IRP 2.1.
Energy flexible and smart-grid/energy ready buildings

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THIBAULT PÉAN
PhD candidate at IREC – UPC
Supervisors: Jaume Salom (IREC) and Ramon Costa-Castelló (UPC)

IREC
Institut de Recerca en Energia de Catalunya
Catalonia Institute for Energy Research

UPC
UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH

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AGENDA

- Introduction
- An applied example of RBC
- Current work on MPC
- Highlights from HPC2017
- Next steps

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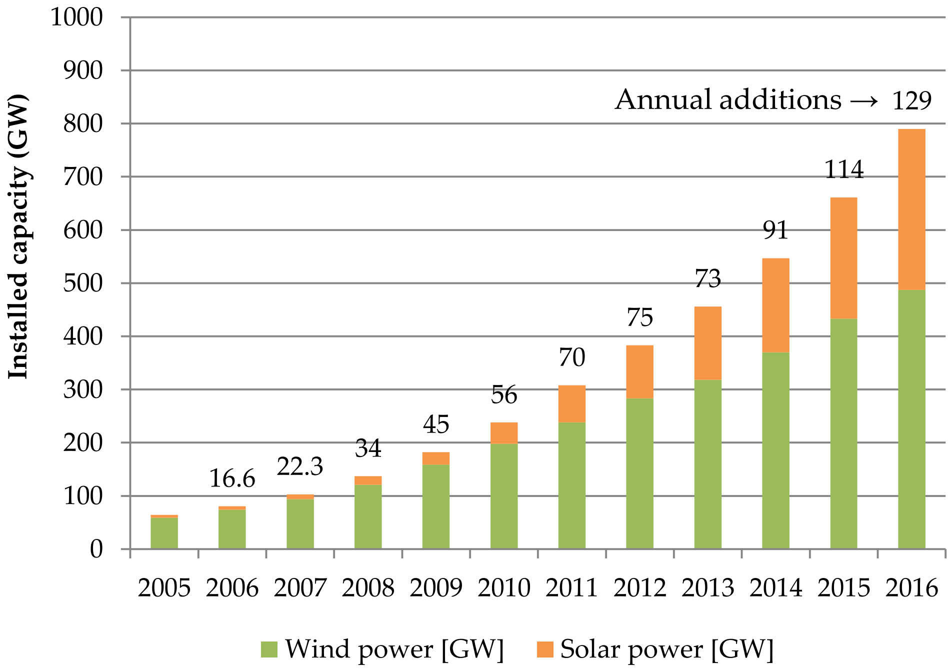
INTRODUCTION

- Challenges faced mostly by the power grid: increased penetration of variable renewables in the grid (solar & wind)
- Buildings possess a built-in thermal storage which presents potential for load shifting
- Heat pumps are a logical solution to play with the flexibility potential, and store thermal energy within the building mass
- To reach the "*consumption on demand*" or "*demand-side management*", smart controls are needed



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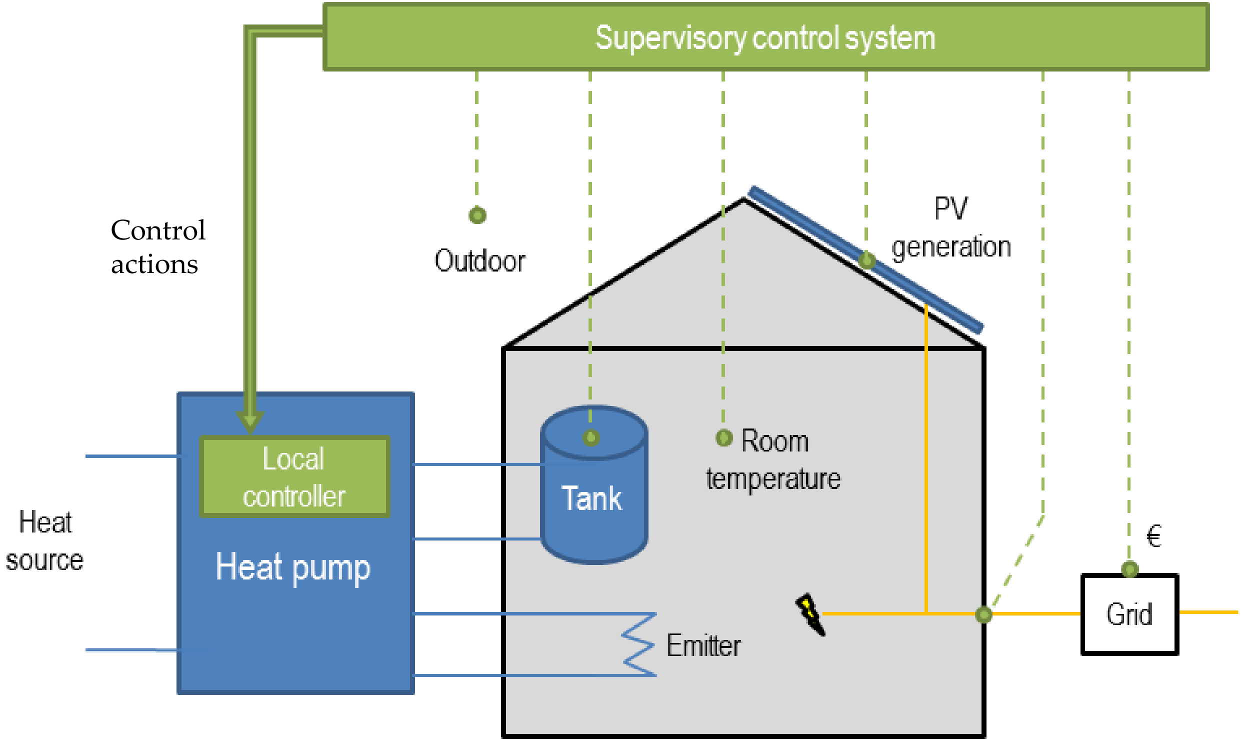
CONTROL STRATEGIES FOR FLEXIBILITY WITH HEAT PUMPS

