Progetto PNRR PE9 (GRINS) - WP2

# Calculating the energy consumption of the Italian residential building stock: a bottom-up modeling approach

**Jacopo Vivian**, Angelo Zarrella

Legnaro (Padova), 22/9/2023

# Intro

## The most famous sentence in building science

**1. Introduction**

In recent years, an increasing number of countries have committed themselves not just to reducing greenhouse gas emissions, but rather to completely avoid them from 2050 (EU) or 2060 (China). This tightening of the climate targets has far-reaching consequences since all sectors have to drive their emissions towards zero. Especially in the building sector, which accounts for 36% of $CO_2$ emissions in the EU (19% worldwide; IPCC 2014), decarbonization is a challenge. In the residential building sector, this is since living space and thus the building-related energy consumption are continuously increasing. Furthermore, due to their long lifespan, 70–80% of the buildi
climate-neutral by 2050 have already been built and
climate-neutral technologies.

[source: Geske, Energy Economics, 2022]

**1. Introduction**

Buildings are responsible for approximately 40% of the energy consumption of the European Union (EU) [1]. Residential buildings in particular accounted for 27% of the final energy consumption of the EU in 2020 [2]. Consequently, in recent years, the EU is making great efforts to decrease energy consumption and improve the energy efficiency of buildings [3,4].

The scientific community has also focused significantly on quantifying the energy consumption of buildings and analysing the causes of high energy consumption in households. The actual energy consumption

[source: Hernandez-Cruz et al, Energy & Buildings, 2023]

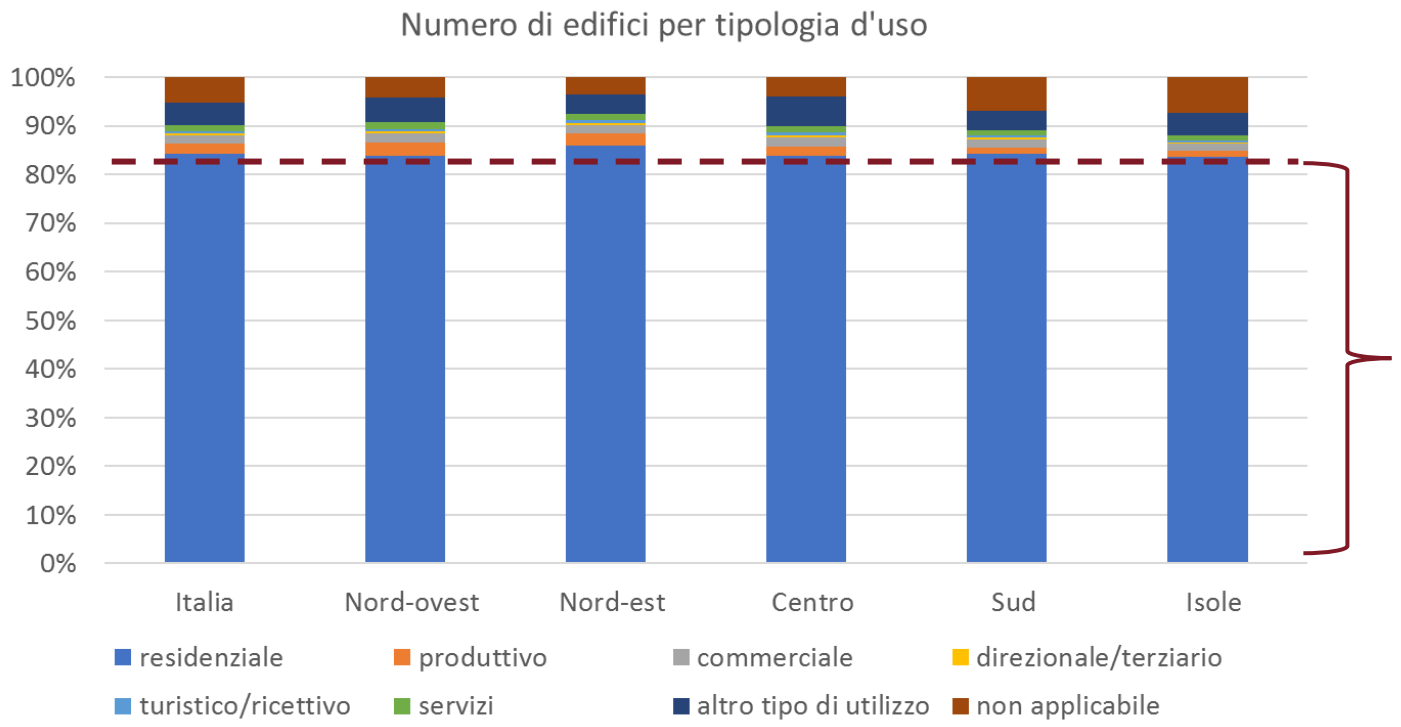
**1. Introduction**

The building sector accounts for approximately 40 % of energy consumption, 36 % of carbon dioxide emission [1], and 50 % of electricity demand [2] in the world. In China, buildings are responsible for 25 % of the national energy demand [3]. Enhancing energy efficiency, especially of existing buildings, has become an imperative for the architecture, engineering, and construction (AEC) industries to achieve green development goals. Although most building energy consumption occurs during the operation phase to maintain indoor thermal environments [4] and provide
ces [5], the energy efficiency is mainly

