Universidad del País Vasco Euskal Herriko Unibertsitatea

FACULTY OF ENGINEERING BILBAO
UNIVERSITY OF THE BASQUE COUNTRY

3rd SMACCs Summer School

Thessaloniki, Greece

Models & public data: calculating building energy needs at regional level using public databases

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MSc in Smart Cities and Communities

SMACCs

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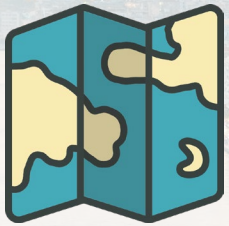
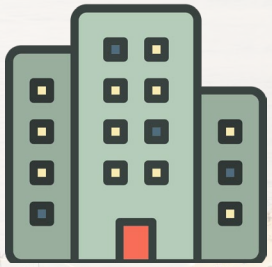
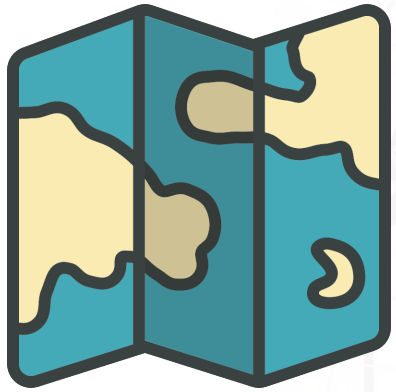




What are the key features of a good model?



Some lessons from cartography...

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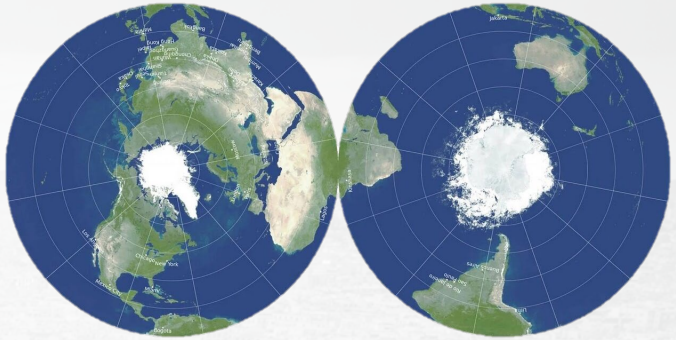
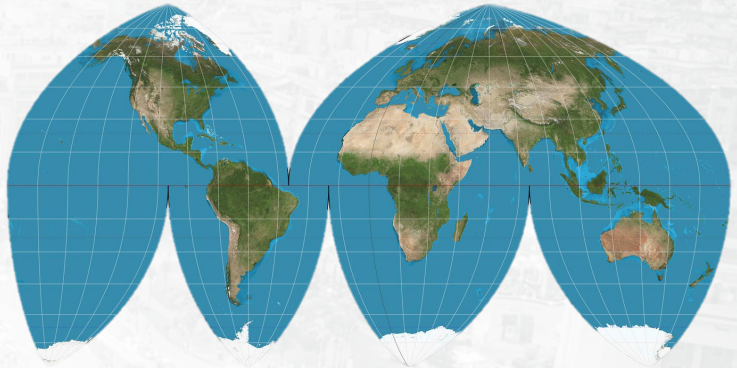


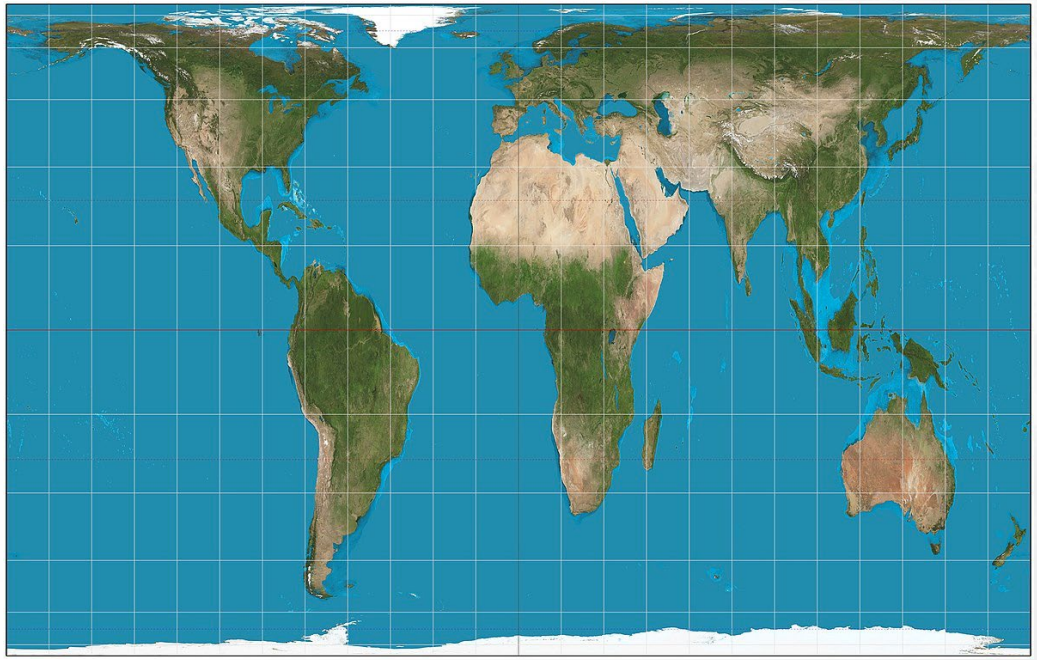
Goode



Winkel-Tripel

Mercator

Gall-Peters



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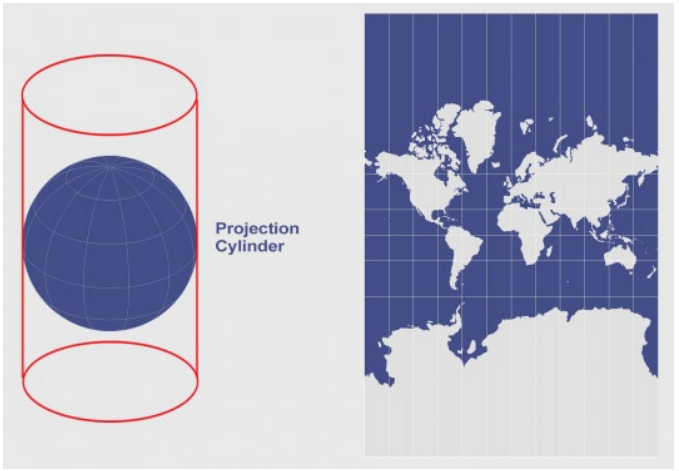

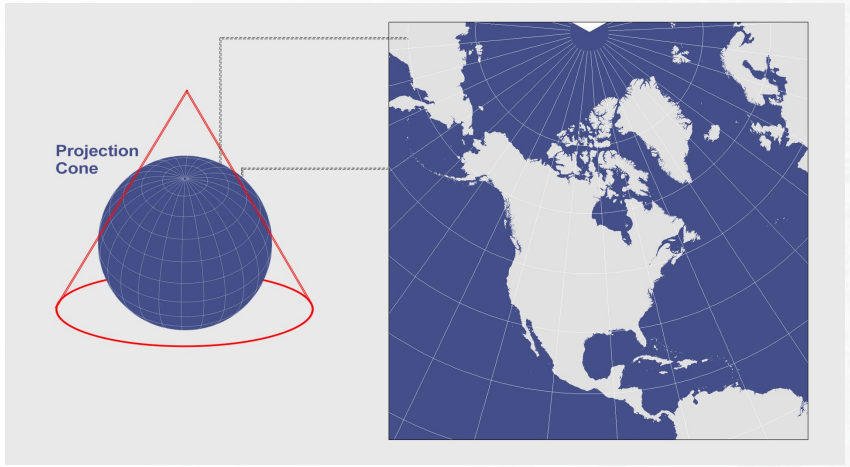

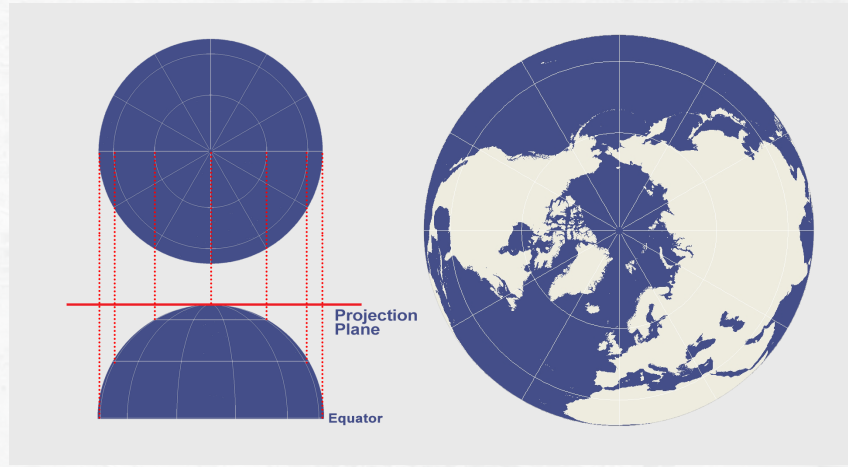

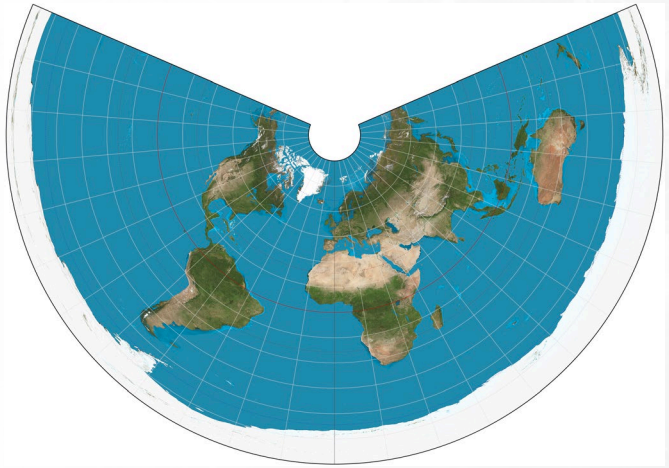

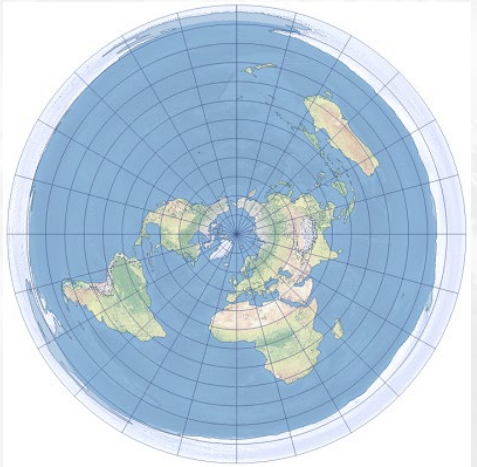

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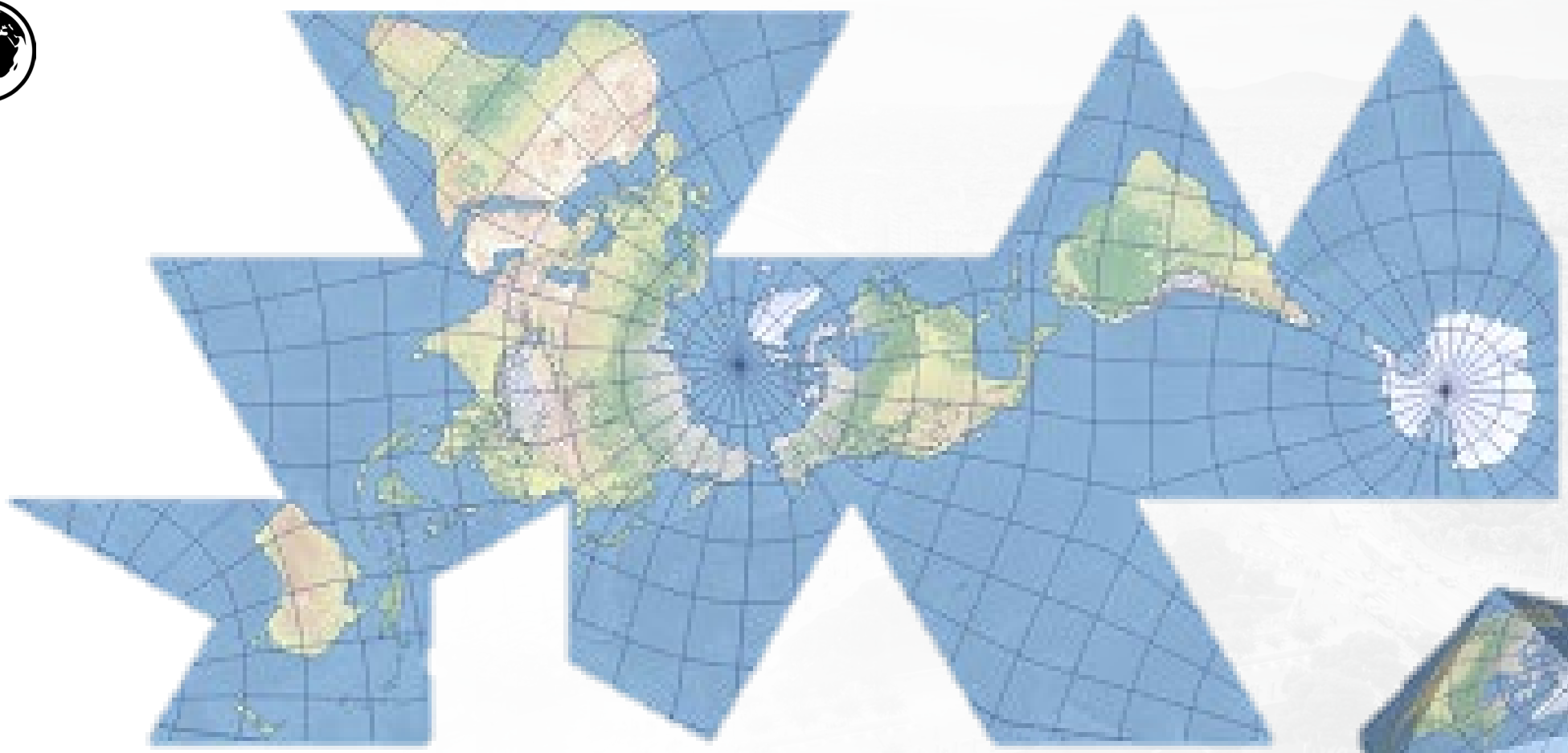

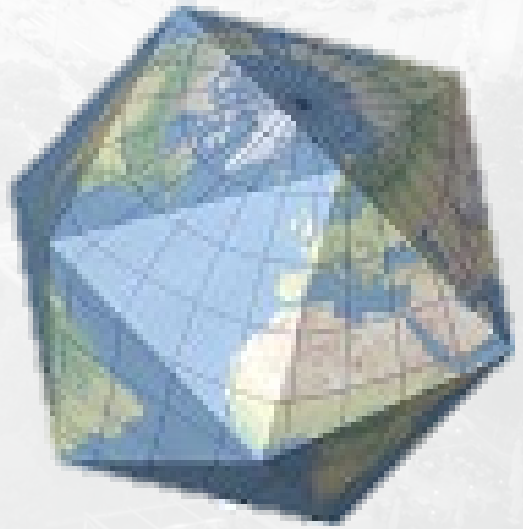

Some lessons from cartography...

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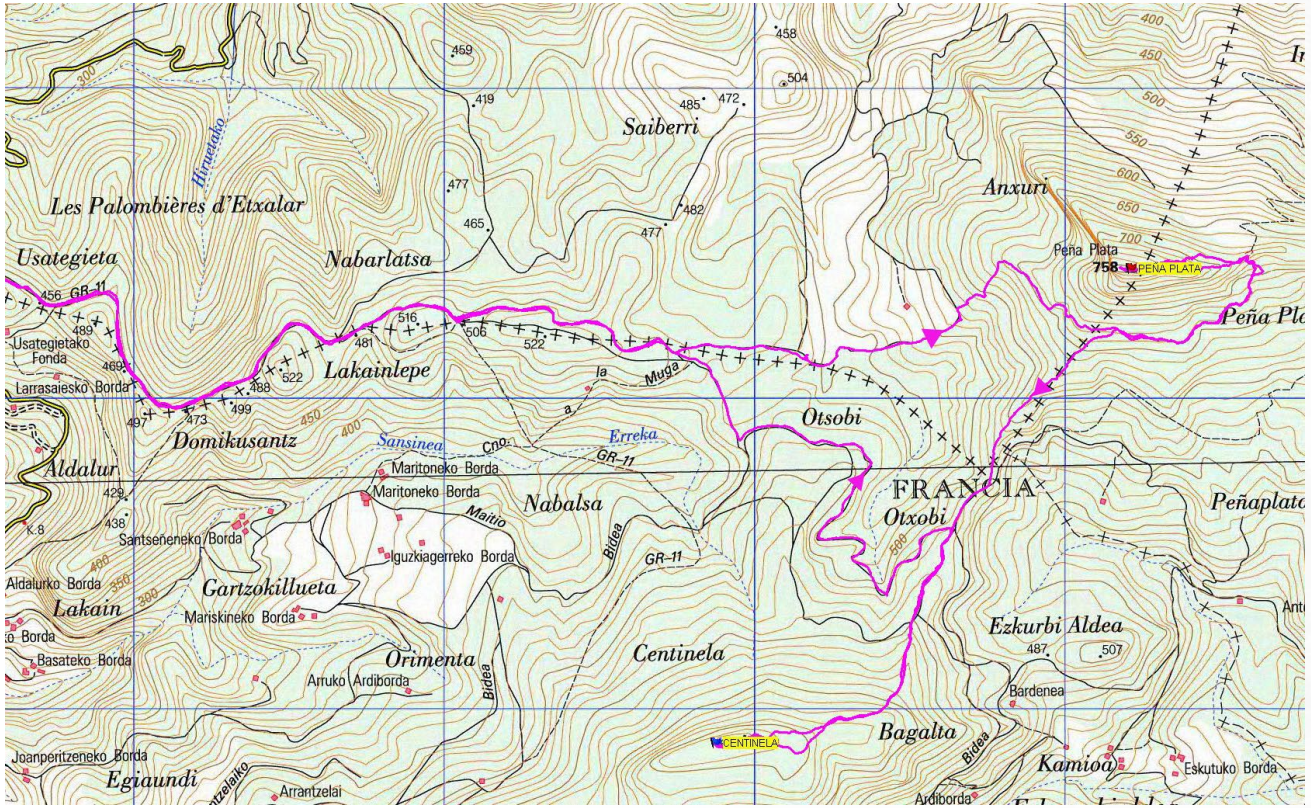

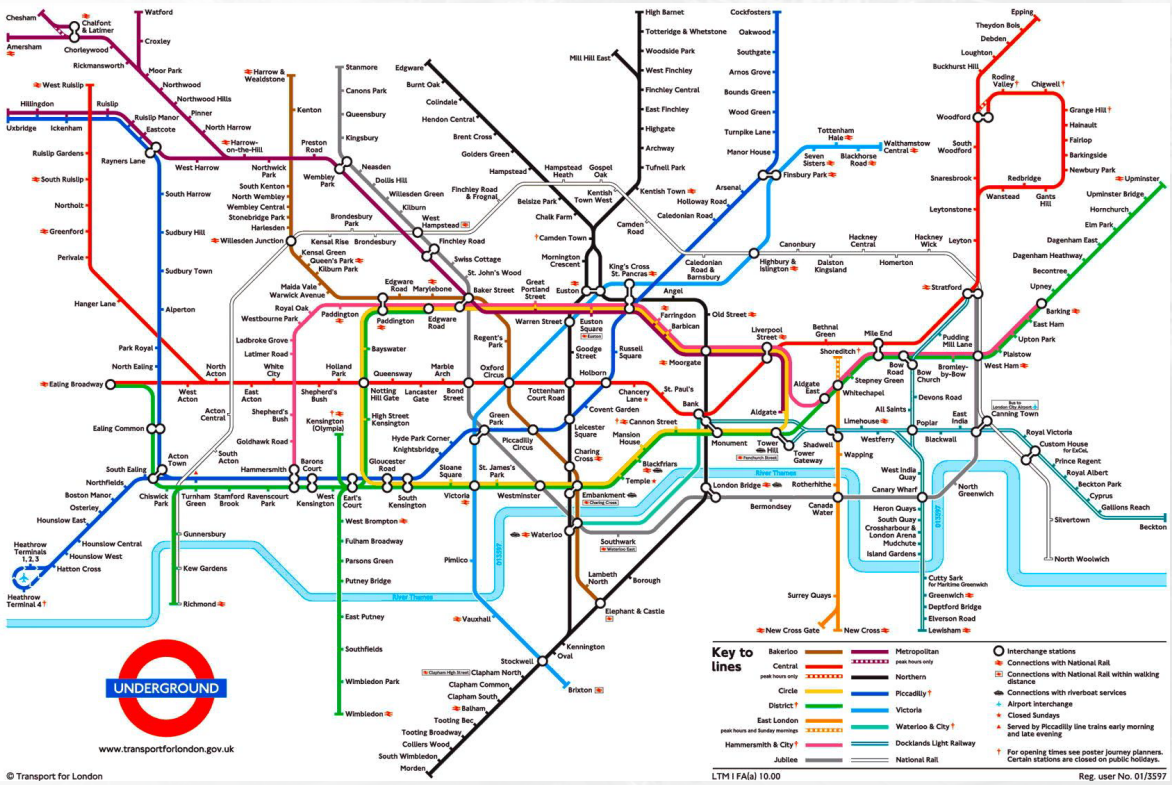

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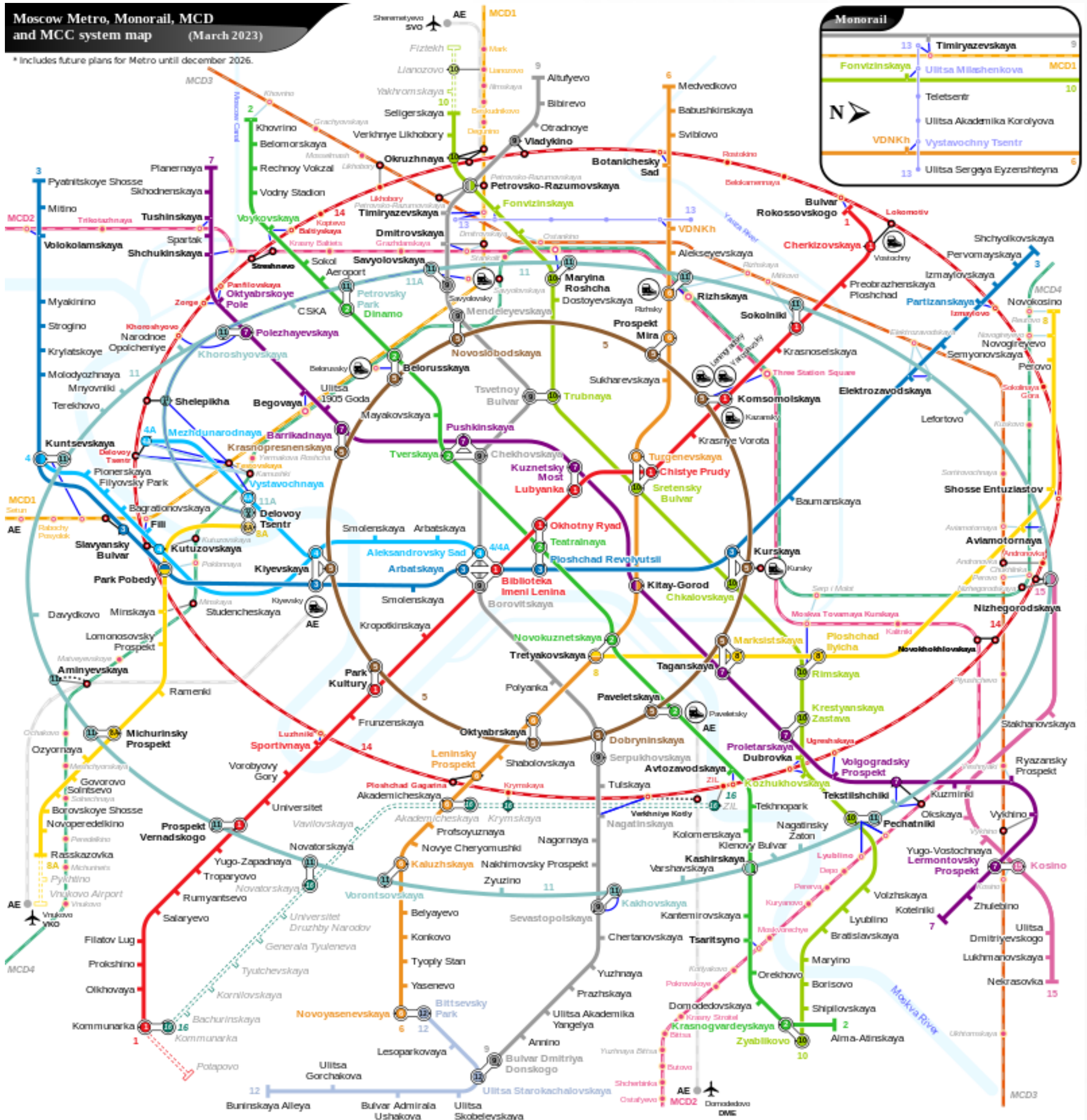

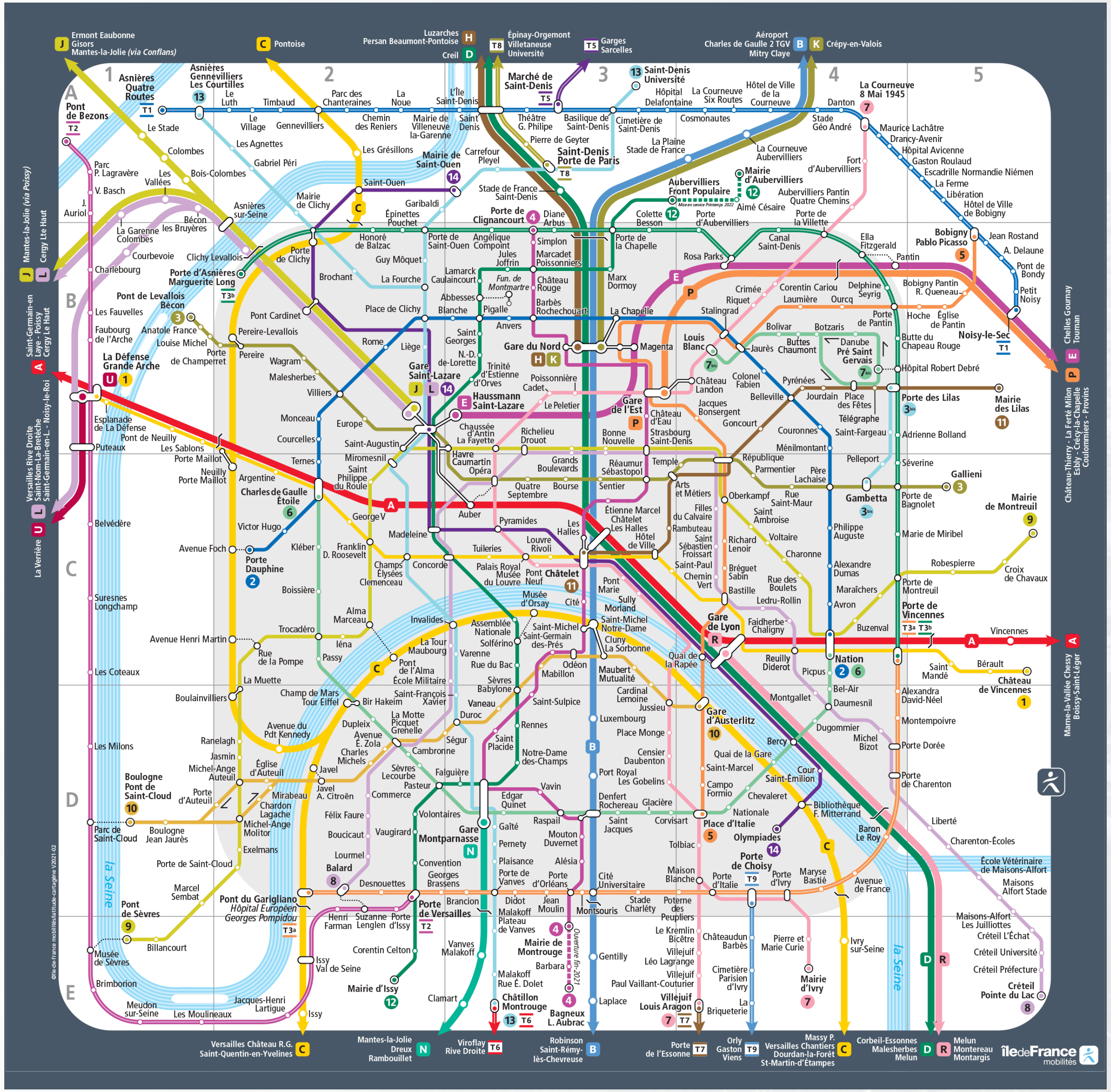

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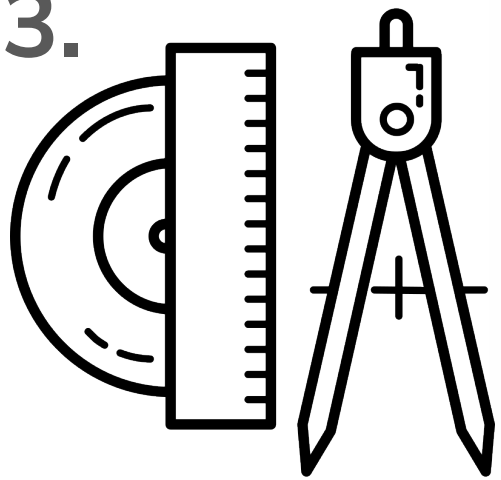

