Controls for improving energy flexibility with heat pumps

12th IEA Heat Pump Conference – Rotterdam, NL – 15th May 2017
WS1 - Heat pumps for nZEB, retrofit and energy flexibility

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AGENDA

- Introduction
- RBC vs. MPC
- An applied example of RBC
- Potential of MPC
- Research questions & Work in Annex67

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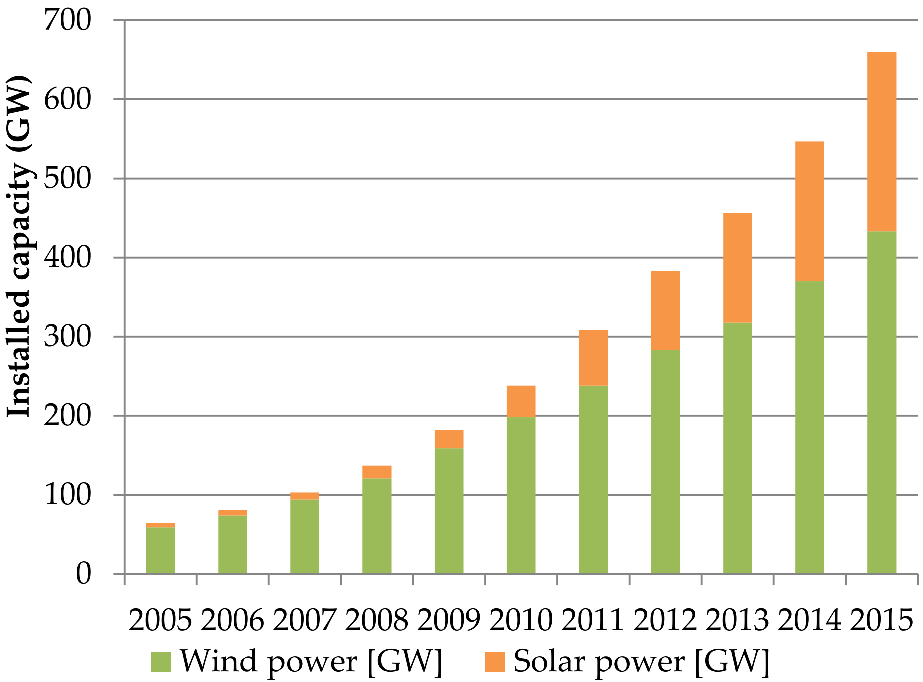
INTRODUCTION

- 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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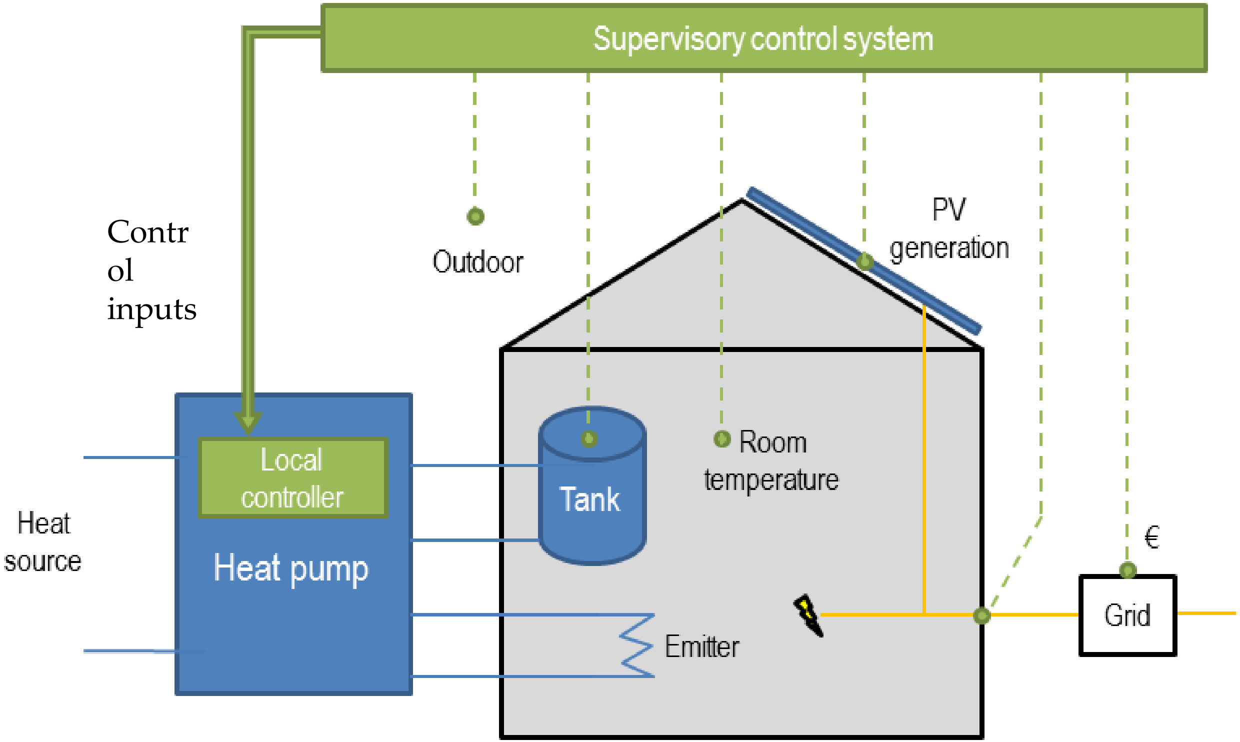
CONTROL STRATEGIES FOR FLEXIBILITY WITH HEAT PUMPS