- Control strategies acting at the supervisory level
- Algorithm which decisions are based on information retrieved from sensors
- Sends signal to the heat pump (local controller)



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RBC vs. MPC

Rule-Based Control (RBC)	Model Predictive Control(MPC)
• Simple algorithm (if condition, then action) • Easy to implement • No need for a model or optimization framework • Overall good performance with regards to the declared objective • Importance of a good tuning • Inability to anticipate/predict	• Optimization problem • Requires a model • Requires computational power • Requires access to external data or prediction of disturbances • Outperforms RBC • Can deal with multi-objectives

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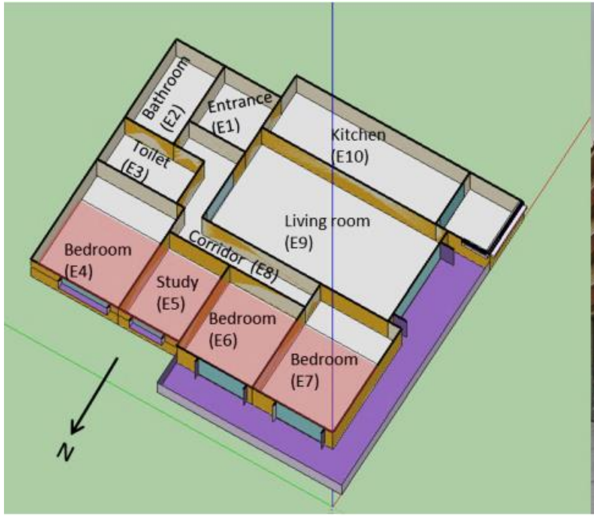
AN APPLIED EXAMPLE OF RBC WITH HEAT PUMP

- Residential flat in Catalonia (Spain)
- Refurbished
- Air/water heat pump + radiators
- Flexibility control strategy
- Model and simulation in TRNSYS



Published article:
Péan T.Q., Ortiz J. and Salom J. ***Impact of demand-side management on thermal comfort and energy costs in a residential nZEB***. Buildings 2017, 7(2), Special Issue “*Towards Decarbonization in the Building Sector: Innovating Net Zero Energy Buildings*”.

