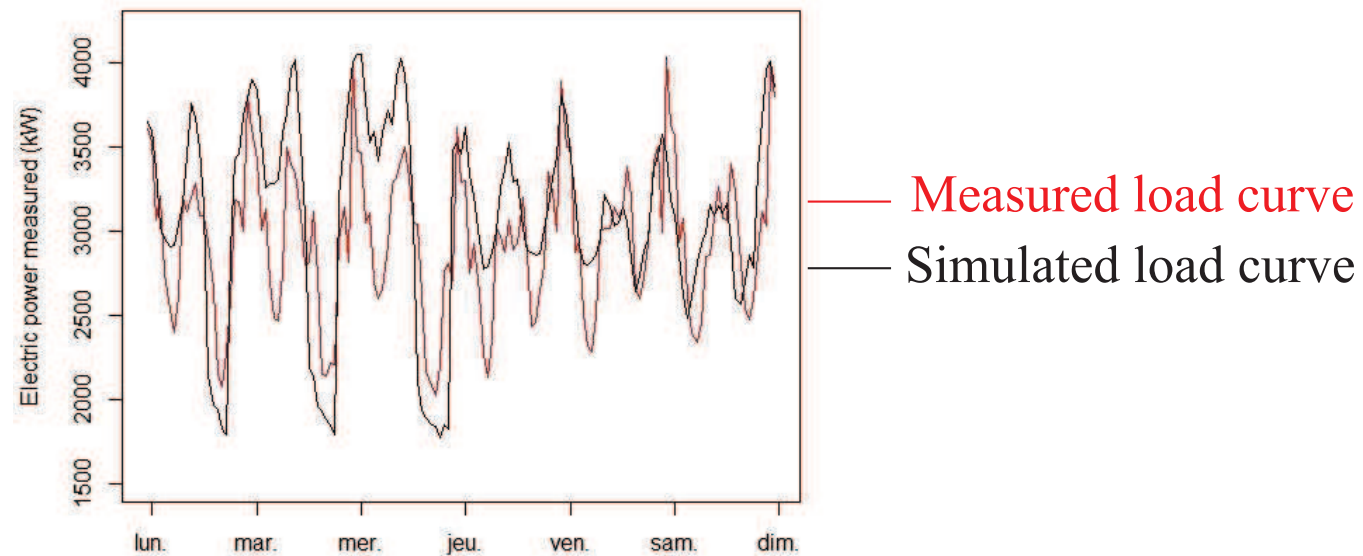


Simplified solve of the algorithm

- ❑ Initial state with an heuristic
- ❑ Optimal re-affectation until convergence

By running the algorithm of matching on all the municipalities

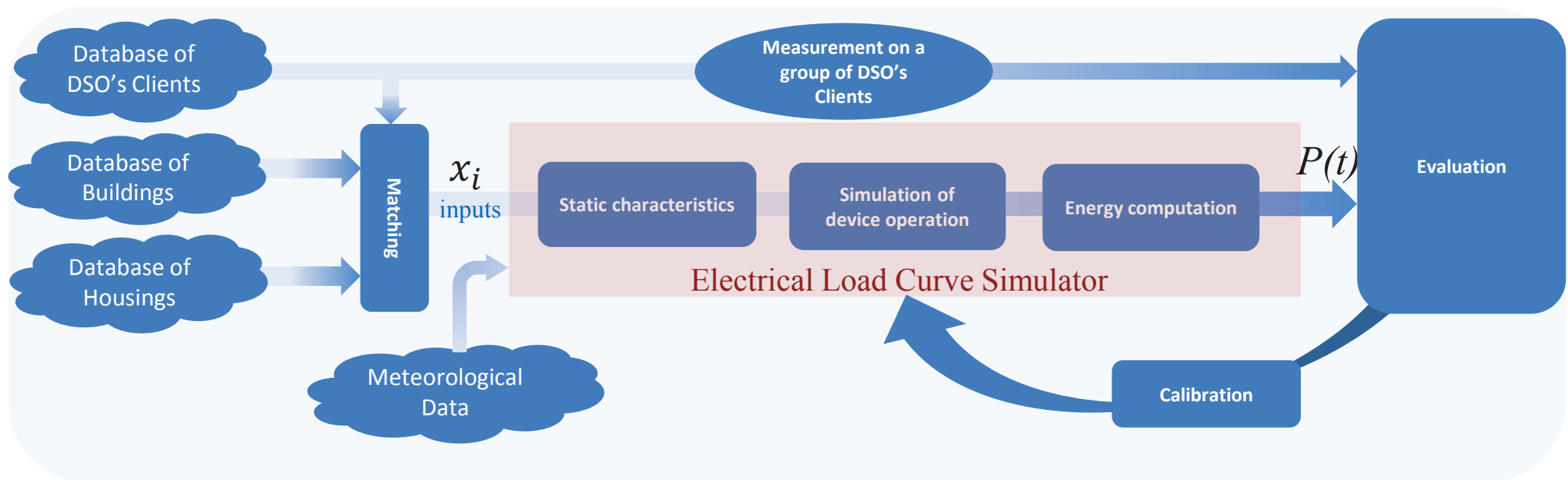
- ❑ We know the housing characteristics of customers
- ❑ We set the inputs of the simulator
- ❑ We can obtain comparable load curves



