ECEEE presentation

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Subject : Challenges of heat pumps coupled with building to make them a flexibility tool for the electricity network

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Introduction and context

Building : **36%** of **total carbon emission** and **40%** of **total primary energy use** (European Commission, 2020)
80% of energy use in buildings due to Space Heating/Cooling + Domestic Hot Water.

EU solution to **limit carbon emission in buildings**:

- ➢ Electrification of heating sector especially with Heat Pump : High efficiency systems instead of fossil devices
- ➢ Renewable energy sources deployment : Low carbon electricity powerplants

Prominent challenge:
- Intermittent renewable energy sources : Stress on the grid

Moreover in some countries :
- More heat pumps connected to the grid : Increase electricity consumption

} More pressure on the grid

➡ Flexibility is needed + buildings will be electrified → **Flexibility with buildings**

Objective of this study

Main goal : State of the art on Flexibility in buildings with Heat Pump

Main findings:

- How flexibility is defined with buildings ?
- How flexibility can be linked with Heat Pump ?
- How to actively address flexibility ?

Program

- I. Flexibility definition
- II. Flexibility with Heat Pump
- III. Control strategy

I. Flexibility definition

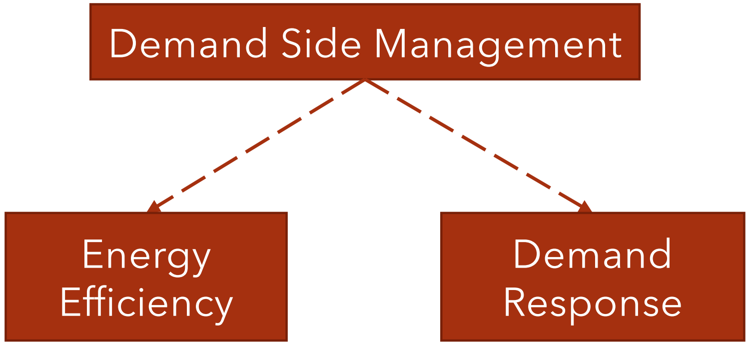
What is flexibility ?

Definition : Modify **demand** to follow **production**.

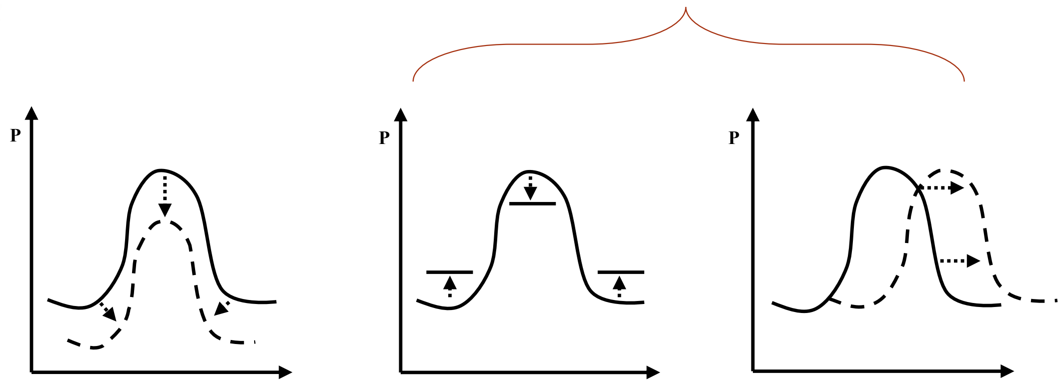
Part of **Demand Side Management**

Need for an energy storage system :

{Heat pump+Building} : native **building thermal inertia** (+ other type of storage if needed)



Flexible way of working
= Demand Response



Energy efficiency

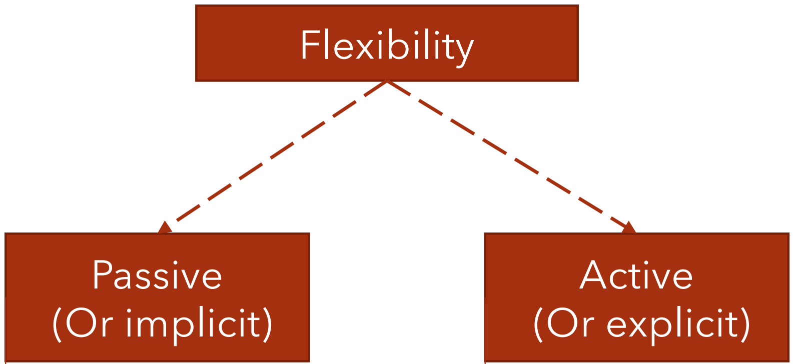
Peak shaving
Valley filling

Load shifting

NIBE

The different flexibility types

Two ways :



