SUSCITY- Energy efficient buildings and consumer behaviour

A project involving Portuguese Universities
and the Massachusetts Institute of Technology

J.M. Serra, S. Freitas, MC Brito, M. Panão,
Universidade de Lisboa

Christoph Reinhart
MIT

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Scope of the doctoral program

The study of Sustainable Energy Systems (SES) involves a complex framework characterized by wide time and spatial scales, requiring a multidisciplinary approach

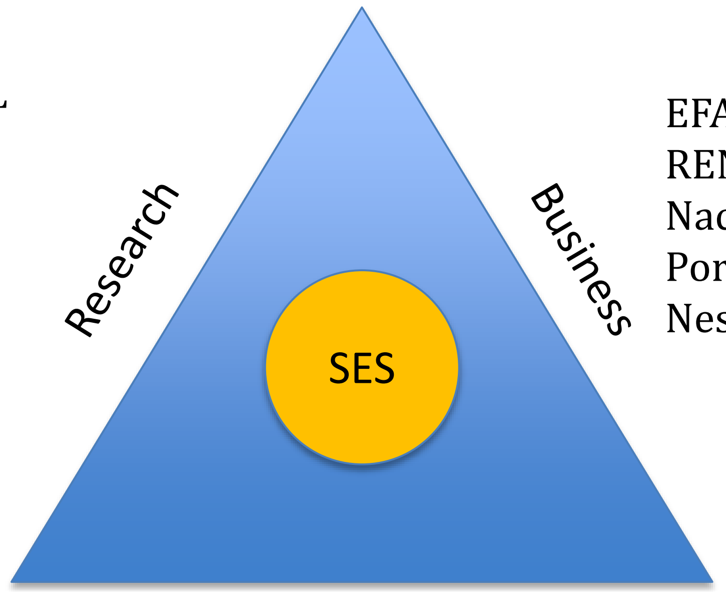
The Sustainable Energy Systems (SES) PhD program aims at educating the leaders that will contribute to the development of so-called Carbon-Free Society.

The program intends to:

- Promote the rational use of energy, energy efficiency (namely in buildings) and the use of endogenous energy resources, in particular renewable energy;
- Reduce energy costs by developing new open energy and ancillary services markets with different agents (generation companies, service providers where even consumers participate) to be able to deal with the new challenges imposed by a strong presence of renewable sources;
- Increase energy security through the diversification of energy sources;
- Deliver extra network capacity and system flexibility to manage large scale integration of renewable power sources in the electric grid.

Affiliated institutions

INESC-TEC (UP), LAETA (UP, UL - IST, UC), LARSYS (UL - FCUL, UL - IST), INESC Coimbra (UC), CICC (UC), IDL (UL - FCUL) and CESA (UL - ISEG)



EFACEC, PT (Portugal Telecom), REN (Redes Energéticas Nacionais), EDP (Energias de Portugal), Galp, IBM, RD Nester and Novabase.

High Education

- **Universidade de Lisboa (UL)** – Faculdade de Ciências (FCUL); Instituto Superior Técnico (IST); Instituto Superior de Economia e Gestão (ISEG)
- **Universidade de Coimbra (UC)** – Faculdade de Economia (FE) and Faculdade de Ciências e Tecnologia (FCT)
- **Universidade do Porto (UP)** – Faculdade de Engenharia (FEUP)
- **Massachusetts Institute of Technology (MIT)**

Suscity

- The Renewable energy group runs the Solar Campus

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- Cities play an important role in both economical and social development. More than 50% of the world population live in cities and more than 80% are foreseen for 2050.

- Cities generate more than 80% of world GDP
- Consume more than 75% of natural resources
- Generate around 50% of global waste

- Therefore cities are an excelent place to increase resource efficiency use in order to contribute for global sustainability of growth

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- There is a large dispersion of data generation tools at the urban level that is often not effective in providing real gains in terms of urban performance
- This project aims to bring a step forward in urban modeling and data representation supported by big data urban information

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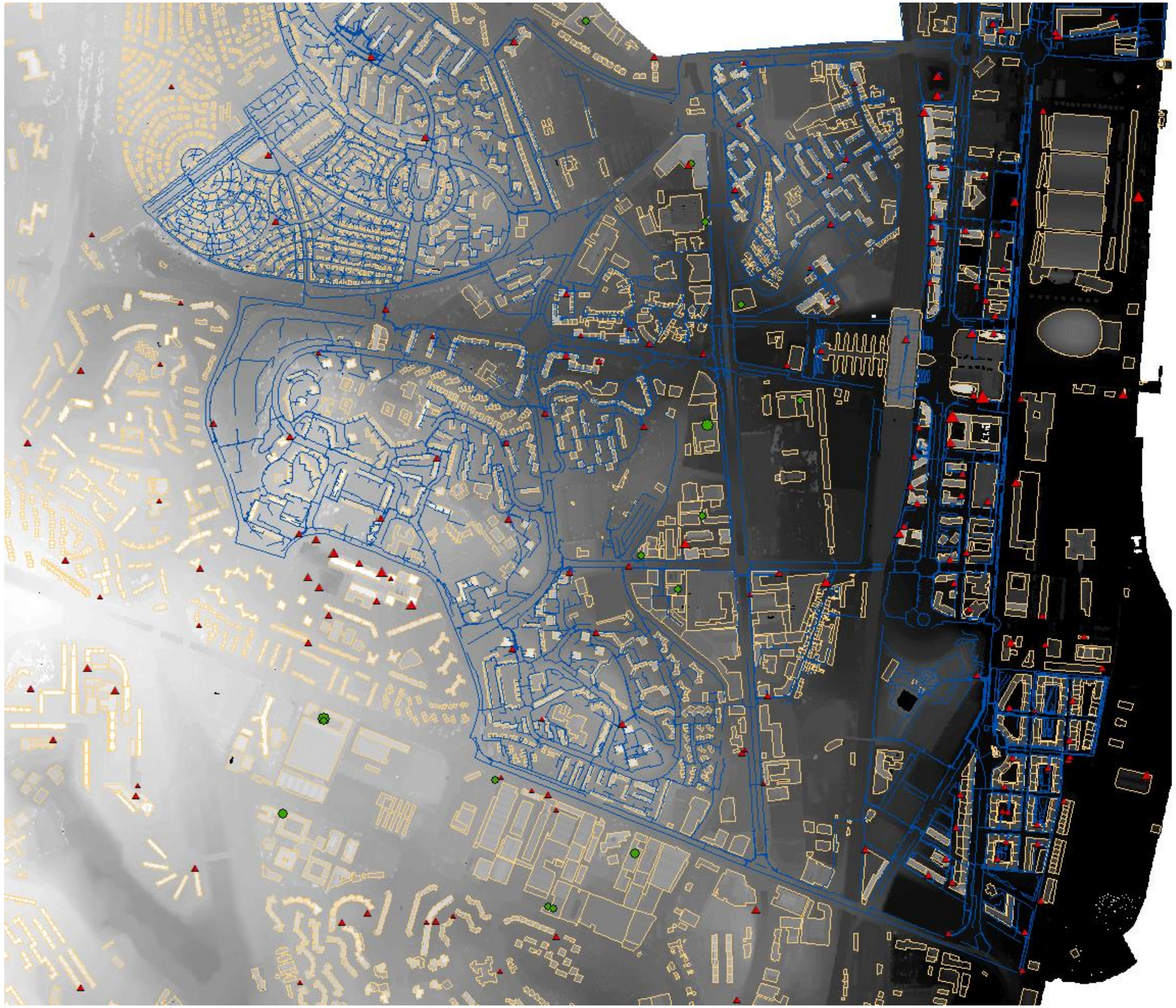
Area: 5,44 km2

Inhabitants: 21.000

The city as a living laboratory



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- The use of renewables, as for example building integrated PV (BIPV) contributes for nearly zero cities, allows new business models associated with aggregation concepts for energy demand and response

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Management of these agregators require

advanced models and distributed control systems with both good spatial and time resolution to deal with the variability of renewables

but also with the dynamics of consumer behaviour in terms of energy consumption (both in house and for mobility)

Consumers become prosumers

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- **URBAN ANALITICS**
- Develop a platform CityView that will integrate models of buildings, their thermal behavior, energy consumption, mobility related issues to guide urban development and LCA of materials involved in that neighbourhood.

