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Machine Learning methods to assist multi-energy systems optimization in a Smart Grid



Dhekra Bousnina,
Gilles Guerassimoff

Agenda:



1

- Multi-energy optimization in a Smart Grid

2

- Machine learning for energy prediction

3

- Machine Learning for energy optimization

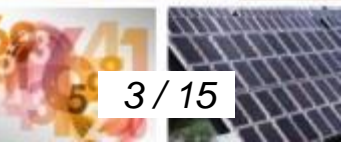
4

- Machine learning for flexibility qualification
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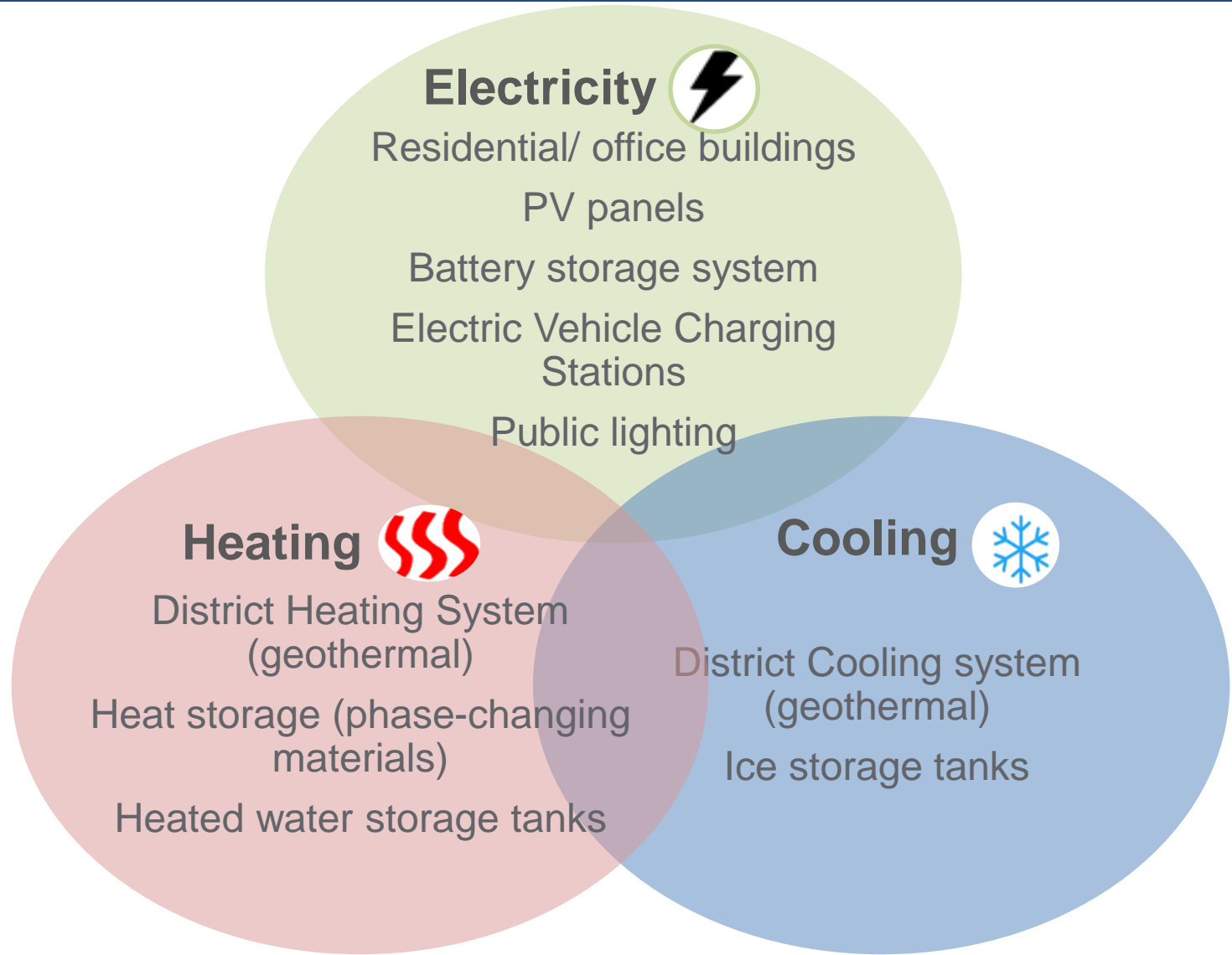
Meridia Smart Energy project