[source: Li et al, Energy, 2021]

# Context

## Italian buildings in numbers



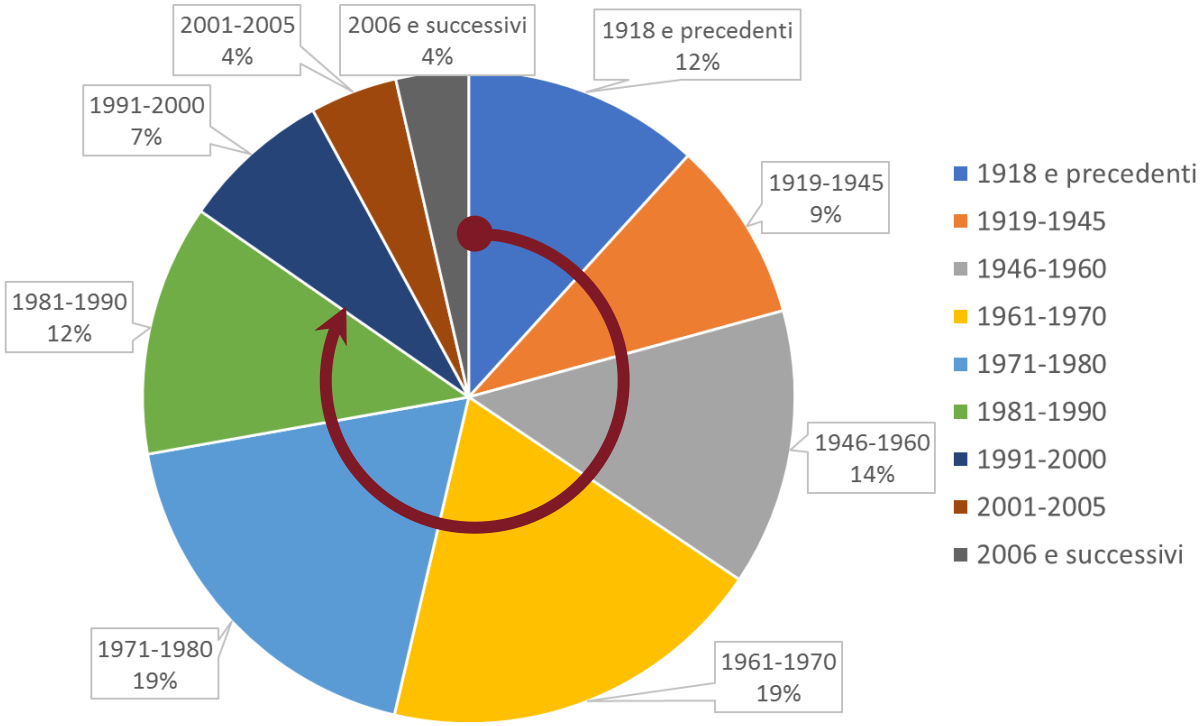

On average, **residential buildings** account for approximately **80%** of the national building stock.

The building stock consists of approx. **12 million buildings**, reaching more than **24 million residential units**. (ISTAT 2011)

Among those, 836 000 belong to the **public housing stock (approx. 3.5%).**

# Context

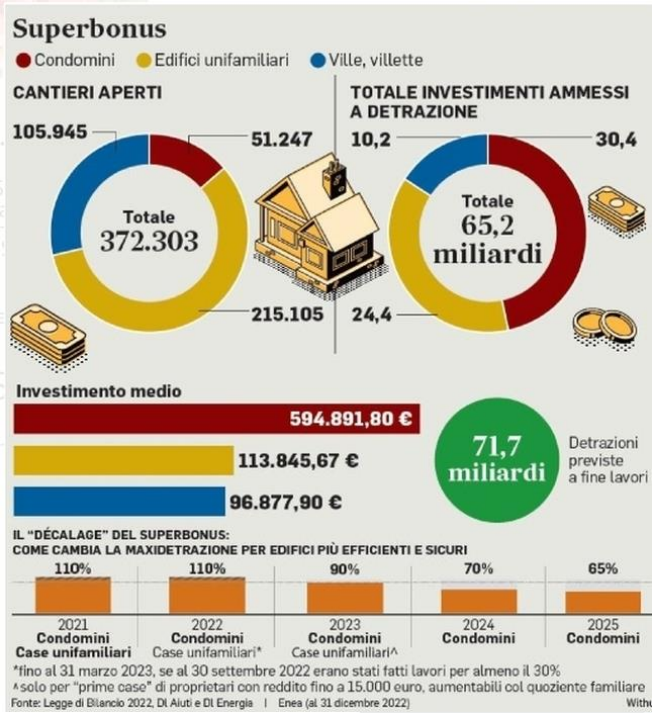
## Italian buildings in numbers




Most buildings (approx. 85%) was built before Legge 10/1991 (ISTAT 2011).