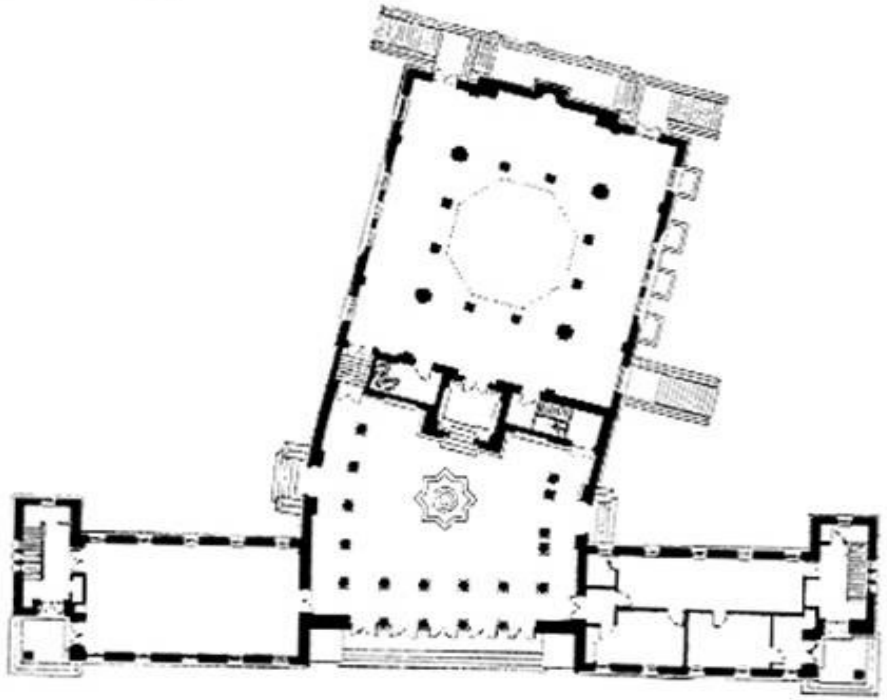

*(from **Pedro Torrijos** - @Pedro_Torrijos)*

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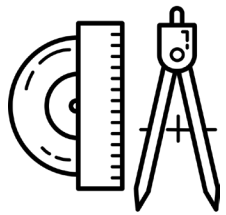

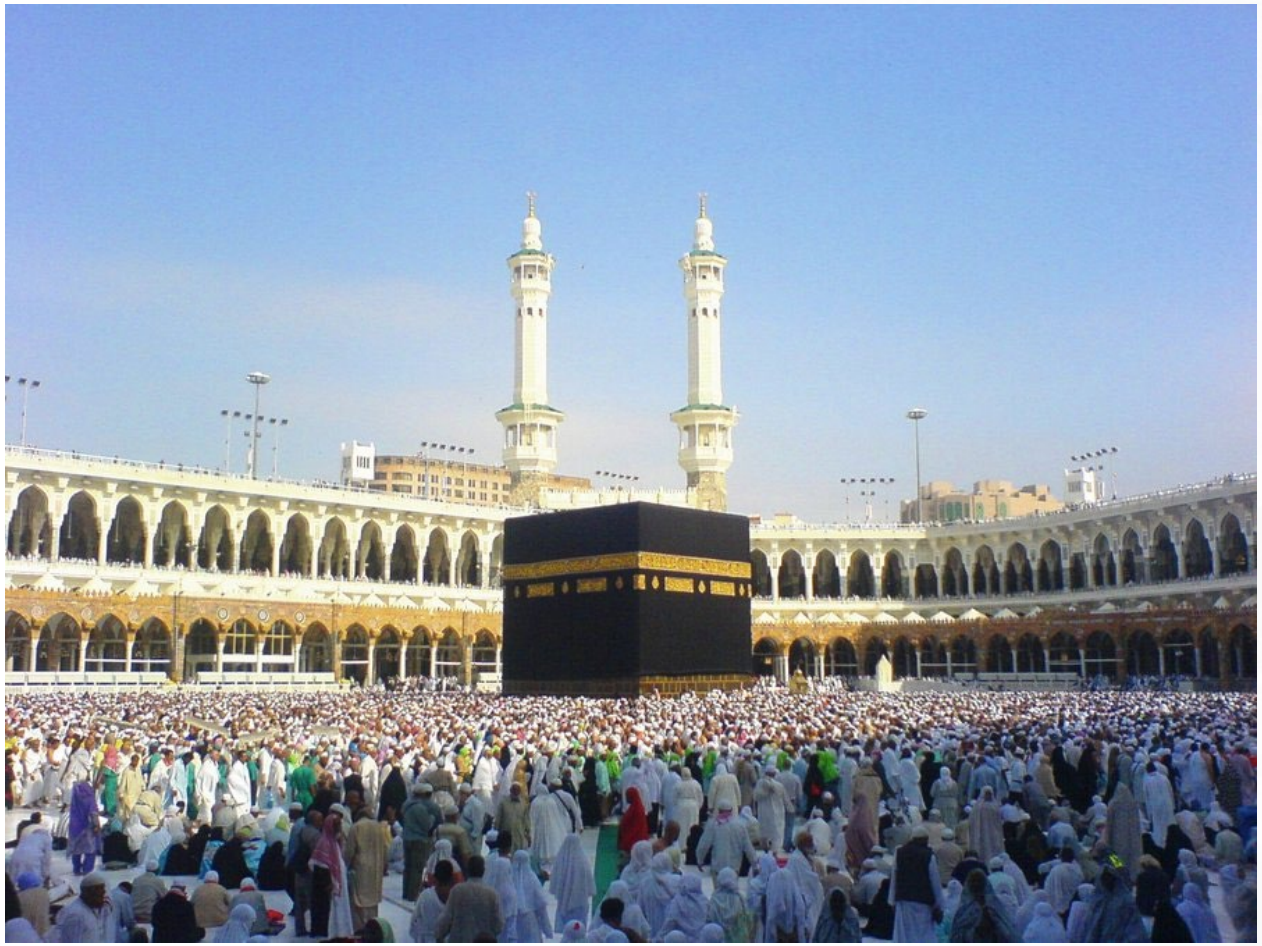

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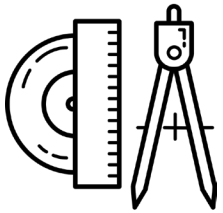

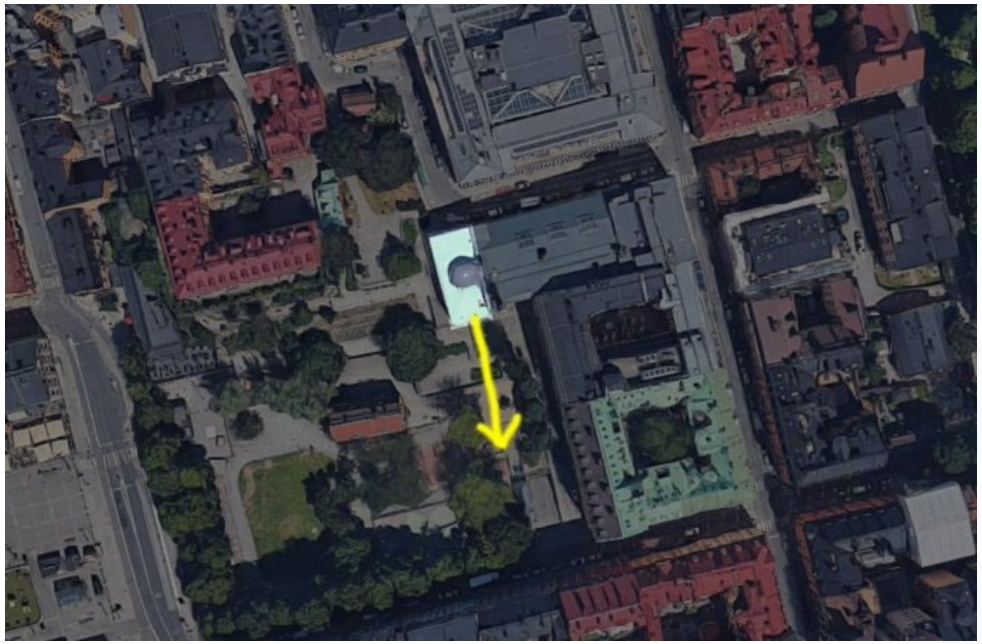

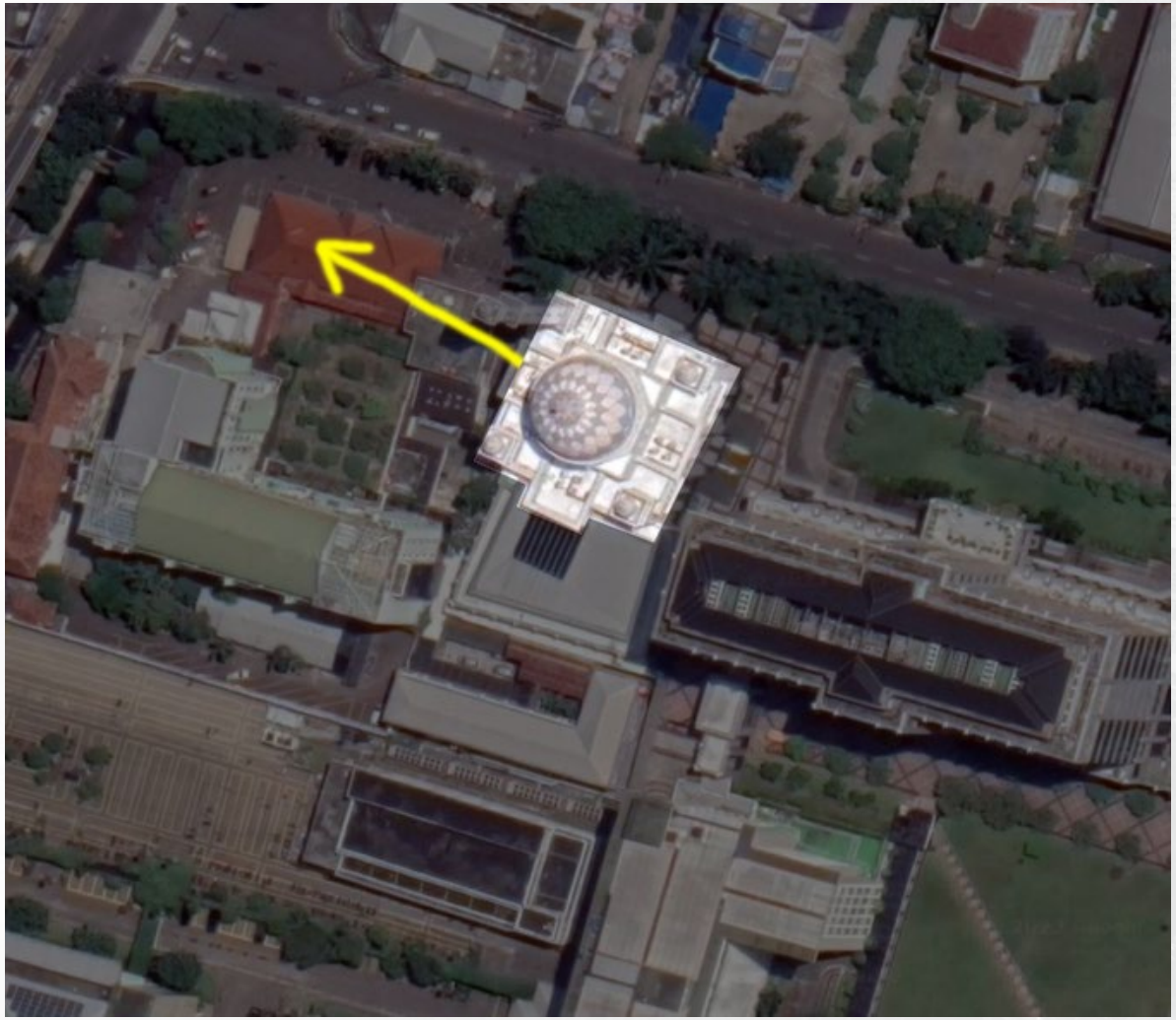

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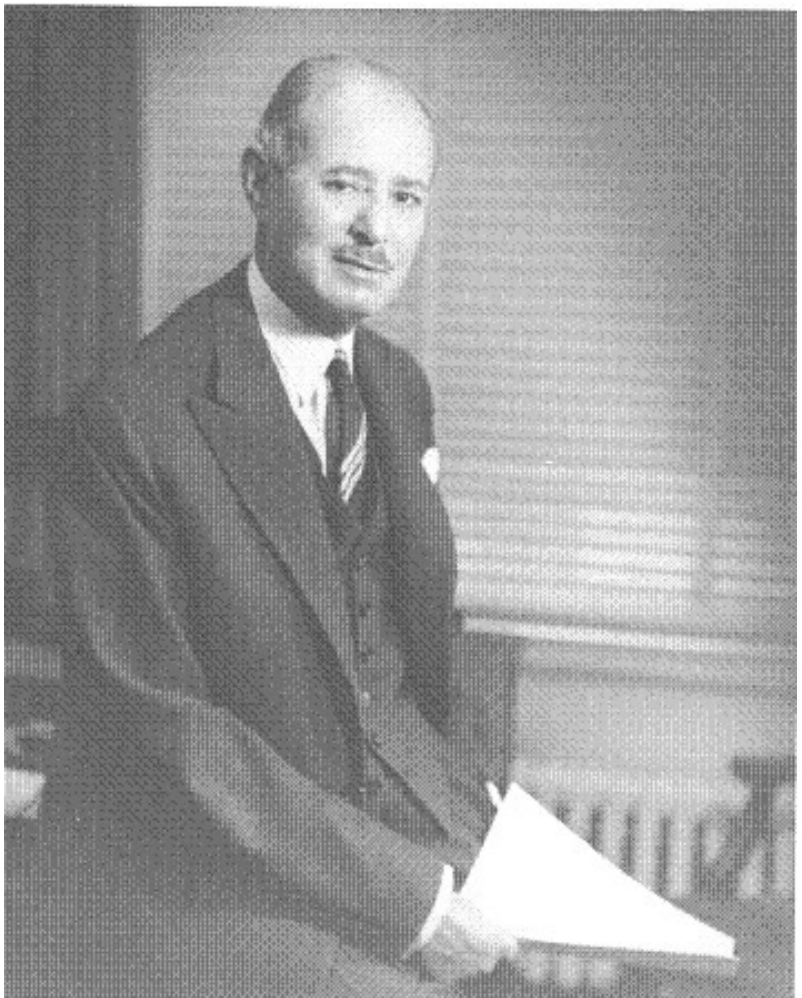

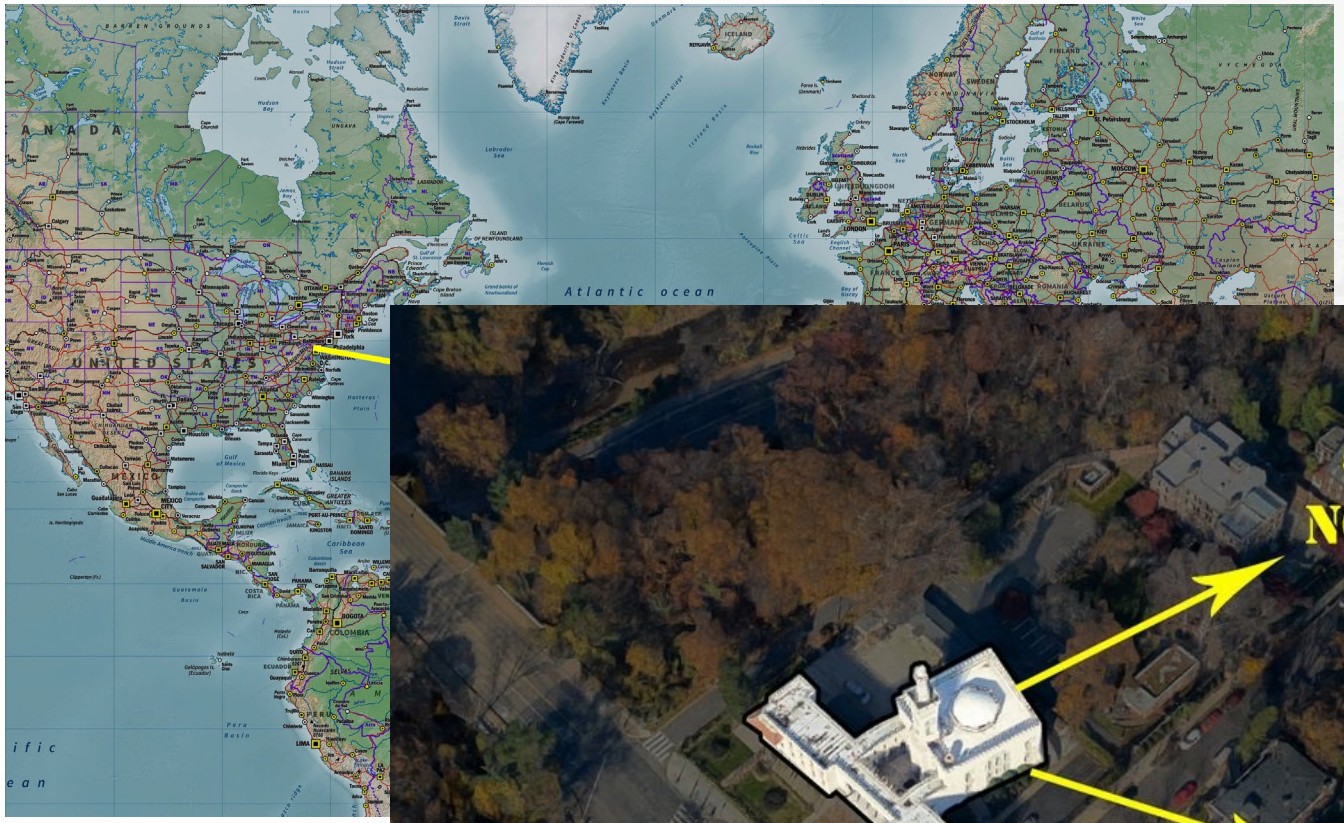

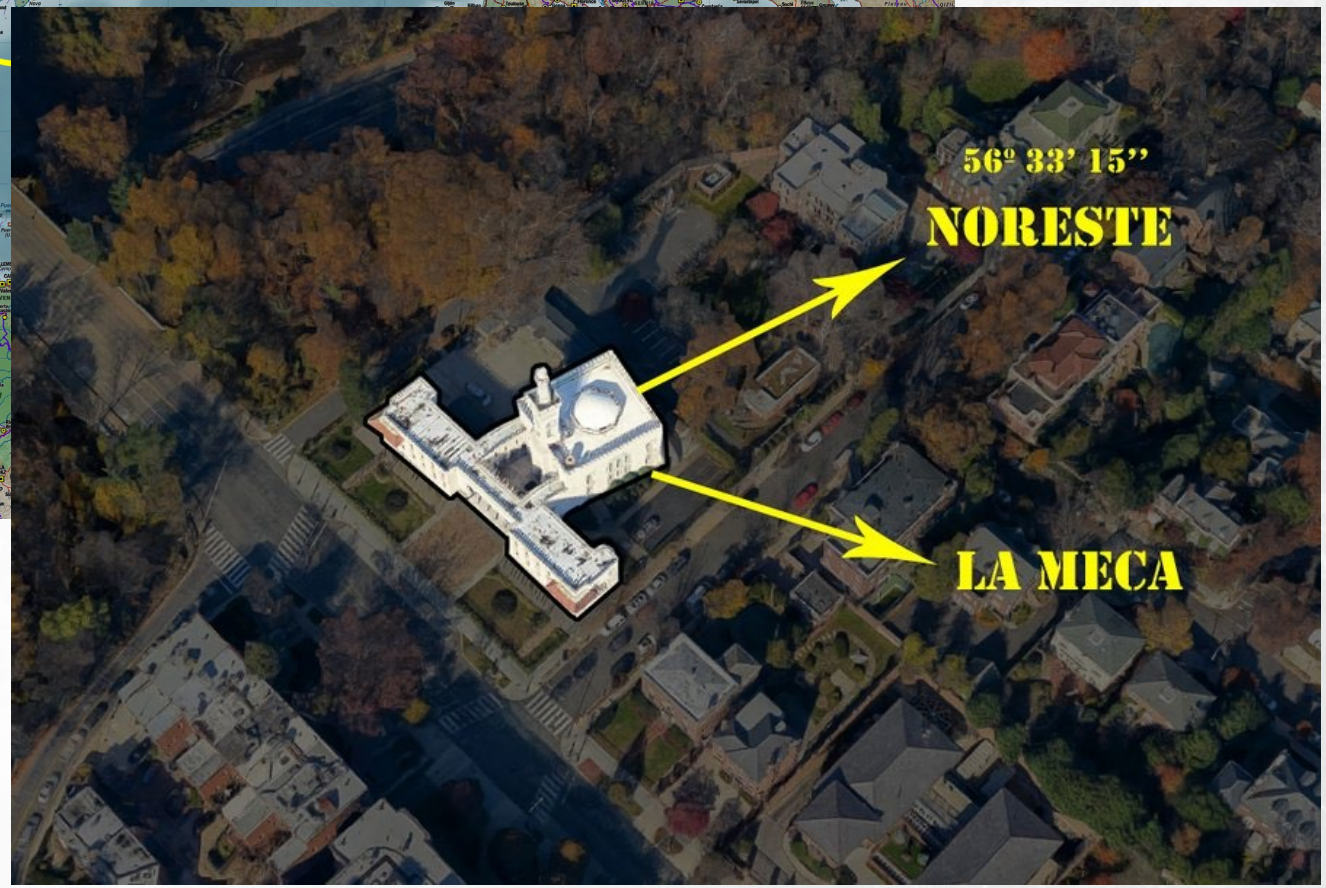

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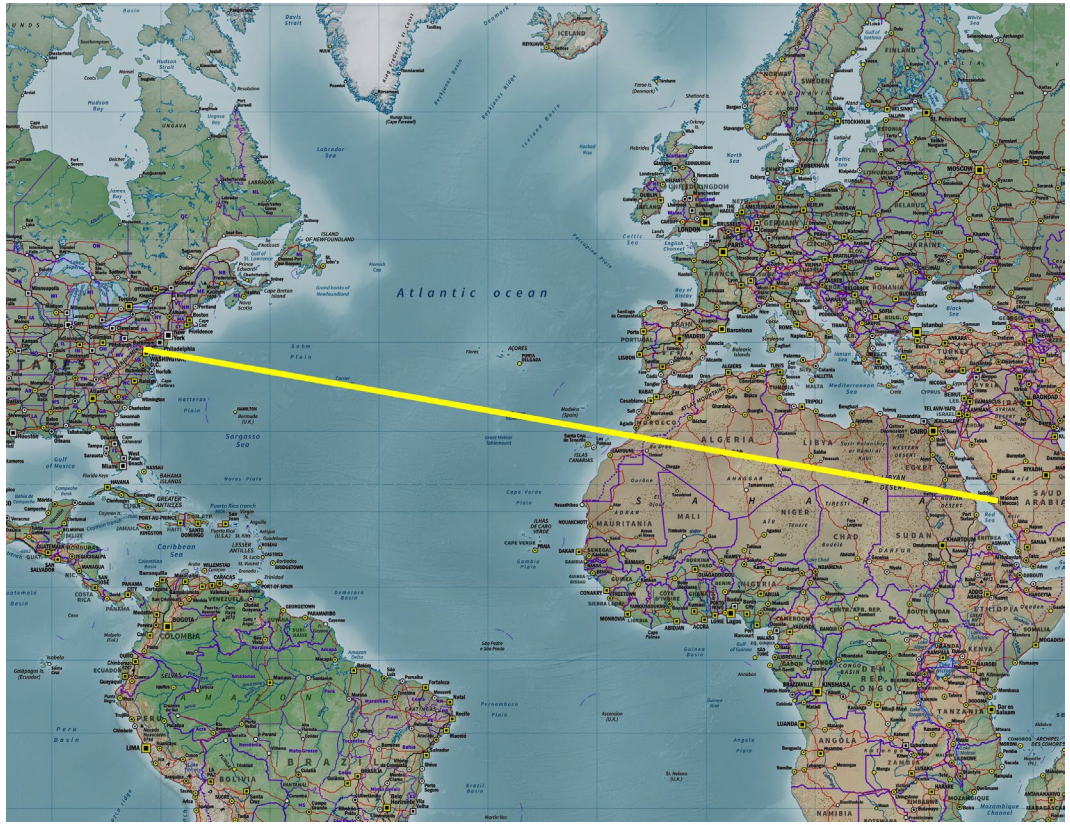

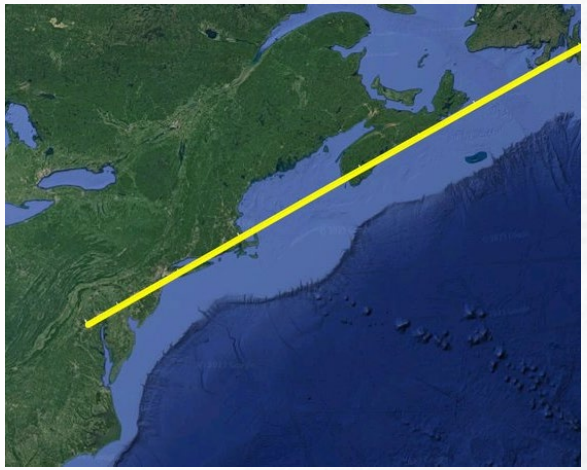

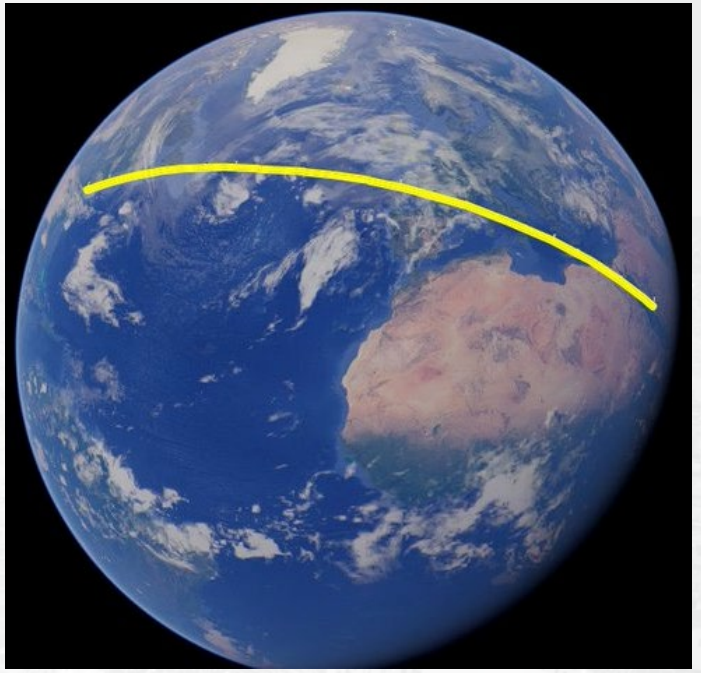

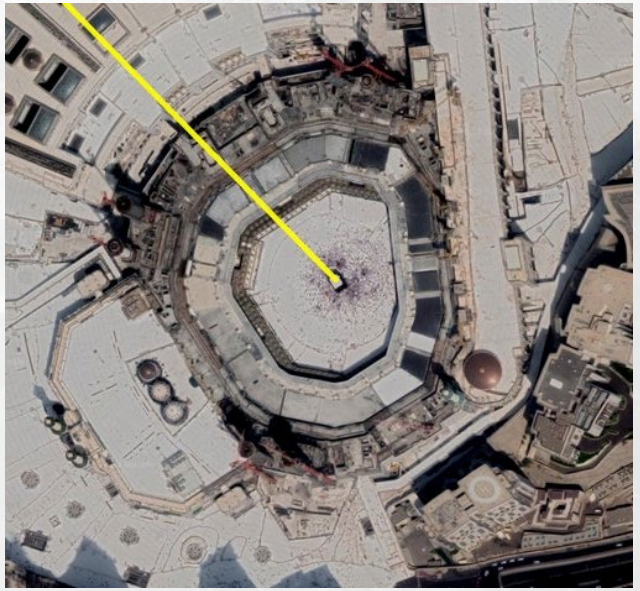

Some lessons from cartography…

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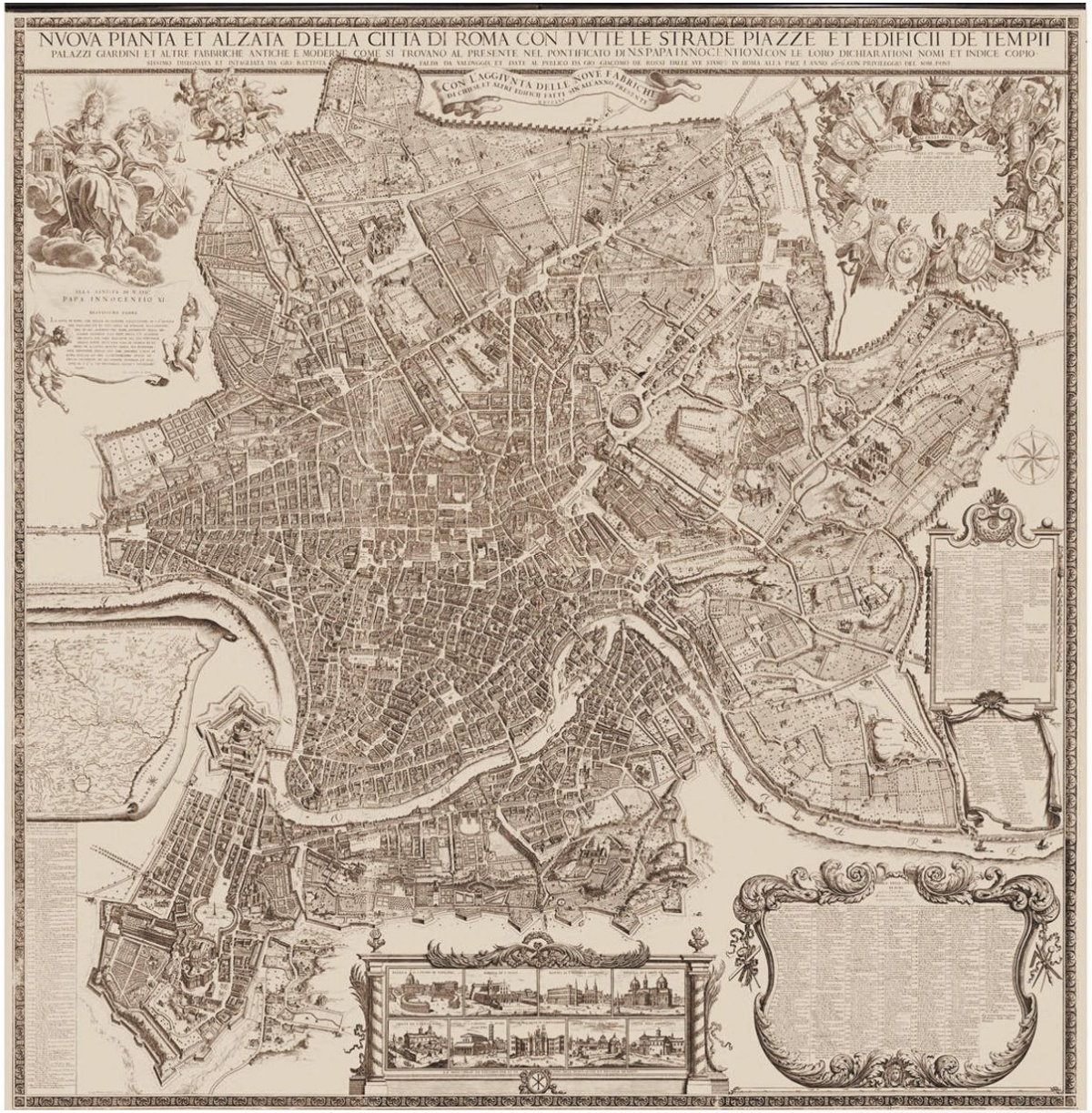