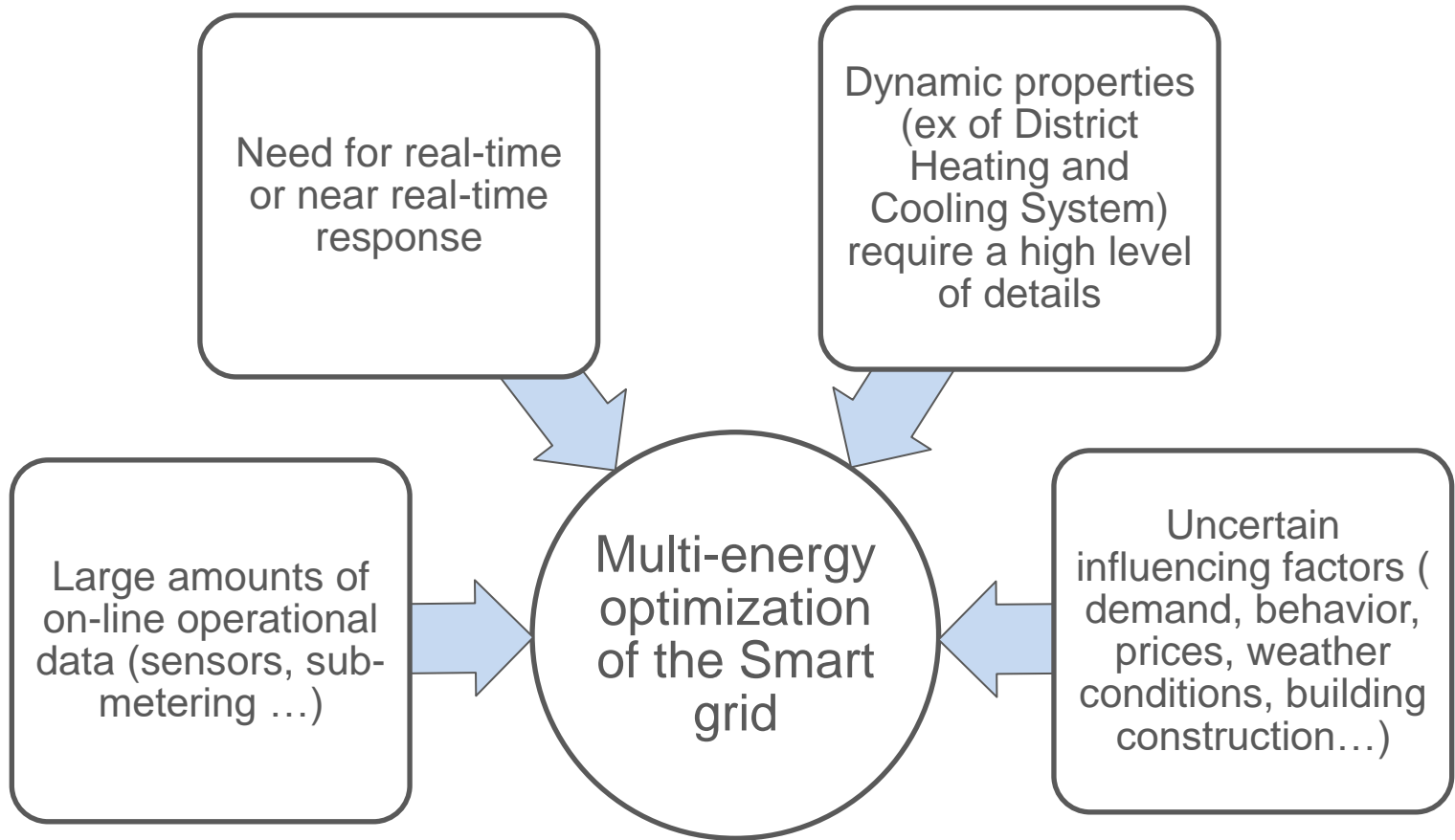
- Maximize self-consumption and energy self-sufficiency of the smart grid
- Reduce energy consumption , Time-of-Use costs, and load peaks
- Minimize GHG emissions of energy consumption and mobility