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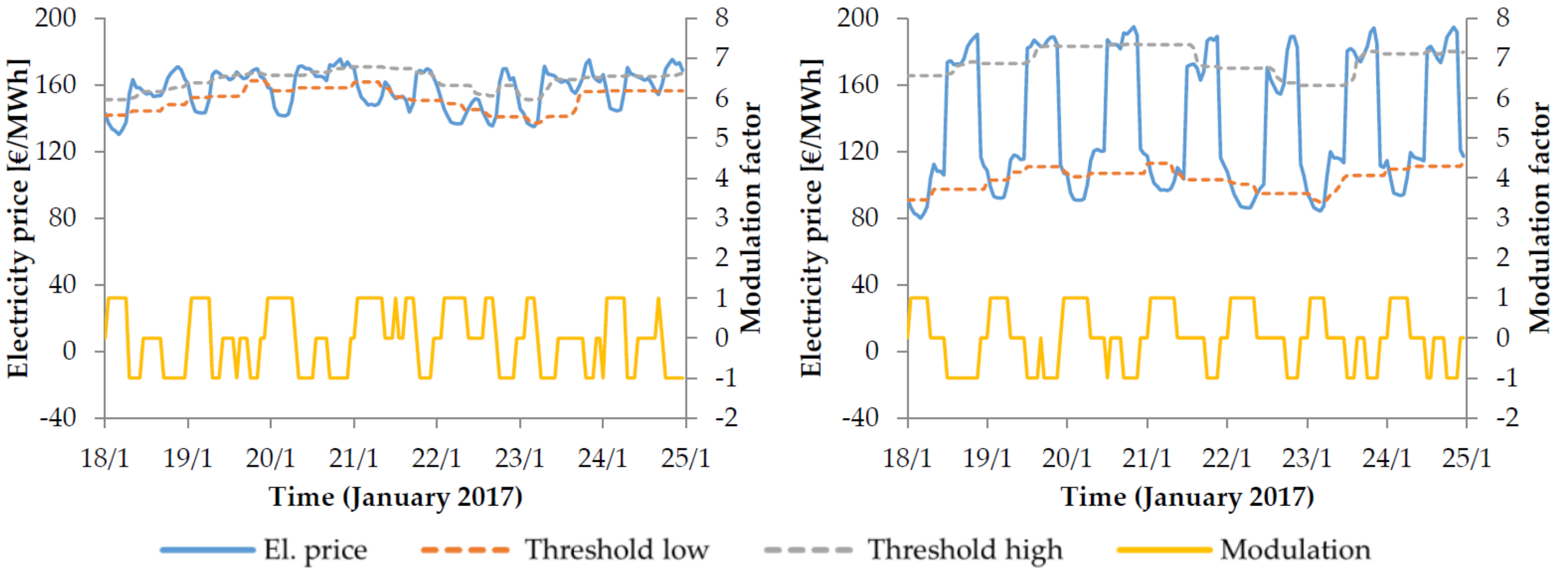
FLEXIBILITY CONTROL STRATEGY (RBC)

- Fixing thresholds on the electricity price
- Consequent modulation of the heating set-points



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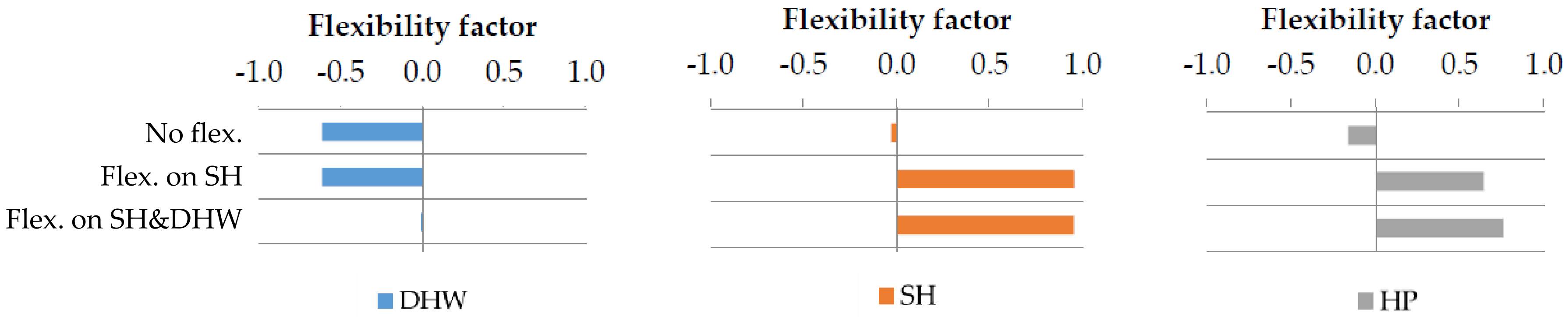
FLEXIBILITY INDICATOR

- Analysis during one week in January 2017
- Flexibility factor varying between -1 (no flexibility) and 1 (high flexibility)
- Significant improvement when the specified strategy is implemented