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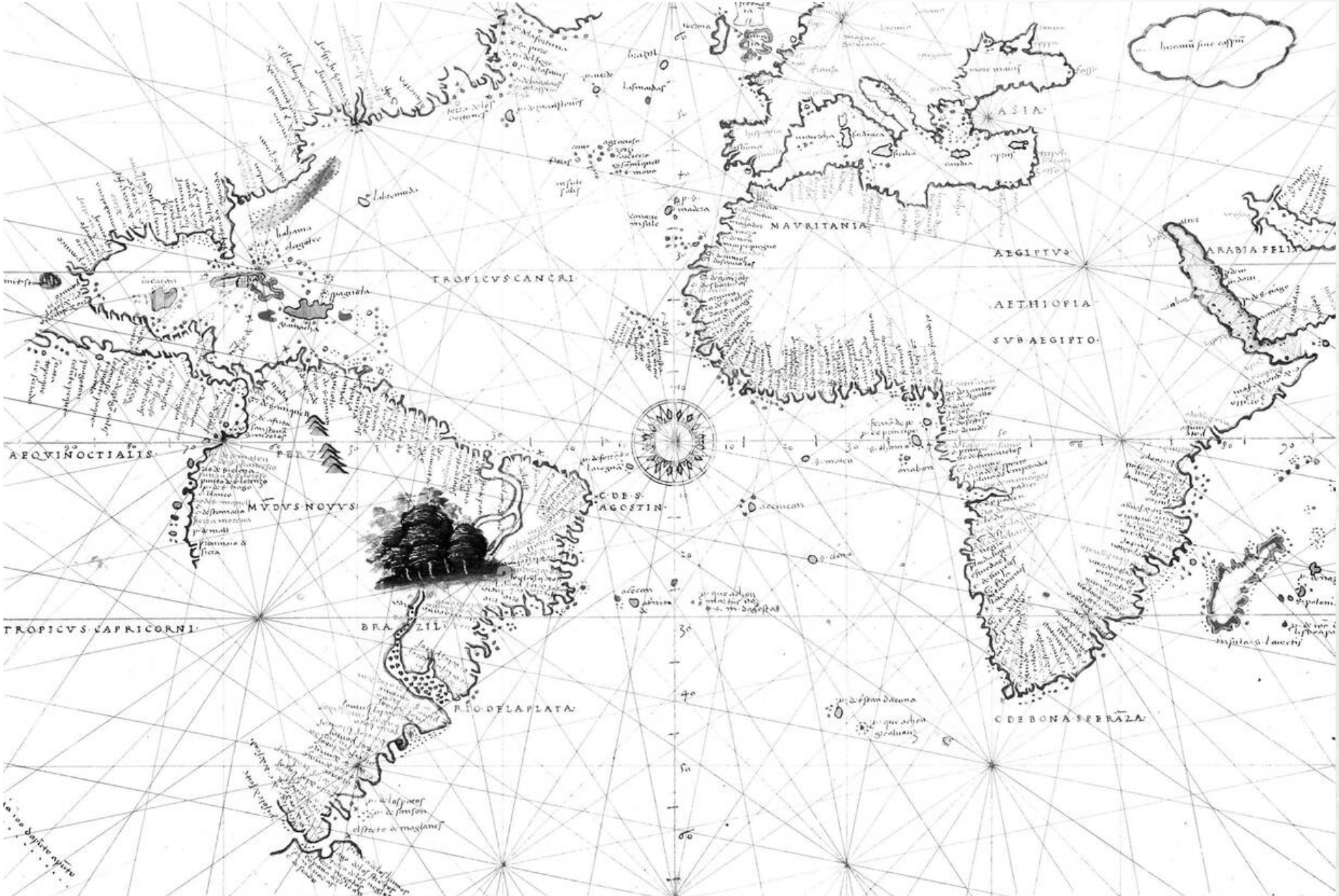
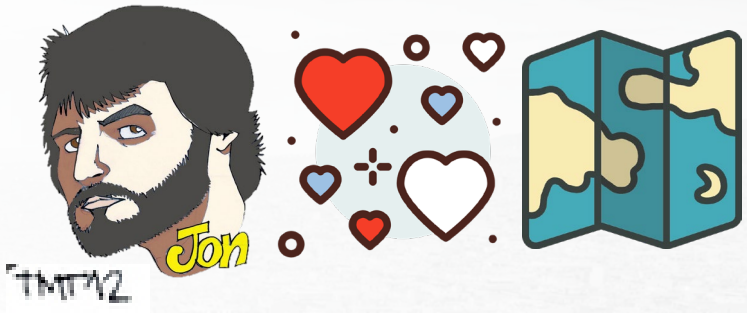


Some lessons from cartography…

What do these previous slides show us?

0 – Jon is fond of maps (and cartography in general)



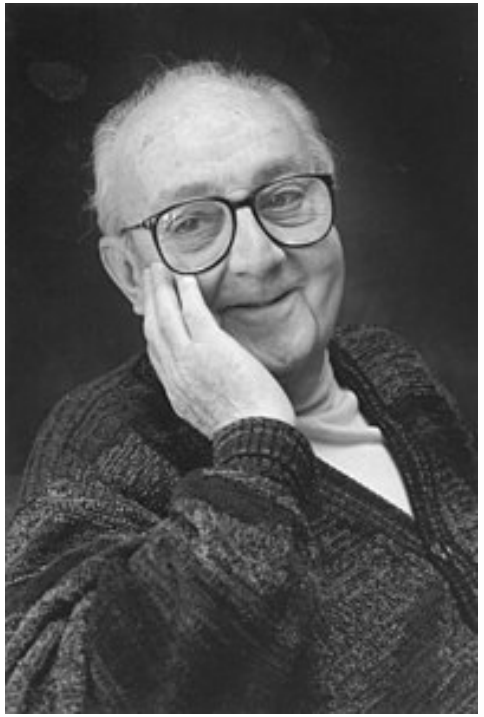
Models are **a simplified description**, of a system or process, to assist calculations and predictions.'

The best model is **the simplest one** which meet the objectives you are looking for

Models will almost always have **limitations**

Models may include **bias,** which can affect the both the results and analysis of them.

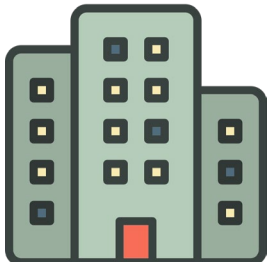
Some lessons from cartography...



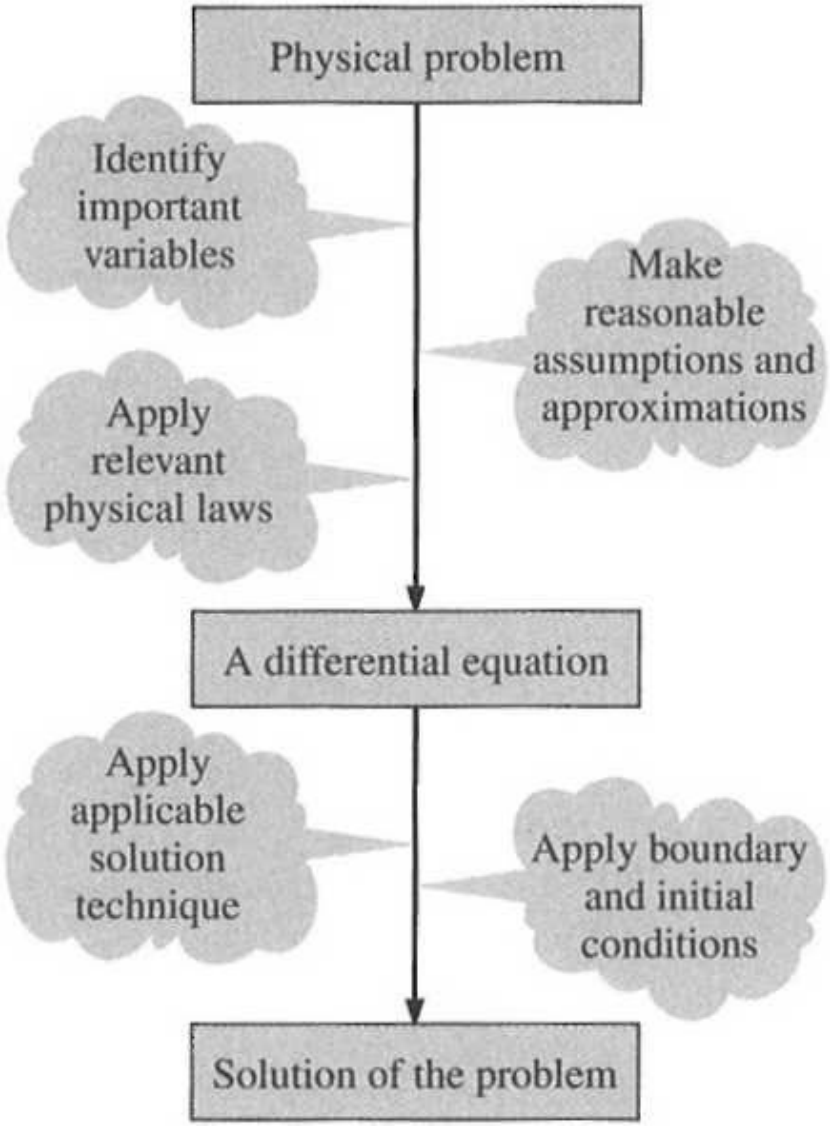
"All models are wrong, some are useful"

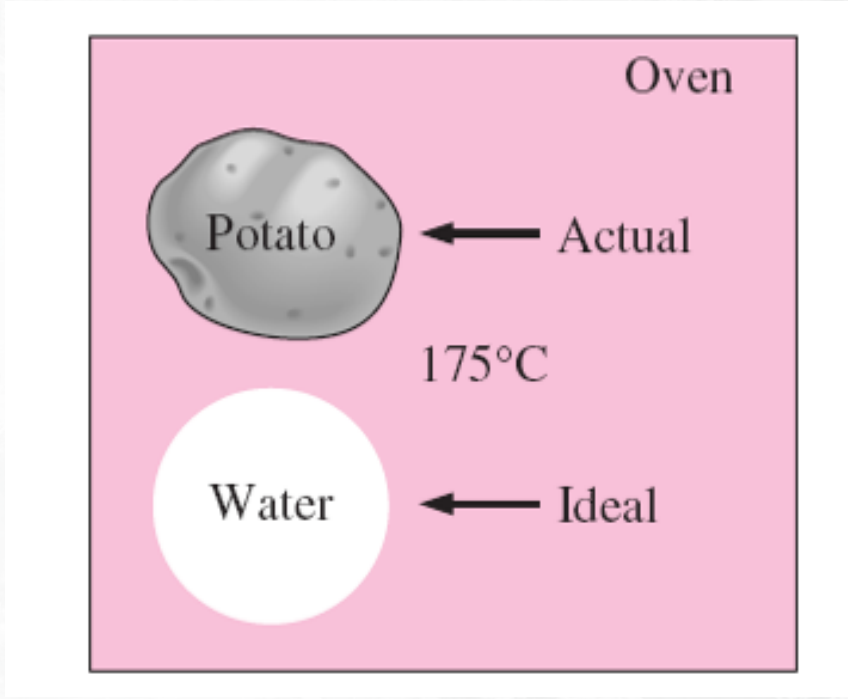
George Box

What about building models?

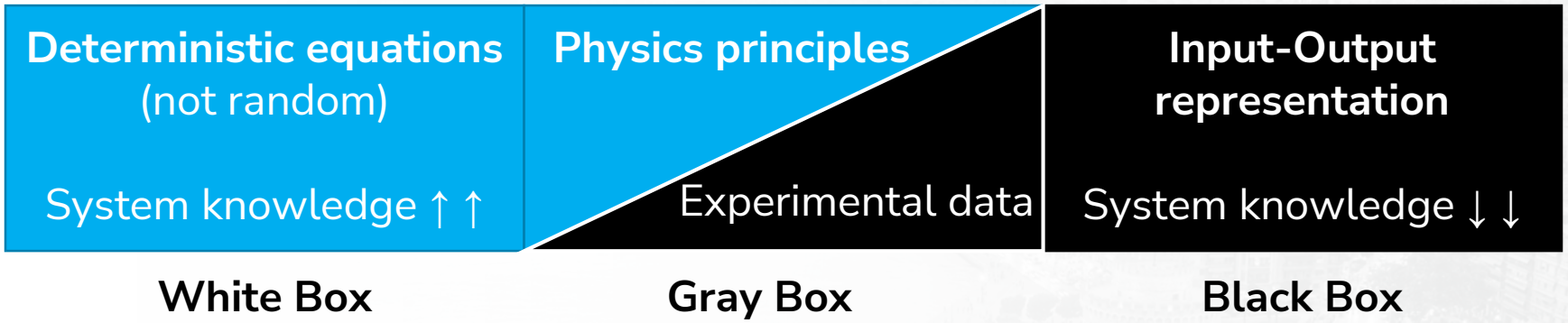


Mathematical models

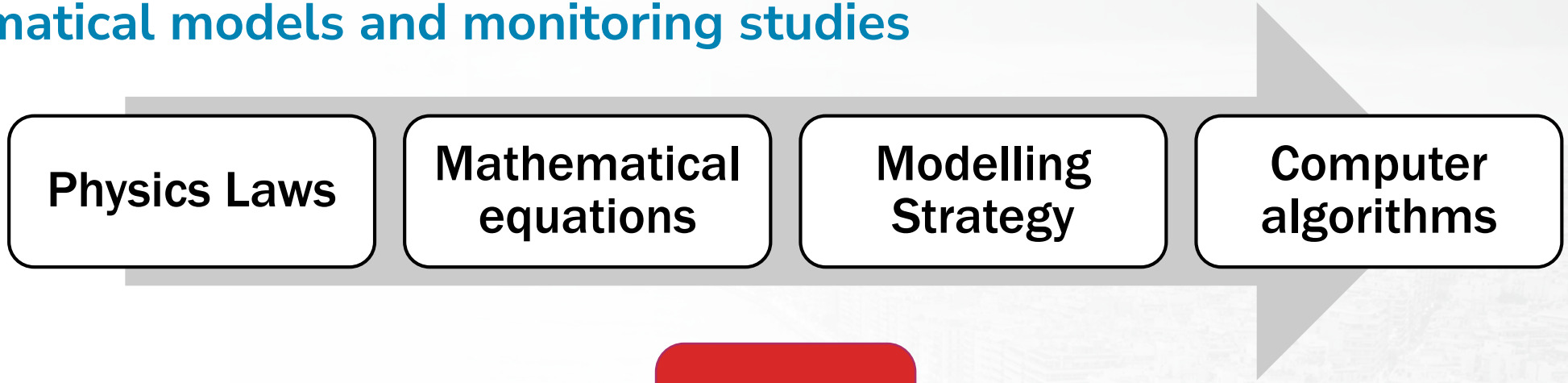


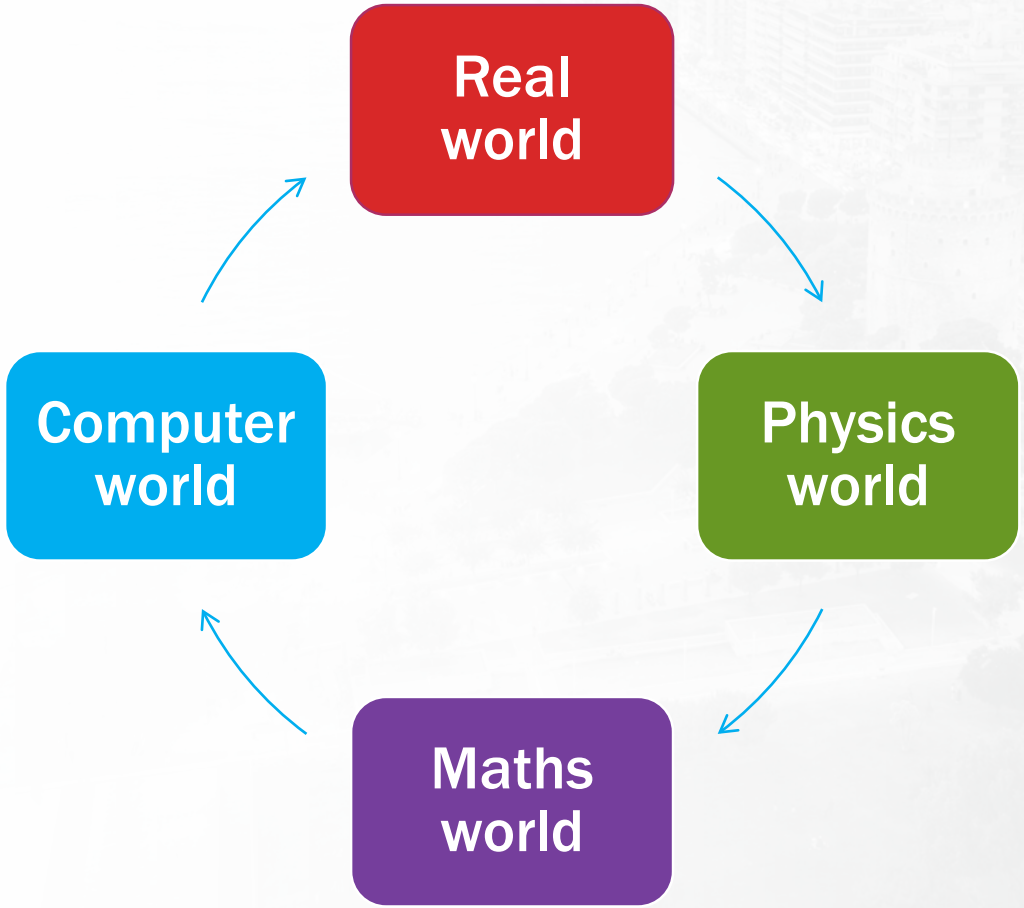


Mathematical models

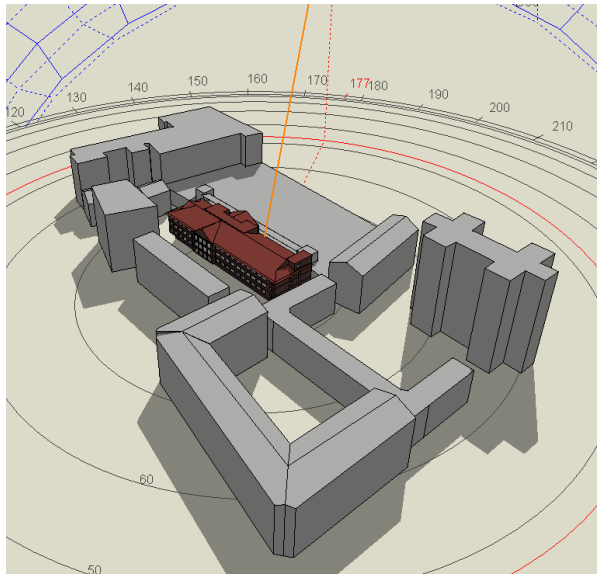


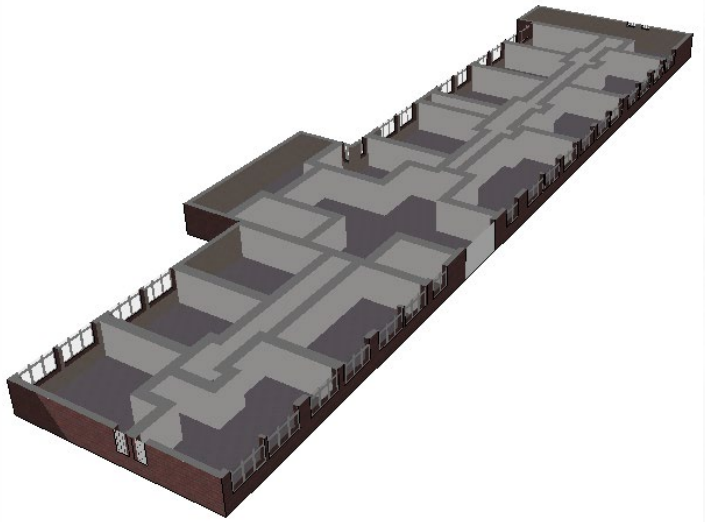
Mathematical models and monitoring studies

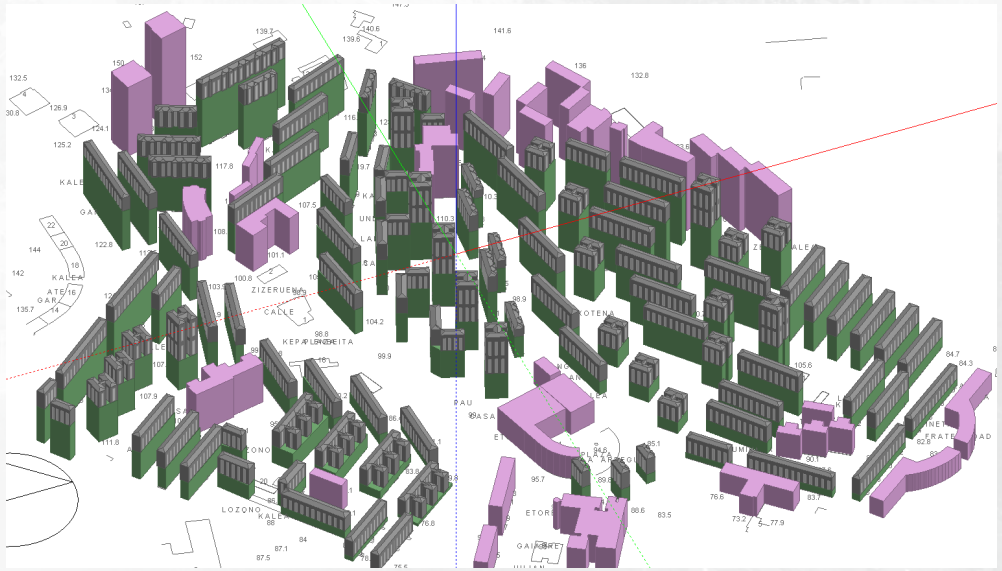




Relevant data to calculate building energy needs (at regional scale)







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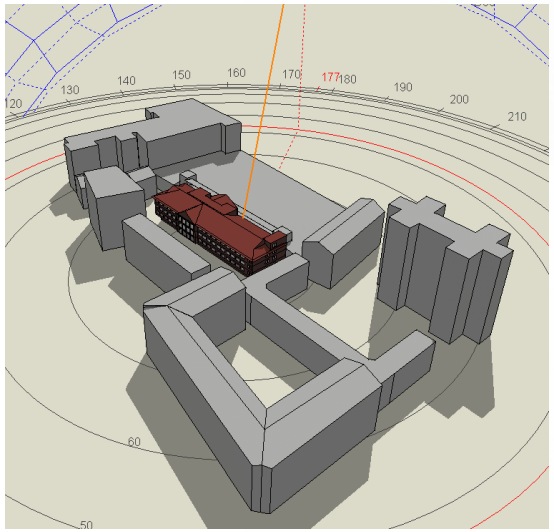
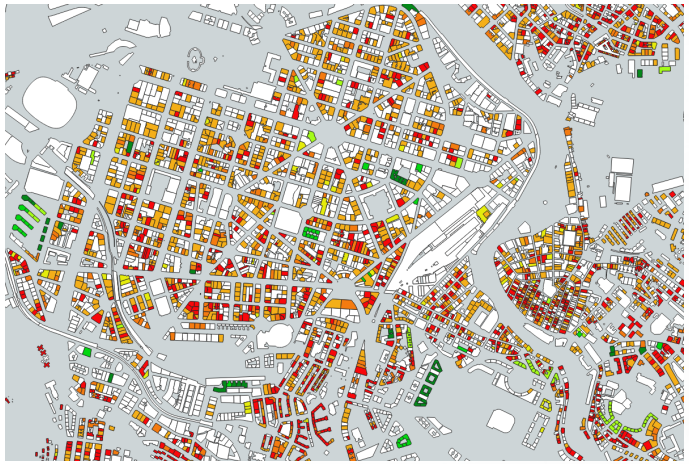
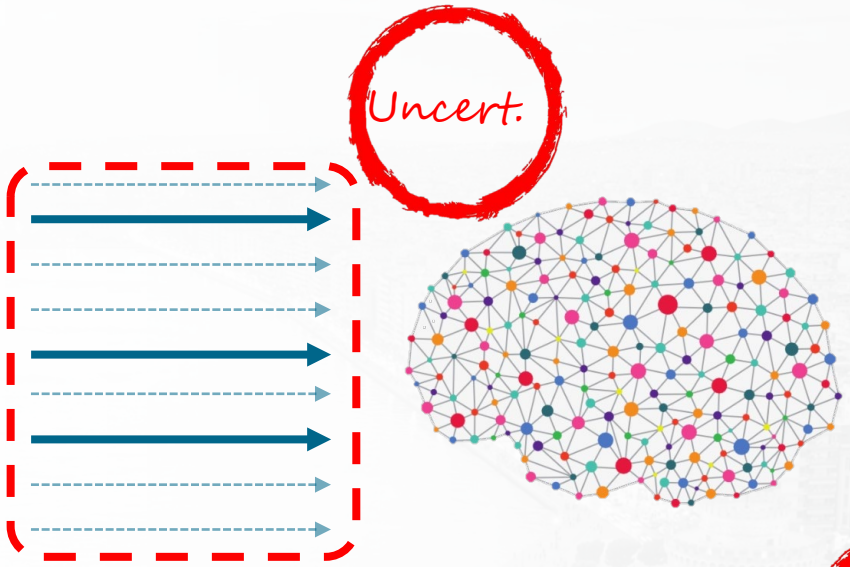
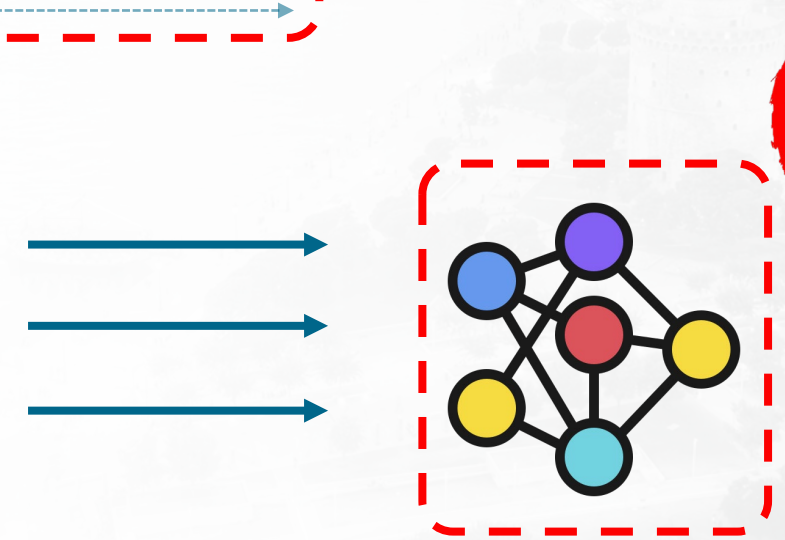






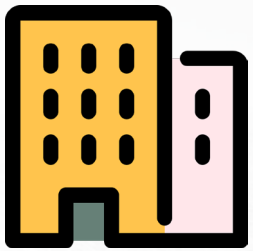
TARGET



TARGET

Data for Buildings' Energy Performance?