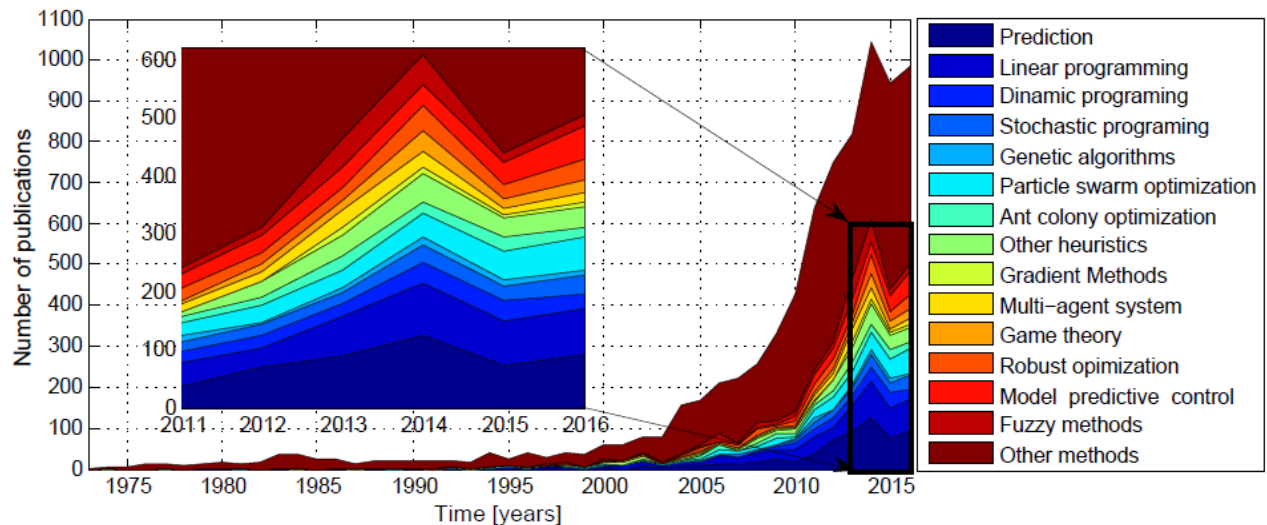
Multi-energy optimization



Main Challenges:



Methods used for energy optimization:



A summary of the Scopus-indexed publications with focus on building energy optimization over years 1972-2016 - a zoom over the years 2011-2016 (Mocanu, 2017)



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Machine Learning for energy prediction

- **Supervised energy prediction methods:**

Electrical load forecast:

Artificial Neural Networks, Recurrent Neural Networks, SVM, Hidden Markov Models, Conditional Restricted Boltzman Machines, FCRBM, GRBM

Thermal load forecast:

SVM, Feed Forward Neural Networks, Regression Trees, *Multi Linear Regression*, Gaussian Mixture Model,

SVM have a higher performance (Idowu, 2018)

GMM is comparable in terms of accuracy but much faster

RT have relatively higher performance error



Machine Learning for energy prediction

- **Unsupervised energy prediction methods:**

Do not require historical data from the considered building. Learning a model for a building and transferring it to another building (Mocanu, 2017)

DBN (Deep Belief Networks) for feature extraction

RL (Reinforcement Learning) for knowledge transfer between building models: **SARSA, Q-learning**

Knowledge transfer to: predict new behavior of existing buildings or completely new types of buildings

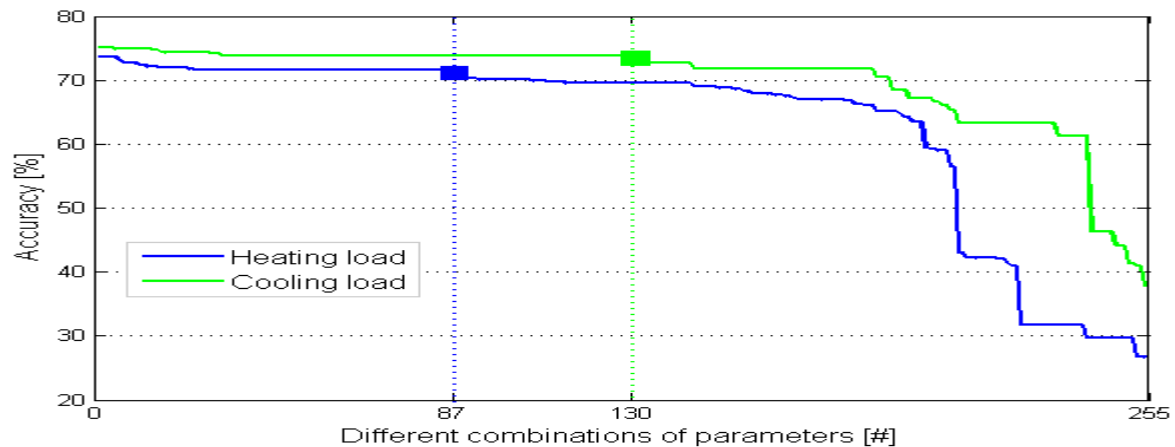


Main Challenges for energy prediction

- **Uncertain influencing factors and complex building energy behavior**
- **Level of aggregation for prediction:**