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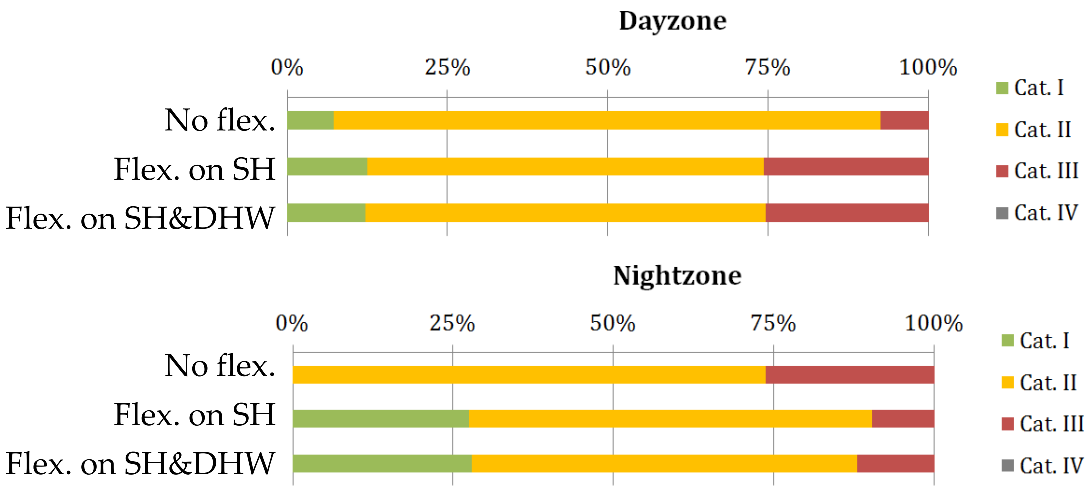
IMPACT ON THERMAL COMFORT

- Acting on heating set-points for energy flexibility
  > risk of thermal discomfort
- Evaluation using the thermal comfort categories of the European standard (EN15251), defined in terms of PMV
- Limited impact on thermal comfort
- Improvement in the night zone



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IMPACT ON ENERGY USE AND COST

- Shifting of loads towards low-price periods
- Increase in electricity use due to the storage-like operation
- Decrease in operational cost (energy cost) aimed by the control strategy

	Electricity use				Electricity cost	
	HP_Tot [kWh]	Var /ref [%]	HP_Grid [kWh]	Var /ref [%]	HP [€]	Var /ref [%]
No flex.	102.8	-	99.7	-	14.1	-
Flex. on SH	105.6	2.7%	104.7	5.0%	12.1	-14.5%
Flex. on SH&DHW	106.8	3.9%	106.3	6.6%	11.9	-16.0%

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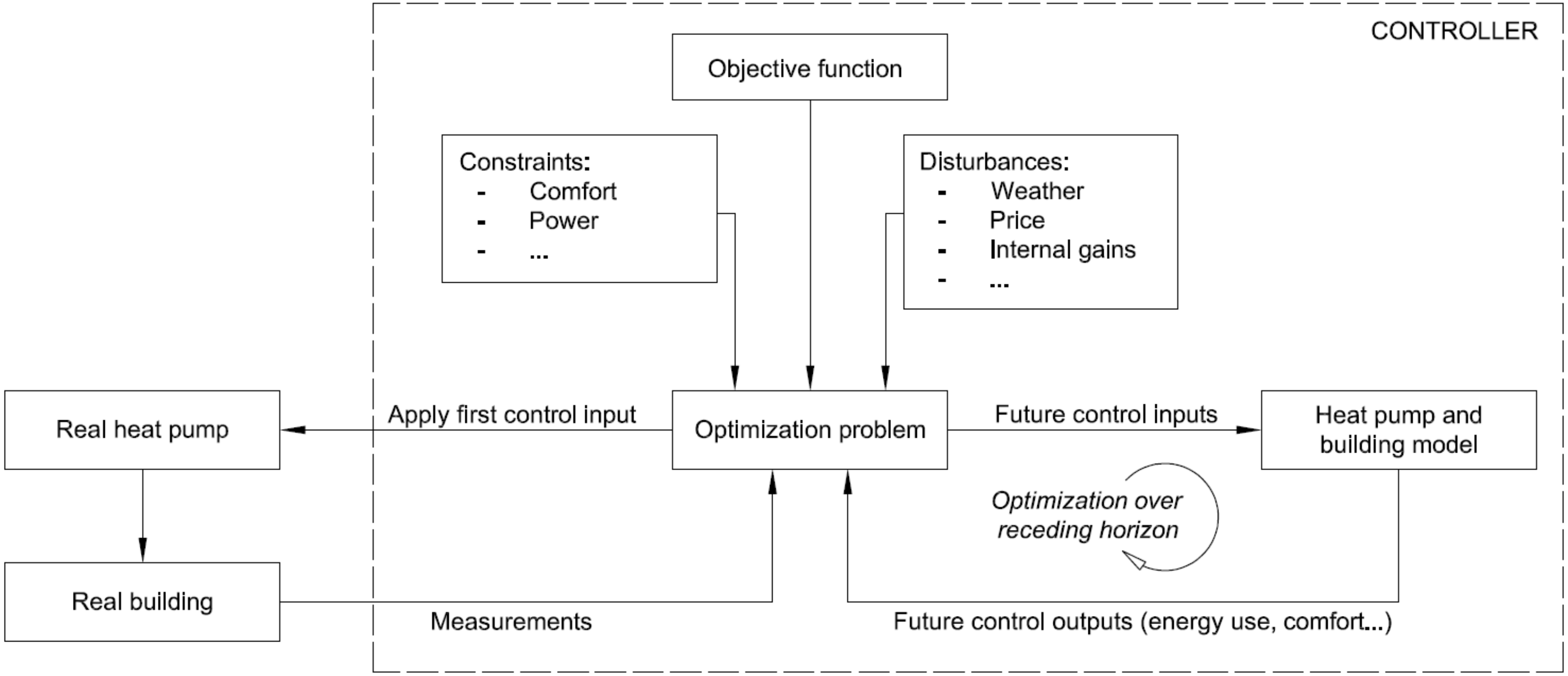
MODEL PREDICTIVE CONTROL