- 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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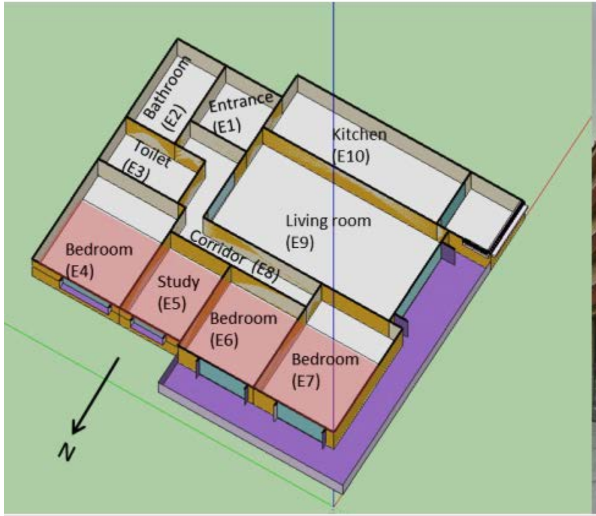
AN APPLIED EXAMPLE OF RBC WITH HEAT PUMP

- 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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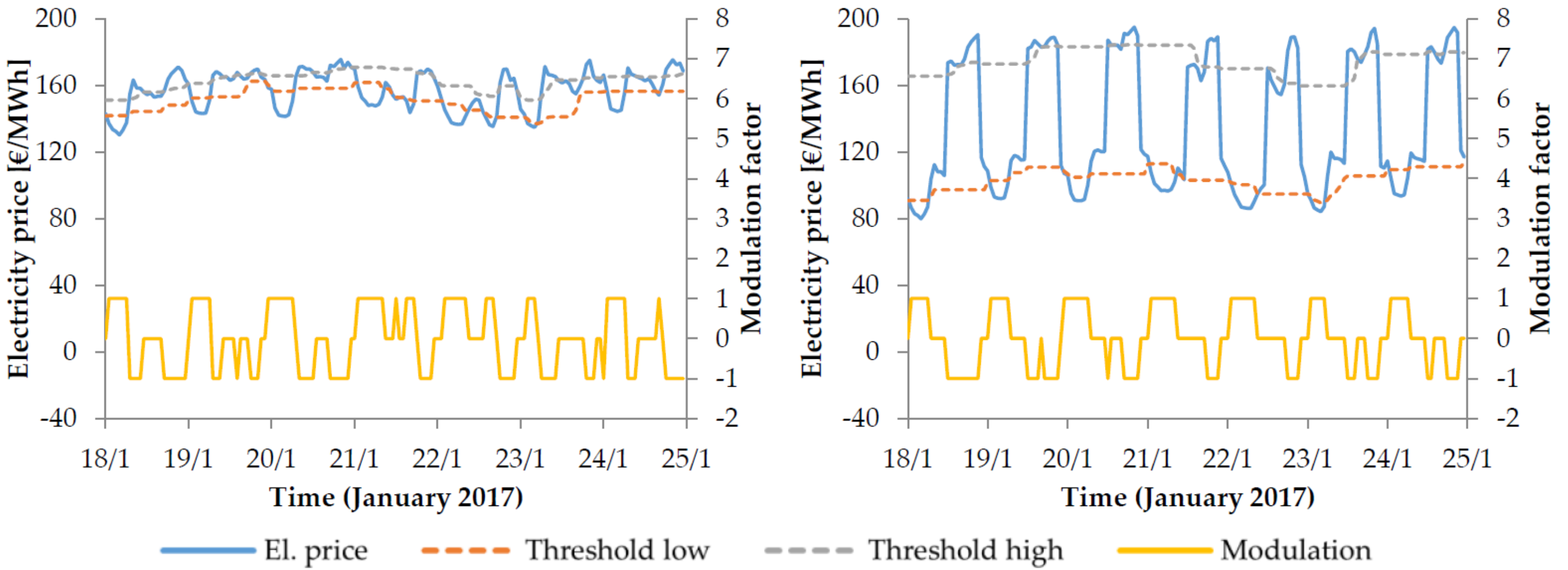
FLEXIBILITY CONTROL STRATEGY (RBC)