- **INFORMATION SERVICES AND BIG DATA PROCESSING**
- TIC platform infrastructure to enable a complete and integrated vision of the city metabolism

- **INTELIGENT SOLUTIONS FOR BUILDINGS**
- Tools for better building construction energy performance

- **MOBILITY AND ENERGY**
- Mobility models, energy input-output from electic vehicules. Mobility patterns

- **SERVICES BASED ON INTELLIGENT GRIDS**
- Micro-grids, Multi micro-grids, integration of localized generation technologies, distributed storage (EV') and charging management

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WP1

- **Potential savings in terms of energy consumption in buildings**
- **Retrofitting benefits**
- **Models for energy consumption**

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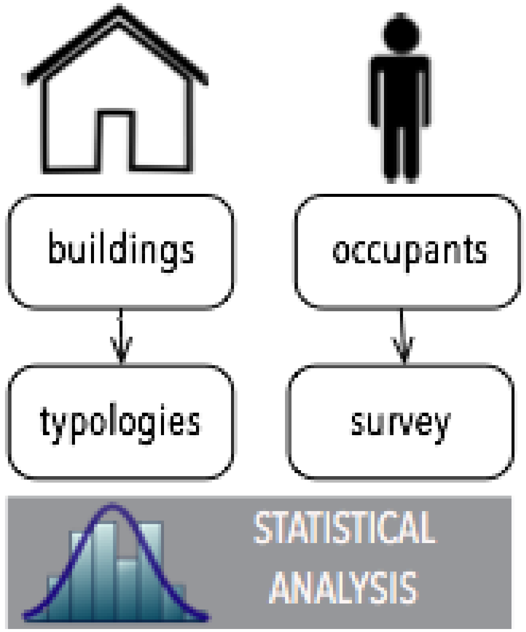
- Energy and people interaction

The **interaction between the building and their occupants** can negatively or positively affect energy outcomes.

Energy Performance Certificates lack of useful information for an accurate estimate of the **potential energy savings** associated with retrofitting measures.

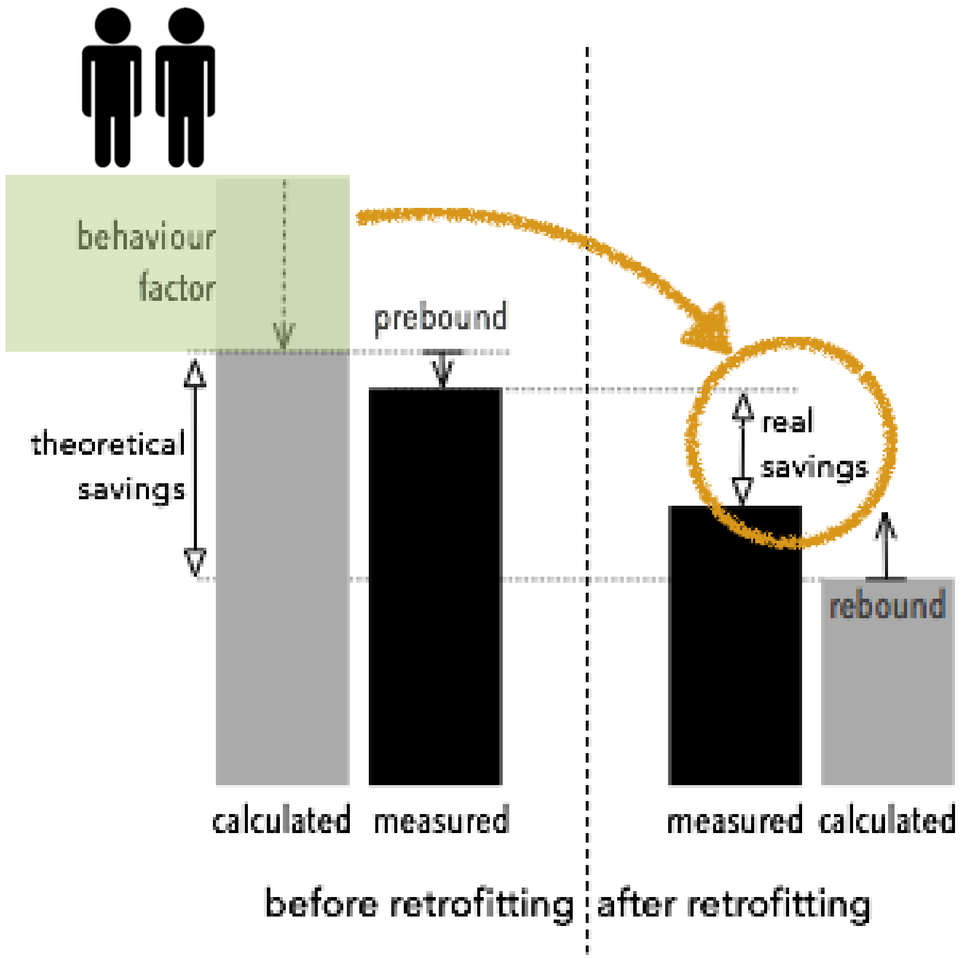


Understanding the prebound effect is important since energy calculations supporting the study of energy efficiency measures should always account for real inhabitants behaviour, which differ from those commonly assumed in policies

If the actual energy consumption is lower than expected, real energy savings will also be lower than theoretically predicted

Occupants presence is determinant, but occupants' behavior can also have a negative impact on the energy use of a building when they are not present.

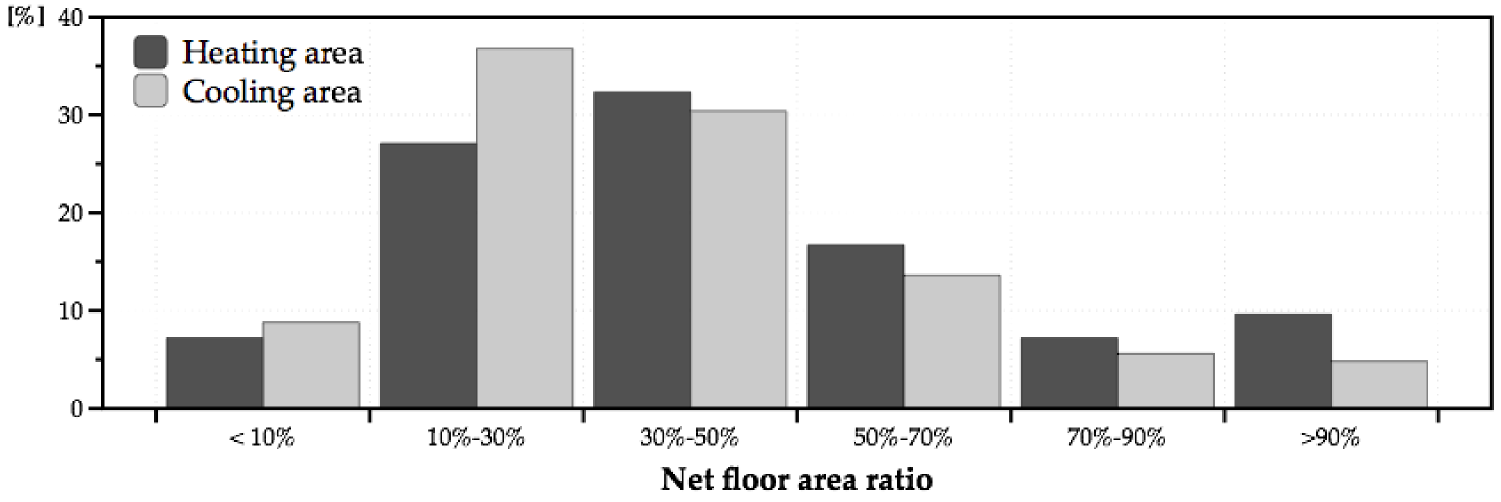
For example it has been shown that programmable thermostats are related to higher energy consumptions since they are used to heat space independently of occupants presence in that period.


behaviour
factor
prebound
theoretical
savings
real
savings
rebound
calculated
measured
measured
calculated
before retrofitting
after retrofitting