Relevant data to calculate building energy needs (at regional scale)



REAL DATA

ESTIMATED DATA

Field measurements

Project information

DATA DIS

PUBLIC DATA

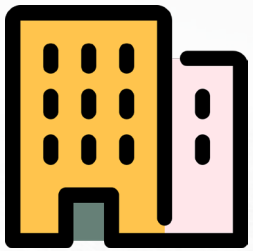
ARCHETYPES

BUILDING PHYSICS

BUILDING PHYSICS

Energy performance data

Relevant data to calculate building energy needs (at regional scale)



REAL DATA

Field measurements

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BUILDING PHYSICS

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BUILDING PHYSICS

Energy performance data

Relevant data to calculate building energy needs (at regional scale)



$$E_T = DHW_{needs} + Q_{needs} + Electricity$$

Standard values (by uses)



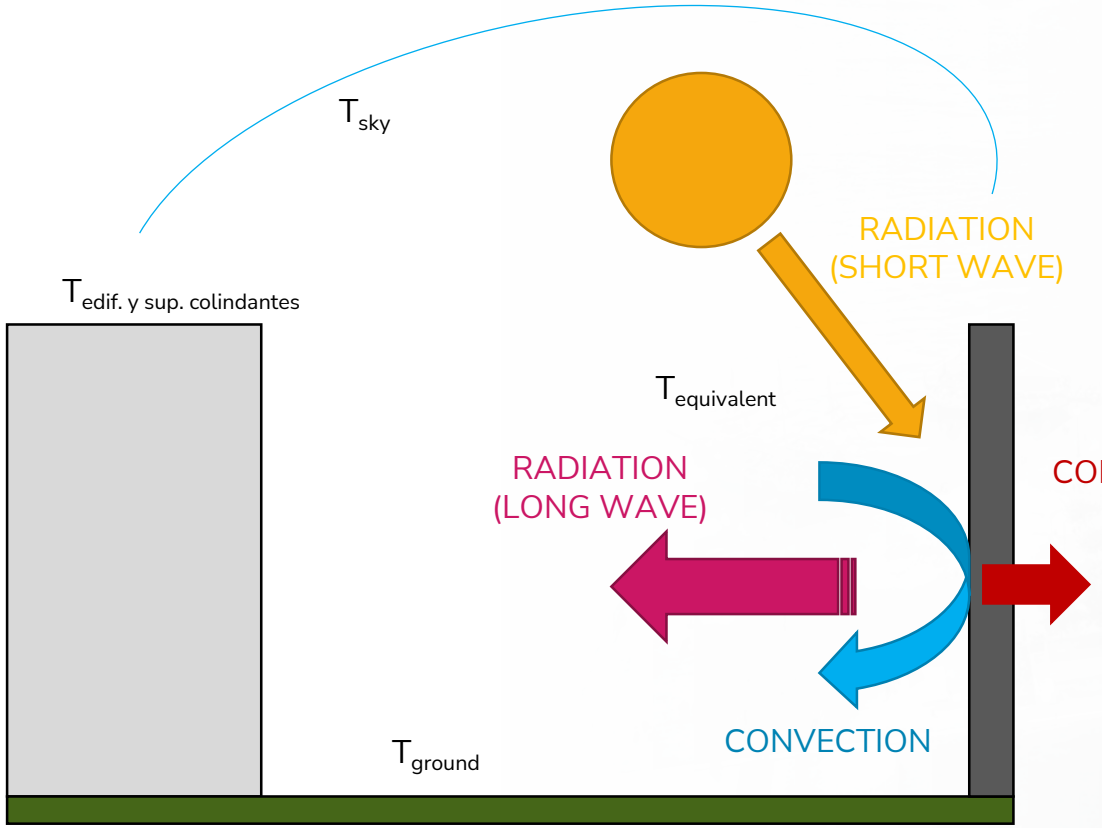
Relevant data to calculate building energy needs (at regional scale)

$$E_T = DHW_{needs} + Q_{needs} + Electricity$$

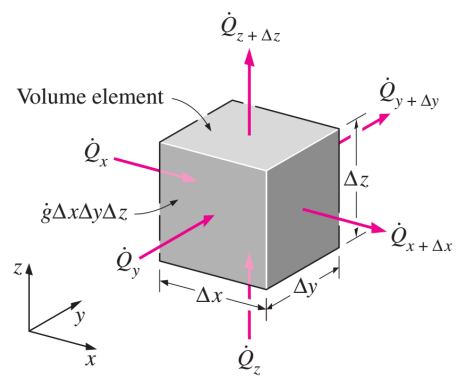
$$Q_{needs} = Envelope + \mathrm{Inf} + Vent \pm Gains_{solar} \pm Gains_{int}$$

Relevant data to calculate building energy needs (at regional scale)

$$Q_{needs} = Envelope + \text{Inf} + Vent \pm Gains_{solar} \pm Gains_{int}$$



CONDUCTION



Constant conductivity:

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}+\frac{\dot{e}_{gen}}{k}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

GENERAL EQUATION OF HEAT CONDUCTION

CONVECTION

FORCED CONVECTION?

Laminar: $\text{Nu}_x = \frac{h_x x}{k} = 0.332\,\text{Re}_x^{0.5}\,\text{Pr}^{1/3}$ $\quad \text{Pr} > 0.60$

Turbulent: $\text{Nu}_x = \frac{h_x x}{k} = 0.0296\,\text{Re}_x^{0.8}\,\text{Pr}^{1/3}$ $\quad 0.6 \le \text{Pr} \le 60$, $\quad 5 \times 10^5 \le \text{Re}_x \le 10^7$

NATURAL CONVECTION?

Empirical correlations for the average Nusselt number for natural convection over surfaces

Geometry	Characteristic length L_c	Range of Ra	Nu
Vertical plate	L	10^4-10^9 10^9-10^{13} Entire range	$\text{Nu} = 0.59\text{Ra}_L^{1/4}$ (9-19) $\text{Nu} = 0.1\text{Ra}_L^{1/3}$ (9-20) $\text{Nu} = \left\{0.825 + \frac{0.387\text{Ra}_L^{1/6}}{[1+(0.492/\text{Pr})^{9/16}]^{8/27}}\right\}^2$ (9-21) (complex but more accurate)
Inclined plate	L		Use vertical plate equations for the upper surface of a cold plate and the lower surface of a hot plate Replace g by $g\cos\theta$ for $\text{Ra} < 10^9$
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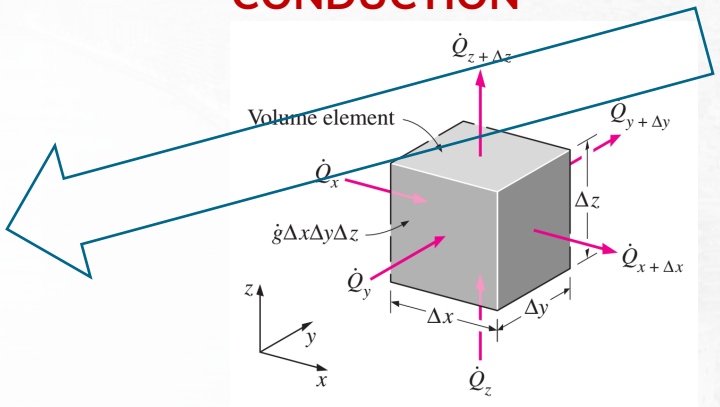
Relevant data to calculate building energy needs (at regional scale)

$$Q_{needs} = Envelope + \text{Inf} + Vent \pm Gains_{solar} \pm Gains_{int}$$

CONDUCTION

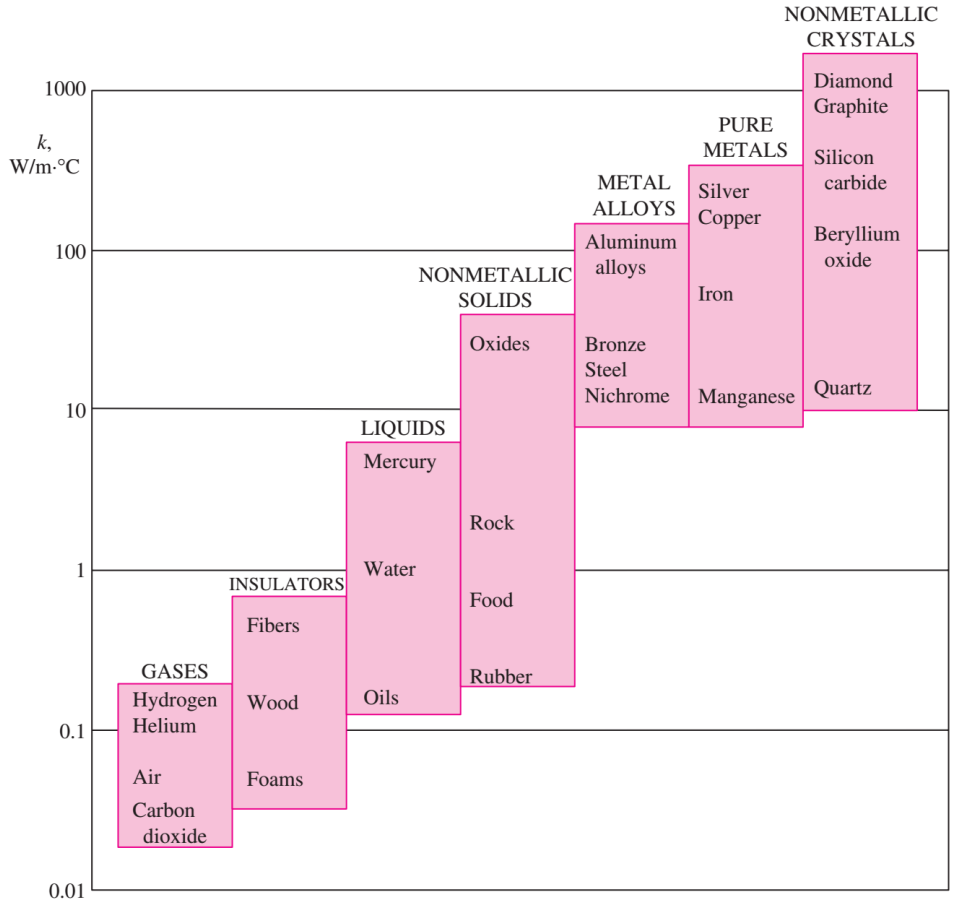


Constant conductivity:

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}+\frac{\dot{e}_{gen}}{k}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

GENERAL EQUATION OF HEAT CONDUCTION

CONDUCTION, RAW MATERIALS



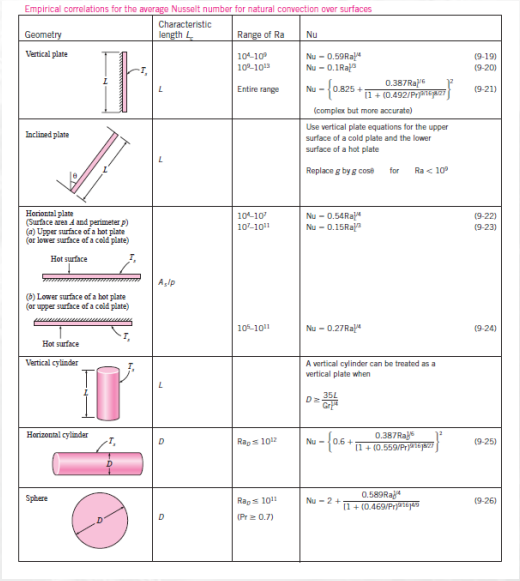
CONVECTION

FORCED CONVECTION?

Laminar: $\text{Nu}_x = \frac{h_x x}{k} = 0.332\,\text{Re}_x^{0.5}\,\text{Pr}^{1/3}$ $\quad \text{Pr} > 0.60$

Turbulent: $\text{Nu}_x = \frac{h_x x}{k} = 0.0296\,\text{Re}_x^{0.8}\,\text{Pr}^{1/3}$ $\quad 0.6 \le \text{Pr} \le 60$, $5 \times 10^5 \le \text{Re}_x \le 10^7$

NATURAL CONVECTION?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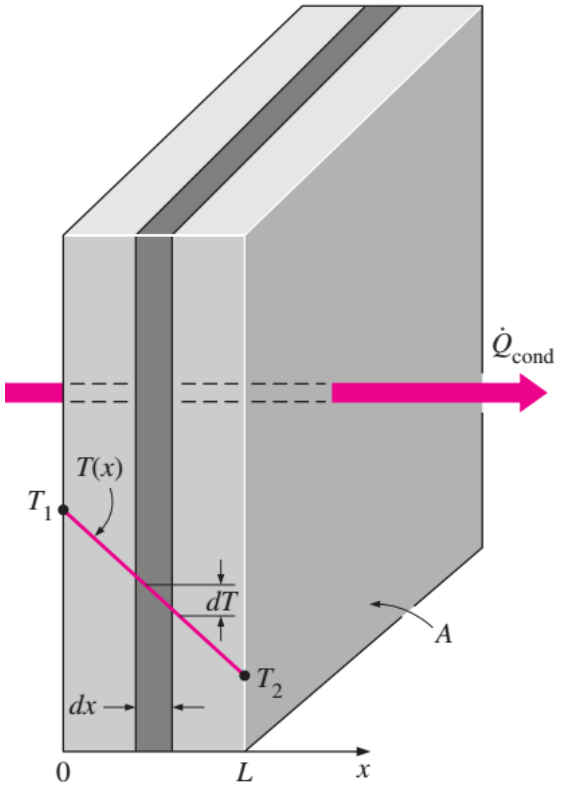
Relevant data to calculate building energy needs (at regional scale)

$$Q_{needs} = Envelope + \text{Inf} + Vent \pm Gains_{solar} \pm Gains_{int}$$



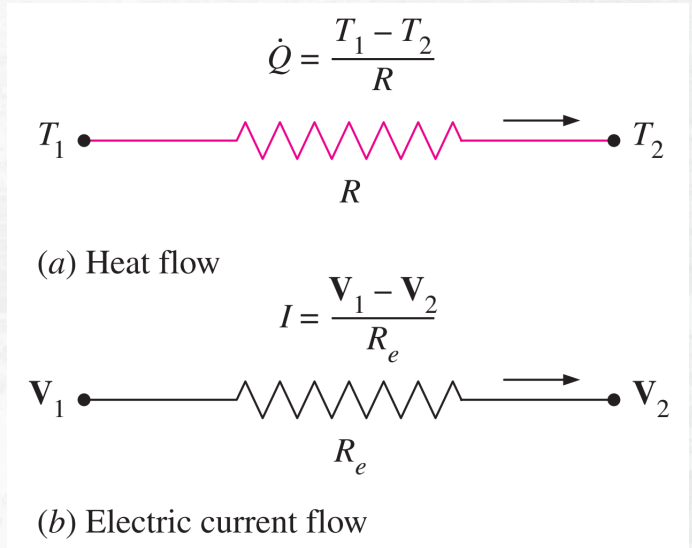
$$\dot{Q}_{in} = \dot{Q}_{out} = \dot{Q}_{cond} = cte$$

$$\dot{Q}_{cond,wall} = -kA\frac{dT}{dx}$$

$$\dot{Q}_{cond,wall} = kA\frac{T_1 - T_2}{L} \Rightarrow$$

$$\Rightarrow \frac{\dot{Q}_{cond,wall}}{A} = \dot{q}_{cond,wall} = k\frac{T_1 - T_2}{L}$$

Thermoelectric Analogy



Conditions:

Steady state (it means static situation)

No heat generation (only heat transfers)

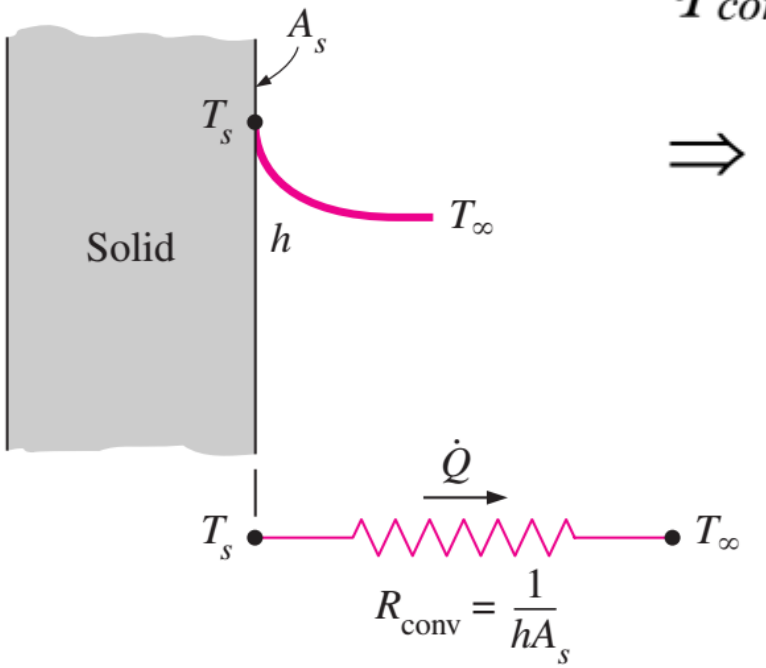
Relevant data to calculate building energy needs (at regional scale)

$$Q_{needs} = Envelope + \text{Inf} + Vent \pm Gains_{solar} \pm Gains_{int}$$

CONDUCTION:

$$R_{wall} = \frac{L}{k}$$

CONVECTION:



$$\dot{q}_{conv} = h \cdot (T_s - T_\infty) \Rightarrow$$

$$\Rightarrow \dot{q}_{conv} = \frac{T_s - T_\infty}{R_{conv}}$$

$$R_{conv} = \frac{1}{h}$$

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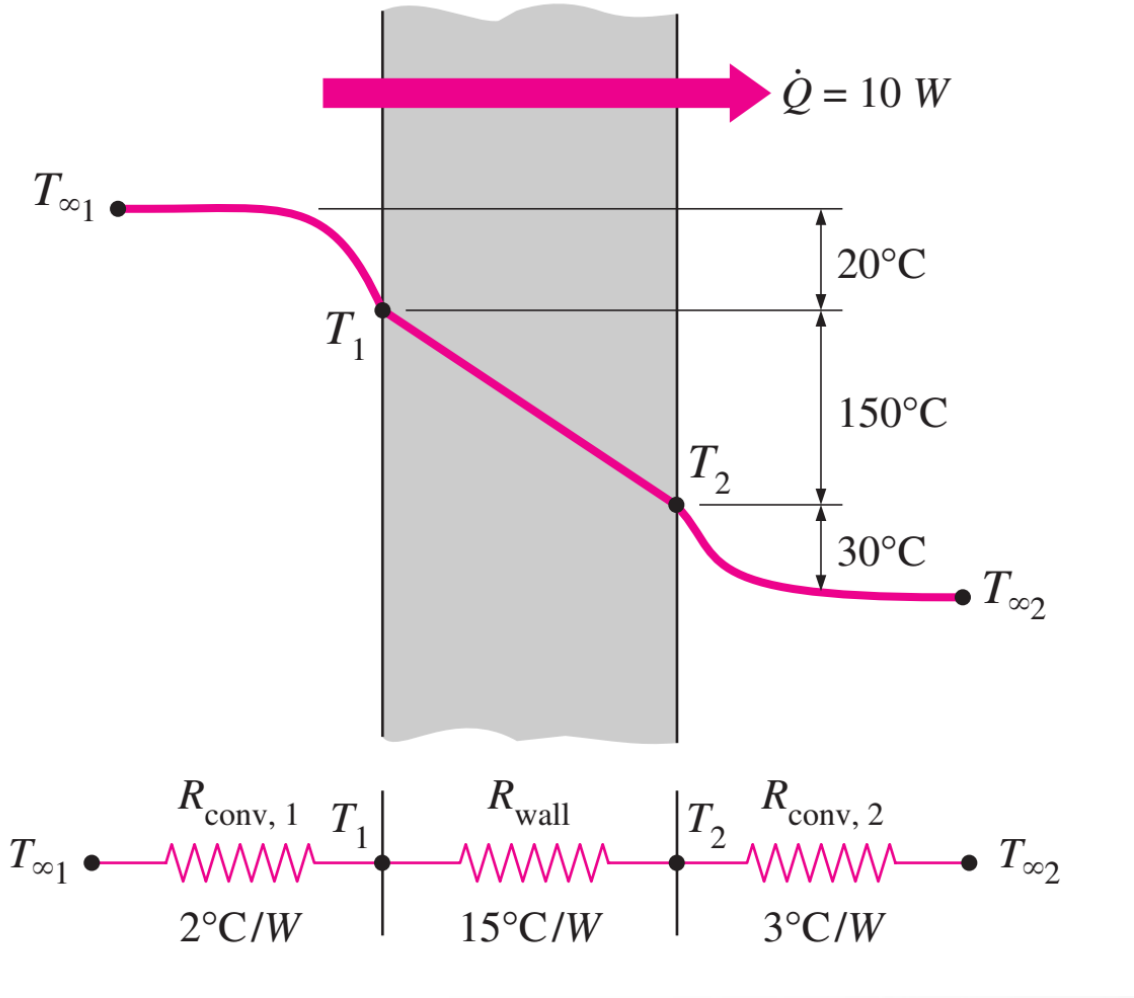

$$\dot{q} = \frac{\Delta T}{\sum R} = U\Delta T$$

$$U = \frac{1}{R_{in} + R_{wall} + R_{out}} = \frac{1}{\frac{1}{h_{in}} + \frac{L}{k} + \frac{1}{h_{out}}}$$

Relevant data to calculate building energy needs (at regional scale)

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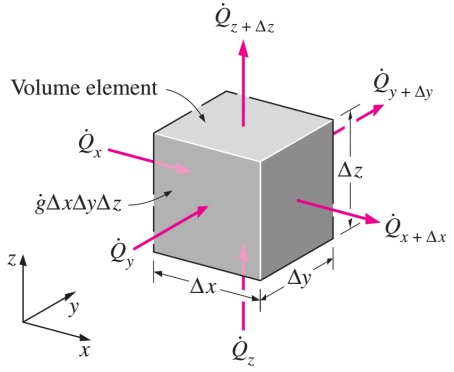

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{\dot{e}_{gen}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

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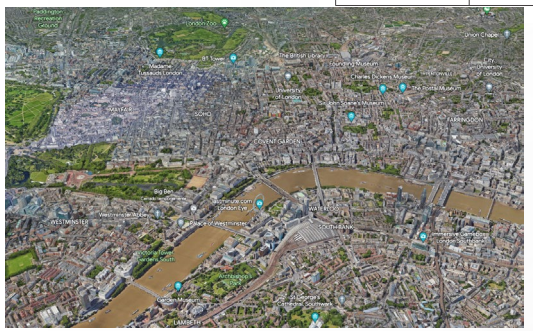


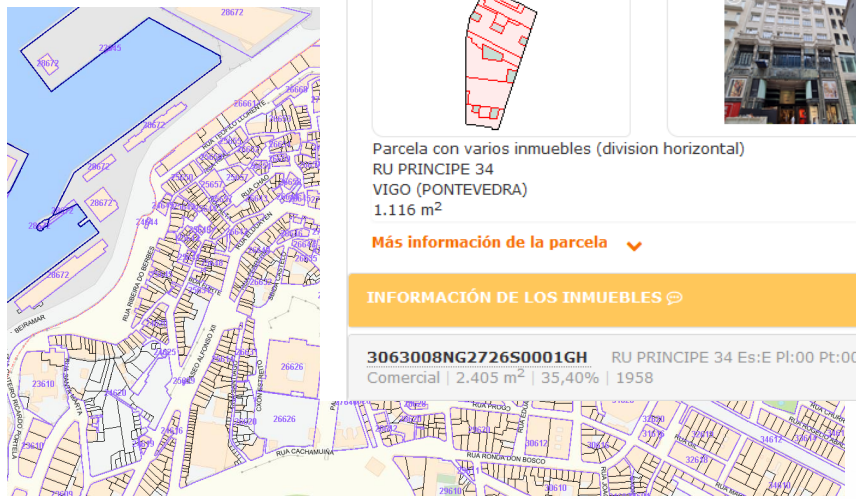
Relevant data to calculate building energy needs (at regional scale)

$$Q_{needs} = Envelope + \mathrm{Inf} + Vent \pm Gains_{solar} \pm Gains_{int}$$

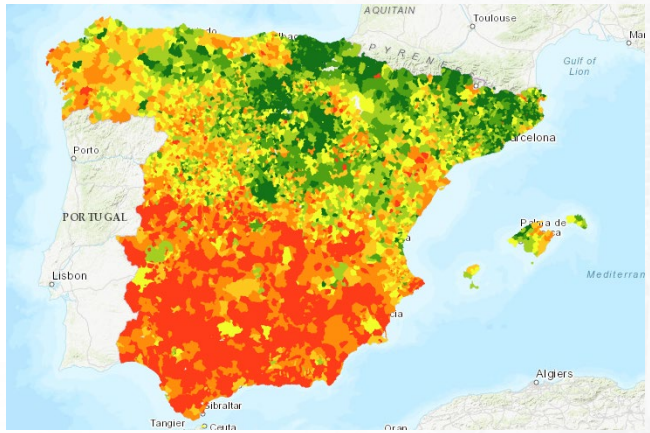
Variable Category	Specific Building Parameter
Envelope characteristics	U-value of roof
	U-value of building façade
	U-value of window
	Window SHGC
	Infiltration losses
Building geometry	South equivalent surface (SES)
	Shape factor
	Roof surface area
	Façade surface area
	Window surface area
Building operation	Internal gains, uses
System configuration	Heating set point temperature
Outdoor climate	HDD, minimum temp, WDF...

Relevant data to calculate building energy needs (at regional scale)

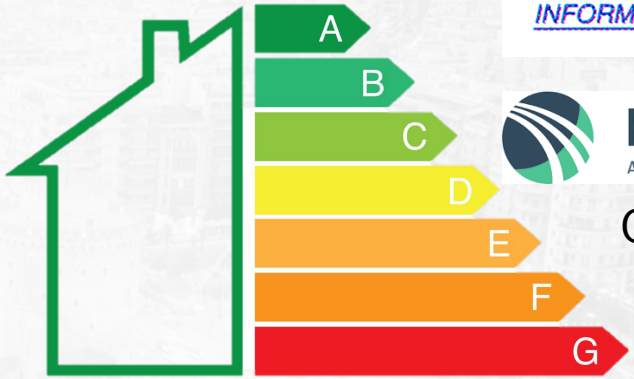
Cadastral data



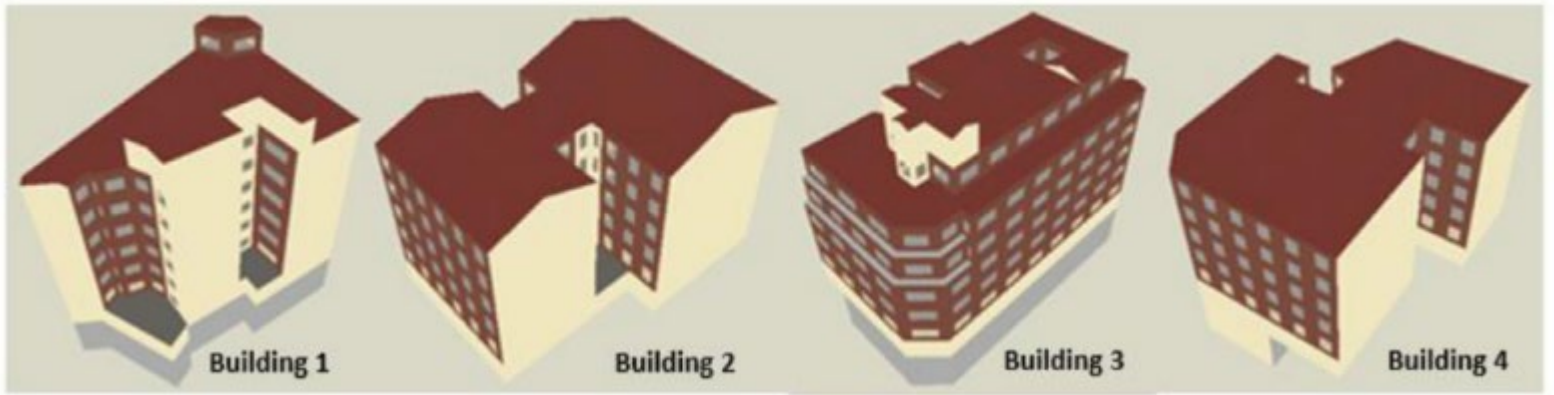
Stats



EPCs

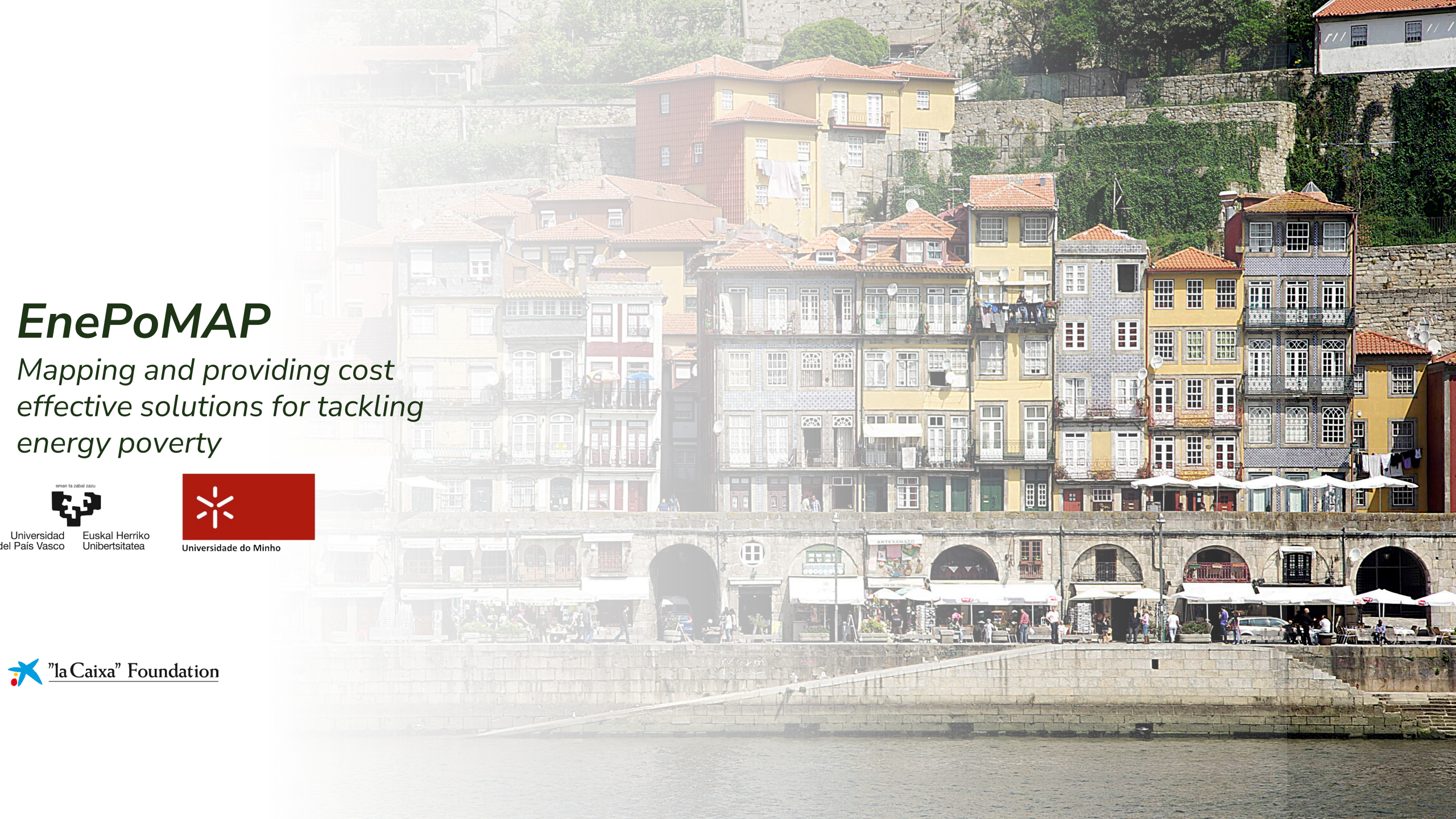


Other sources



(from J. Fernández et al. *"A novel residential heating consumption characterisation approach at city level from available public data: Description and case study"* Energy and Buildings, art number 110082, vol 221, (2020)

How these data can be organised for energy performance calculations?