# Context

## Energy efficiency in buildings: controversial policies?




[source: www.ilgazzettino.it, Feb 2023]

**Approvata la direttiva europea "case green", ecco cosa prevede**

**15 marzo 2023**

Arriva dal **Parlamento europeo** il via libera alla **direttiva Ue sulle "case green":** il provvedimento avanzato dalla Commissione europea per **migliorare le performance energetiche degli edifici** inserito nel pacchetto di riforme Fit for 55.
Il testo della direttiva **Energy performance of building directive (Epbd)** – nato con la mission di riqualificare il parco immobiliare dell'Ue e migliorarne l'efficienza energetica - potrà subire modifiche rispetto a quelle già registrate prima di diventare definitivo.

L'obiettivo del provvedimento è di **agire in modo prioritario sul 15% degli edifici più energivori per ogni stato membro,** collocati nella classe energetica G (la più bassa).

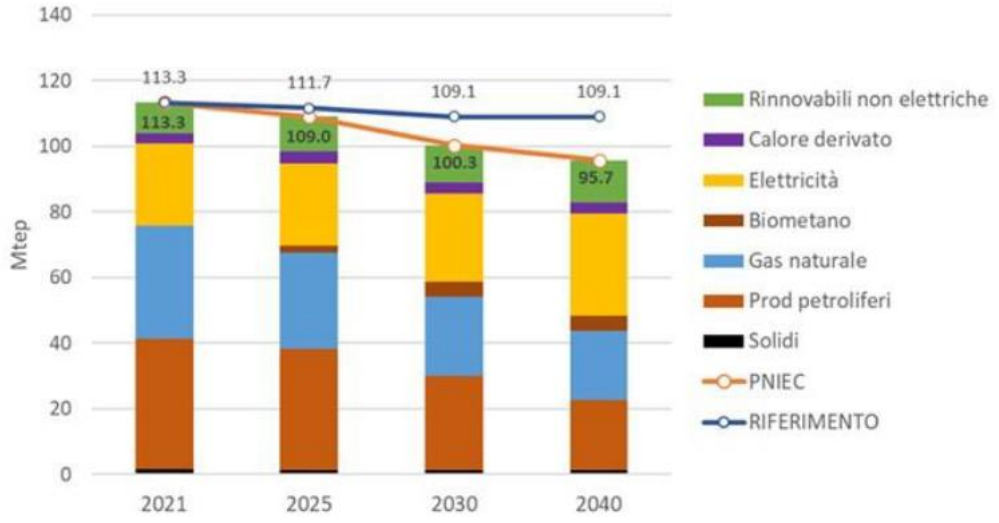
# Objectives

The **main objective** is to develop a tool to help evaluate building-related energy policy choices on a national level.

## Research questions

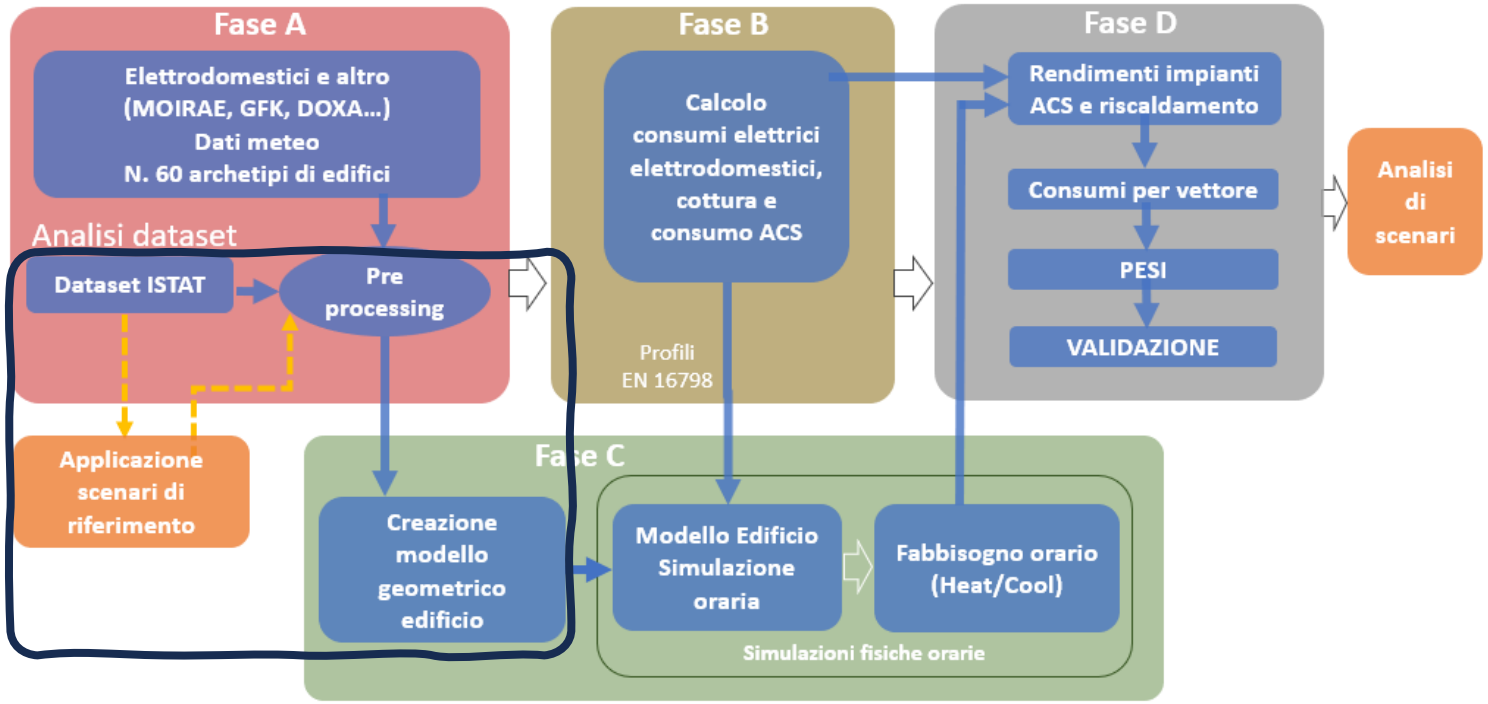
- How much do residential buildings contribute to the **national energy consumptions and emissions**?
- To what extent will **climate change** and **user habits** affect such energy consumption and emissions?
- To what extent do current and future **energy policies** (e.g., different incentives on building retrofits) help reduce such energy consumption and emissions and achieve **energy efficiency targets**?