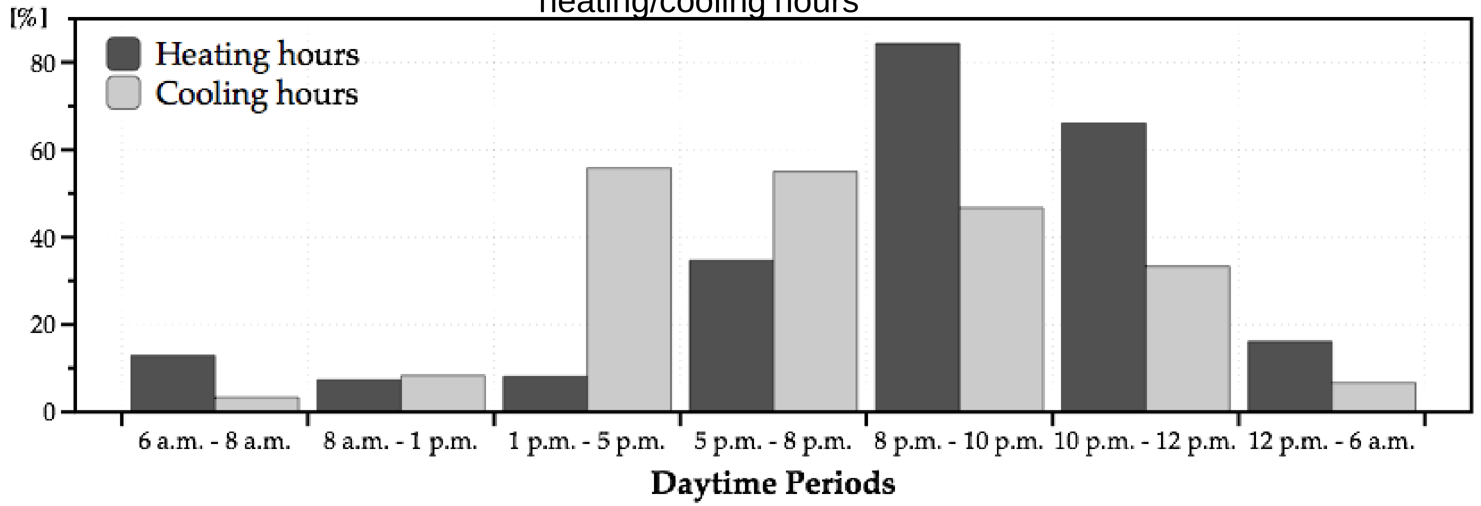
SURVEY results

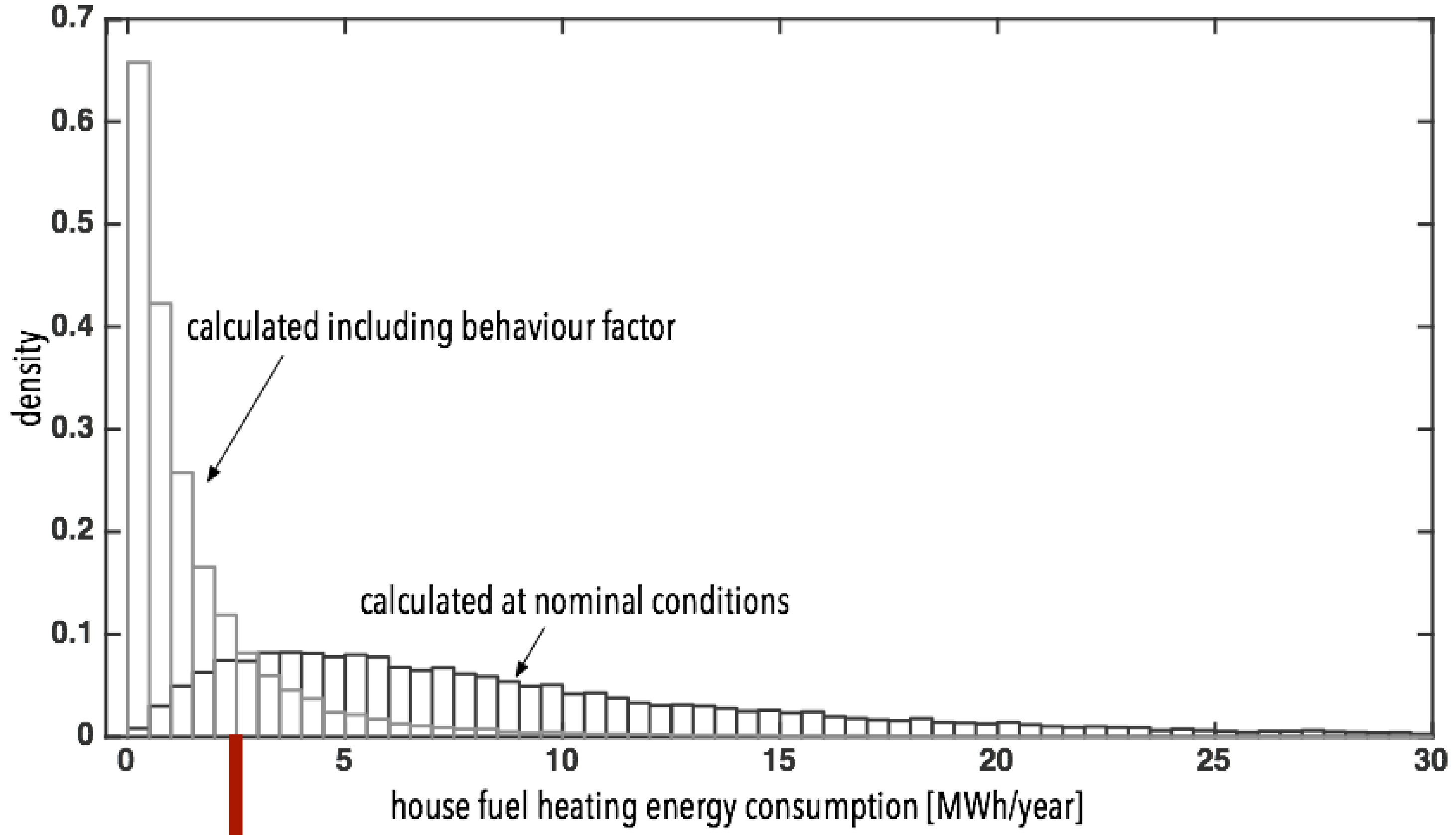
answering some important questions such as: how often inhabitants heat/cool their houses? Are houses totally or partially heated/cooled?

heating/cooling floor area



heating/cooling hours





average
annual fue
heating

National statistics

2.4 MWh/year

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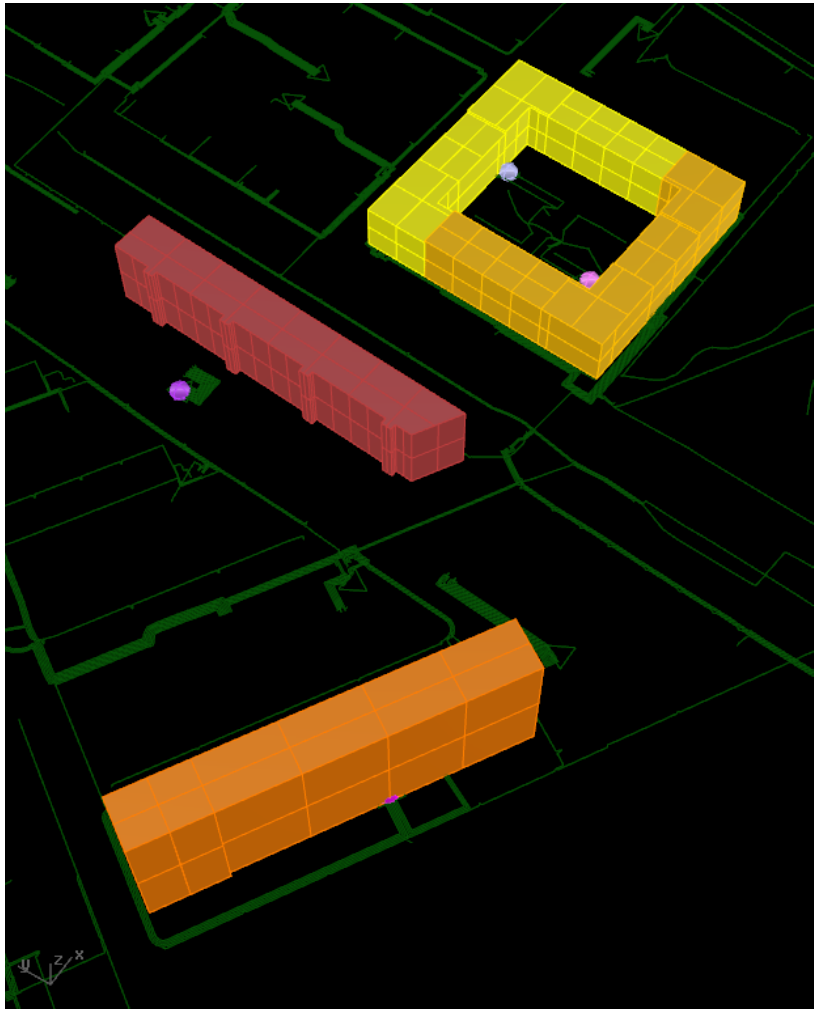
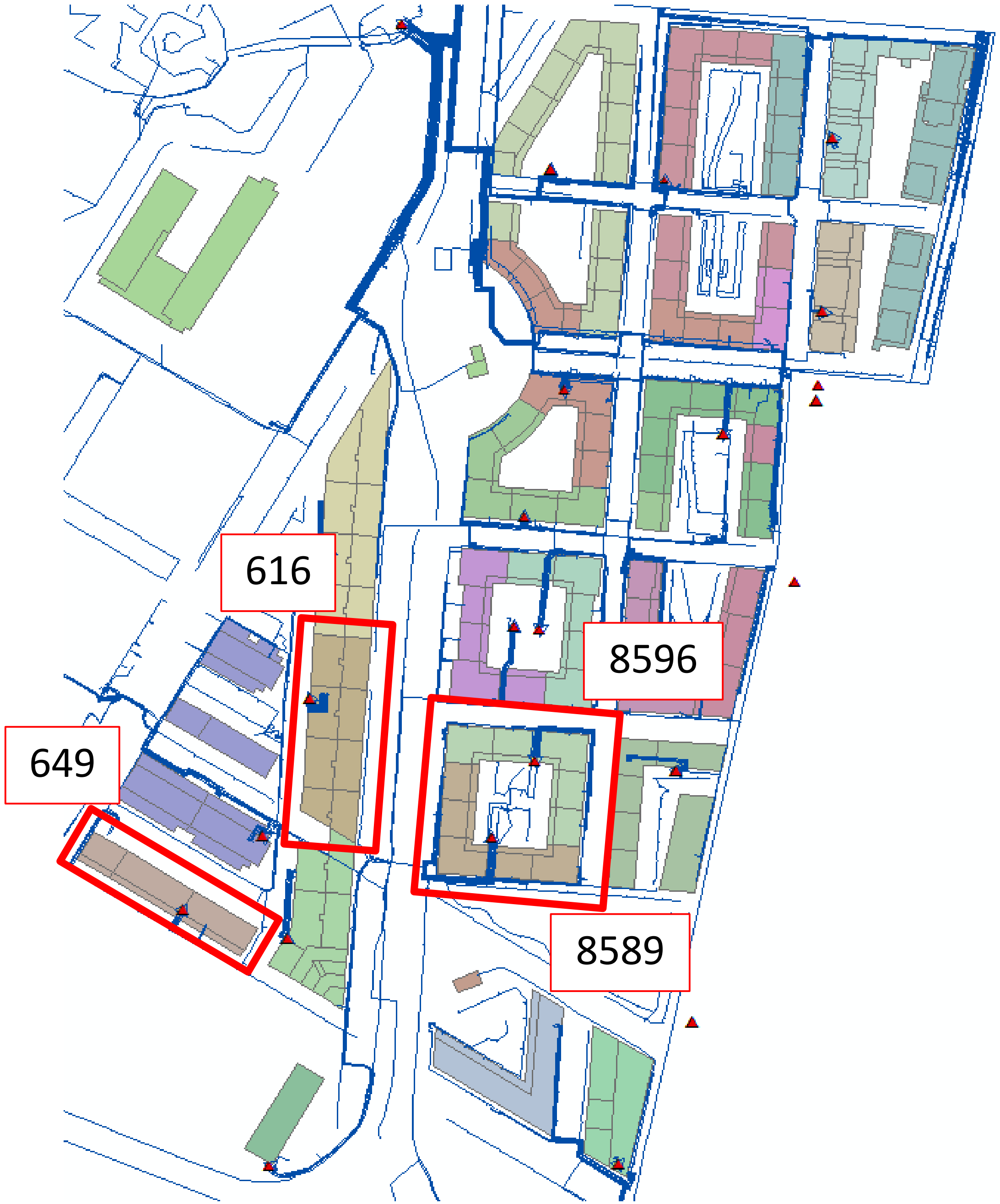
WP3

