Impact of heat pumps flexibility in a French residential eco-district

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16 laboratories, 100 researchers, Grant 1.7M€ for 4 years (2017-2020)
**RESEARCH FRONTS**

**FR 1:** interactive systems to involve occupants of connected buildings
- Coordination: G-SCOP

**FR 2:** Emerging behaviors, from individual to communities
- Coordination: GAEL

**FR 3:** Interactions modeling between buildings / grids
- Coordination: PACTE

**FR 4:** Architectures for integration of on-the-spot renewable
- Coordination: G2ELAB

**FR 5:** Integration of components into systems
- Coordination: LMGP

- Concepts
- Models
- Tools
- Methods

New knowledge for future urban energy systems
Cambridge
Projet urbain 2016/2034

- **Activités, recherche**
  En construction ou attribués / à attribuer

- **Logements**
  En construction ou attribués / à attribuer

- **Equipements publics**
  Livrés ou prévus / envisagés

- **Universités, logements étudiants**
  En construction ou prévus / envisagés

- **Bâtiments existants**

- **Secteurs constructibles à concerter**

- **Potentiel constructible**

- **Lignes de tramway en fonctionnement**

NEW RESIDENTIAL/COMMERCIAL DISTRICT
Outline

- CityZen project: Cambridge district
- Flexibility analysis using transfer rate profiles
  - Standard profile VS Simulated profile
- Different ways of modeling using available data
- Flexibility results and models comparison
City-zen project

- UE Project: FP7/ENERGY/SMART-CITIES-2013 / 8.8.1
- 2014 - 2019
- 27 partners from 5 countries (NL, FR, BE, UK, IT)
- 2 cities: Grenoble & Amsterdam
- Total budget: 41 M€, 25 M€ as City-zen grant

Objectives

+ 59 000 tonnes CO₂ saved per year
+ 76 000 m² renovated residential buildings
+ 10 000 dwellings connected to a Smart Grid
Technological innovation themes

- Residential Retrofit
- Heating and cooling
- Smart Grid

+ Metropolitan energy roadmap
+ Users Empowerment
+ Technical & social monitoring
+ Communication & dissemination
Heat pump on groundwater

70kW COP=4

groundwater

Isère River

drainage network

PAC Free Cooling

SUSTAINABLE PLACES 2018
Peak power problematic

- Residential building heating consumption
- Grenoble daily electricity consumption (min, mean, max)
Peak power due to heating at district level

Cambridge:
- 20 buildings, 31400m² heated
- Peaks load of 200kW in the morning

Flexibility objectives:
- For clients:
  - Optimization of the subscribed power and avoid overtaking
  - Optimization of electricity bill by shifting consumption on the most advantageous tariff periods
- For DSO:
  - Reduce peak load: avoid power lines reinforcement, minimize expensive energy
  - Stability of power equilibrium, considering uncontrolled loads: renewable production and electric vehicle anticipation.
Our objectives

- **Quantify** load shedding effects
- **Model** building heating needs, with available information
- **Optimize** load shedding sequences, minimizing discomfort and maximizing benefits.
Indicators to quantify the rebound effects

**Two indicators: dynamic and long-term**

- **Dynamic**
  
  How the energy is transferred each hour following the load shedding?

  \[
  \text{Transfer rate } [h; h+1] = \frac{E_{\text{transferred}}[h; h+1]}{E_{\text{cut off}}}
  \]

- **Long-term**

  How much energy is saved?

  \[
  \text{Savings rate } [h; h+1] = \frac{E_{\text{cut off}} - E_{\text{anticipated}} - E_{\text{transferred}}}{E_{\text{cut off}}}
  \]
Experimental results from the GreenLys project

Construction of a standard transfer profile
- One-hour residential heat load shedding
- Without and with pre-heating

1 hour load shedding

With 50% pre-heating
Goal: Local peak-shaving
- Morning consumption peak from 5am to 10am

Strategy: Multiple one-hour heat shedding
- Differing the heat load shedding building per building through the entire district

What about thermal comfort?
**Comfort evaluation**: Thermal Building Simulation

- Building model **using available data**.

How to model Buildings?

- Use of **statistical data** and archetype models
- Use of building **envelope data** if available
- Re-use existing thermal models from **mandatory studies**

⇒ **Fast building models generation**
**Automatic generation of thermal models**

- Python script generates modelica models

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**Dymola interface for the generated model**

- Weather file
- Air Handling Unit
- Internal gains
- Temperature set-points for heating
- Temperature set-points for cooling
- Single zone RC-model
Two possibilities:

- Data enrichment from statistical databases:
  - TEASER can generate a building model with few parameters
  - Main advantage: requires few information about the building

- Data enrichment by hand:
  - TEASER can be used with the construction data
  - Main advantage: more accurate data
Building Energy Simulation sometimes available

- design offices perform dynamic thermal simulation of buildings during their design (it is mandatory)

Cambridge buildings
Models comparison (Standard and from BES)

Comparison of transfer profiles obtained by a standard profile or BES results

- Standard profiles model established from experimental results (standard model)
- Automatic model generation with only the 5 minimal parameters (reduced model)
- Automatic model generation with building envelope data (reduced model with enriched data)
- Detailed model from the mandatory BES study with Comfie-Pléiades software (complex model)
Model comparison: Heating profiles for constant temperature

Example of simulated heating profiles during a week of January

Accuracy results:
1. Complex model
2. Reduced enriched model
3. Reduced model (stat. data)

Similar dynamic estimation

Heating consumption difference relative to complex BES model heating consumption during January
Comparison on transfer rate & temperature
One-hour heat shedding
Comparison on transfer rate & temperature
With one-hour pre-heating

One-hour heat load shedding after one-hour over-heating
Comparison on Energy savings rate

### Energy savings rate

<table>
<thead>
<tr>
<th>Model</th>
<th>Energy savings rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard profile</td>
<td>10 %</td>
</tr>
<tr>
<td>Reduced model (from stat. data)</td>
<td>10 %</td>
</tr>
<tr>
<td>Reduced enriched model (from bldg envelop. data)</td>
<td>13 %</td>
</tr>
<tr>
<td>Complex model</td>
<td>5,5 %</td>
</tr>
</tbody>
</table>

### Energy savings rate variation

- **Heat load shedding from 7am to 8am**
  - Standard profile: 10%
  - Reduced model (from stat. Data): 10%
  - Reduced enriched model (from bldg envelop. Data): 13%
  - Complex model (mandatory simulation): 5.5%

- **Heat load shedding from 5am to 6am after a one-hour over-heating**
  - Standard profile: 10%
  - Reduced model (from stat. Data): 3.1%
  - Reduced enriched model (from bldg envelop. Data): 3.5%
  - Complex BES model: 2.4%
Conclusions

- Modeling buildings at district scale is a challenge to get data for all buildings

- **Require multiple way of modelling:**
  1. **Standard profile** is fast but hazardous solution
  2. **Reduced model** generated from statistical data is a good approach
  3. When building data are available, it is possible to build a **reduced enriched model**
  4. When **detailed model** is already available it has to be used

- **For district simulation you may have to mix these approaches:**
  - Some models are **easier to connect** than others (Modelica VS black box software)
  - **Accuracy** is not guaranty, but it is **sufficient to evaluate flexibility**, and then

  ⇒ Quantify load shedding effects on power and temperature
  ⇒ Optimize load shedding sequences, minimizing discomfort and maximizing profit
  ⇒ Evaluate the distributed load shedding capacity of the district
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Thanks,

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Questions?

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