Figura 92 - Evoluzione dei consumi finali per fonte al 2040 [Fonte: RSE]



# Methods

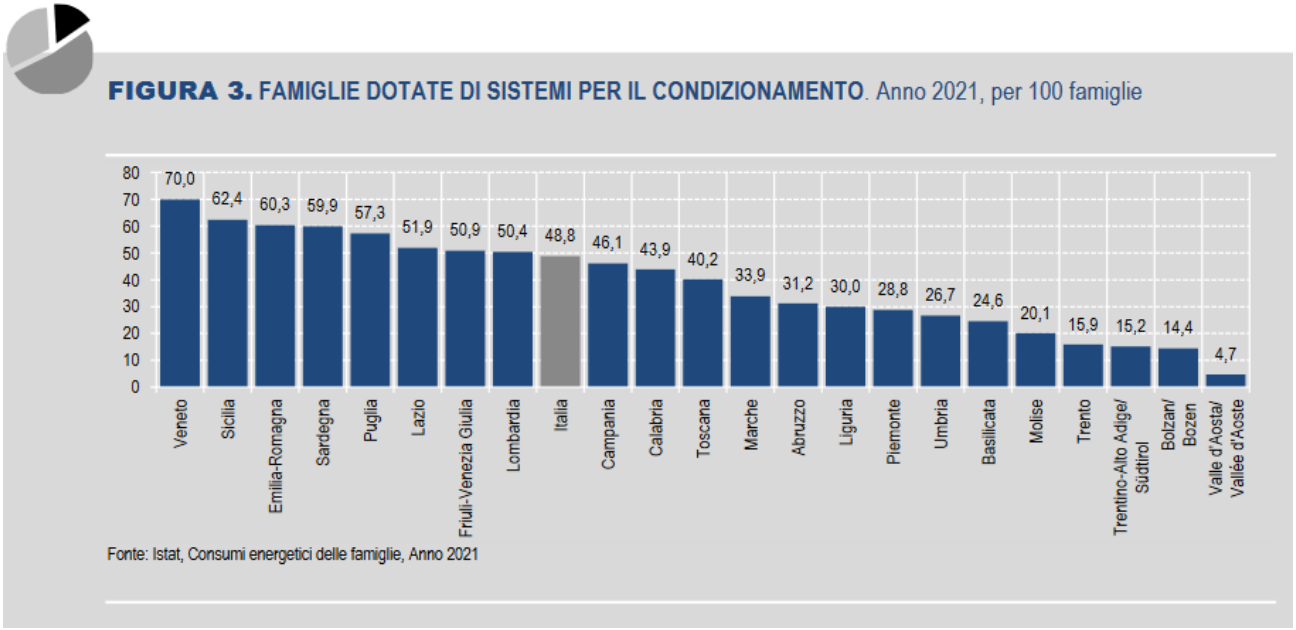
A physics-based, **bottom-up modelling approach**



