DS²BE

Doctoral Seminars on Sustainability Research in the Built Environment

Decision-aiding tools based on a multi-scale and dynamic energy mapping of a regional building stock

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I. RESEARCH FIELD & BACKGROUND

➢ **Smart city & Buildings Energy** field. A smart city is an urban area integrating information and communication technology to optimize city efficiency services while supplying electronic data information to citizens, authorities and decision makers [1].
➢ In Wallonia Region, Belgium, a lot of buildings are more than 50 years old, poorly insulated and thus less energy performing [2].
➢ Wallonia building stock is composed of more than 1.7 million buildings [3-4].
➢ The actual heating system performance varies between 80% to 100% [5].
➢ Some cities propose platforms which link decision makers and stakeholders for a smart city management [6].

II. RESEARCH QUESTIONS & HYPOTHESES

➢ How can we asses Wallonia buildings' **annual** heat consumption (HC), heat demand (HD) and electricity consumption (EC) and map them on different territorial scales?
➢ Can **hourly** HD and EC be assessed for different building types?
➢ How to analyze and predict the obtained results?
➢ If the annual heat consumption (HC) and HD are assessed on building level, they can be mapped on different territorial scales (statistical sector (SS), municipality and urban regions scales).
➢ When the annual HD and EC are assessed, they can be the inputs to assess hourly HD of a building type on a given period.
➢ If considering different scenarios such as climate, HC, HD and EC can be analyzed and predicted.

III. AIMS & OBJECTIVES

Our study aims to develop tools related to smart energy management of the building stock in Wallonia. The objectives are:
➢ Annual HC, HD and EC assessment of all residential, tertiary and industrial buildings in Wallonia
➢ Mapping HC, HD and EC on different territorial scales
➢ Dynamic modelling (hourly) of HD and EC of a building stock on a given period
➢ Development of a platform to visualize the results (ongoing)
➢ Multi-criteria decision aid (MCDA) analysis and 2050 projections

IV. METHODOLOGY

➢ Data from the cadastral database (over 1 700 000 buildings), energy reports [3-4] and monitoring reports are cleaned using R software and grouped in a new database, created in PostgreSQL with PostGIS extension.
➢ A top-down approach and a bottom-up approach are combined to assess HC, HD and EC of the Walloon building stock.
➢ Annual HC, HD, EC are mapped on different territorial scales using QGIS software.
➢ The dynamic modelling is performed using Python software.
➢ The platform of visualization is being created using Python, PostgreSQL & Django in back-end technologies and HTML, CSS, Bootstrap, JS and jQuery in front-end technologies.
➢ Statistical analysis and forecast scenarios are useful for analyzing main types of consumers and their future trends.
➢ A strategic decision support tool will be created by bringing together energy maps, forecast scenarios, energy indicators and PROMETHEE method [7] to attain European objectives.
➢ The developed tools will be tested and validated on the urban areas of Liège and Charleroi using real metered data (monitoring data).

VI. NEXT STEPS

In the third year of this PhD research:
➢ Development of a platform of results visualization (maps, graphs and plots) for a smart energy management of Wallonia.
➢ Dynamic modelling on municipality or urban region scales: using HD & EC profiles of different building types in the chosen area and on a given period
➢ Statistical analysis, multi-criteria analysis and forecast scenarios (for 2050)

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V. SOME OF THE ACTUAL RESULTS

Residential, Tertiary and Industrial Buildings Heat Demand (HD) per Municipality in Wallonia

Tertiary
Annual HD (GWh)
· 2.77 - 22.88
· 22.89 - 57.03
· 57.04 - 158.84
· 158.85 - 443.23
· 443.24 - 823.23

Industrial
Annual HD (GWh)
· 0.19 - 81.71
· 81.72 - 253.32
· 253.33 - 704.16
· 704.17 - 1543.91
· 1543.92 - 3470.40