- NZEB
- It is acknowledged that solar PV is one of the key players in future's energy matrix of almost all countries in the world, which is mainly due to the drop in the prices of this technology.
- Also, the PV market has been offering more solutions for aesthetical integration of PV in the building envelope, which make it popular and appealing to residents in urban environments and architects.
- Thus, self-consumption regulations have emerged in several countries, so that people can become both consumers and prosumers. As such, it becomes relevant to study the outcomes of PV penetration on the electricity grid

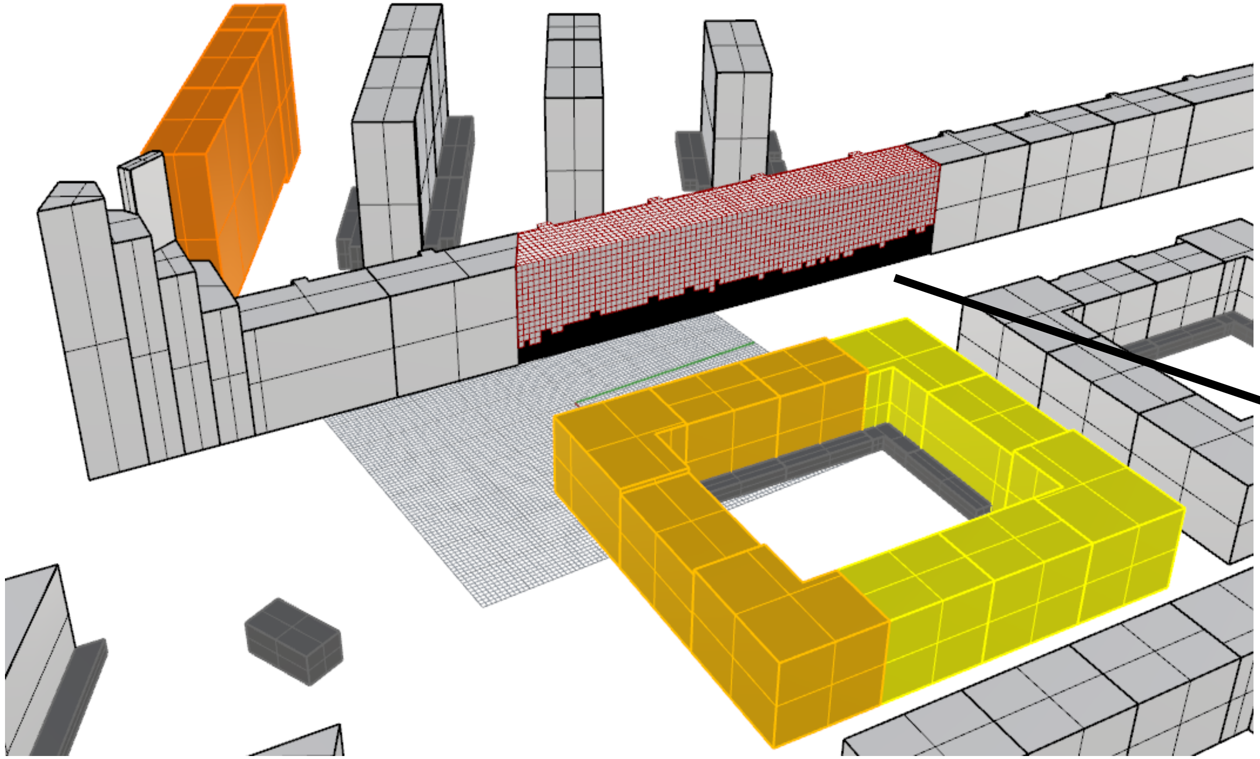
Selected PTs and blocks

(block = all buildings connected to 1 PT)





PT 616 – Block PV potential



irradiation < 1000 kWh/m2/year

1) DIVA to find irradiation and 2) ArchSim for PV estimation

ARCHSIM + DIVA-FOR-RHINO

PV only where irradiation > 1000 kWh/m2/year:

Rooftop PV - 15% efficiency panels on 60% area
~1060 m^2
256 MWh/year

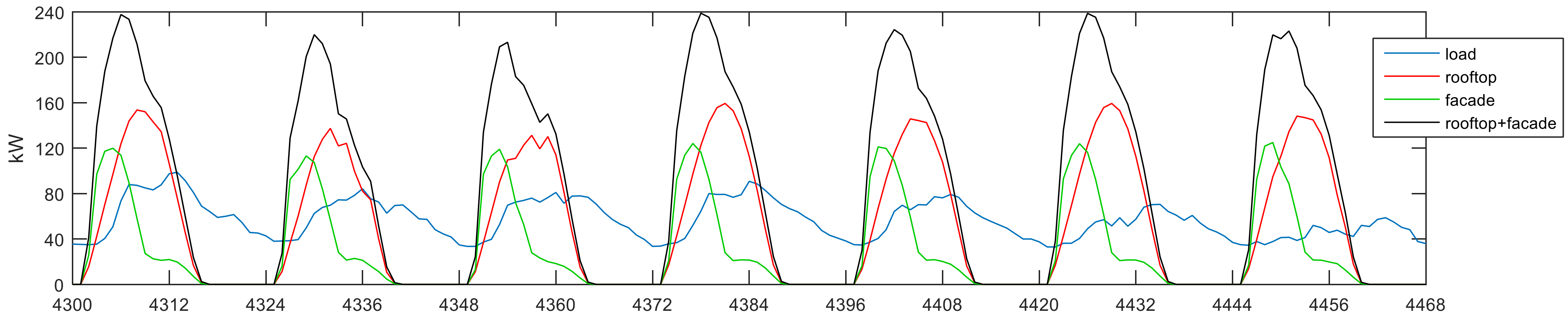
Facade PV - 15% efficiency panels on 50% area
~1030 m^2
157 MWh/year