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



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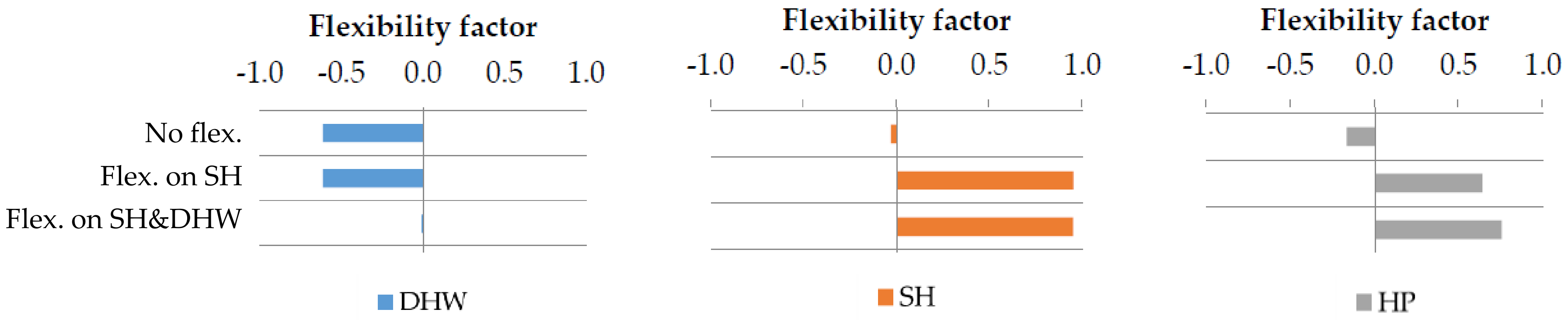
FLEXIBILITY INDICATOR

- 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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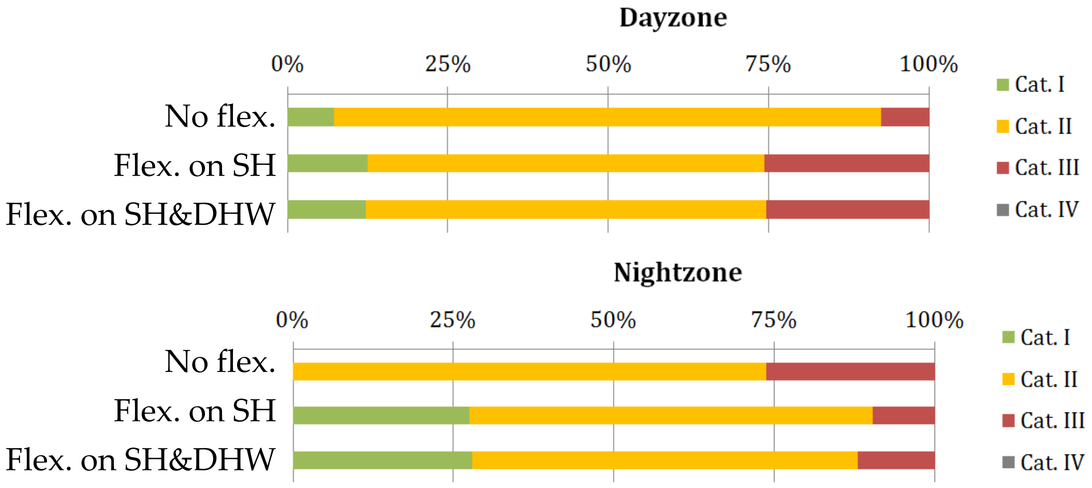
IMPACT ON THERMAL COMFORT