EnePoMAP

Mapping and providing cost effective solutions for tackling energy poverty

eman ta zabal zazu

Universidad del País Vasco

Euskal Herriko Unibertsitatea

Universidade do Minho

"la Caixa" Foundation

1. EnePoMAP context

Energy Poverty

II Call "Social Research" (Fundación La Caixa)

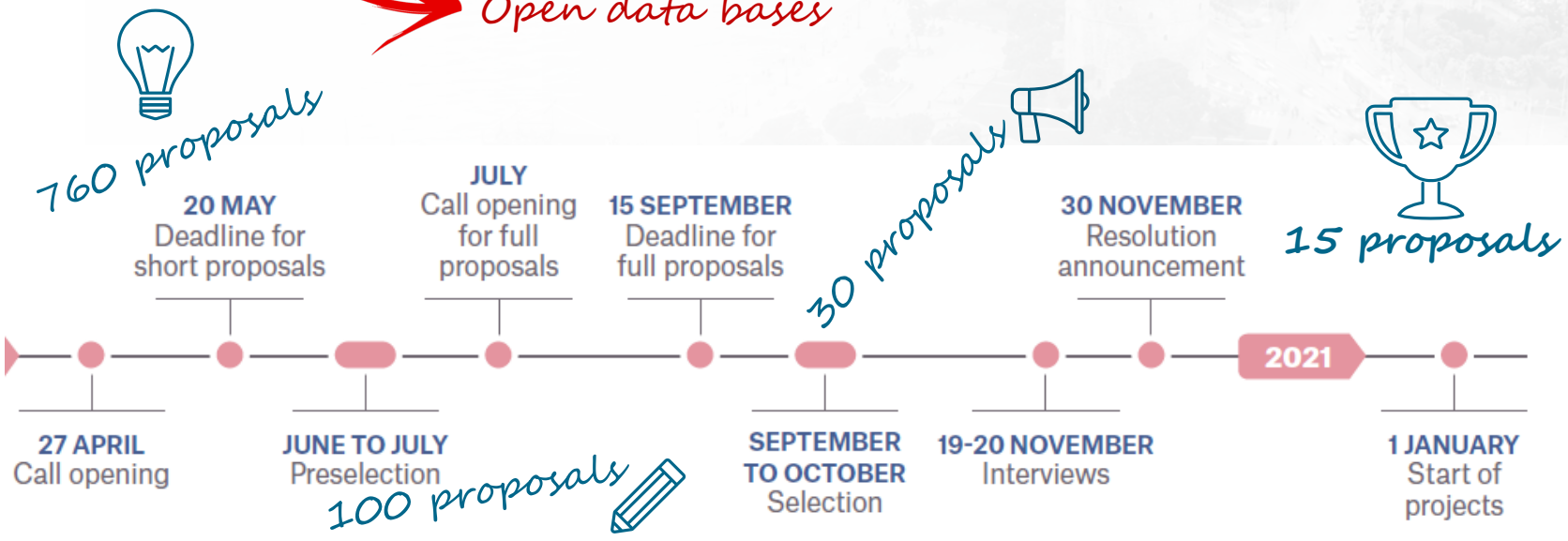
"**rely on data** to provide robust quantifiable evidence and insights about **current and emerging social challenges in Spain and Portugal**. (...) This call is intended to promote social research projects based on sound **quantitative data analysis to produce reliable evidence for policy decision-makers and practitioners**, building bridges between science and society.

"The research must involve **existing data** (and) new data especially generated for the research project and/or **new forms of data**"

Universidade do Minho

Open data bases

GIS



1. EnePoMAP context

What is “Energy Poverty”?

Roots in MEDICAL SCIENCE (NHS in UK)

Effect on Indoor temperature, but also in other related aspects:

- Mold
- Humidity

Health effects

- Respiratory diseases
- Cardiovascular diseases
- Mental diseases

1. EnePoMAP context

What is “Energy Poverty”?

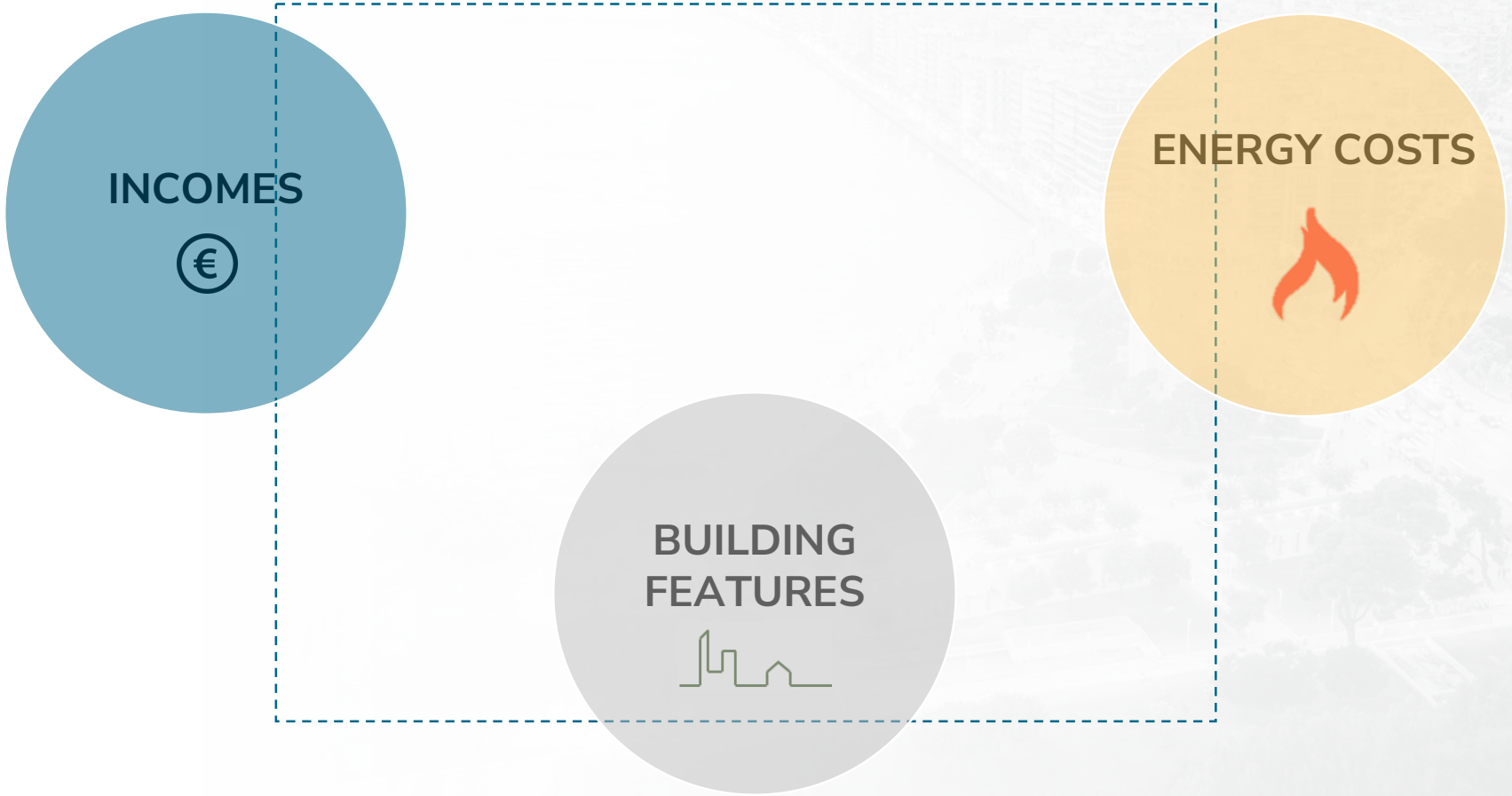
Situation in which households are unable to access essential energy services and products. It occurs when energy bills represent a high percentage of consumers’ income, or when they must reduce their household's energy consumption to a degree that negatively impacts their health and well-being.

Source: EU Energy Poverty Observatory: https://www.energypoverty.eu/

MULTIDIMENSIONAL AND COMPLEX PROBLEM

1. EnePoMAP context

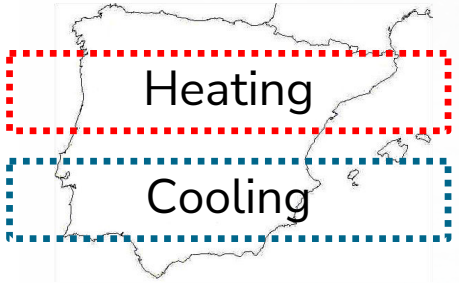
What is “Energy Poverty”?



1. EnePoMAP context

What is “Energy Poverty”?

BUILDING FEATURES



ENERGY COSTS

Energy dependence

INCOMES

Share of incomes for energy expenses

Energy renovation → Reduction of Energy demand

RES implement. → Reduction of energy consumption

1. EnePoMAP context

“Energy Poverty” Indicators

First indicator: BRENDA BOARDMAN 1991

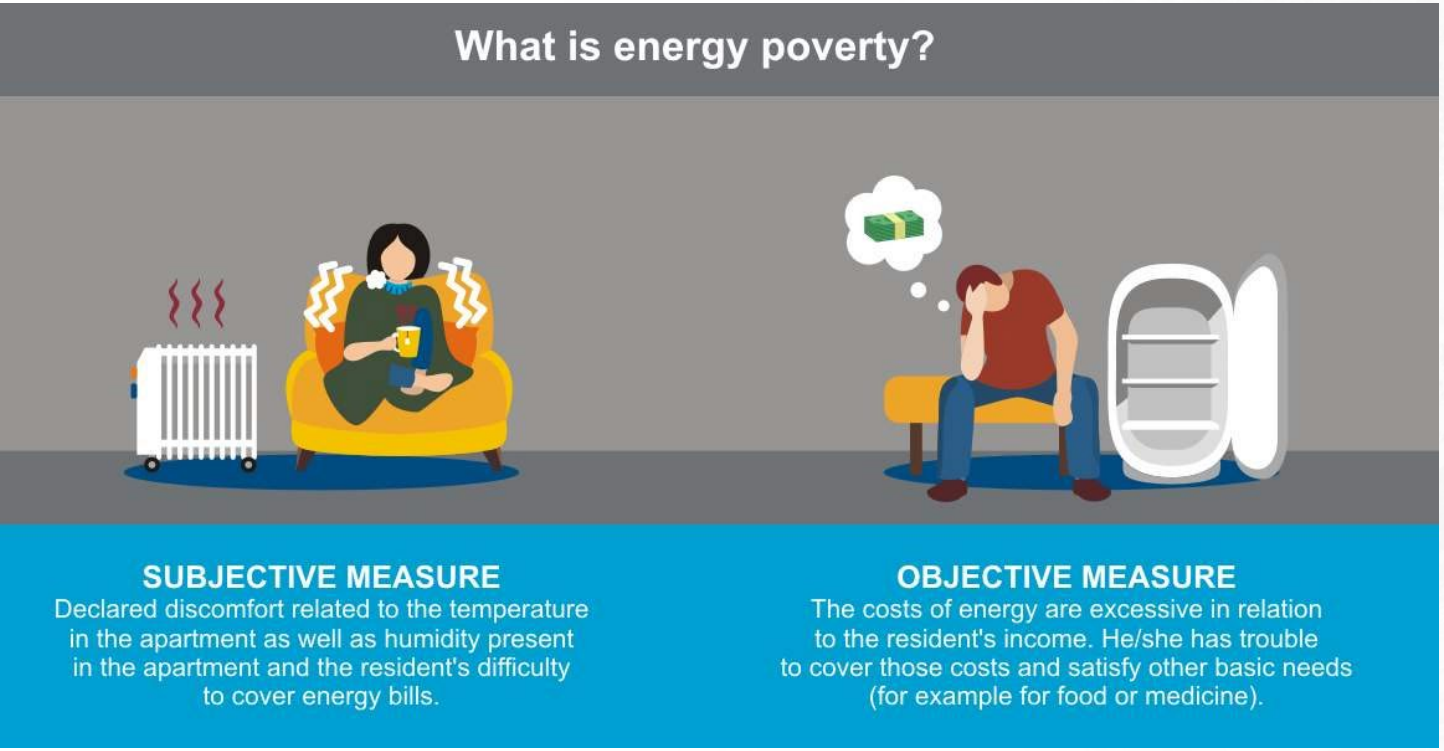
Ten Per cent Rule (TPR): ratio between energy expenses and household incomes

$$Vulnerability \rightarrow \frac{Energy\ expenses}{household\ incomes} > 10\%$$

REAL VALUES, based on energy bills

1. EnePoMAP context

“Energy Poverty” Indicators



Absolute – Relative

- *“Ten Percent Rule”* (TPR): **ABSOLUTE**
- (2M), (M/2): **RELATIVE**

Objective - Subjective

- Surveys: Declared discomfort, inability to cover energy bills (auto-perception) **SUBJETIVE**
- Estimated energy demands, i.e. UK (Low Income High Cost, LIHC) **OBJETIVE**

(Expenses) Real – Calculated

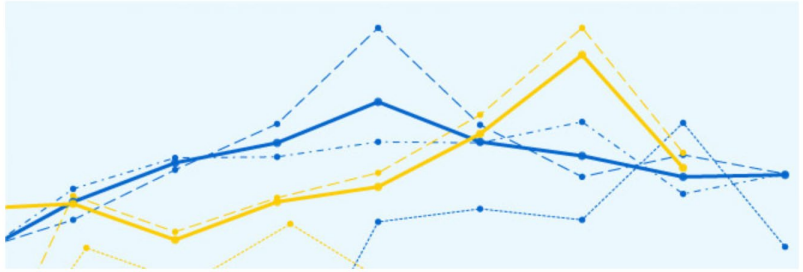
- TPR
- 2M, M/2…
- LIHC

1. EnePoMAP context

“Energy Poverty” Indicators

PRIMARY INDICATORS

EPOV provides four different primary indicators for energy poverty, of which two are based on self-reported experiences of limited access to energy services (based on EU-SILC data) and the other two are calculated using household income and/or energy expenditure data (based on HBS data).



Arrears on utility bills

Share of (sub)population having arrears on utility bills.

Low absolute energy expenditure (M/2)

Share of households whose absolute energy expenditure is below half the national median.

High share of energy expenditure in income (2M)

The 2M indicator presents the proportion of households whose share of energy expenditure in income is more than twice the national median share.

Inability to keep home adequately warm

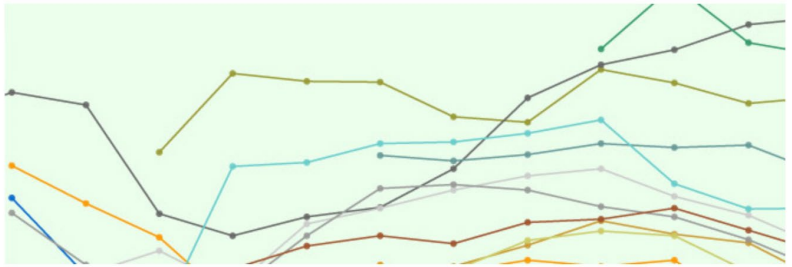
Share of (sub)population not able to keep their home adequately warm.

https://www.energypoverty.eu/indicators-data

EU ENERGY POVERTY Observatory | European Commission

SECONDARY INDICATORS

EPOV gathers data on a number of secondary indicators that are relevant in the context of energy poverty, but not directly indicators of energy poverty itself. Indicators include e.g. energy prices and housing-related data. Their development can be compared to the development of primary indicators in the graph tool when selecting a single country.



Fuel oil prices

Average household prices per kWh generated from fuel oil

Biomass prices

Average household prices per kWh generated from biomass

Coal prices

Average household prices per kWh generated from coal

Household electricity prices

Electricity prices for household consumers, band DC 2500-5000 kWh/yr consumption, all taxes and levies included

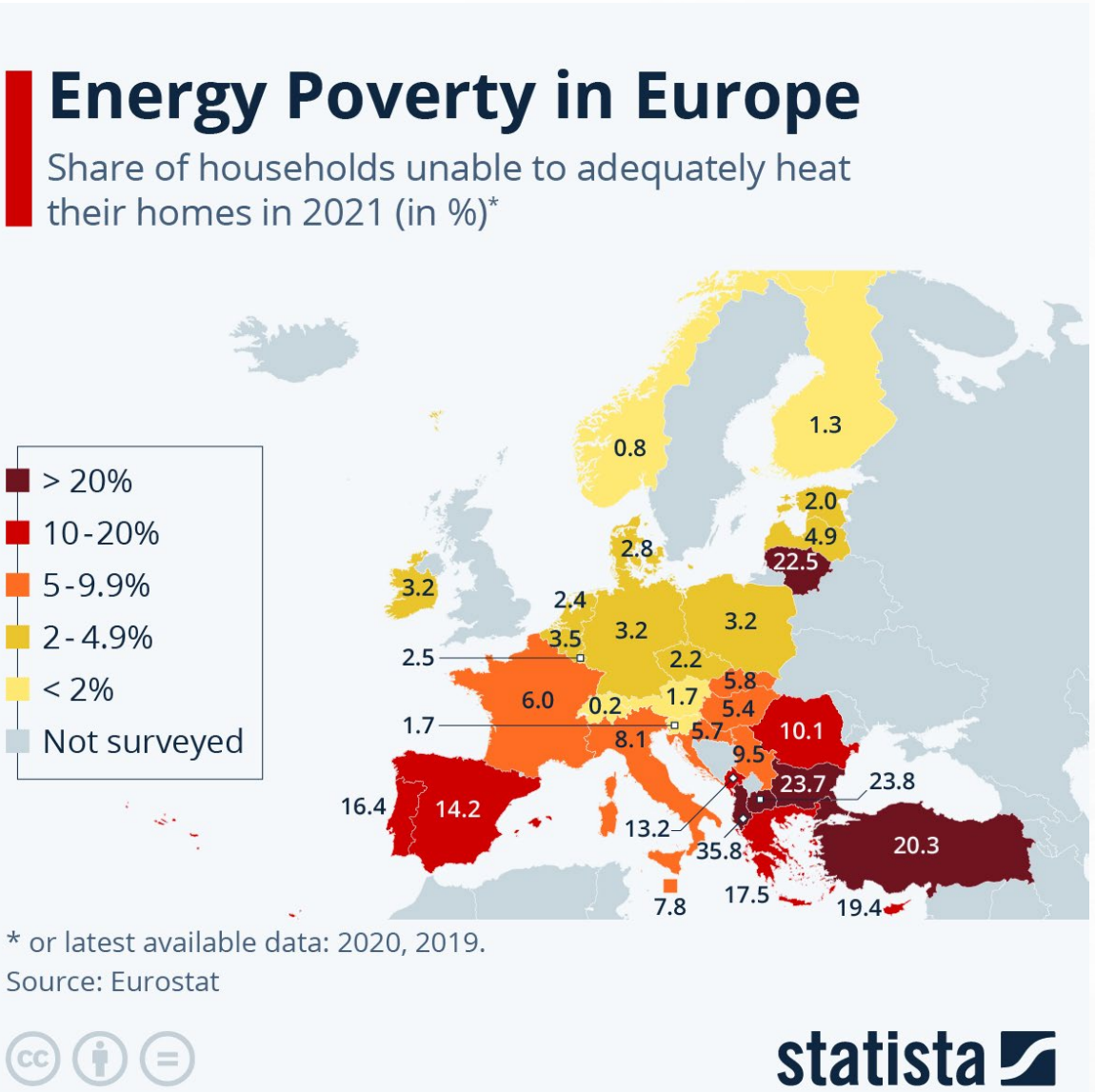
District heating prices

Average household prices per kWh from district heating

Household gas prices

Natural gas prices for household consumers, band 20-200GJ consumption, all taxes and levies included

1. EnePoMAP context



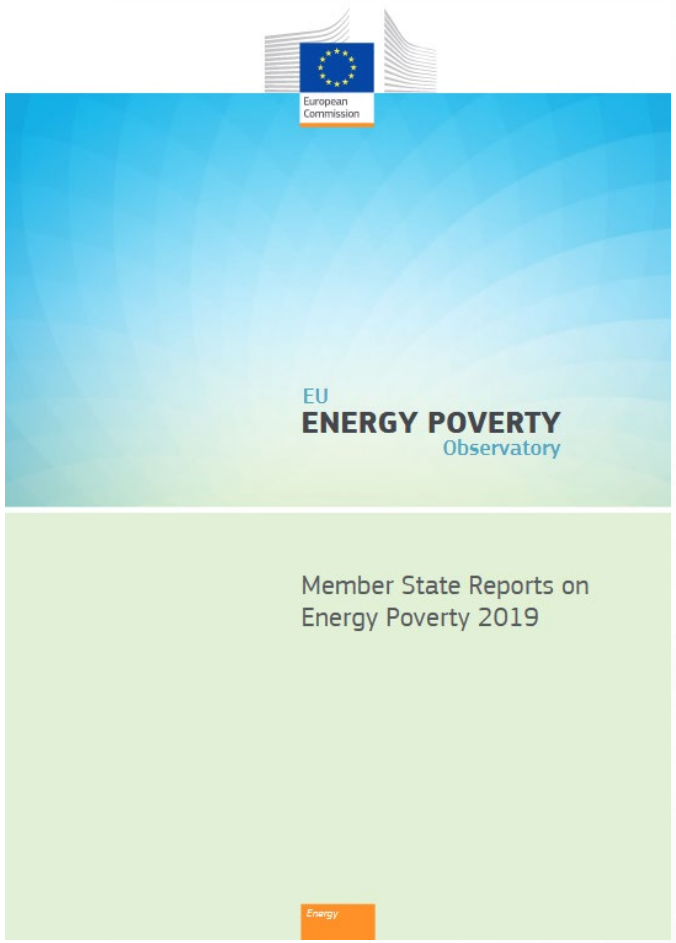
*"People in **inefficient buildings** are more exposed to cold spells, heatwaves and other impacts of climate change. Inadequate comfort and sanitary conditions in housing and work environments, such as inadequate indoor temperatures, deficient air quality and exposure to harmful chemicals and materials, **contribute to lower productivity, health problems and higher mortality and morbidity**"*

1. EnePoMAP context

Energy Poverty Advisory Hub (EPAH)

1. EnePoMAP context

Energy Poverty Advisory Hub (EPAH)



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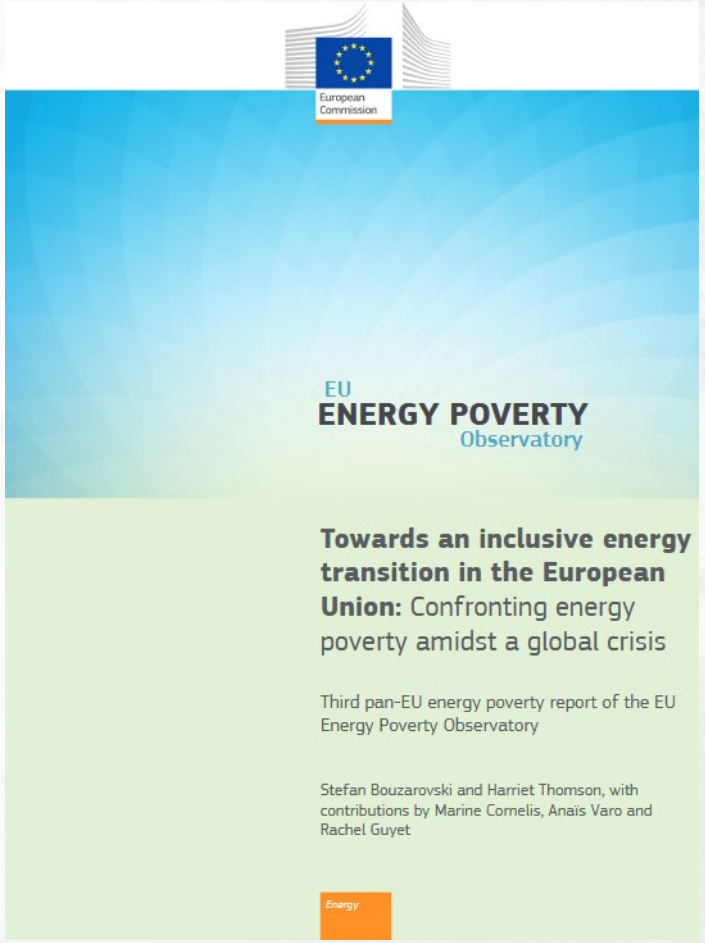
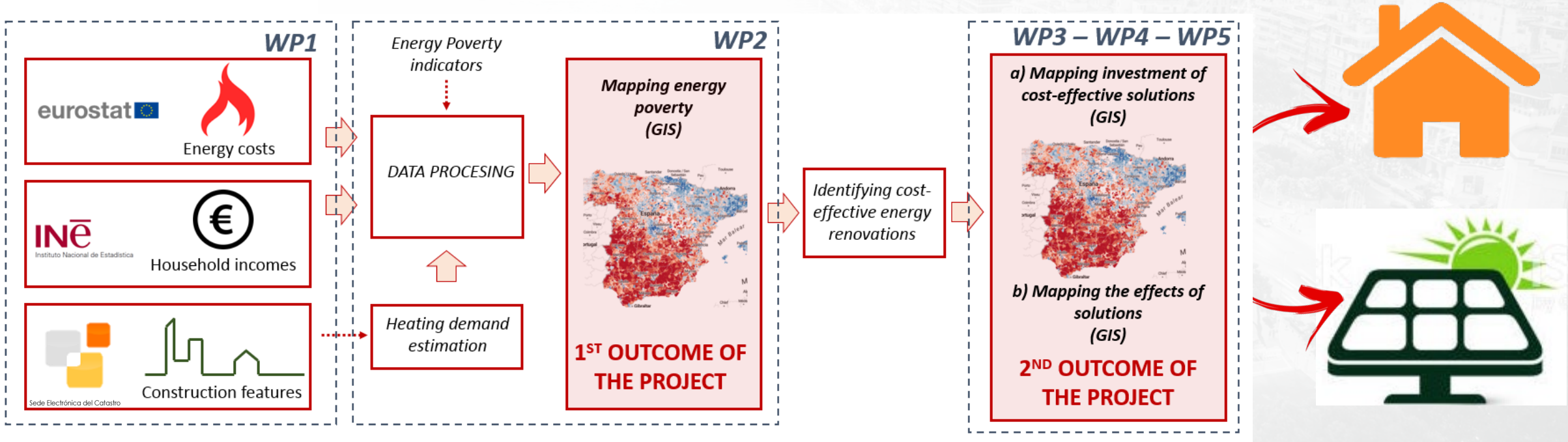


[link]

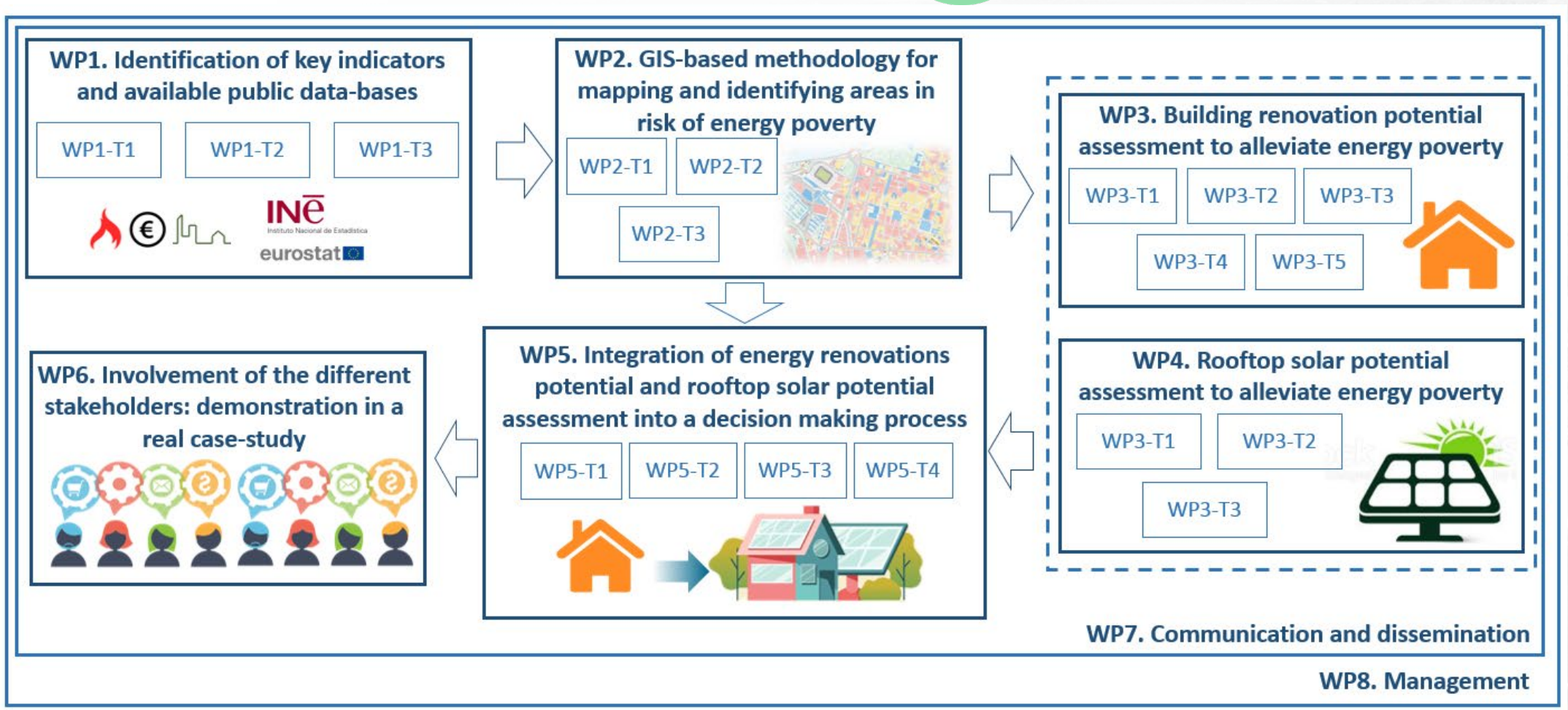
1. EnePoMAP context

2. EnePoMAP objective

"This proposal will develop a **comprehensive methodology aimed at integrating available big data sets** from different sources and applying a data processing for mapping the EP risk in any district located in Spain or Portugal"



3. EnePoMAP methodology



3. EnePoMAP methodology

WP1. Identification of key indicators and available public data-bases

WP1-T1 | WP1-T2 | WP1-T3

WP2. GIS-based methodology for mapping and identifying areas in risk of energy poverty

WP2-T1 | WP2-T2 | WP2-T3

WP3. Building renovation potential assessment to alleviate energy poverty

WP3-T1 | WP3-T2 | WP3-T3 | WP3-T4 | WP3-T5

WP4. Rooftop solar potential assessment to alleviate energy poverty

WP3-T1 | WP3-T2 | WP3-T3

Diagnosis

Potentials: Energy Efficiency

Potentials: RES implementation

Stage 1.