# Methods

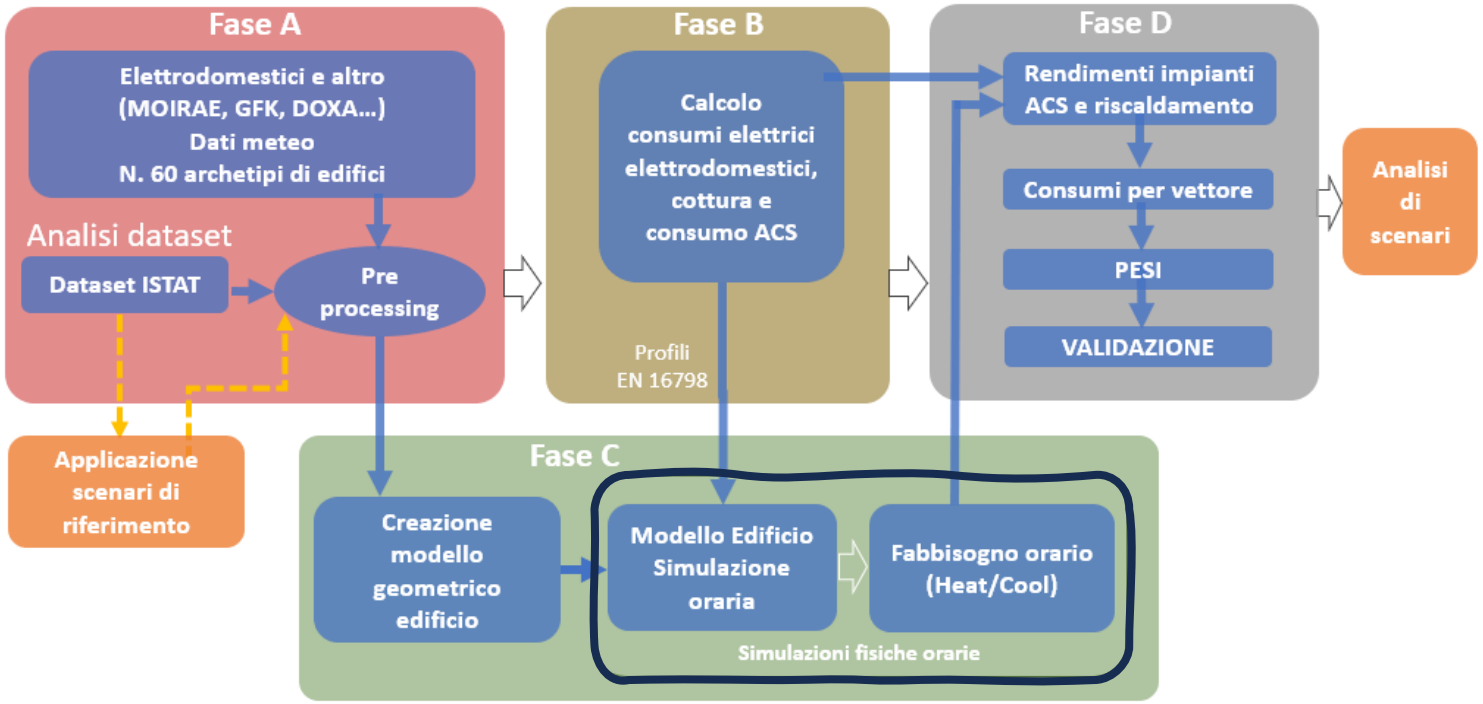
## A physics-based, **bottom-up modelling approach**

A survey from ISTAT on a representative sample of more than 54.000 «families» distributed among regions according to the population.