Passive (Or implicit)

- Variable Prices :
  - Time Of Use
  - SPOT
- Penalty Signal

Active (Or explicit)

- Direct load control
- Interruptible load
- Activation of auxiliary services

With these 2 ways we can address 2 objectives :

- Increase demand when Supply > Demand in the electric grid → **Absorption**
- Decrease demand when Supply < Demand → **Shaving**

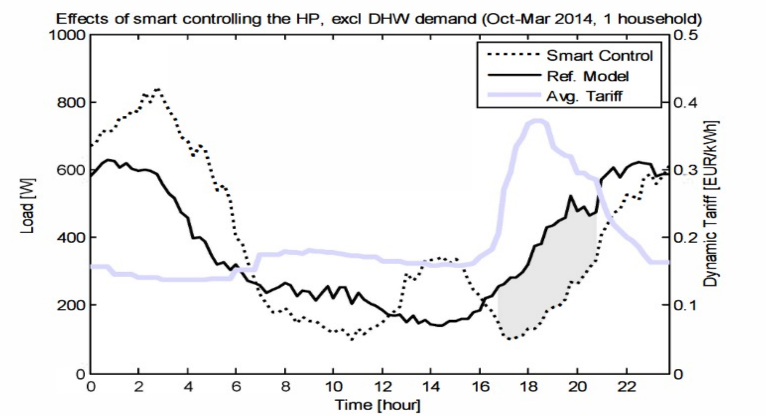
NIBE

II. Flexibility with Heat Pump

HP Flexibility : A real potential for the grid

Klaasen et al., 2015

Goal : Control a pool of 38 HP

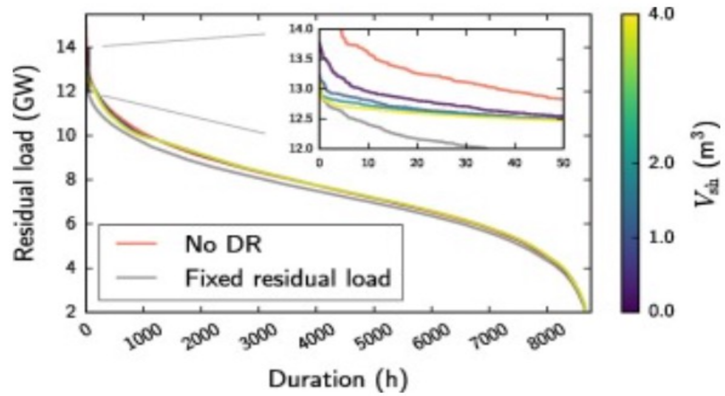


React to price signal over 1 day

→ Successfully reduce load at high price areas

Baeten et al., 2017

Goal : Control a pool of 500 000 HP



Observe demand across the year (descending order)

→ Successfully reduce load by hundreds of MW during coldest periods

Need for an adapted way of evaluating

Not an easy task to evaluate flexibility

Example : Might be counterproductive to evaluate only energy savings or bill reduction.

When addressing flexibility :
- Wide variety of configurations (Building, Heat pump, On-site production, Electrical storage,…)
- Wide variety of objectives (Improve on-site consumption, reduce the consumption bill,…)

To evaluate those systems : Development of a many **KPI** (Key Performance Indicator)
2 Price centred examples :

$$FF = \frac{\int_{t_{low-price\ start}}^{t_{low-price\ end}} Q dt - \int_{t_{high-price\ start}}^{t_{high-price\ end}} Q dt}{\int_{t_{low-price\ start}}^{t_{low-price\ end}} Q dt + \int_{t_{high-price\ start}}^{t_{high-price\ end}} Q dt}$$

$$GSC_{abs} = \frac{\sum_{i=1}^{n} W_{el}^{i} G_{s}^{i}}{W_{el} \overline{G_s}}$$