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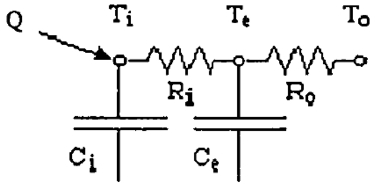
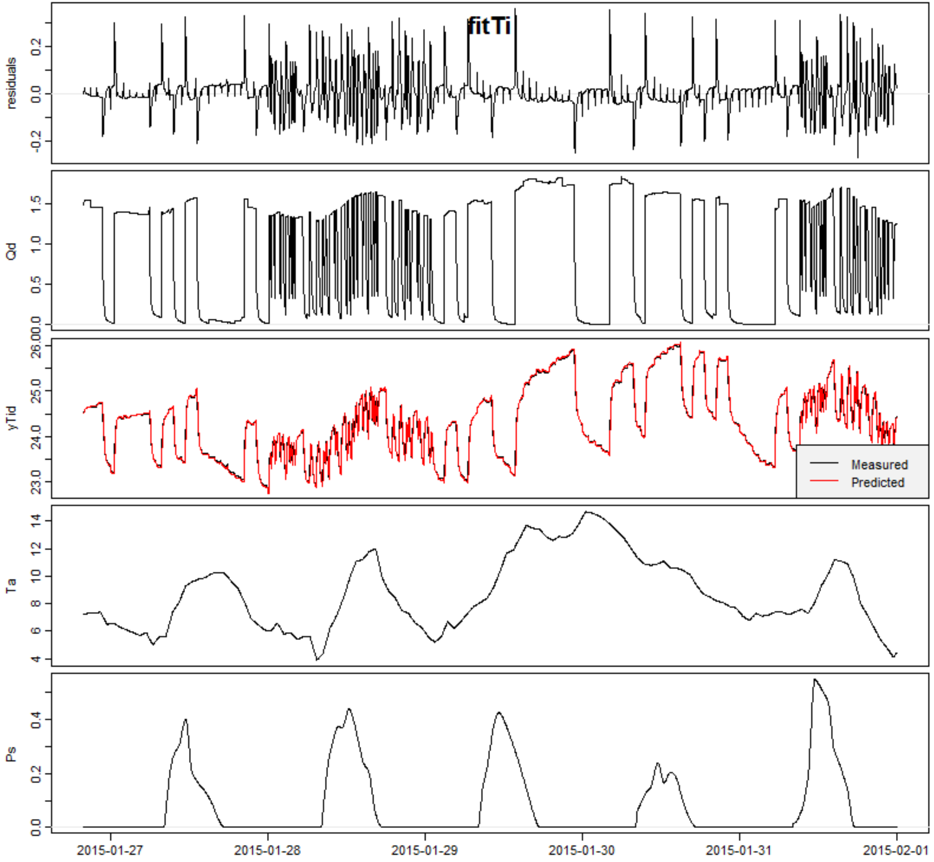
MODEL PREDICTIVE CONTROL

- Possibility to deal with weighted multi-objectives
- Economic MPC is predominant
- Other flexibility objectives to be researched further
- Literature reviews on-going (within task B.2.1 in Annex67)

MODEL IDENTIFICATION

- Use of the CTSM-R tool (Continuous Time Stochastic Modelling for R)
- Development of simplified RC-models (analogy with electrical networks)
- Identification of the parameters and statistical analysis of the residuals
- Forward approach: increasingly complex models