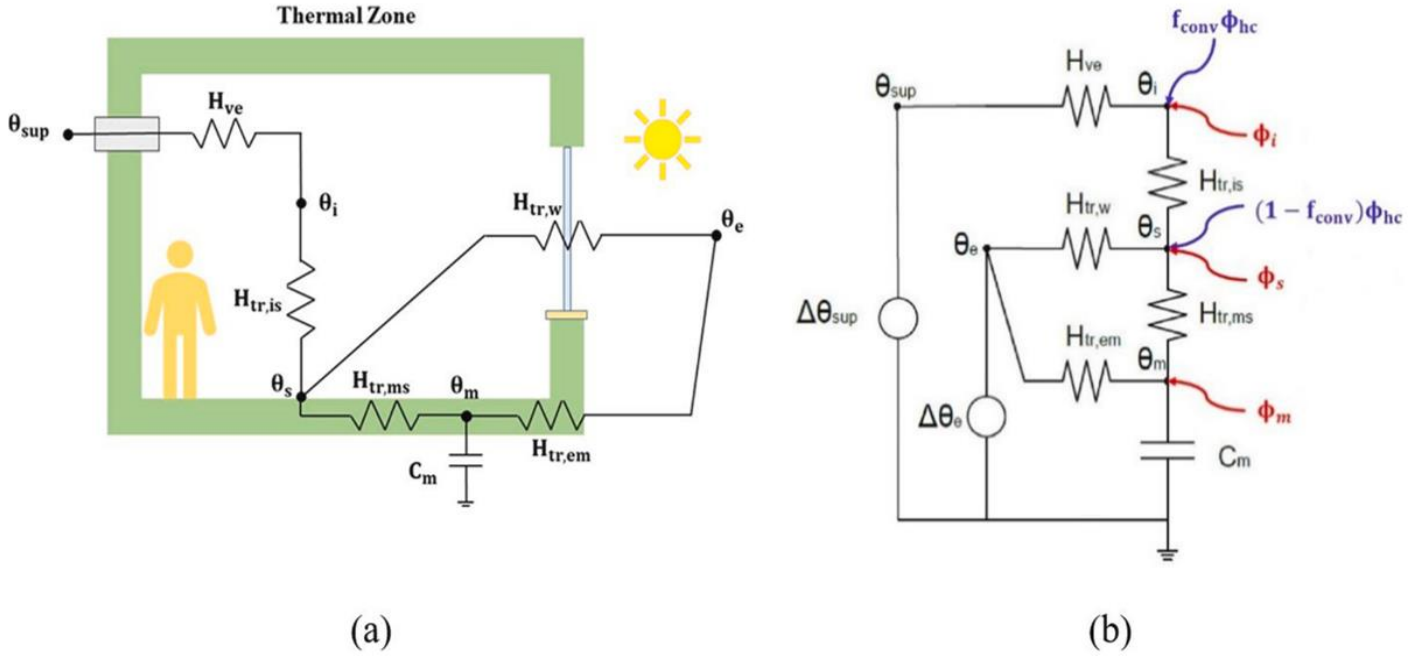
# Methods

## A physics-based, bottom-up modelling approach



# Methods

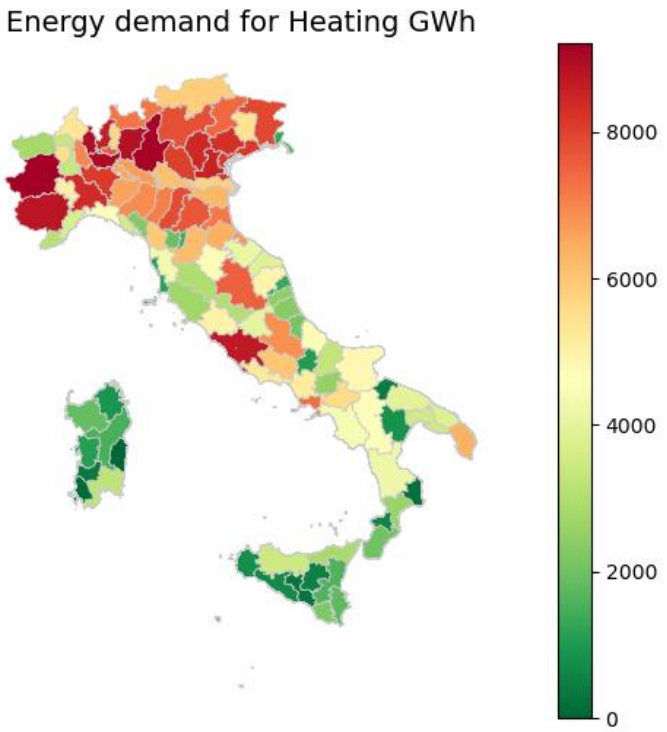
## A physics-based, bottom-up modelling approach

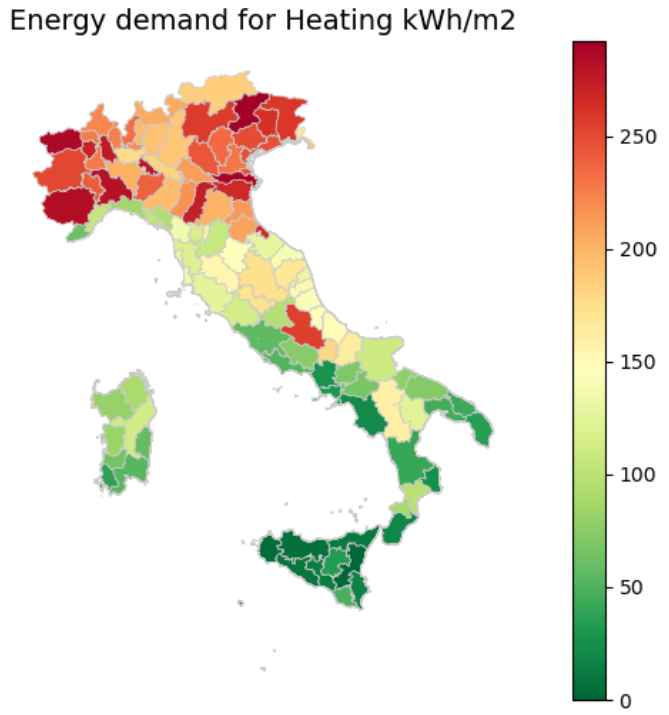



5R1C Model from ISO 13790: (a) representation of the building's energy balance, (b) equivalent thermal network based on the electrical analogy [source: Prataviera et al, 2020]