Residential
Annual HD (GWh)
13.52 - 79.40
79.41 - 152.60
152.61 - 328.71
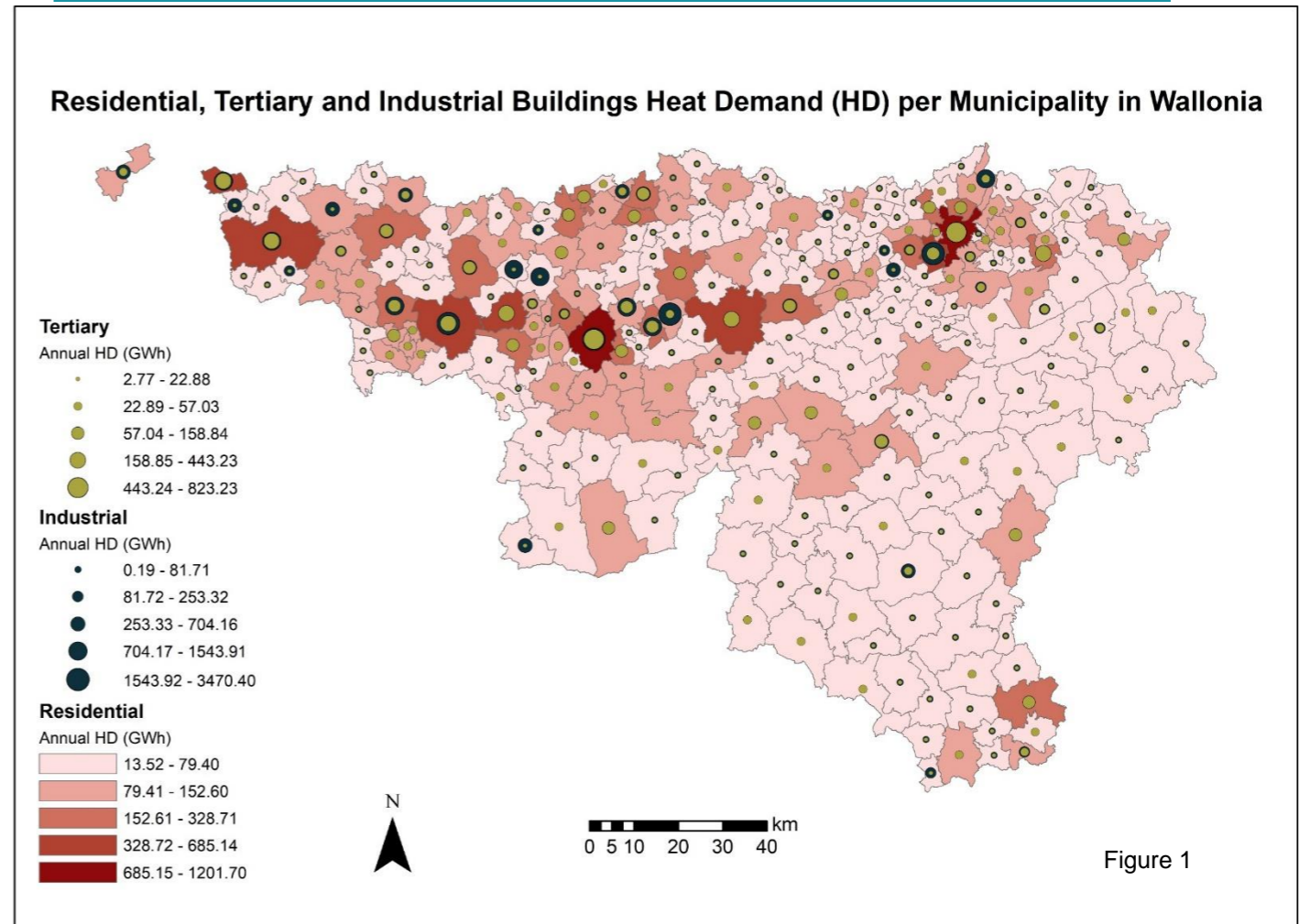328.72 - 685.14
685.15 - 1201.70