Identified challenges regarding HP flexibility

- A proper evaluation of **flexibility potential** at grid scale and user scale
- **Comfort** issue
- **Loss of performances** for the heat pump : COP loss when addressing flexibility
- **Social acceptability** issue : loss of user control over the heating system
  Sweetman et al., 2019 : People actively changed the controller tuning

→ Emphasize the need for :

- **Sensibilization** towards the need for flexibility
- **Incentives + Flexibility market**

NIBE

III. Control strategy

Principles of Heat Pump control

Main goal : Adapt the delivered heat to outside conditions and indoor needs

3 main steps (Air to water variable speed HP) :

- Find the supply water temperature setpoint according to outdoor temperature : **Heat curve**
- Track the setpoint by modifying the compressor frequency : **PI controller**
- Shut down the heat pump when it is too warm : **Hysteresis controller**

→ Works well to ensure thermal comfort

But not designed for flexibility. In the literature, **2 identified strategies**.

"Simple" way to tackle flexibility : RBC Controller

RBC = Rule Based Controller

Mainly composed of "if condition".

Example :

- *If* Price is low *then* setpoint temperature increased by 2°C.
- *If* Solar Irradiation is high *then* setpoint temperature decreased by 2°C.

Pros : Performs quite well / Fast to design

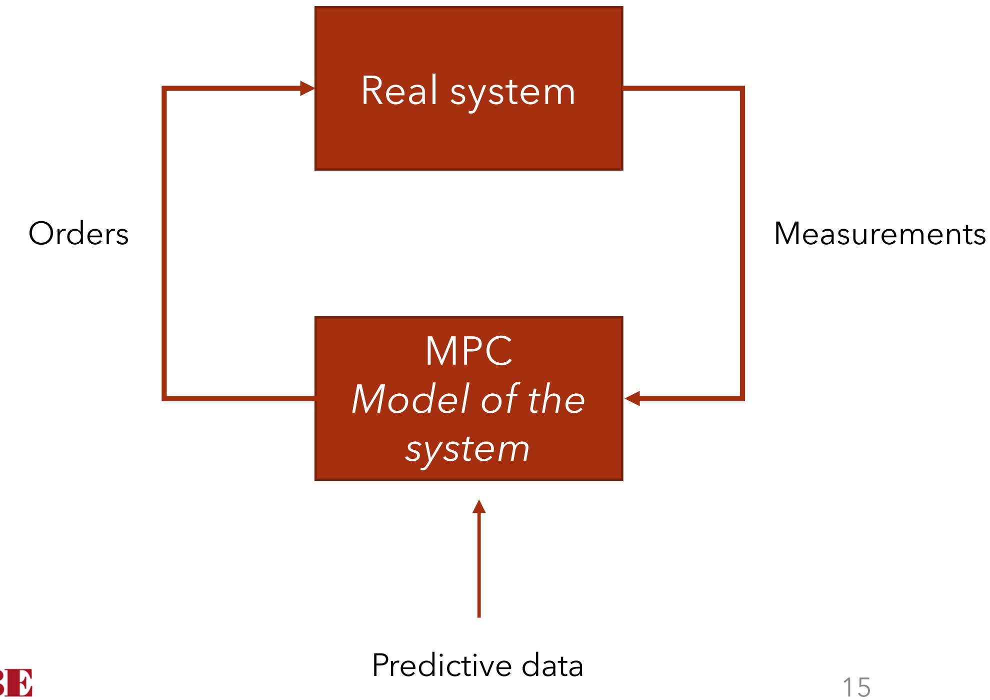
Cons : Rely on predefined rules = non optimal / Non-adaptive

MPC Controller

MPC = Model Predictive Control
Optimization based control strategy

Mathematical framework :
- A **model** of the system {Building + Heat Pump}
- A set of **constraints**
- An **objective function**

→ Better results compared to RBC



Identified challenges regarding actual MPC

- **Scalability** : Due to model determination
- Not considering enough **typical heat pump behaviours** (defrosting, cycling effect, DHW charging) → Real MPC integration shows <u>less optimistic results</u>
- **Computational cost**
- Too much **price centred**

Conclusion

Flexibility for buildings thanks to heat pump : Major research subject in the years to come

My thesis work falls within this topic.

Focusing at the system level, our **goals** :

- **Minimize** the Heat Pump performance losses
- Be **adaptive** to multiple configurations (Building and Heat Pump)
- **Address** both passive and active flexibility
- **Keeping** high comfort level for the end user

Methodology : Data driven MPC to control real HP