PT 616 – Block PV potential

15min load to 1h load

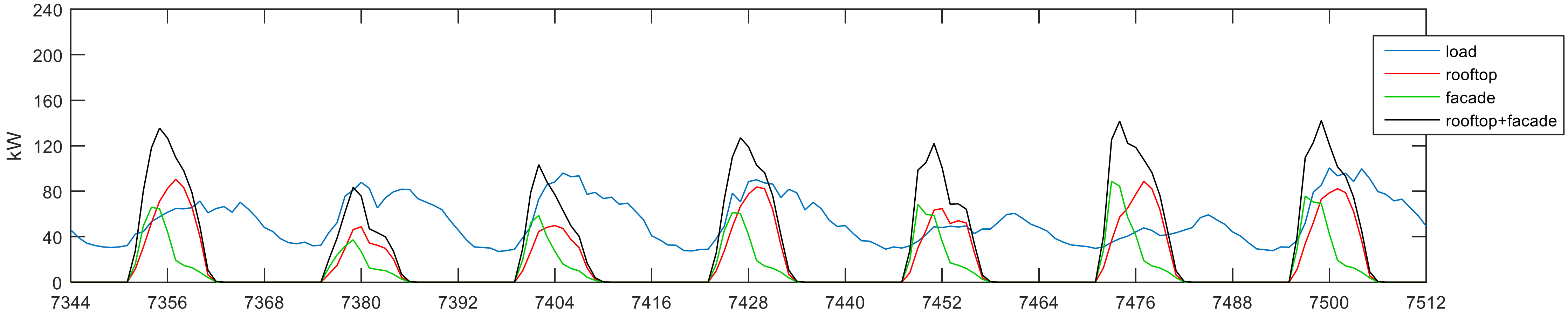
June

There's power

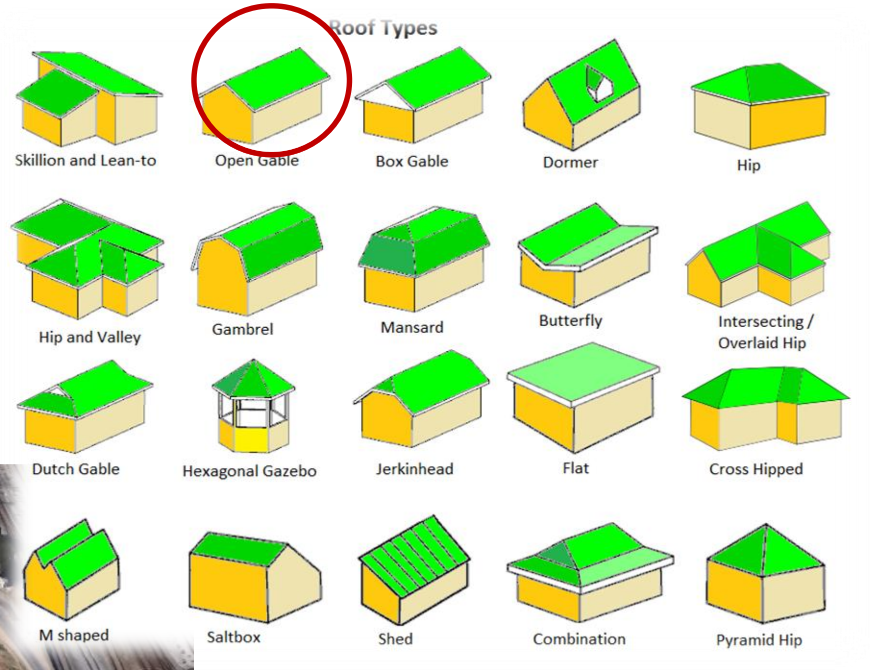


November

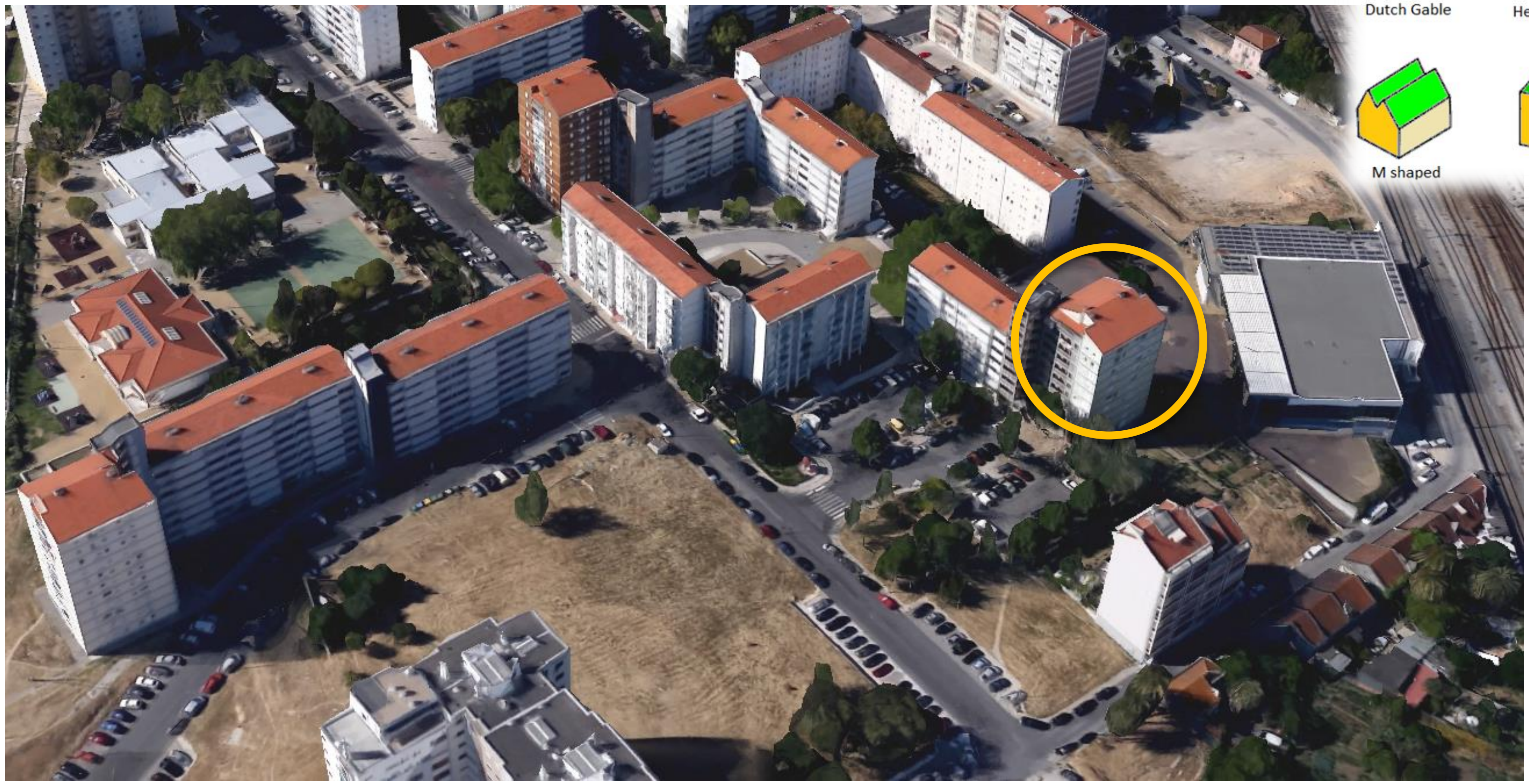
There's energy, but not enough power



2. Example of <u>gable</u> rooftop structures

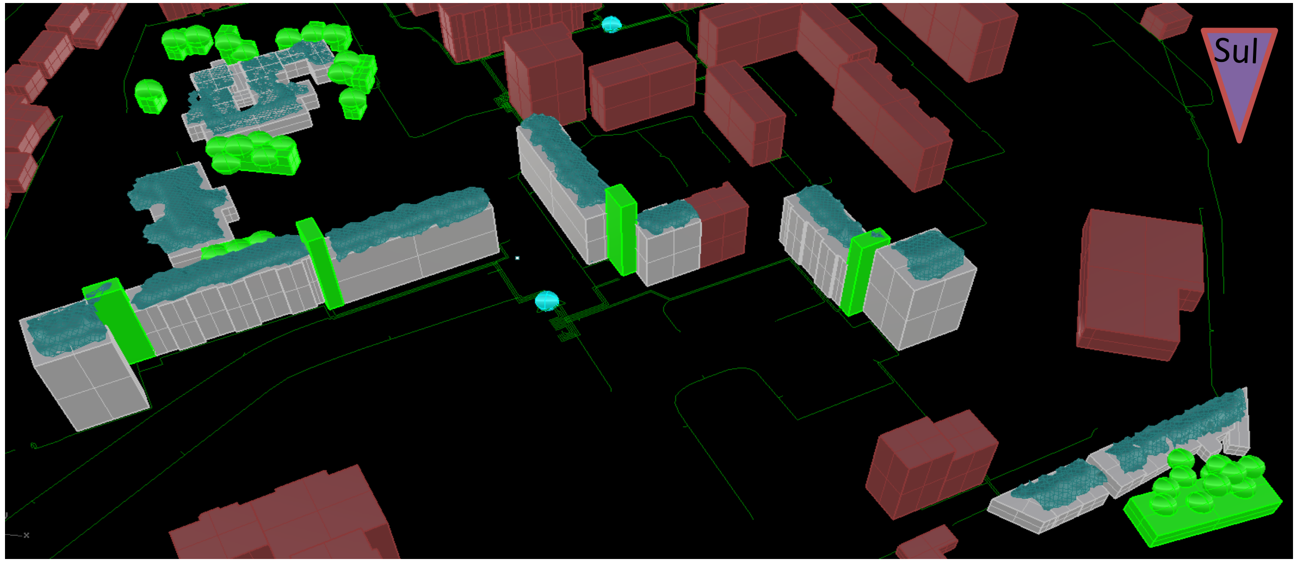