# Preliminary results

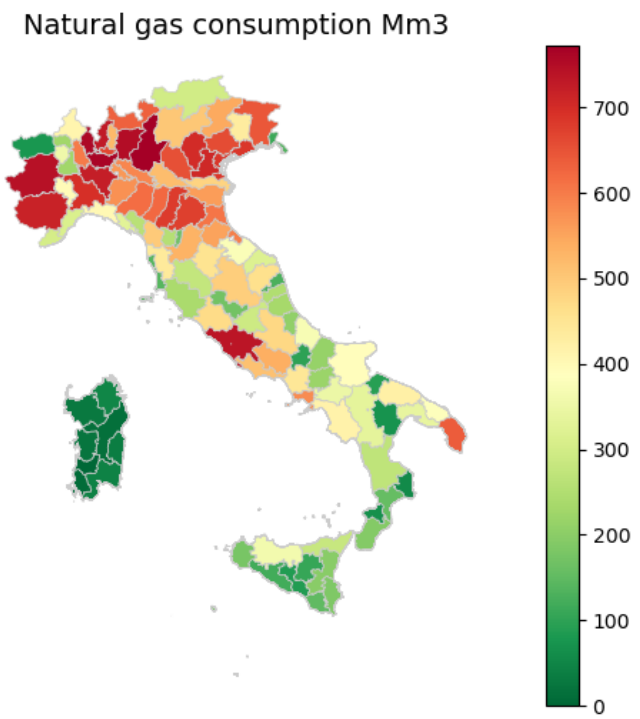
Energy end use for space heating, cooling, DHW, cooking, lighting, other electrical appliances

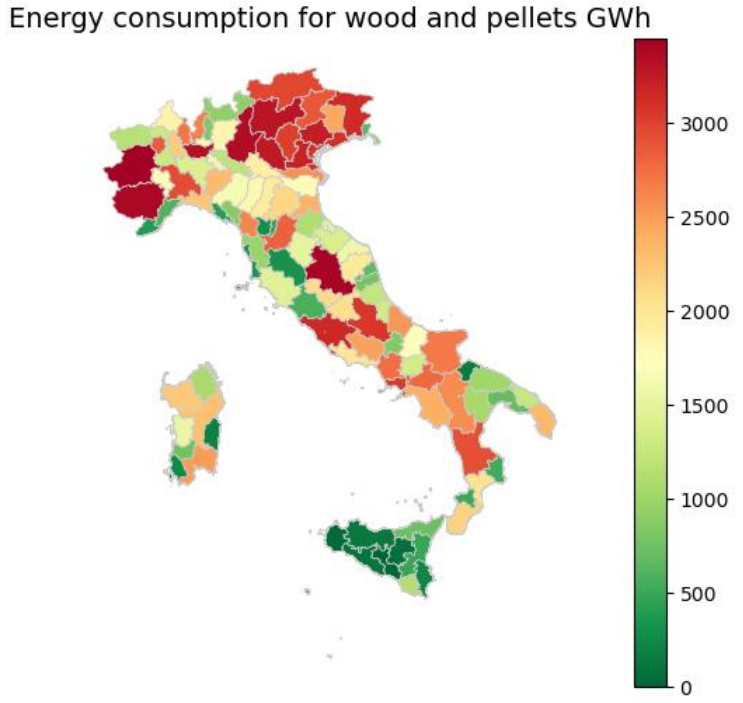


# Preliminary results

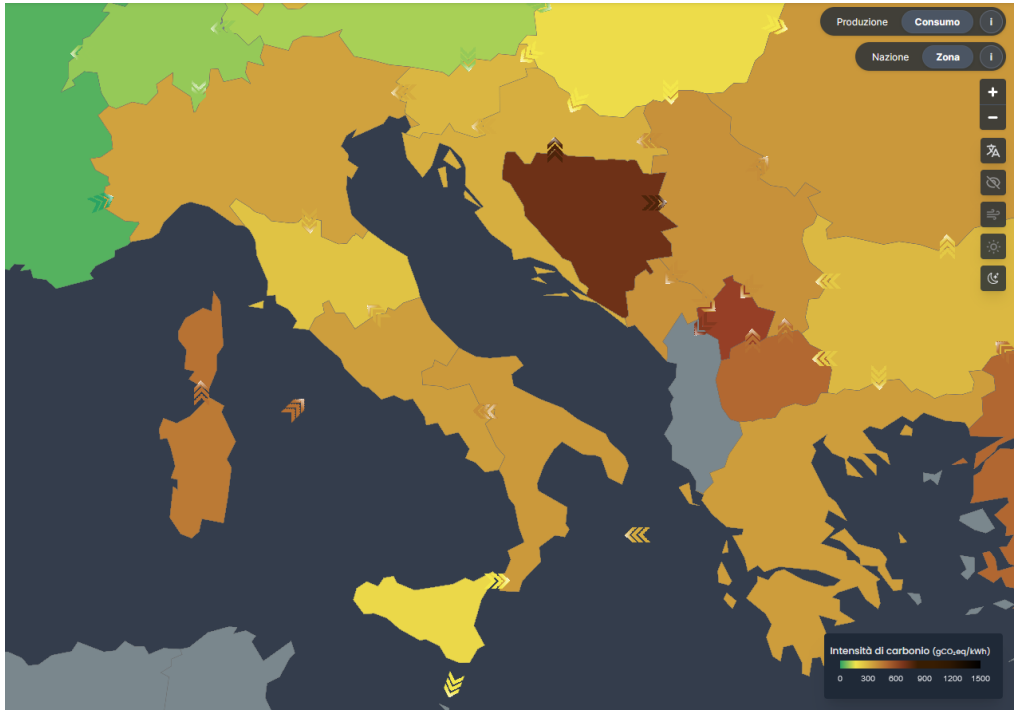
Energy consumption from different energy carriers