km 0 5 10 20 30 40

Figure 1

Fiure1:
▪ HD is lower than HC between 9.26 to 16.44%
▪ Figure 1: HD is the highest in Liège and Charleroi municipalities for residential and tertiary buildings, whereas for industrial buildings HD is higher in Seraing and Charleroi municipalities
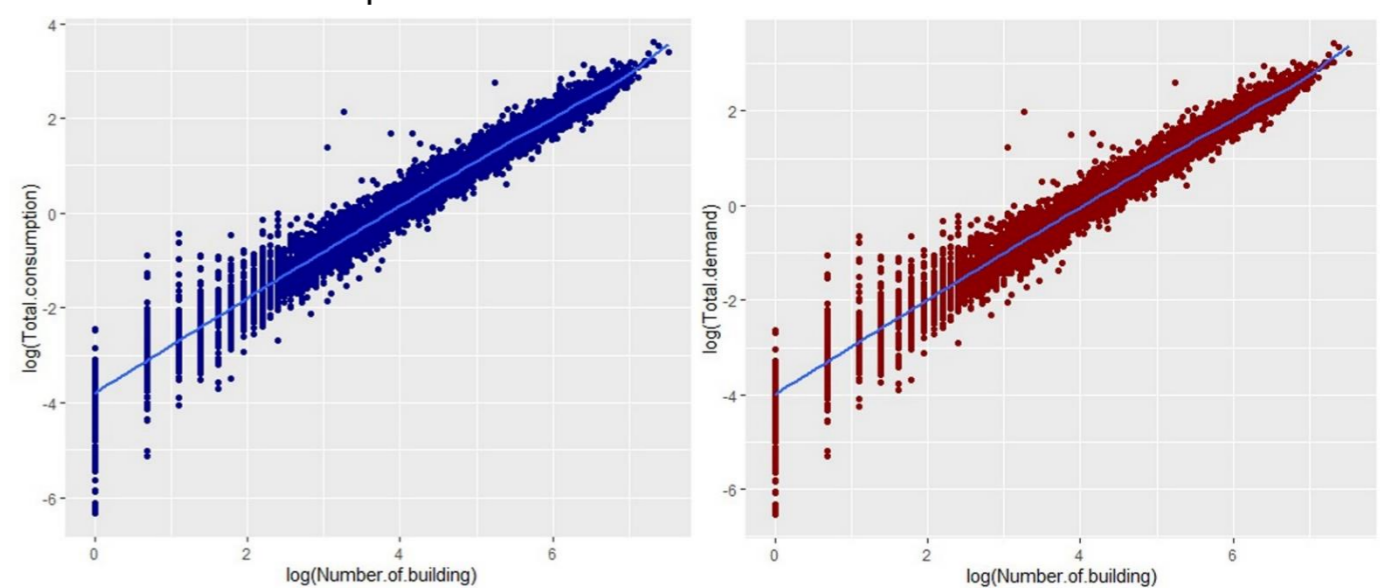

Figure 2

Figure 2: Residential HC (left) and HD (right) per number of dwellings in a statistical sector (SS). For every 1% increase in the number of dwellings, the HC increases by about 0.9259% and the HD increases by about 0.9309% in the same SS

**Buildings Energy Consumption & Demand in Wallonia**

Heat consumption, heat demand and electricity consumption which are assessed for each building in Wallonia, are represented on statistical sector, municipality and urban region scales. The estimation is performed for more than 1 700 000 (of 3 sectors: residential, tertiary and industrial) buildings in Wallonia.

Keyword (Heat, Electricity, etc) | Statistical sector | Municipality (All)
Max annual heat consumption (GWh) (All) | Max annual electricity consumption (GWh) (All)

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Figure 3
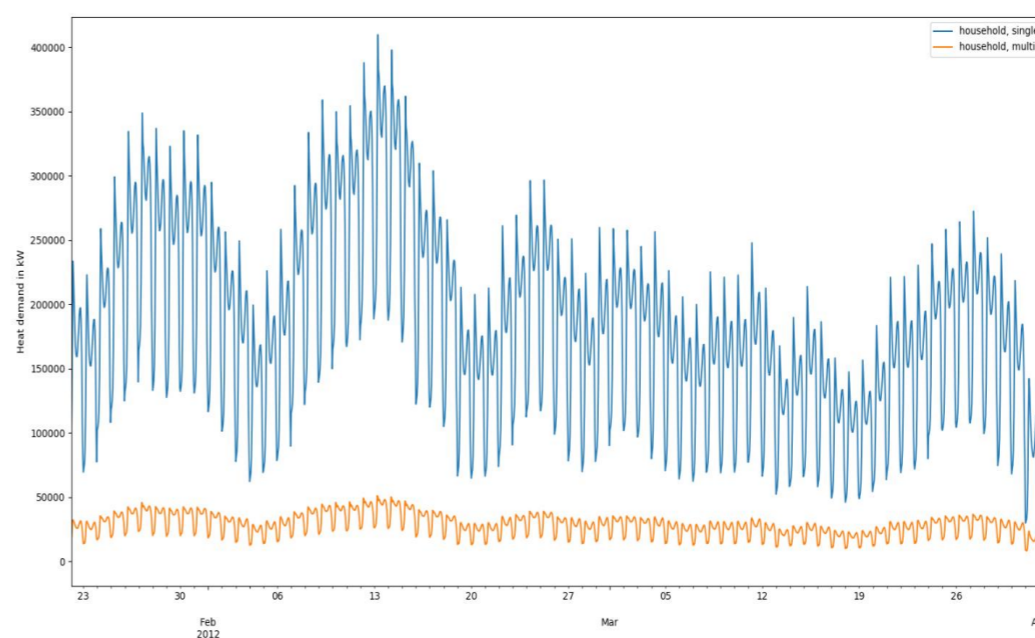
Figure 4

▪ Figure 3: Platform creation (still under development).
▪ Figure 4: HD in kWh of residential households in Liège municipality for the year 2012.

Conclusion:
This research is very helpful for public authorities, stakeholders and HD, EC network managers to know the existing buildings' energy, thus take considerable decisions to fulfil European goals in terms of energy.