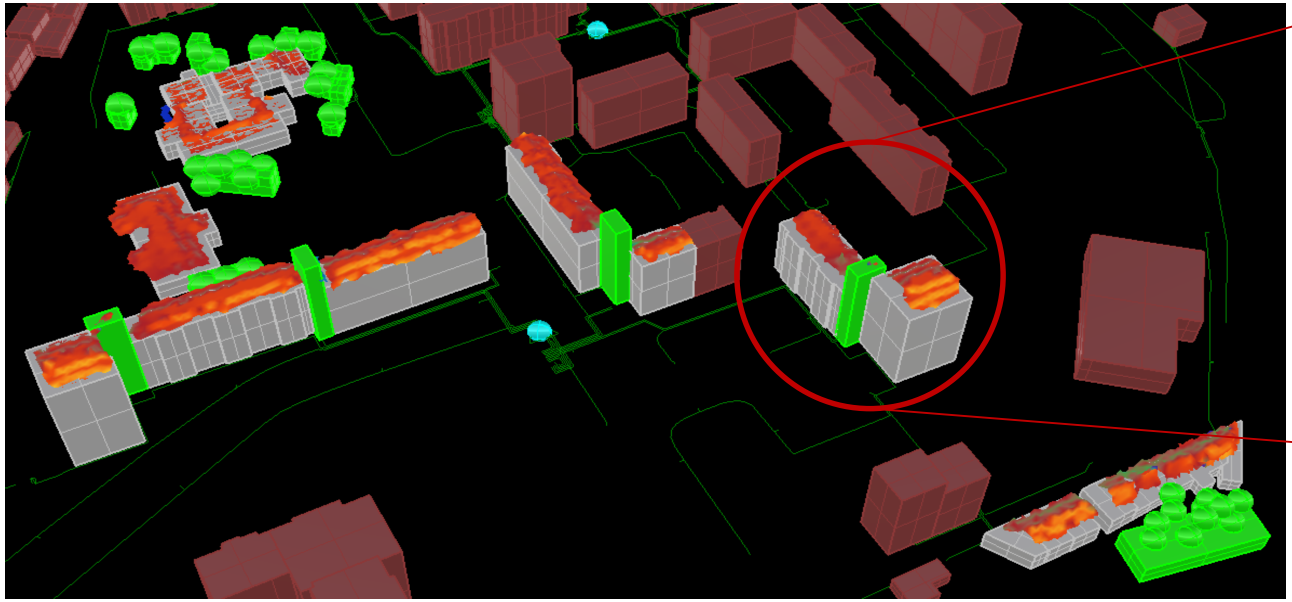
Sul

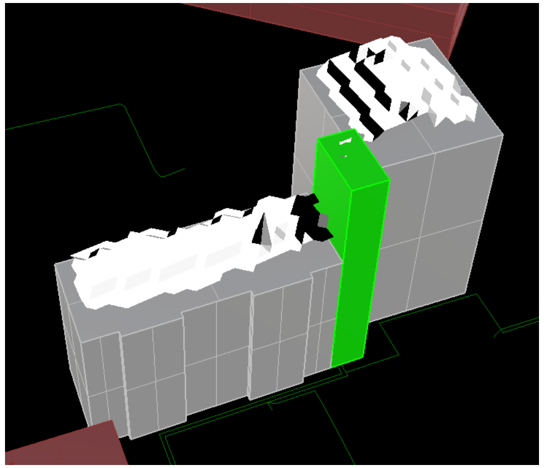


2. Example of gable rooftop structures

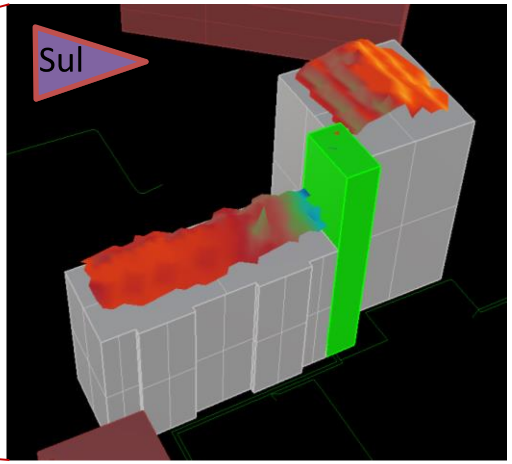
Rooftop reconstruction from:
DSM point cloud (LiDAR)







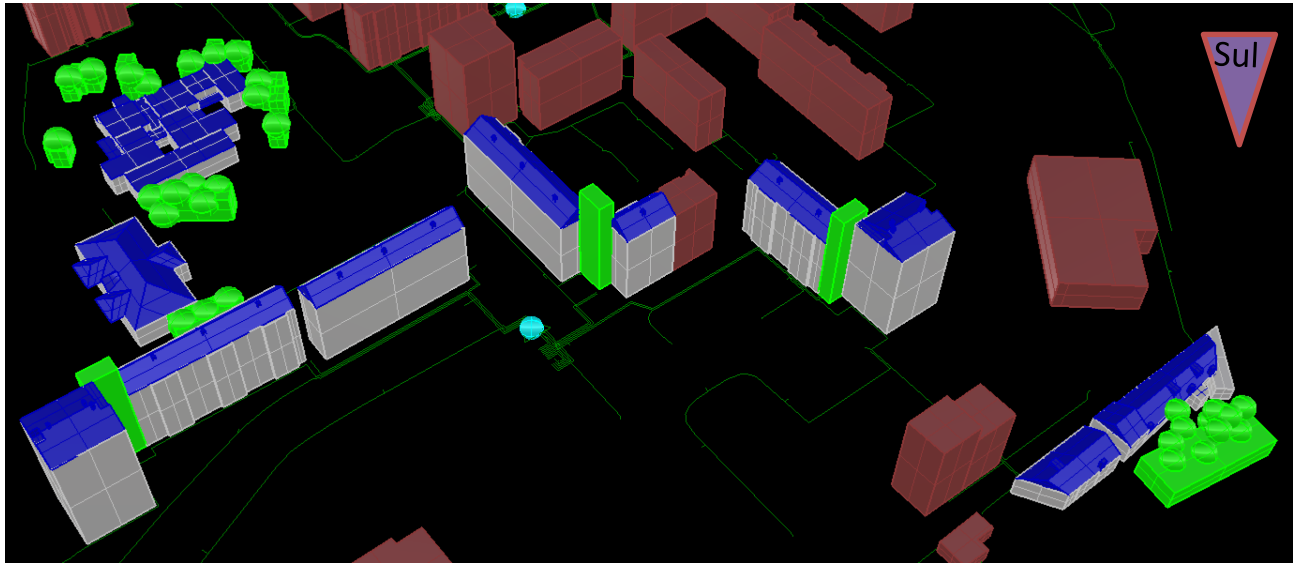
PV for areas with irradiation
> 1000kWh/m2/year (branco)