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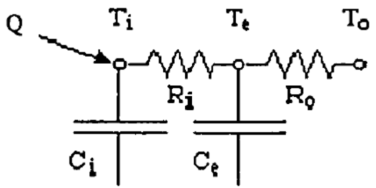
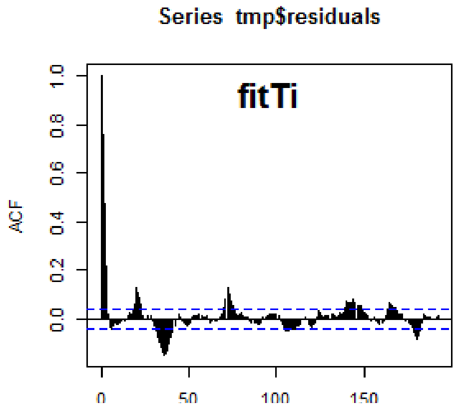
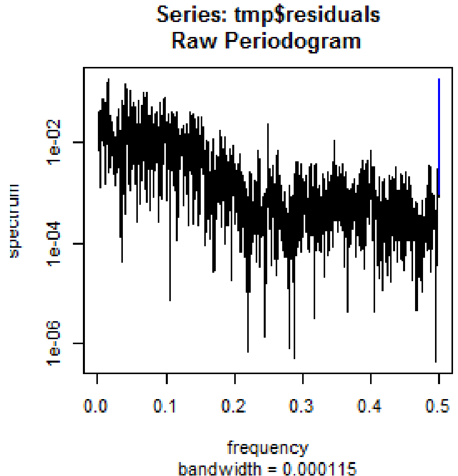




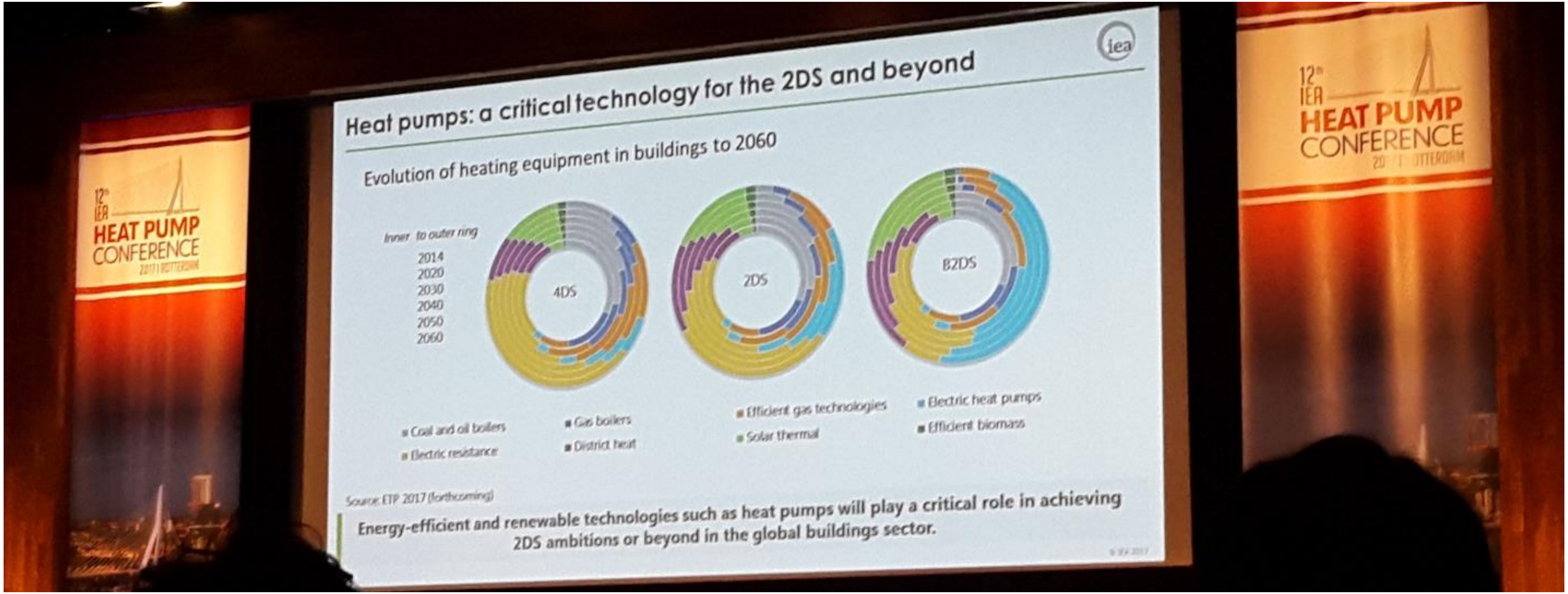


NEXT STEPS IN MPC DEVELOPMENT

- Finish model development and validation
- Implementation of the MPC framework
- Test of different objective functions: COP, flexibility, cost, primary energy, CO_2 emissions…
- Evaluate performance with a standard building, and after it is refurbished
- Evaluate the flexibility potential in heating or cooling operation (different seasons)
- Test in semi-virtual environment (SEILAB in Tarragona)

HIGHLIGHTS FROM HPC2017

Role of heat pumps in the energy transition



HIGHLIGHTS FROM HPC2017

Fischer, D., Wolf, T. & Triebel, M.-A. Flexibility of heat pump pools: The use of SG-Ready from an aggregator's perspective. *12th IEA Heat Pump Conf.* 1–12 (2017).