Diagnosis

3. EnePoMAP methodology

Diagnosis

Main objective: a procedure to evaluate energy vulnerability on a regional scale:

- ❑ enabling the identification of priority areas
- ❑ insights into the main weaknesses in those areas

Prioritise areas at regional level for energy renovation in buildings

Requirements

limited amount of indicators

the indicators should be derived from **public databases**

they should be **updated periodically**

Sufficiently disaggregated to determine inequalities within municipalities

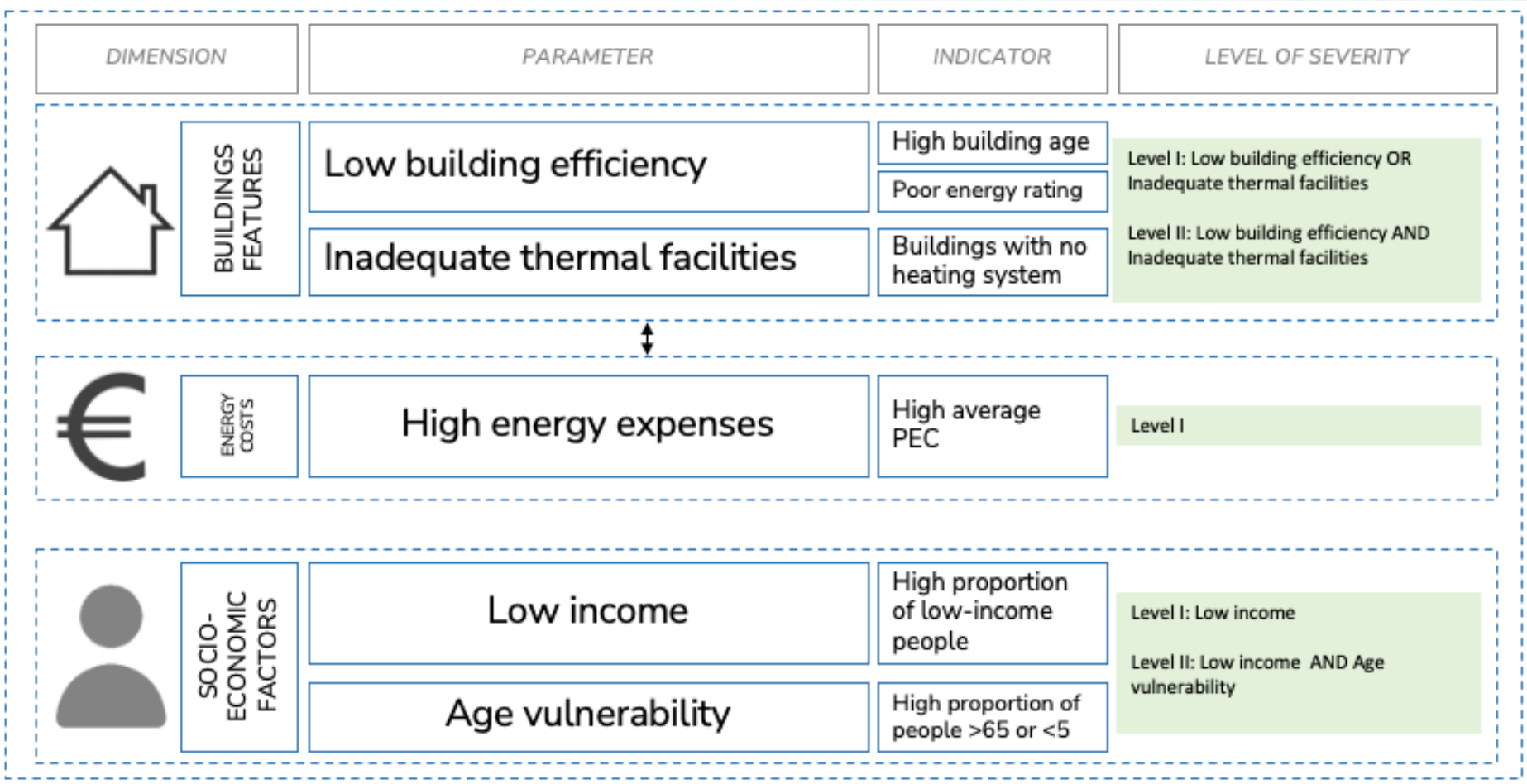
3. EnePoMAP methodology

Diagnosis

DIMENSION	PARAMETER	INDICATOR		Threshold	Data source
BUILDINGS FEATURES	Low building efficiency	High building age	% buildings built before 1979	Q1	Cadastre
		Poor energy rating	% of buildings with G rating	1.5 x reg. mean	EPCs
	Inadequate thermal facilities	Buildings with no heating system	% of dwellings	1.5 x reg. mean	EUSTAT/INE
ENERGY COSTS	High energy expenses	High average PEC	Average PE consumption in kWh/m²/year	2 x reg. median	EPCs
SOCIO-ECONOMIC FACTORS	Low income	High proportion of low-income people	% of households with incomes <60% of the regional median	1.5 x reg. mean	INE
	Age vulnerability	High proportion of people >65 or <5	% of people >65 or <5)	1.5 x reg. mean	INE

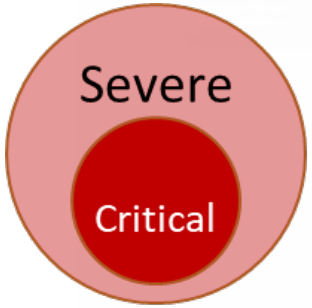
3. EnePoMAP methodology

Diagnosis



3. EnePoMAP methodology

Diagnosis



Highest-level severity for at least two out of three dimensions

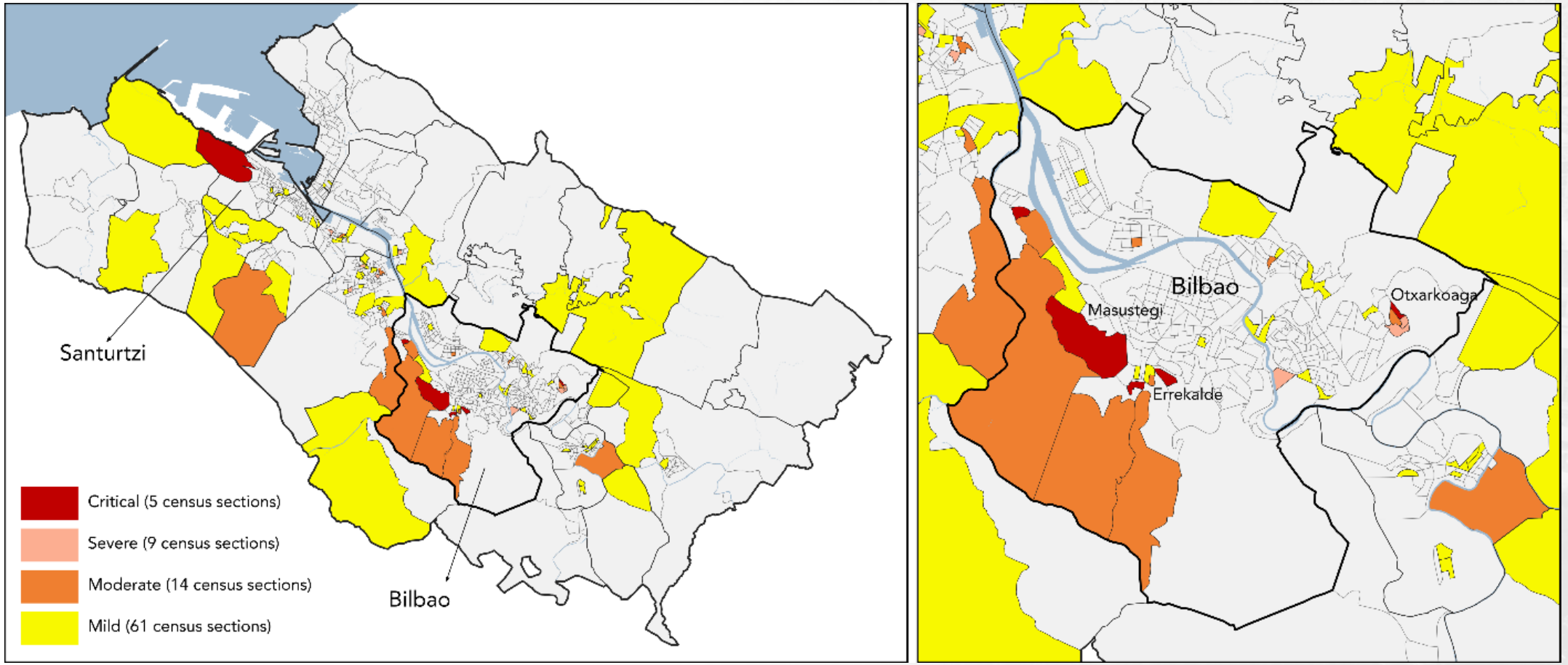
Critical: a sub-category of Severe, the census section is additionally identified as red in the Atlas of Urban Vulnerability in Spain

Level 1 severity for all three dimensions

Highest-level severity is reached for at least one dimension and at least Level 1 is reached for a second dimension. Further study is required.

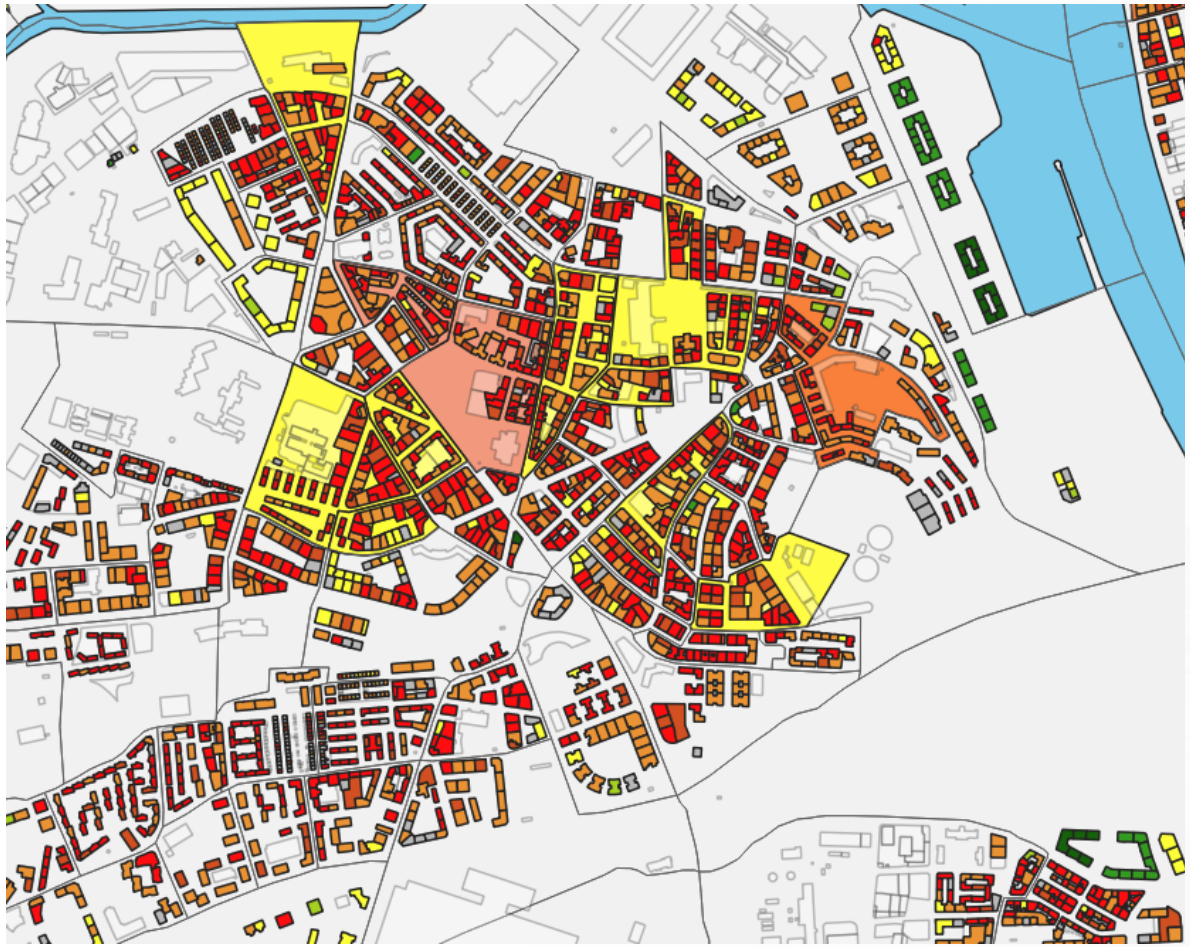
3. EnePoMAP methodology

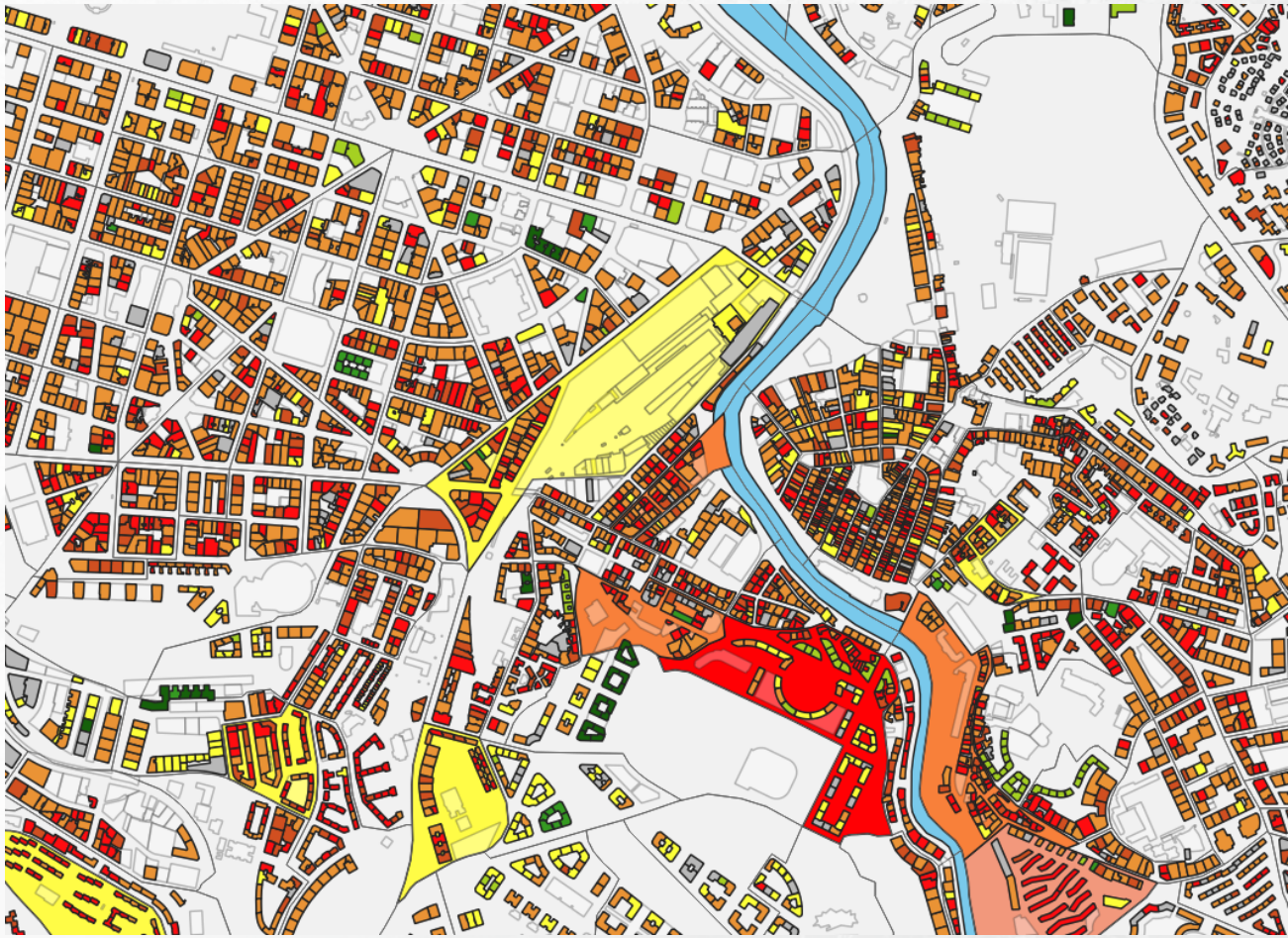
Diagnosis



3. EnePoMAP methodology

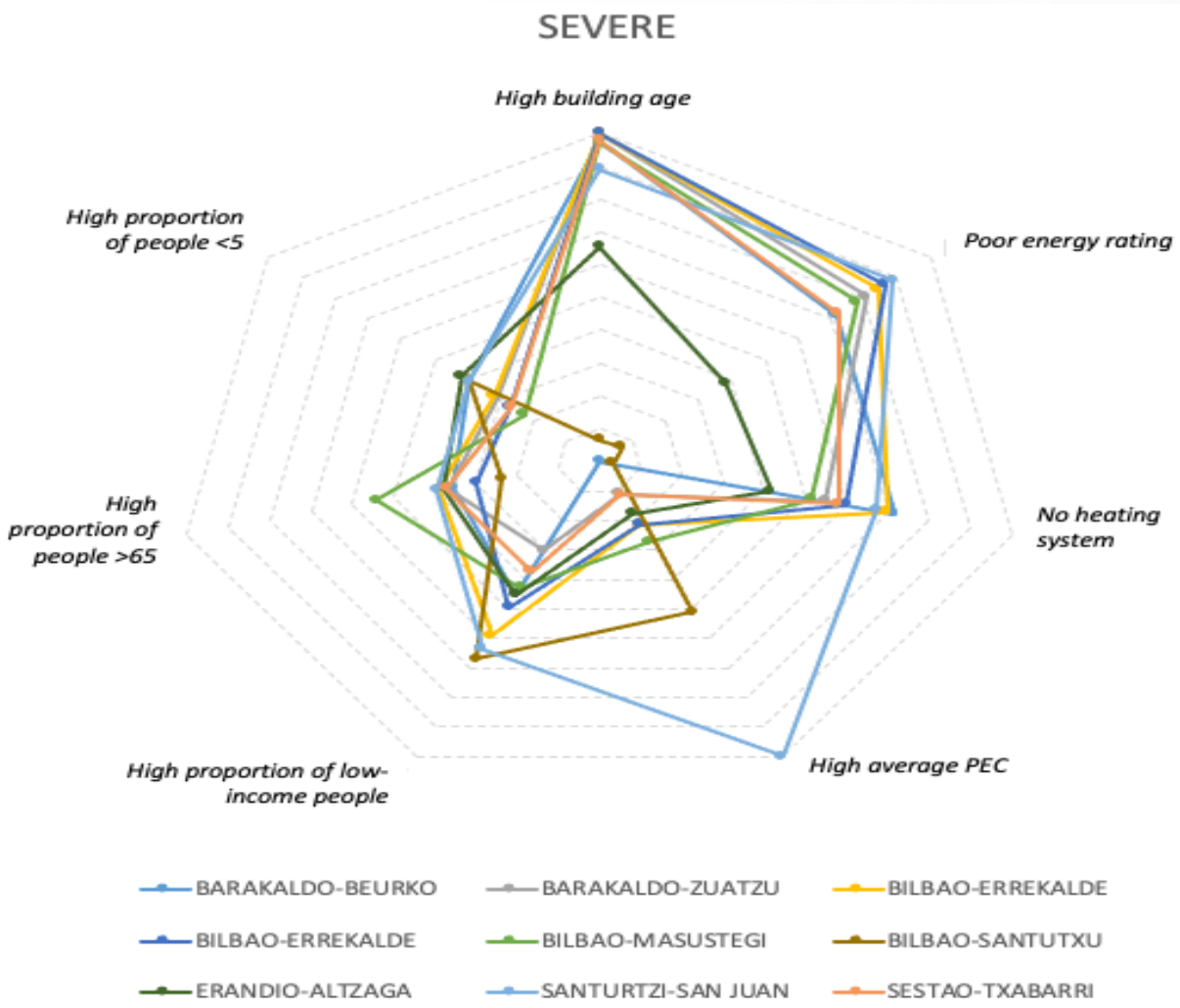
Diagnosis

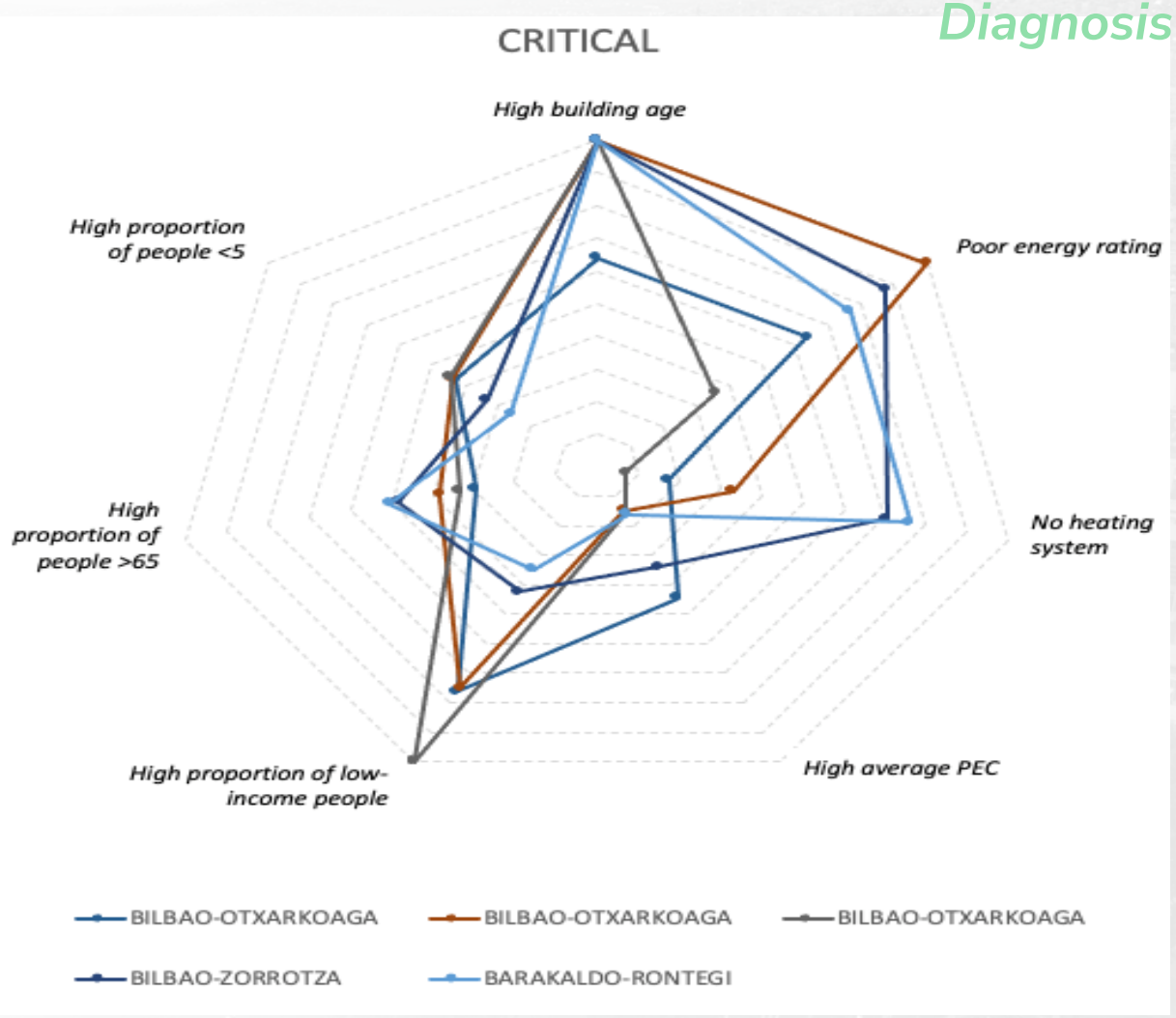




3. EnePoMAP methodology

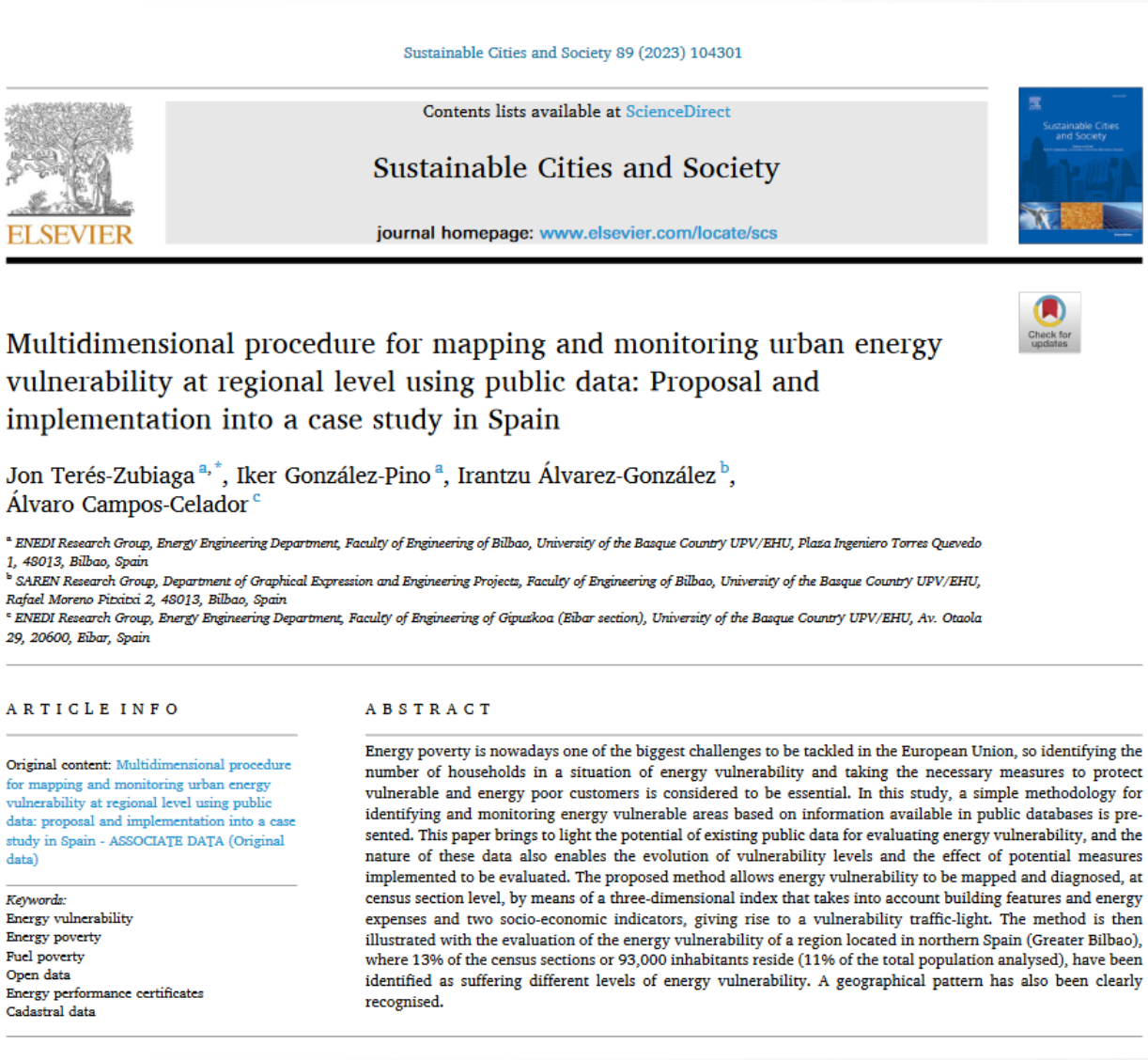
Diagnosis





3. EnePoMAP methodology

Diagnosis



Sustainable Cities and Society 89 (2023) 104301

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Multidimensional procedure for mapping and monitoring urban energy vulnerability at regional level using public data: Proposal and implementation into a case study in Spain

Jon Terés-Zubiaga [a,*], Iker González-Pino [a], Irantzu Álvarez-González [b], Álvaro Campos-Celador [c]

[a] ENEDI Research Group, Energy Engineering Department, Faculty of Engineering of Bilbao, University of the Basque Country UPV/EHU, Plaza Ingeniero Torres Quevedo 1, 48013, Bilbao, Spain
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[c] ENEDI Research Group, Energy Engineering Department, Faculty of Engineering of Gipuzkoa (Eibar section), University of the Basque Country UPV/EHU, Av. Otaola 29, 20600, Eibar, Spain

ARTICLE INFO

Original content: Multidimensional procedure for mapping and monitoring urban energy vulnerability at regional level using public data: proposal and implementation into a case study in Spain - ASSOCIATE DATA (Original data)

Keywords:
Energy vulnerability
Energy poverty
Fuel poverty
Open data
Energy performance certificates
Cadastral data

ABSTRACT

Energy poverty is nowadays one of the biggest challenges to be tackled in the European Union, so identifying the number of households in a situation of energy vulnerability and taking the necessary measures to protect vulnerable and energy poor customers is considered to be essential. In this study, a simple methodology for identifying and monitoring energy vulnerable areas based on information available in public databases is presented. This paper brings to light the potential of existing public data for evaluating energy vulnerability, and the nature of these data also enables the evolution of vulnerability levels and the effect of potential measures implemented to be evaluated. The proposed method allows energy vulnerability to be mapped and diagnosed, at census section level, by means of a three-dimensional index that takes into account building features and energy expenses and two socio-economic indicators, giving rise to a vulnerability traffic-light. The method is then illustrated with the evaluation of the energy vulnerability of a region located in northern Spain (Greater Bilbao), where 13% of the census sections or 93,000 inhabitants reside (11% of the total population analysed), have been identified as suffering different levels of energy vulnerability. A geographical pattern has also been clearly recognised.