- 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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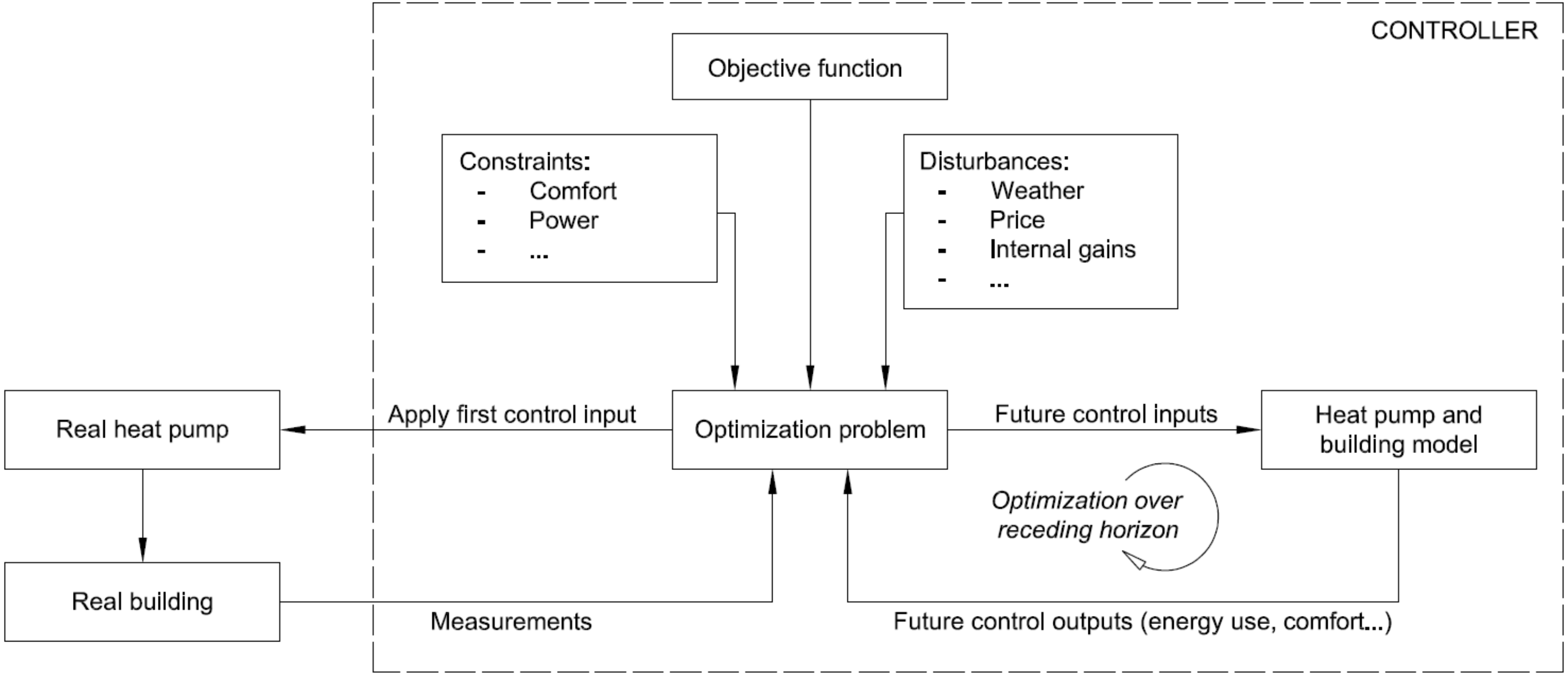
MODEL PREDICTIVE CONTROL



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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)

	Reference	Economic term	Energy term	(Dis)comfort term	Flexibility term	CO_2 term	Robustness term/slack variable	Peak shaving term
Simulation	Masy et al. (2015)[31]	X		X				
	Tahersima et al. (2012)[44]	X		X				
	Li and Malkawi (2016)[45]	X		X				
	Verhelst et al. (2012)[42]	X		X				
	Pedersen et al. (2013)[46]	X		X				
	Kajgaard et al. (2011)[47]	X		X			X	
	Halvgaard et al. (2012)[48]	X					X	
	Santos et al. (2016)[49]	X					X	
	Bianchini et al. (2016)[50]	X			X			
	Knudsen and Petersen (2016)[51]	X				X		
	Sichilalu et al. (2015)[52]	X						
	Mendoza-Serrano et al. (2014)[53]	X						
	Salpakari and Lund (2015)[54]	X						
	Toersche et al. (2012)[55]							X
Both	Ma et al. (2014)[56]	X						X
	Sturzenegger et al. (2013)[57]		X					
	Oldewurtel et al. (2013)[58]		X					
Exp.	De Coninck et al. (2016)[44]	X		X	X			
	Vana et al. (2014)[60]	X		X			X	

RESEARCH QUESTIONS AND WORK IN ANNEX67

- *What are the pros and cons of different control configurations aimed at improving energy flexibility in buildings equipped with heat pump (MPC for example)?*
- *Which benefits can they provide, and how to quantify these benefits?*
- *How do they perform in realistic conditions?*
  - Experiments will be carried out with a heat pump in semi-virtual environment
  - Analysis of data from MPC implementation in real buildings
  - In relation with the task B.3.2 of Annex67 (testing)
- *What is the potential for energy flexibility with reversible heat pumps for heating and cooling, and the aggregation potential in order to offer services to the grid?*

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Thanks for your attention!

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