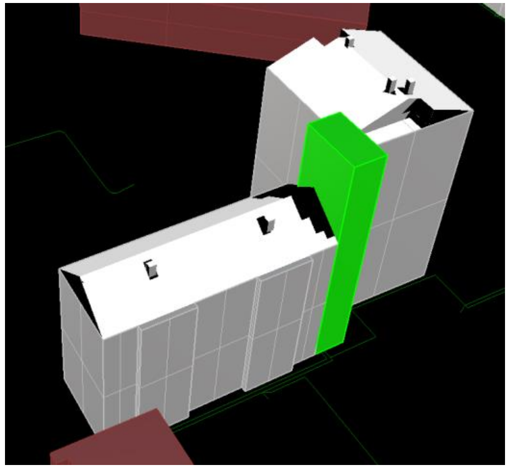


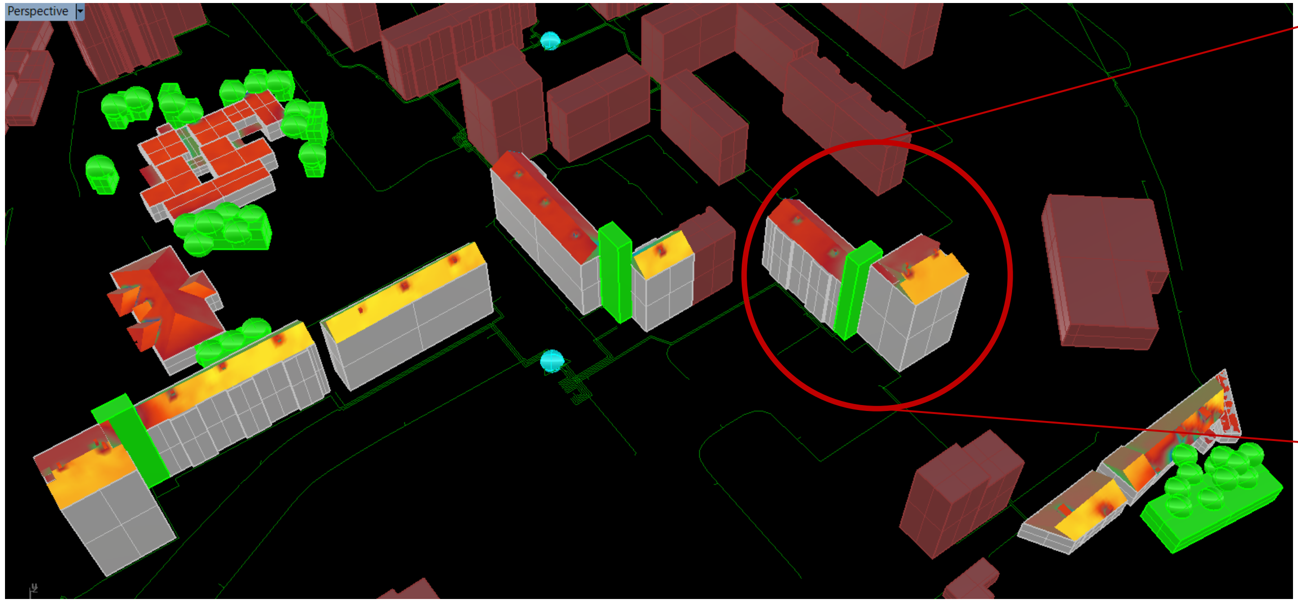
2. Example of gable rooftop structures

Rooftop reconstruction from:

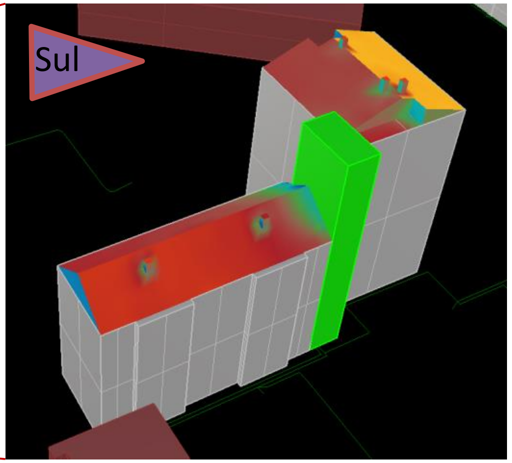
<u>sketch</u>







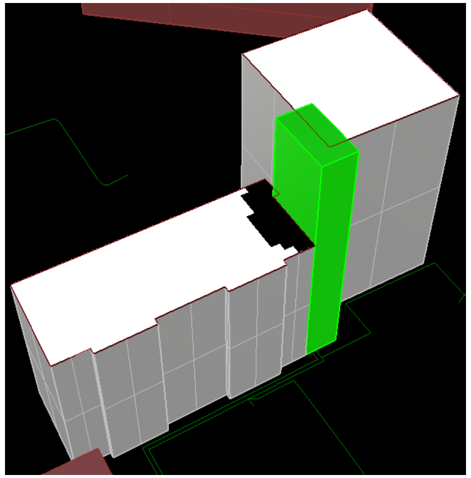
PV for areas with irradiation > 1000kWh/m2/year (branco)

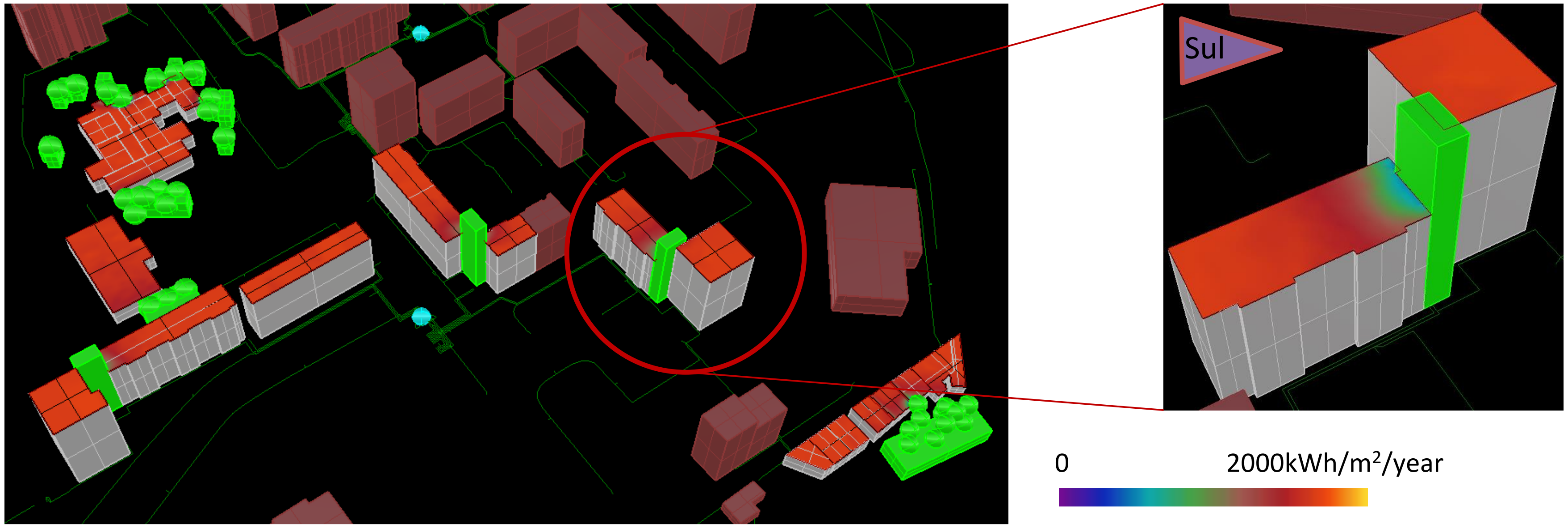


2. Example of gable rooftop structures

Rooftop reconstruction from:

footprint

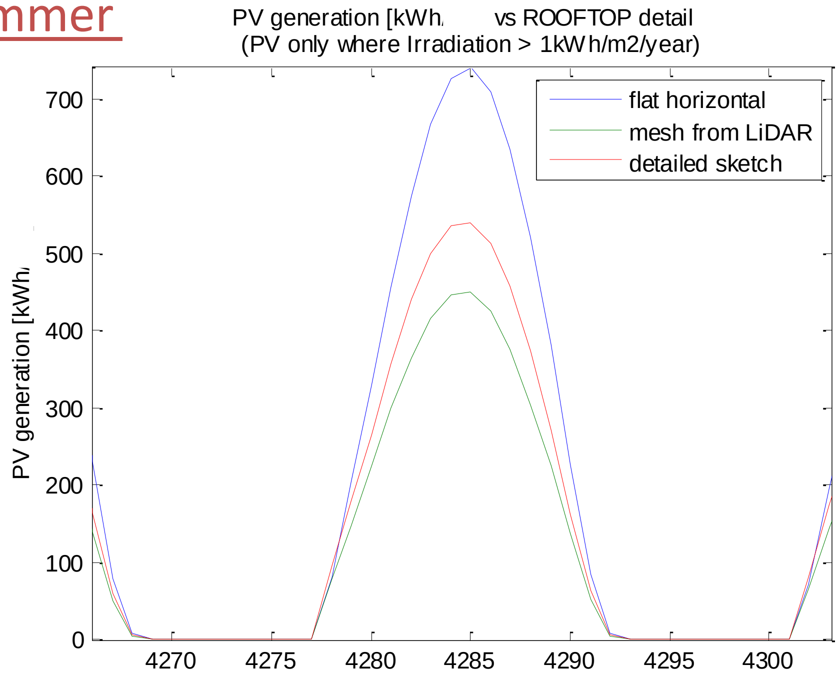




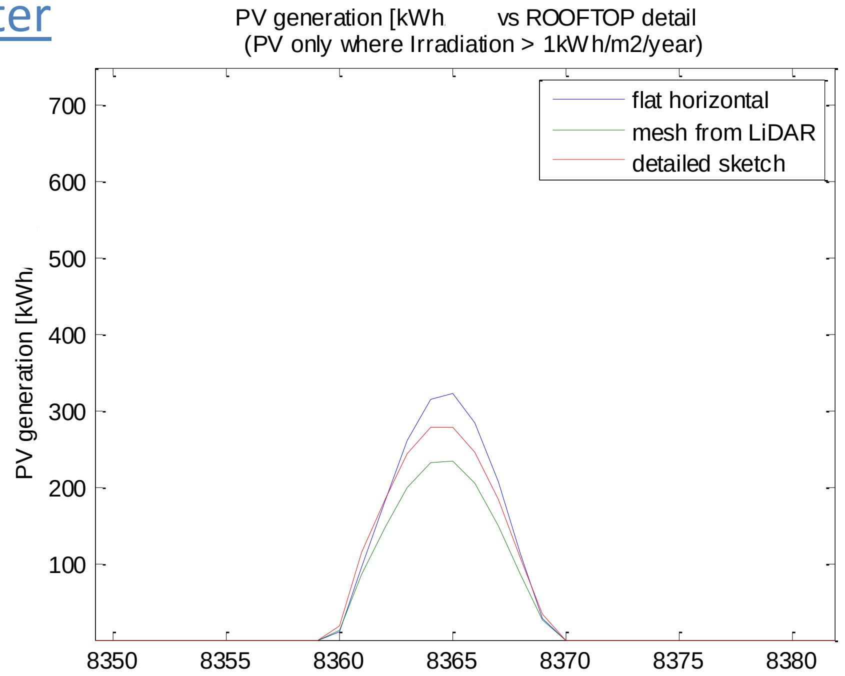
PV for areas with irradiation
> 1000kWh/m2/year (branco)

2. Example of gable rooftop structures

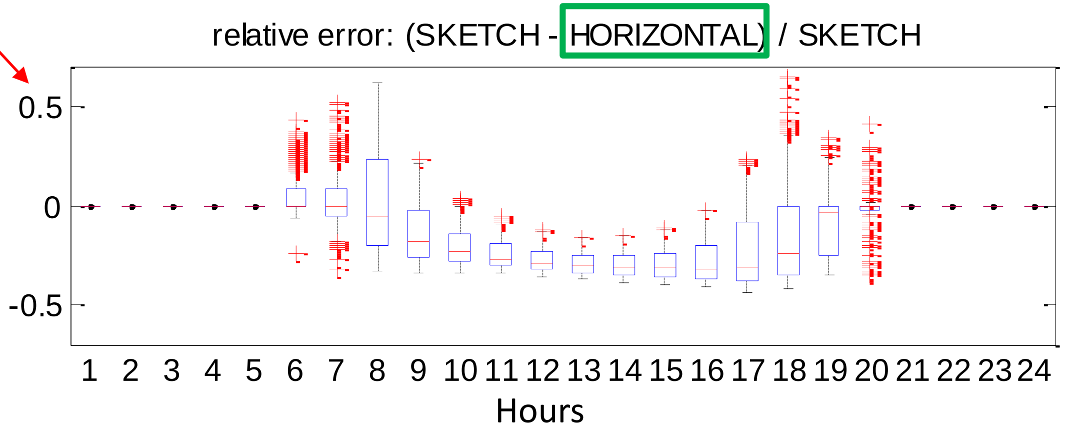
Summer

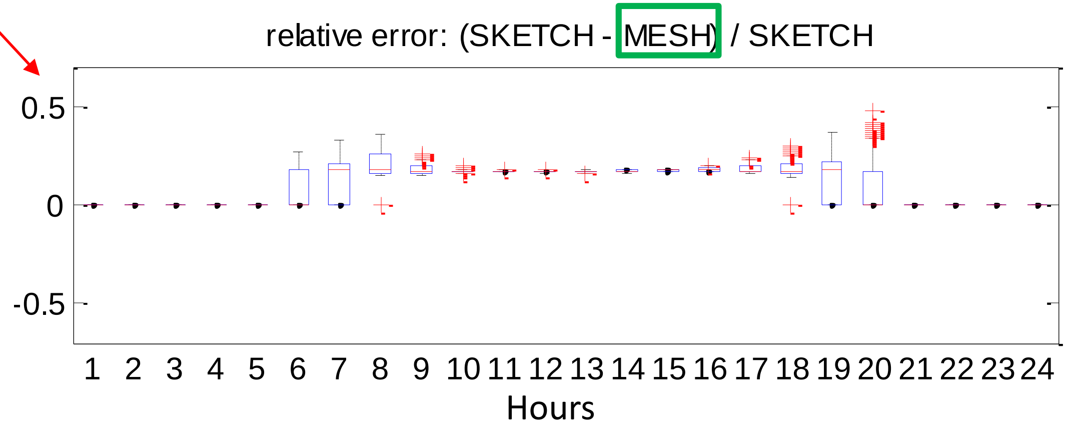


Winter



Overview (reference = sketch)



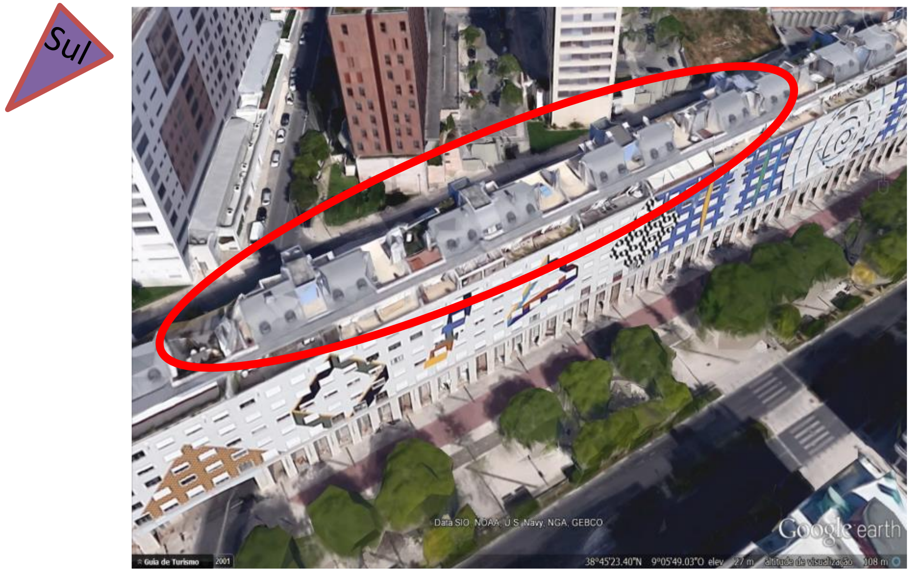


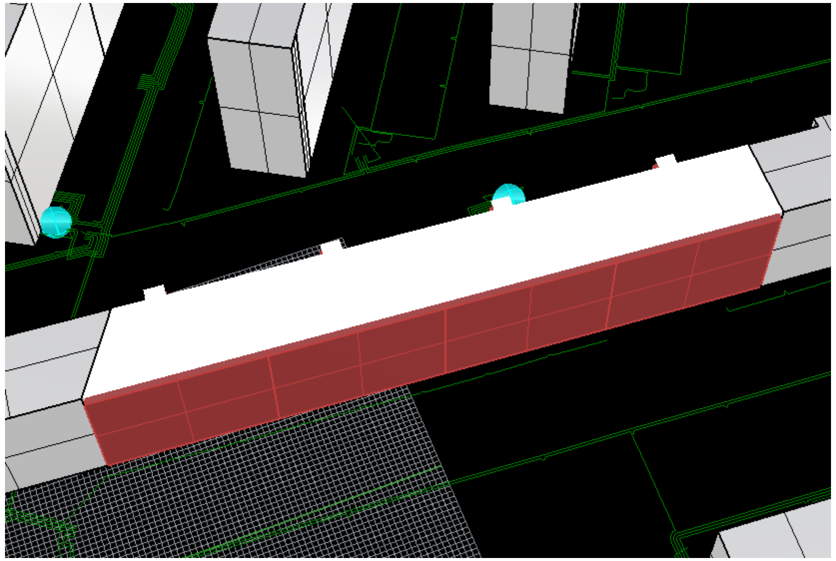
VAMOS UTILIZAR OS DADOS LIDAR!

1. Example of a complex rooftop structure

Rooftop reconstruction from:

<u>footprint</u>





PV for areas with irradiation
> 1000kWh/m2/year (branco)

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Understanding the difference between calculated and measured energy in buildings before retrofitting - **the prebound effect** - is important since energy calculations supporting the study of energy efficiency measures should account for real inhabitants behaviour, to **prevent real energy savings be lower than those theoretically predicted**.

The net floor area is only partially heated (average of 44%) and cooled (average of 37%);
{ Daytime periods with heating and cooling are much lower than a 24 hours
period, namely an average of 6 hours for heating and 7 hours for cooling;

These tools and data allowed for the simulation of hourly PV generation profiles for the whole year, showing the importance of renewables penetration (PV) in buildings neighbourhoods.