Jon Terés-Zubiaga, Iker González-Pino, Irantzu Álvarez-González, Álvaro Campos-Celador,

Multidimensional procedure for mapping and monitoring urban energy vulnerability at regional level using public data: Proposal and implementation into a case study in Spain,

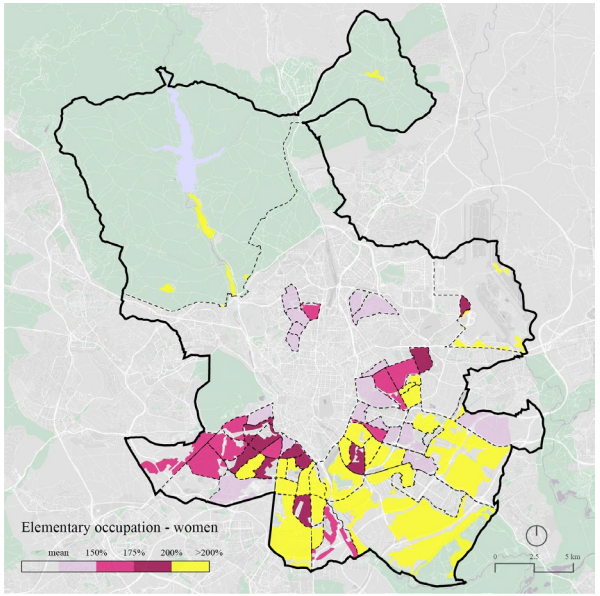
Sustainable Cities and Society, Vol 89,104301,

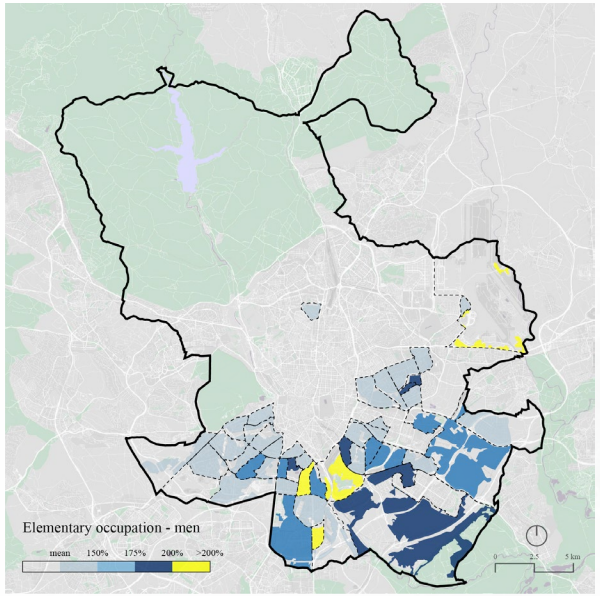
2023

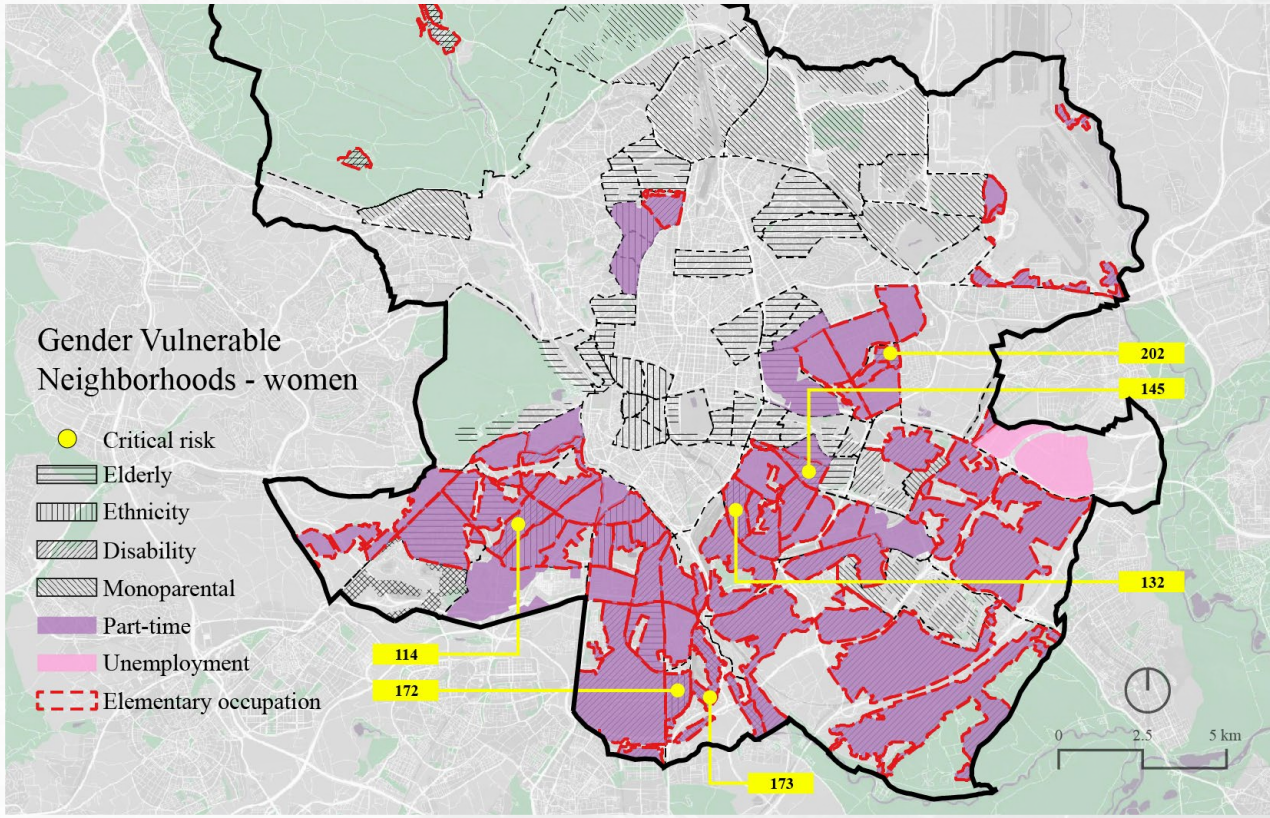
https://doi.org/10.1016/j.scs.2022.104301.

3. EnePoMAP methodology

Diagnosis







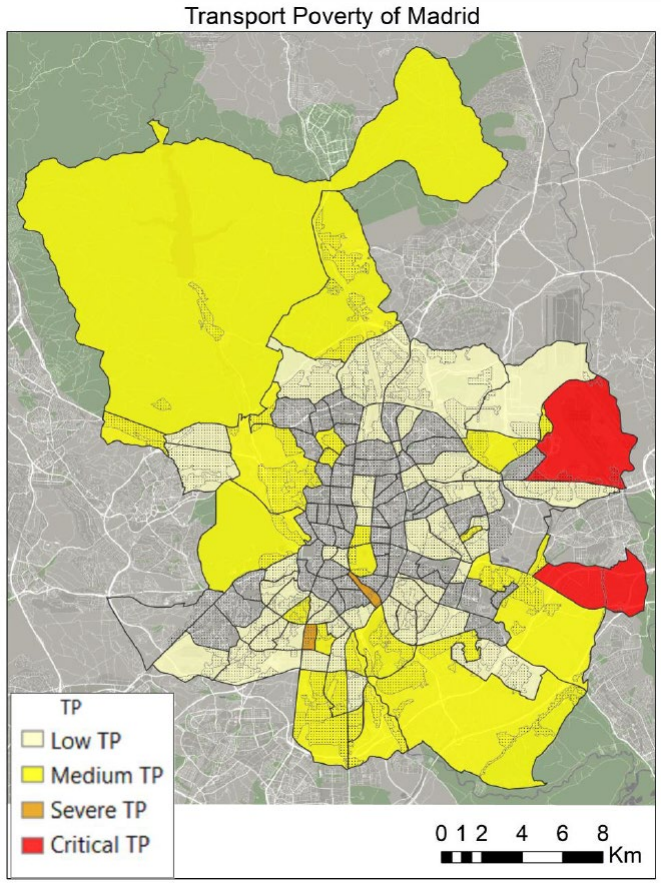
SMACCs Master Thesis (2023): Mapping gendered vulnerability to energy poverty: Case study of Madrid

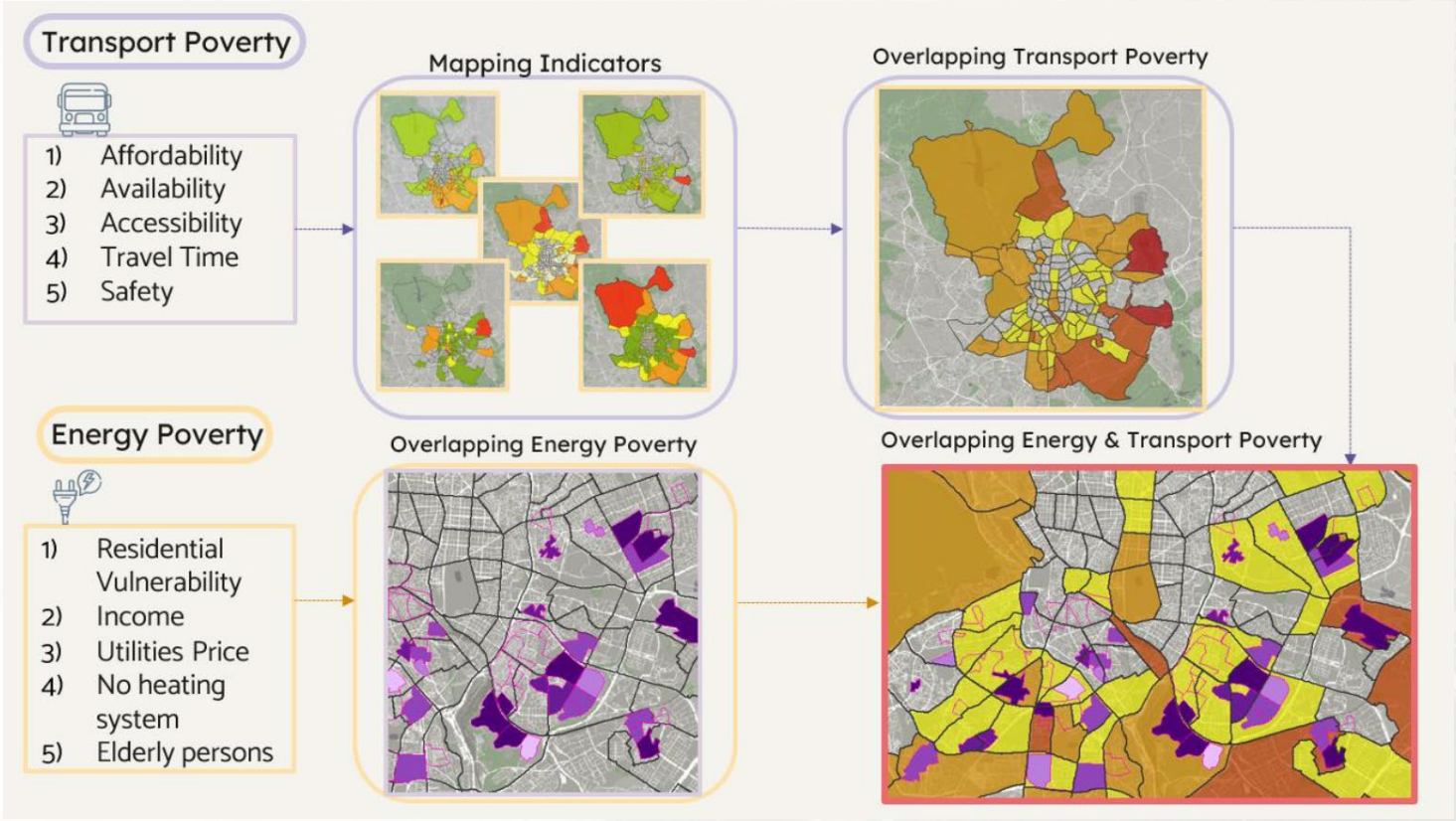
Nayely B. Capetillo Ordaz

Supervised by F. Martín-Consuegra (IETcc), C. Alonso Ruíz de Rivas (IETcc), S. Koutra (UMons), J. Terés Zubiaga (UPV/EHU)

3. EnePoMAP methodology

Diagnosis





SMACCs Master Thesis (2023): Exploring Double Energy and Transport Poverty: Case study of Madrid

Mariia Kotova

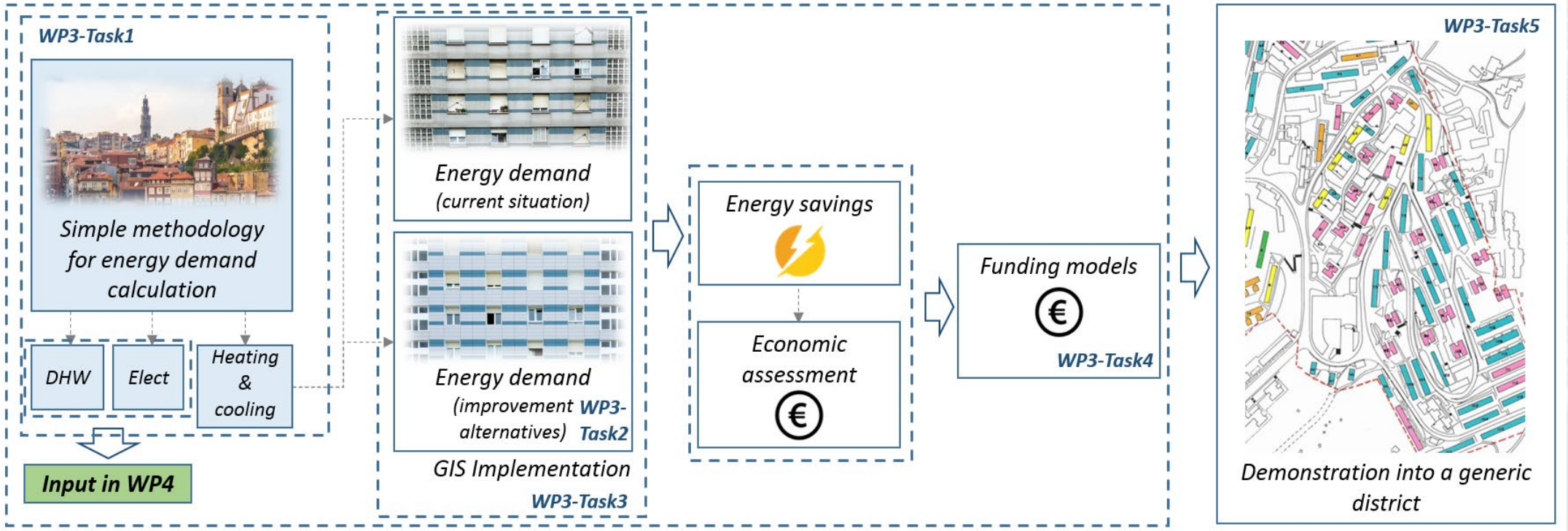
Supervised by F. Martín-Consuegra (IETcc), F. de Frutos (IETcc), J. Terés Zubiaga (UPV/EHU)

Stage 2.

Energy Efficiency

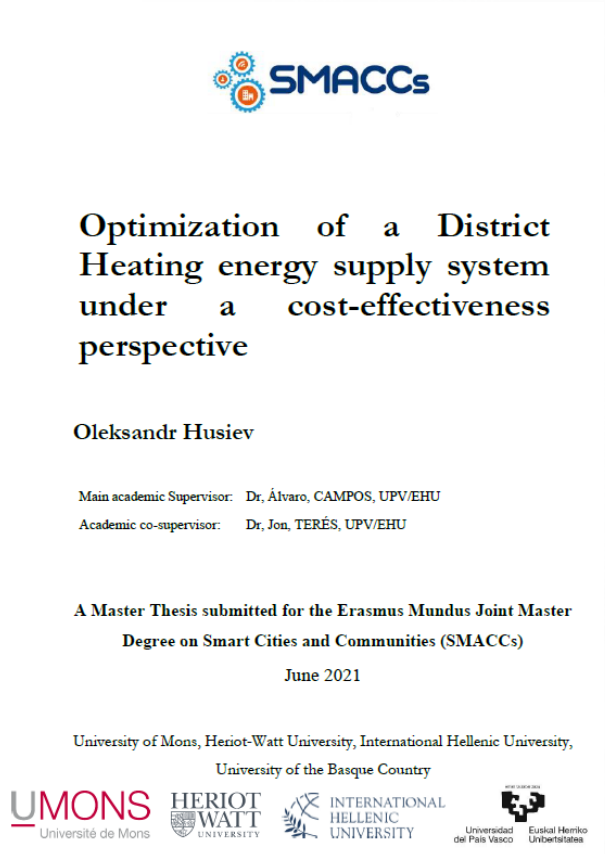
3. EnePoMAP methodology

Energy Efficiency



3. EnePoMAP methodology

Energy Efficiency



SMACCs

Optimization of a District Heating energy supply system under a cost-effectiveness perspective

Oleksandr Husiev

Main academic Supervisor: Dr, Álvaro, CAMPOS, UPV/EHU
Academic co-supervisor: Dr, Jon, TERÉS, UPV/EHU

A Master Thesis submitted for the Erasmus Mundus Joint Master Degree on Smart Cities and Communities (SMACCs)

June 2021

University of Mons, Heriot-Watt University, International Hellenic University, University of the Basque Country

UMONS Université de Mons · HERIOT WATT UNIVERSITY · INTERNATIONAL HELLENIC UNIVERSITY · Universidad del País Vasco · Euskal Herriko Unibertsitatea

Energy & Buildings 295 (2023) 113288

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ELSEVIER

Why district renovation is not leading the race? Critical assessment of building renovation potential under different intervention levels

Oleksandr Husiev [a], Alvaro Campos-Celador [b], Milagros Álvarez-Sanz [c], Jon Terés-Zubiaga [c,*]

[a] Faculty of Engineering, University of Deusto, Avda Universidades 24, 48007 Bilbao, Spain
[b] ENEDI Research Group, Department of Energy Engineering, Faculty of Engineering of Gipuzkoa, University of the Basque Country UPV/EHU, Spain
[c] ENEDI Research Group, Department of Energy Engineering, Faculty of Engineering of Bilbao, University of the Basque Country UPV/EHU, Plaza Ingeniero Torres Quevedo 1, 48013 Bilbao, Spain

ARTICLE INFO

Keywords:
Energy renovation
Nearly zero energy districts
Renewable integration in buildings
Urban energy transition
Cost-effective assessment
Large-scale building renovation

ABSTRACT

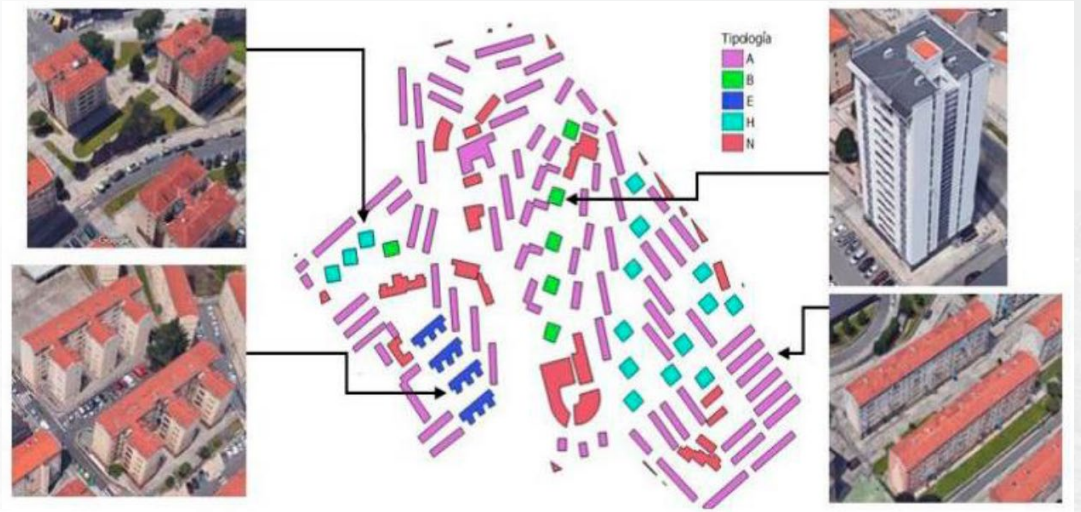
Building is one of the main sectors in which significant energy savings can be achieved with a consequent reduction in emissions. This paper assesses the large-scale renovation of buildings, exploring the quantitative and qualitative factors that determine their replicability potential from three different perspectives, namely dwelling, building and district intervention level. Different passive and active measures are assessed, covering energy saving measures, the improvement of energy supply systems and the integration of renewable energy sources. Different scenarios are defined for each intervention level, which are evaluated using the methodology developed in the IEA-EBC Annex 75 project. The methodology is applied to a residential district located in Bilbao (Northern Spain). The analysis is based on the results obtained from the simulation of 41 combinations of different renovation options, obtained by simulation in the Design Builder software. The assessment is carried out from the evaluation of different key performance factors, including annualised cost and annual primary energy consumption, as well as the CAPEX and OPEX requirements. The results show that energy renovation of buildings offers a great opportunity for energy reduction at affordable investment costs, obtaining the cost optimal values when the intervention focus on the energy system and reaching net NRPE values close to zero when the intervention is carried out in a comprehensive way, considering energy systems and thermal improvement of the envelope. Additionally, the different energy reduction scenarios show that, while interventions at district level offer the greatest potential for minimising annual costs and primary energy consumption levels, intervening at building level offers only slightly worse results. However, there are other issues which can better explain the current low rate of renovation works in the urban environment. Thus, if the additional existing social, material and legal barriers and constraints are included in the analysis, it becomes clear why renovation from a district perspective is not actually leading the race. Given this situation, some measures and policies are proposed to realise the true potential of large-scale building renovation.

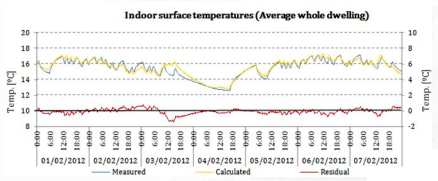
SMACCs Master Thesis (2021): Optimization of a District Heating energy supply system under a cost-effectiveness perspective

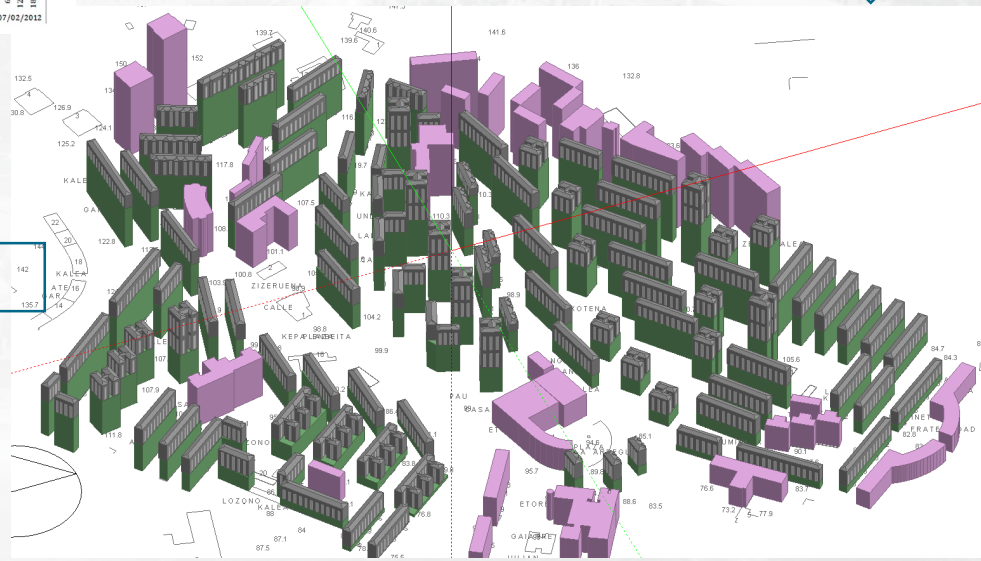
Oleksandr Husiev

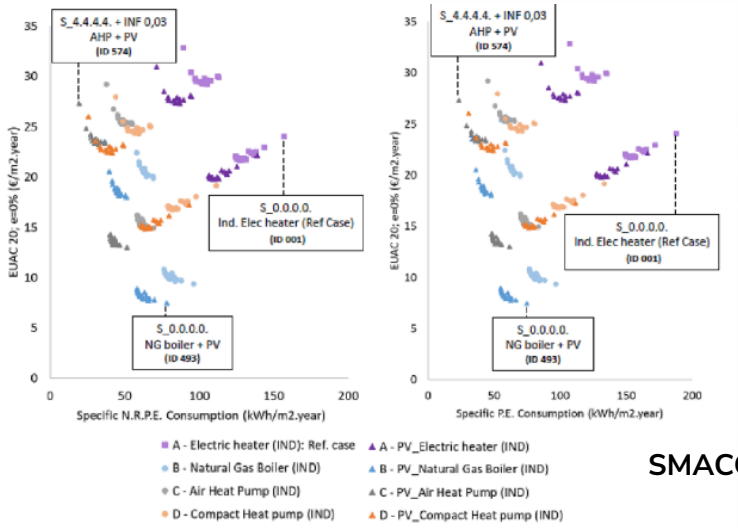
Á. Campos-Celador (UPV/EHU), J. Terés Zubiaga (UPV/EHU)

3. EnePoMAP methodology









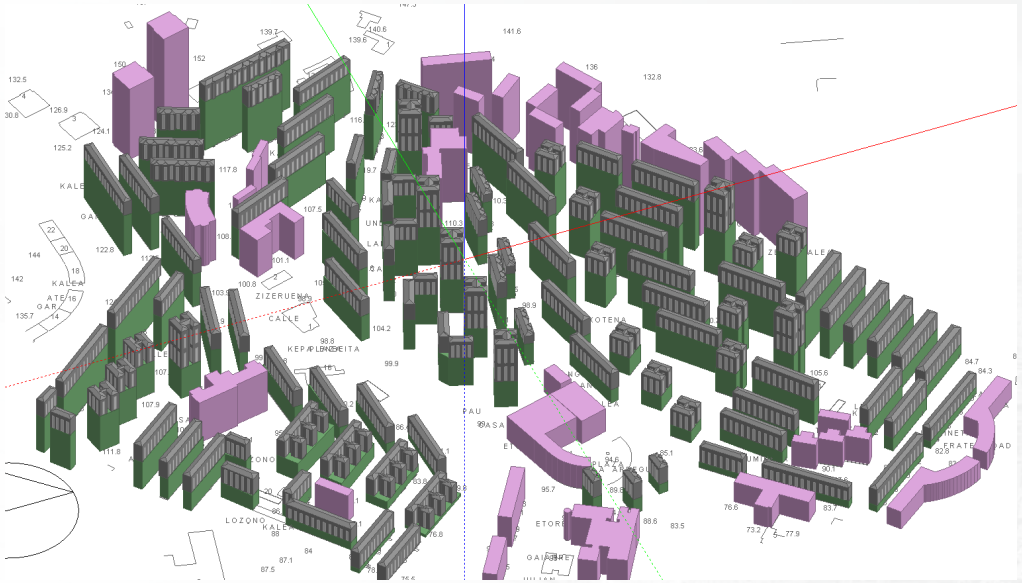
ESM

Energy Systems

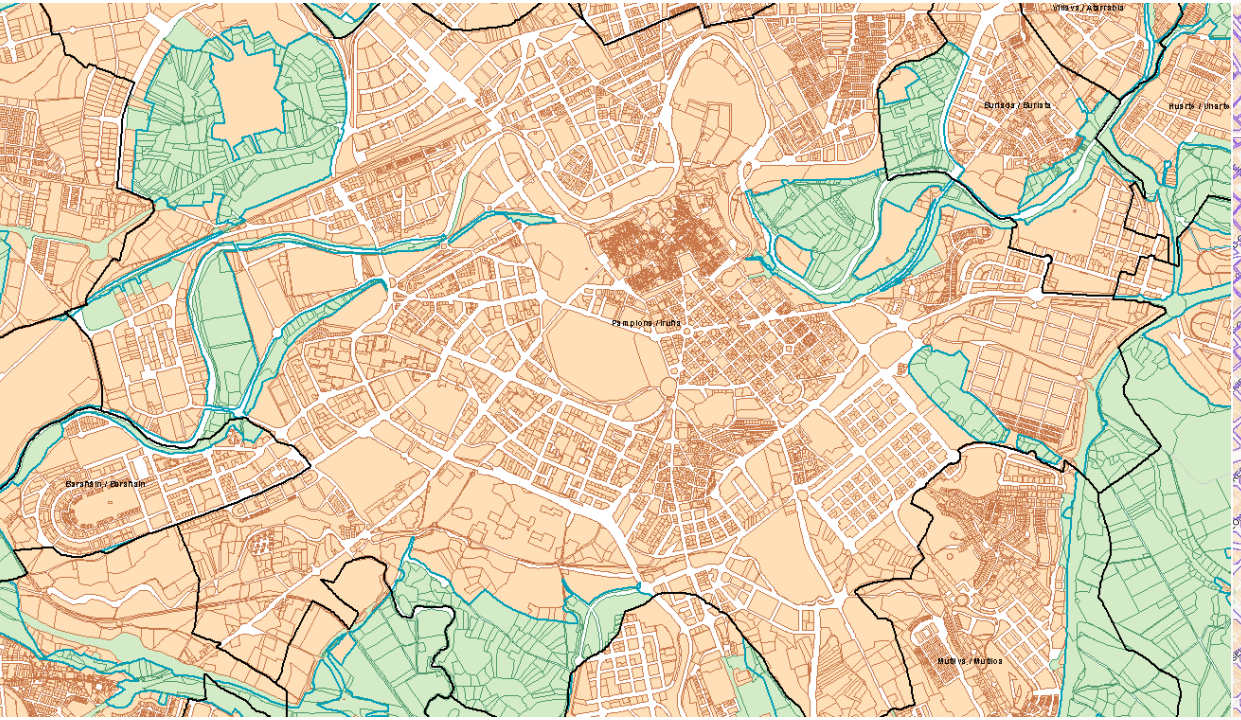
SMACCs Master Thesis (2021): Optimization of a District Heating energy supply system under a cost-effectiveness perspective