- SG ready is a label for HPs in Germany
- Not standardized, only recommendations

Table 1. SG-Ready according to the specifications and the implemented system response in the simulation.

SG Ready	**Corresponding name in this study**	**SG-Ready recommendation** [20]	**Implementation in simulation**	**SH storage set temperatures in simulation***	**DHW storage set temperatures in simulation**
Off (1)	Off	HP is switched off. This mode might be realised as fixed times for a maximum of 2 hours.	HP is switched off.	[HC, HC+5°C]	[45.0°C, 52.5°C]
Normal (2)	Normal	HP operates in normal energy efficient mode.	HP operates with normal set-points.	[HC, HC+5°C]	[45.0°C, 52.5°C]
Recommended on (3)	On	HP is operating in an enhanced heating mode. The switch on has to be seen as a recommendation.	HP is switched on, hystereses are increased.	[HC+5°C, HC+10°C]	[50.0°C, 57.5°C]
Forced on (4a)	Superheat (HP)	HP has to switch on.	HP is switched on, temperatures increased to max.	[55°C, 60°C]	[52.5°C, 60.0°C]
Forced on with BH (4b)	Superheat (BH+HP)	HP and back-up heater have to switch on. Optional is the increase of the storage temperatures.	HP and back-up heater are switched on, temperatures increased to max.	[55°C, 60°C]	[52.5°C, 60°C]

*HC = Set temperature according to ambient temperature dependent heating curve

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HIGHLIGHTS FROM HPC2017

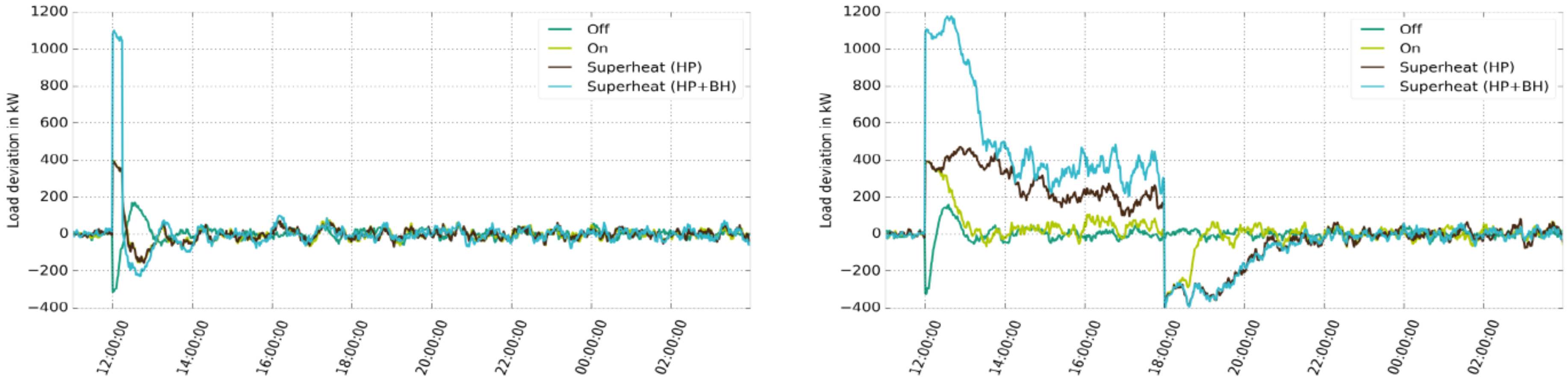

Fig. 3. Exemplary response of the heat pump pool to a 15 Minutes signal (left) and a 360 Minutes signal (right).