load curve of an HTA feeder (red curve) and the simulated load curve (black curve), for a week, with as inputs the housing characteristics of the results of the matching problem

V. Automatic calibration

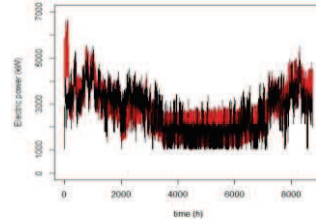
How to deal with the large amount of inputs and outputs ?



V. Automatic calibration



Case study



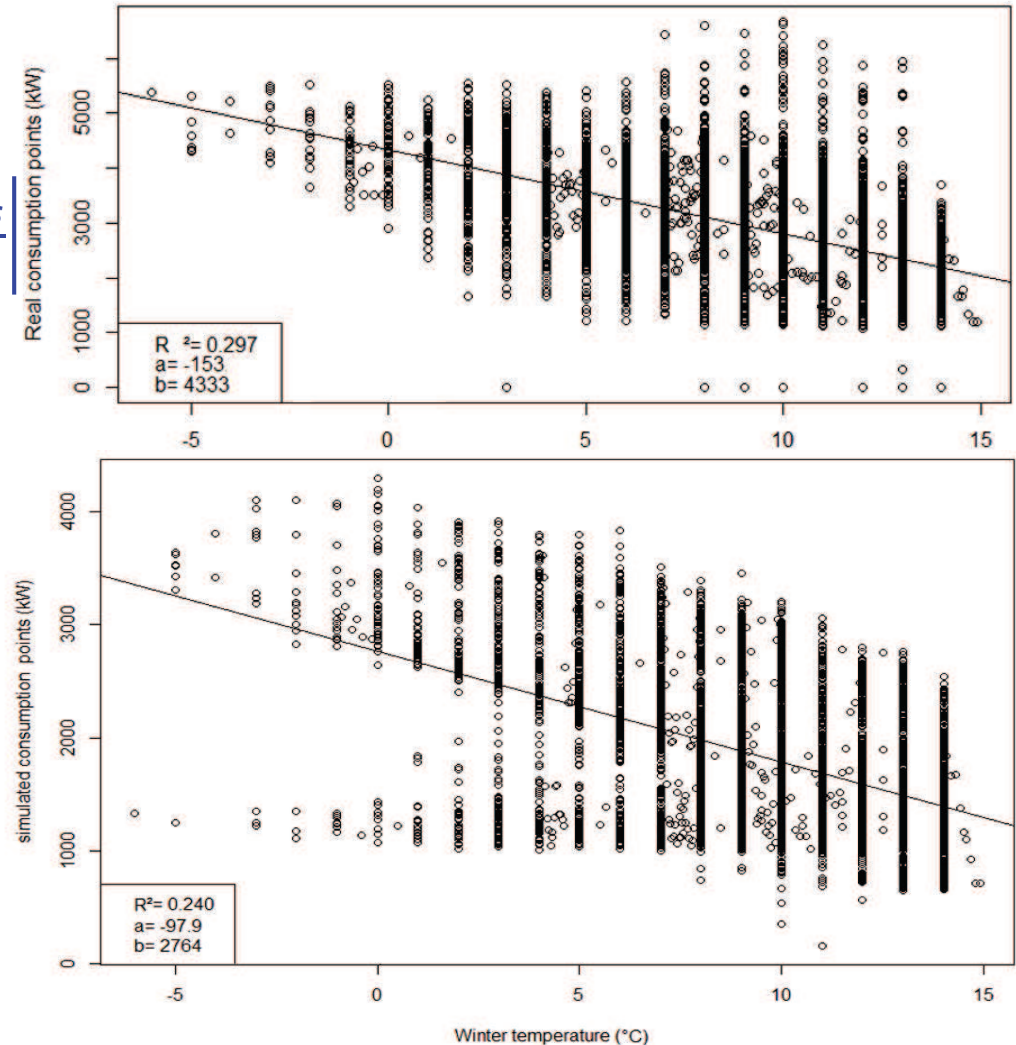
- Evaluation criterion: thermosensitivity