Most of the methods (ANN, RNN, SVM, CRBM, FCRBM) perform better when predicting in the aggregated level than when predicting the demand of intermittent appliances

- **Importance of feature selection in energy prediction:**



The accuracy, in descending order, achieved by different combinations of parameters for Heating load (HL) and cooling load (CL) [Mocanu, 2017]



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Energy Time-of-Use Cost minimization, load peak reduction:

- Linear Programming
- Dynamic Programming
- Heuristics (PSO...)
- Game theory
- Fuzzy methods

A wide range of methods

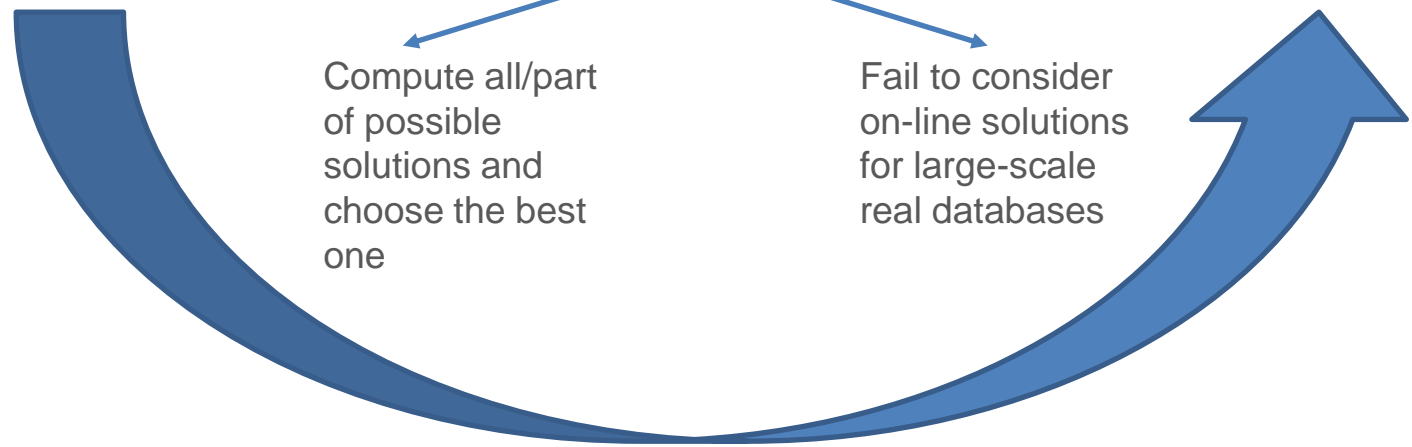
Time consuming procedures

- A hybrid method between RL and DL
- DQN (Deep Q-Learning), DPG (Deep Policy Gradient)

Deep Reinforcement Learning

Compute all/part of possible solutions and choose the best one

Fail to consider on-line solutions for large-scale real databases





Machine Learning for energy optimization

Deep RL

After it learns how to act, it can make decisions (exp choosing the optimal control action) in a few ms

PSO (and other heuristics)

Need to re-run the costly optimization process for each decision





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Machine Learning for flexibility qualification

Objectives:

- Quantify the flexibility of the Smart Grid's buildings
- Determine how much flexibility can be used at a certain time instant
- Estimate the optimized energy consumption