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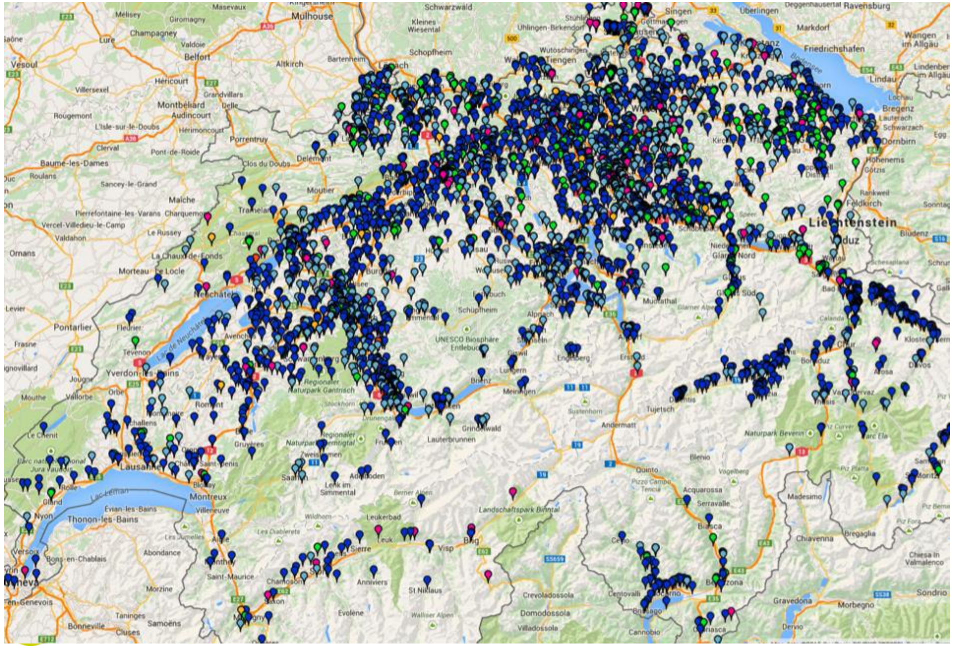
HIGHLIGHTS FROM HPC2017

Geidl, M., Arnoux, B., Plaisted, T. & Dufour, S. A fully operational virtual energy storage network providing flexibility for the power system. ***Proc. 12th IEA Heat Pump Conf. Rotterdam, Netherlands*** **(2017).**

https://tiko.ch/



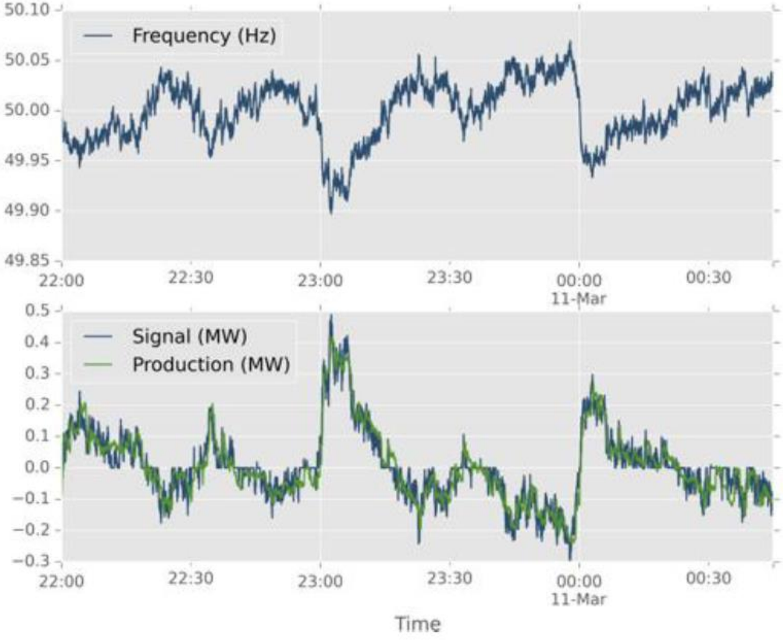


Fig. 12. Example for production of primary control.

NEXT STEPS

- Finish development and validation of RC-models of building case
- Implementation of the MPC framework & simulation work
- Preparation of experiments planned in early 2018 in SEILAB (Tarragona)
- Next conferences/meetings/publications:
  - CISBAT Conference, Lausanne (6-8th Sept. 2017): paper about RBC tuning
  - 5th Expert Meeting of IEA EBC Annex 67, Graz & Vienna (27-29th Sept. 2017): paper about representation of flexibility results
  - INCITE Workshop#3 in Munich (14-16th November 2017)
  - COBEE2018, Melbourne (upon acceptance): paper about boiler experiment
  - Literature review paper submitted to Journal of Process Control
- Secondment in 3E (consulting company in Brussels) in Sept.-Nov. 2017: Analysis of data from implementation of MPC in real buildings

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Thanks for your attention!

tpean@irec.cat