$$\sum \left| \frac{\Delta E}{E} \right| = \left| \frac{a - a_{meas}}{a_{meas}} \right| + \left| \frac{b - b_{meas}}{b_{meas}} \right| + \left| \frac{R^2 - R^2_{meas}}{R^2_{meas}} \right|$$

- a : linear coefficient
- b : intercept coefficient
- R^2 : coefficient of determination

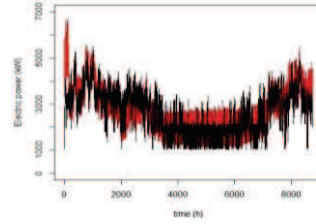
- Inputs

- T_{target} : mean target temperature for electric heaters.
- ΔR_a : variation of the mean thermal assembly resistance



Thermo-sensitivity plot for a Brittany HTA feeder measured (top) and simulated (down), with $R_{surf} = 0,9 \text{ W/}^\circ\text{C}$ (medium) and $T_{target} = 19^\circ\text{C}$

V. Automatic calibration



Case study

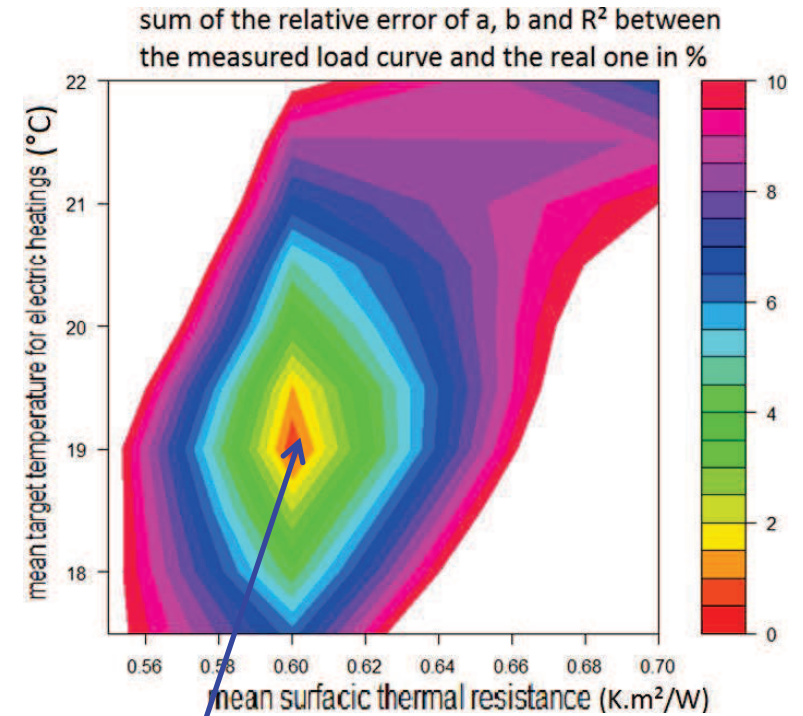
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□ Inputs

- T_{target} : mean target temperature for electric heaters.
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Couple (T_{target}, R_{surf})

which minimizes $\sum \left| \frac{\Delta E}{E} \right|$

VI. Conclusion

Load curve simulator

- ❑ Comprehensible, flexible tool for electricity consumption simulation
- Simple and generic implementation of an electric load curve simulator for residential and tertiary sector
- Physical sense and rapidity of simulation of models
- Both microscopic and macroscopic inputs

Novel kind of validation

- ❑ Promising matching algorithm to generate automatically inputs to assess comparable load curves
- ❑ Comparison and automatic calibration of parameters to benefit from large DSO's measurements

Thank you for your attention

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thibaut.barbier@mines-paristech.fr



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