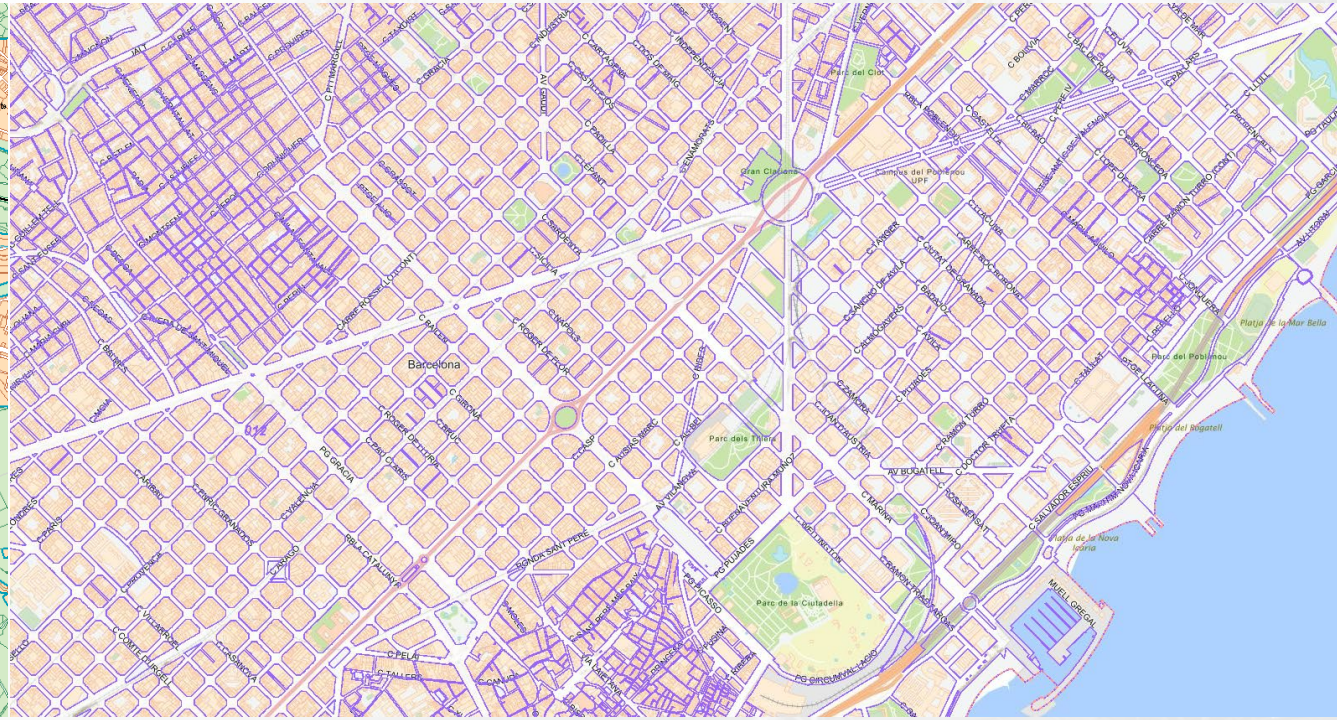
Oleksandr Husiev

3. EnePoMAP methodology



Energy Efficiency



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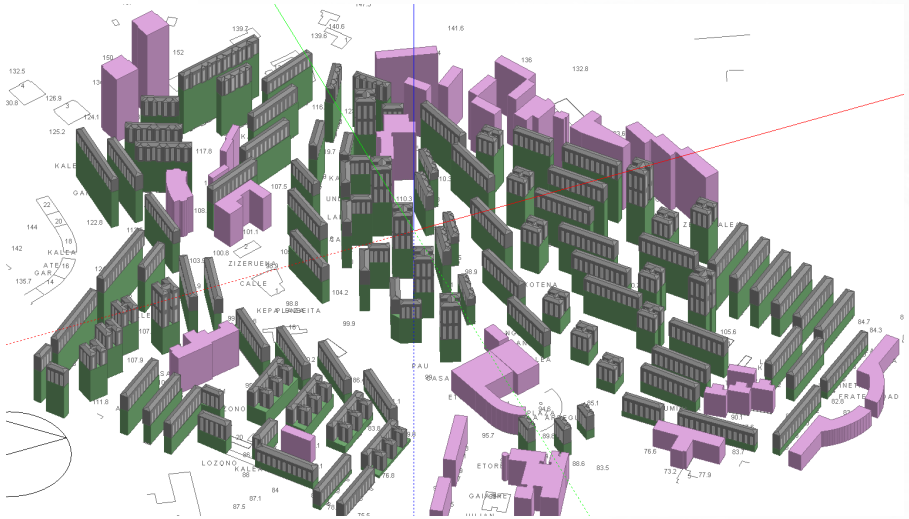
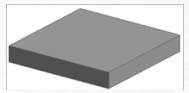
PANIC

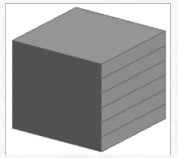
3. EnePoMAP methodology

Energy Efficiency





SF = 0.849



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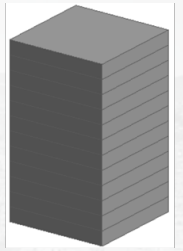
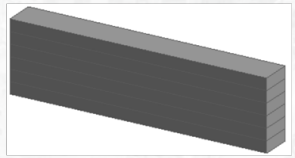
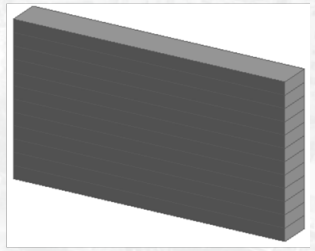


SF = 2.832

SF = 0.720



SF = 1.874
(reference building)



SF = 1.959

2 approaches

Direct Regression

Input data
Envelope characteristics
Building geometry
Building operation
System configuration
Outdoor climate

→ **Machine learning model** → **Annual heating demand**

Indirect Regression

Input data
Envelope characteristics
Building geometry
Building operation
System configuration
Outdoor climate*

→ **Machine learning model** → **Building base temperature** → **Degree Days Method** ⇢ **Annual heating demand**

HDD → **Degree Days Method**

3. EnePoMAP methodology

Energy Efficiency

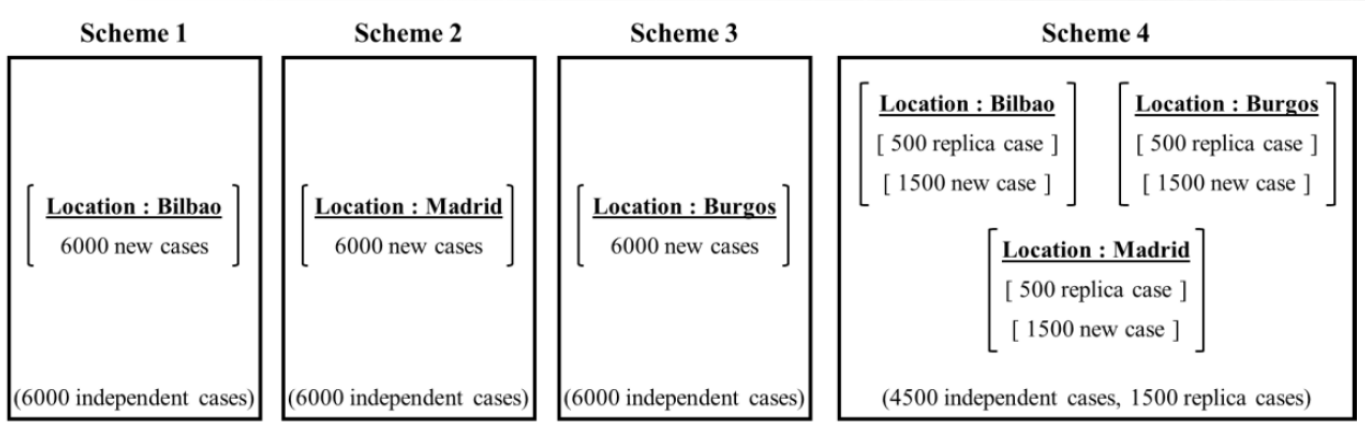
Variable Category	Specific Building Parameter	Unit
Envelope characteristics	U-value of roof	W/m²K
	U-value of building façade	
	U-value of window	
	Window SHGC	-
	Infiltration loss	W/K
Building geometry	South equivalent surface (SES)	m^2
	Shape factor	m
	Roof surface area	m^2
	Façade surface area	
	Window surface area	
Building operation	Internal gain	W/m^2
System configuration	Heating set point temperature	°C
Outdoor climate	HDD	K year

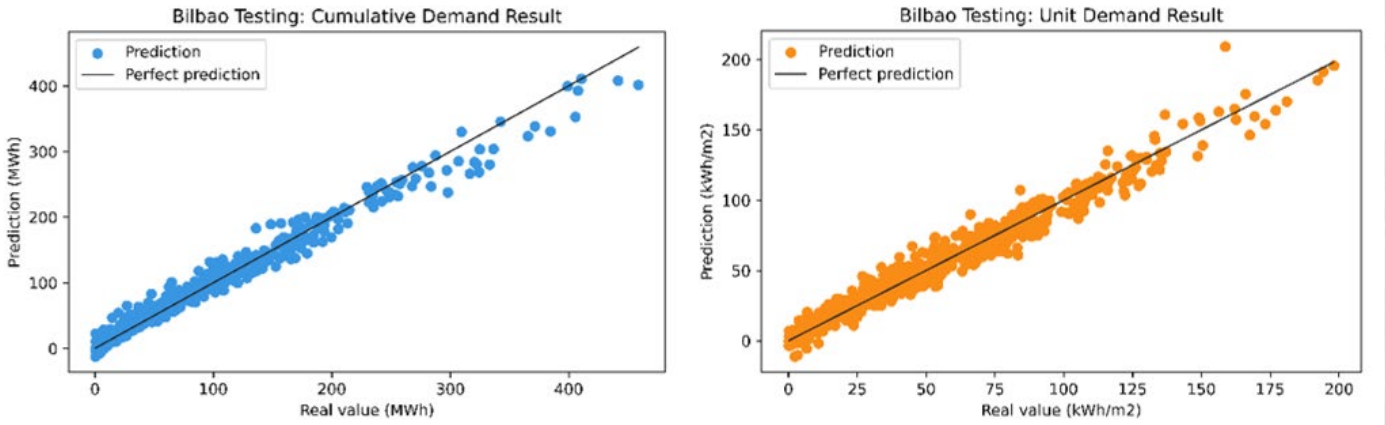
Sources

SEDE ELECTRÓNICA DEL CATASTRO

3. EnePoMAP methodology

Energy Efficiency



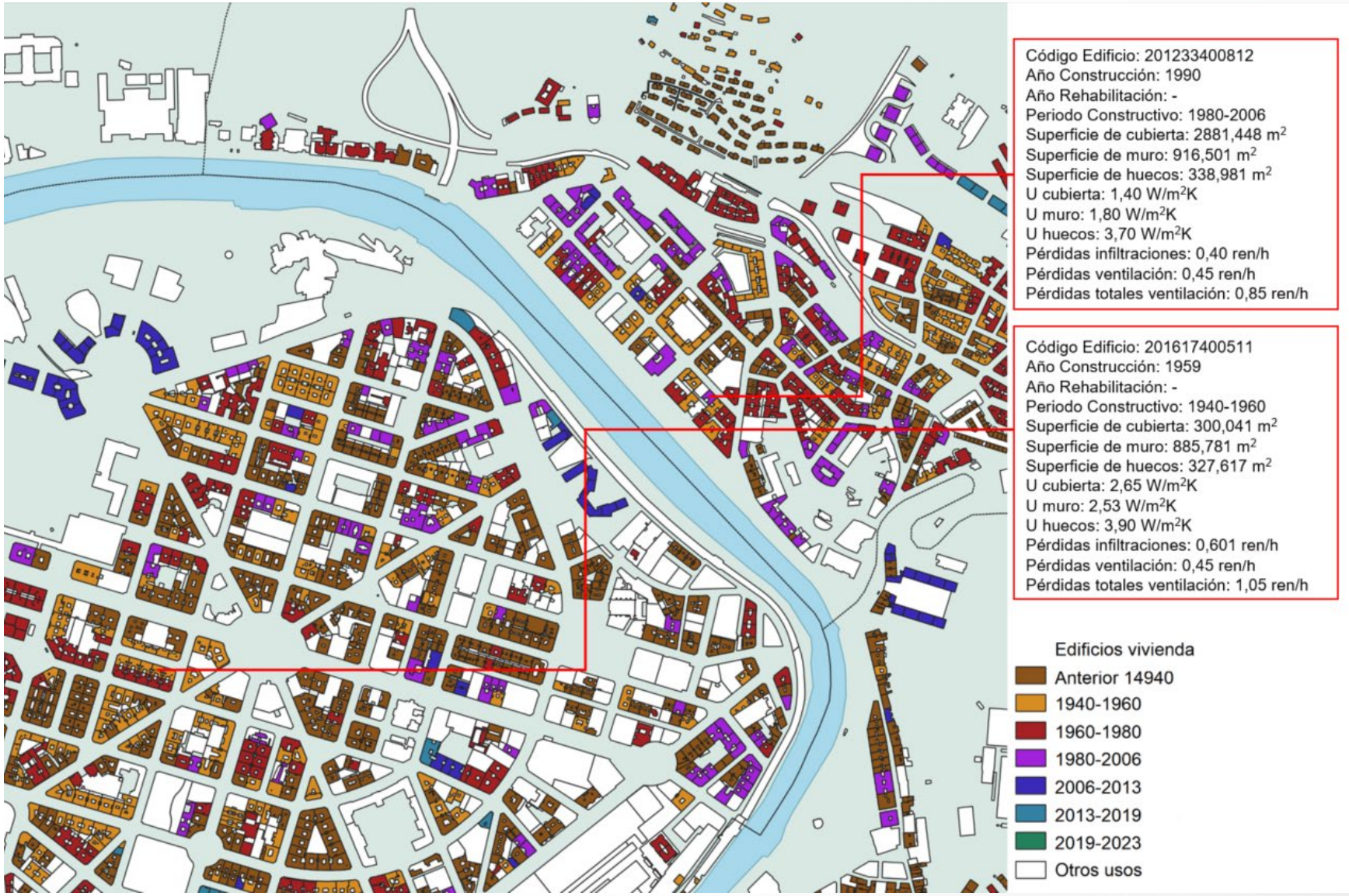


SMACCs Master Thesis (2023): Forecasting Residential Heating Demand, Leveraging Modern Machine Learning Approach and Conventional Degree Days Method

Felicia A. Satriya

Supervised by C. Berberidis (IHU), J. Terés Zubiaga (UPV/EHU), K. Martín Escudero (ENEDI – UPV/EHU)

3. EnePoMAP methodology



Energy Efficiency

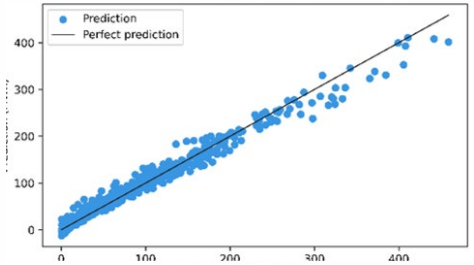
Geometric and thermal characterization of buildings at urban scale based on open data

Cristina Villanueva Díaz, Milagros Álvarez Sanz, Álvaro Campos Celador, Jon Terés Zubiaga

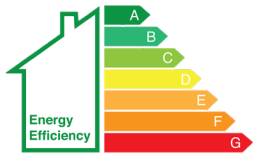
14th International Conference on Energy Efficiency and Sustainability in Architecture and Urbanism (EESAP 14). 2023

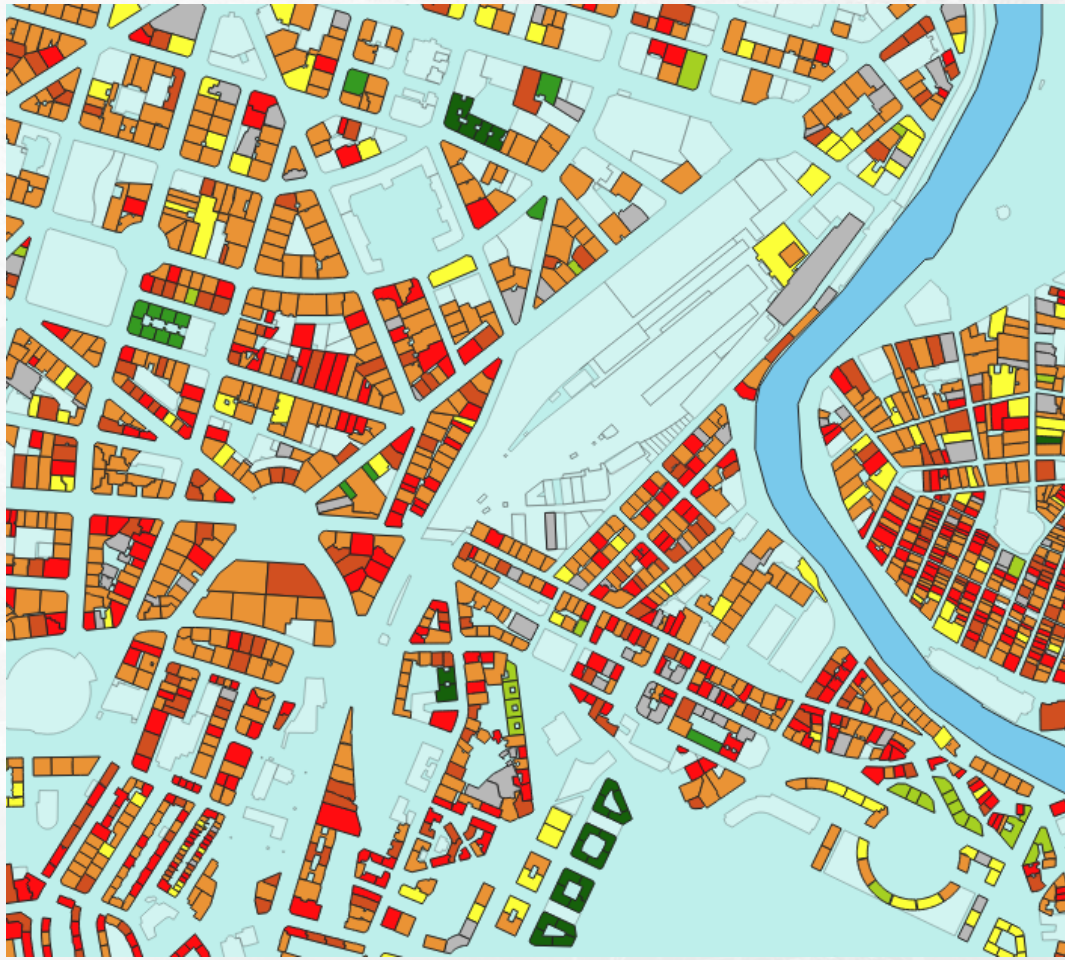
3. EnePoMAP methodology

Energy Efficiency



Sede Electrónica del Catastro



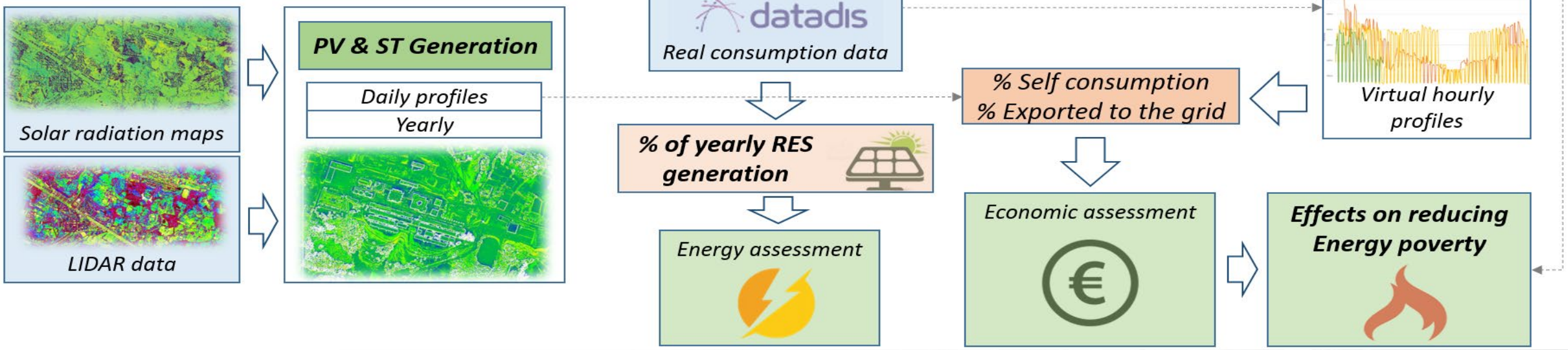


Stage 3.

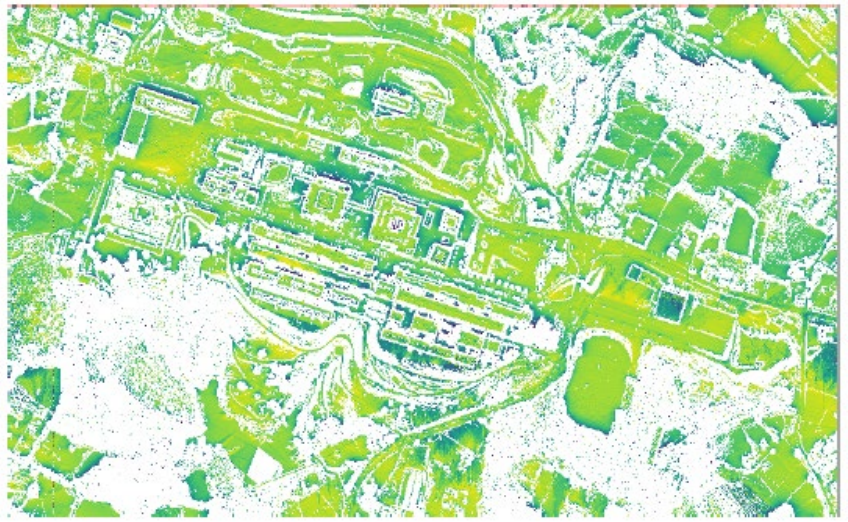
RES implementation

3. EnePoMAP methodology

RES implement



3. EnePoMAP methodology



RES implement

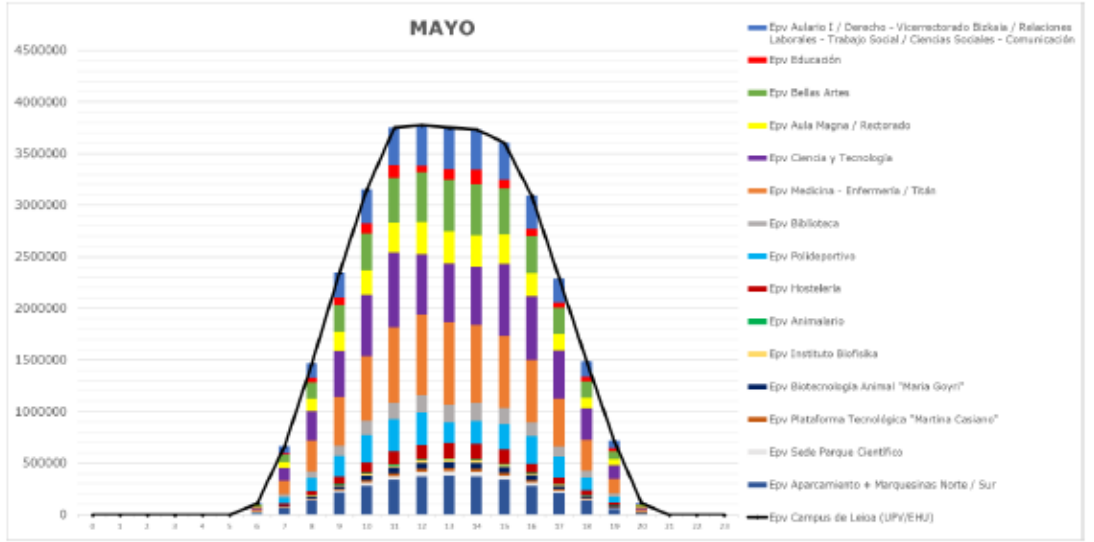


Imagen 4-7. Producción horaria para el mes de mayo, por zonas o facultades [Wh].

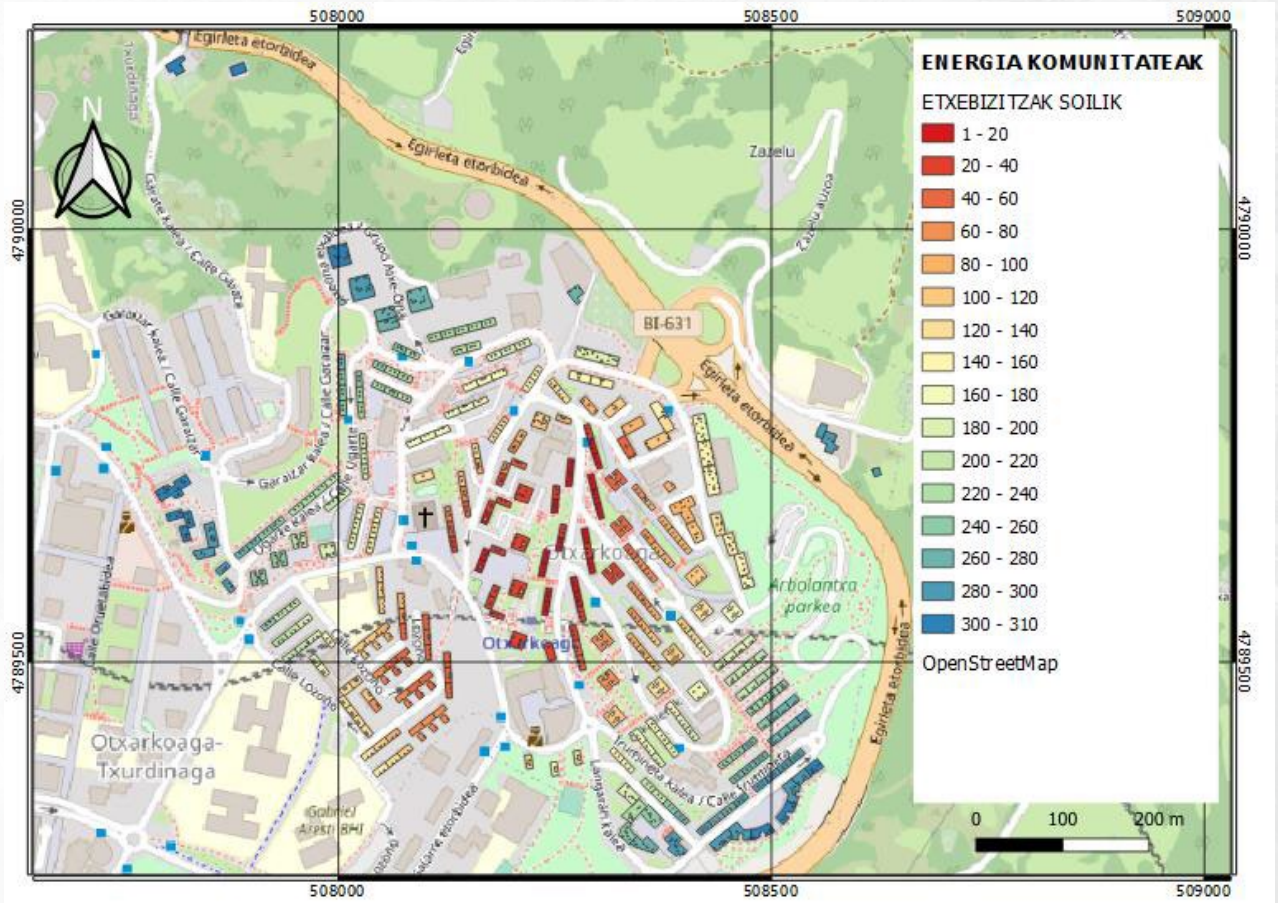
Master Thesis (2020): Potencial Tecnoeconómico de energía fotovoltaica en el Campus de Leioa de la UPV/EHU

Danel de Prado Requena

Á. Campos-Celador (UPV/EHU), J. Terés Zubiaga (UPV/EHU)

3. EnePoMAP methodology

RES implement



Master Thesis (2021): Auzo Mailako partekatutako autokonsumo potentzialaren azterketa

Aratz Errementeria Nikolas

Á. Campos-Celador (UPV/EHU), J. Terés Zubiaga (UPV/EHU)

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FACULTY OF ENGINEERING BILBAO
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3rd SMACCs Summer School

Thessaloniki, Greece

Models & public data: calculating building energy needs at regional level using public databases

PhD Jon Terés-Zubiaga

Department of Energy Engineering

University of the Basque Country

MSc in Smart Cities and Communities

SMACCs

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