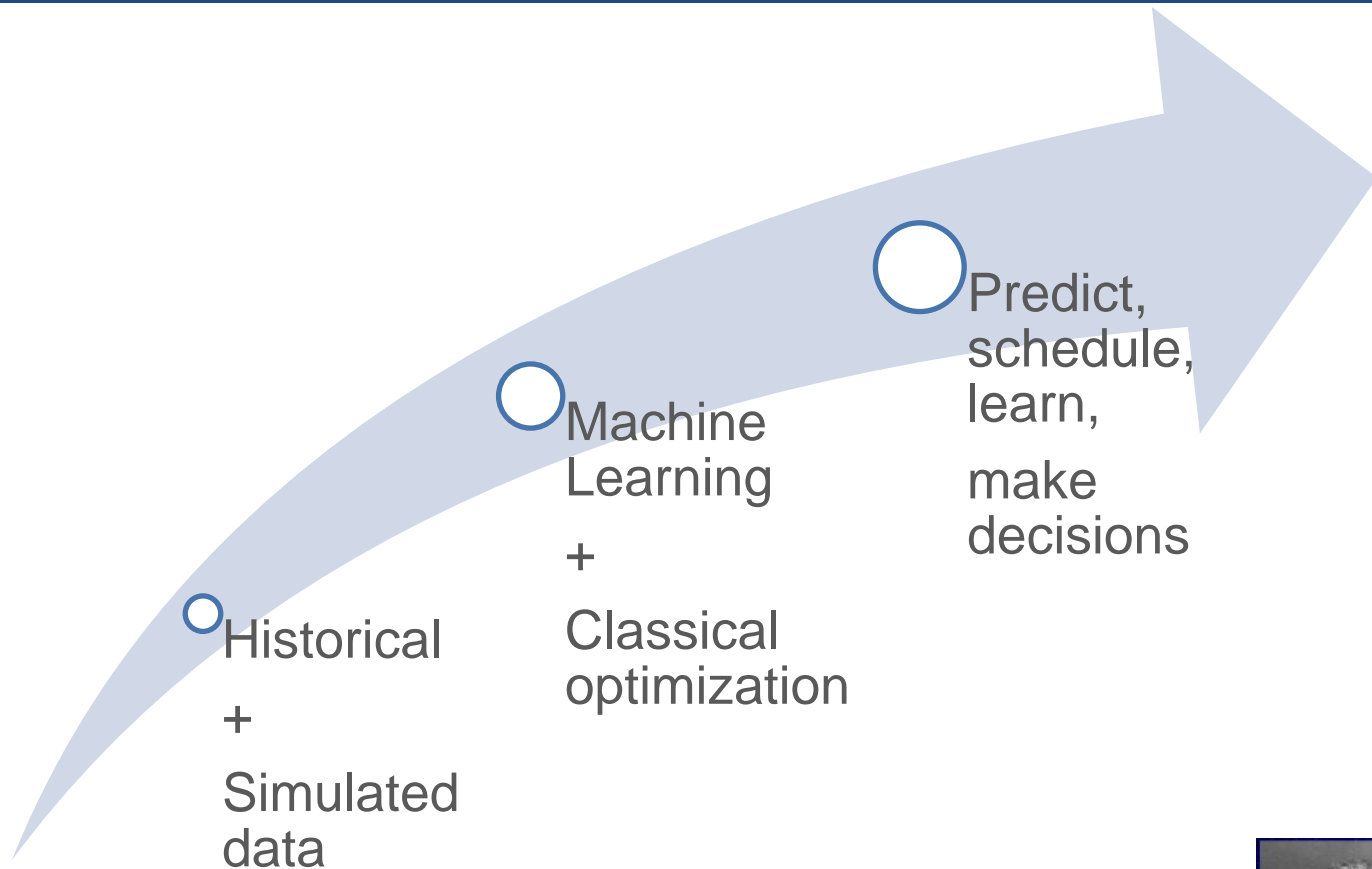
Classification Methods for energy disaggregation (extraction of appliance-level energy consumption signals from aggregated energy consumption): SVM, KNN, NB, AdaBoost

Restricted Boltzman Machines for feature extraction (to improve the performance of these classification methods)

Deep learning methods for prediction



Conclusion:



« It is difficult to make predictions, especially about the future... »
Niels Bohr





Some references:

E. Mocanu, 2017, « Machine Learning applied to smart grids ».

S. Idowu, C. Åhlund, and O. Schelén, 2014, “Machine learning in district heating system energy optimization,” in 2014 IEEE International Conference on Pervasive Computing and Communication Workshops (PERCOM WORKSHOPS), pp. 224–227.

S. Idowu, S. Saguna, C. Åhlund, and O. Schelén, Dec, 2016, “Applied machine learning: Forecasting heat load in district heating system,” Energy and Buildings, vol. 133, pp. 478–488.

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