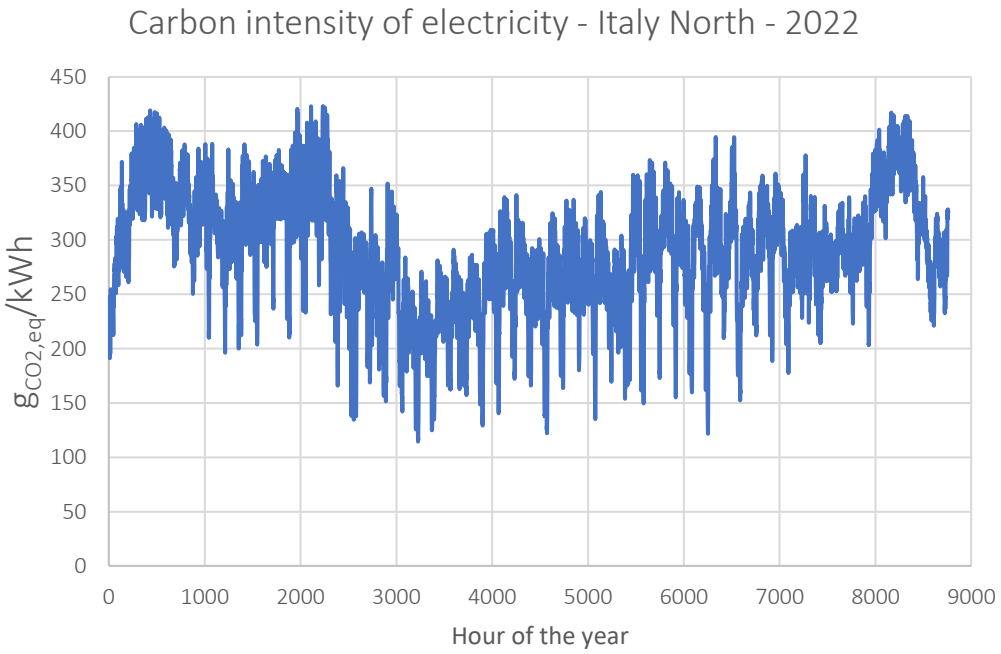


# A note

GHG and pollutant emissions: why are both time and space important?

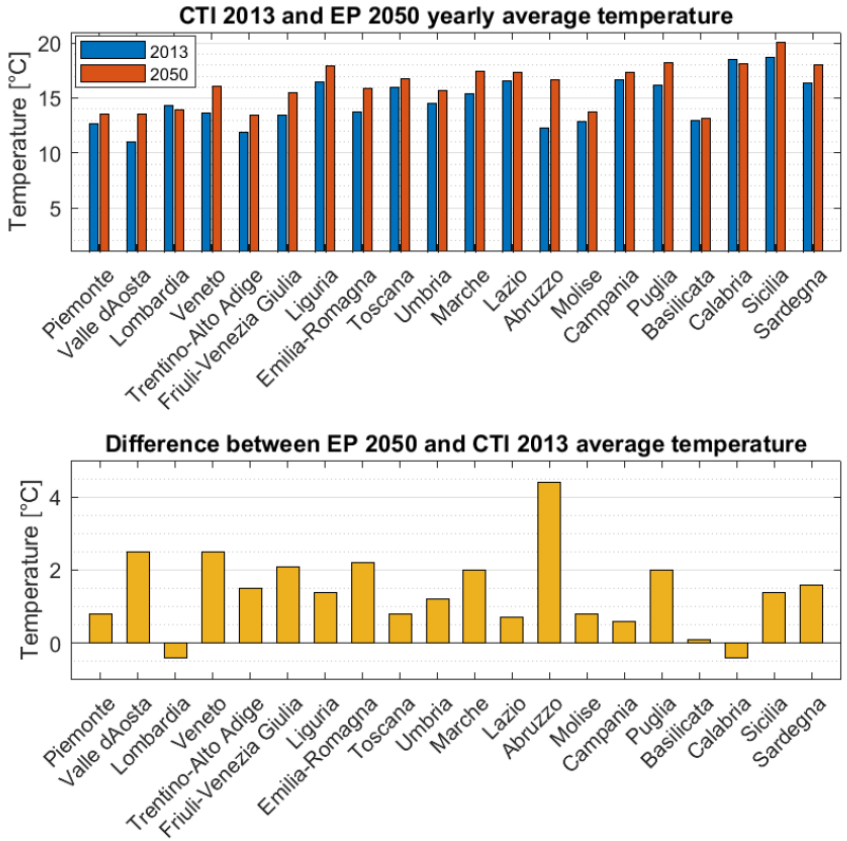


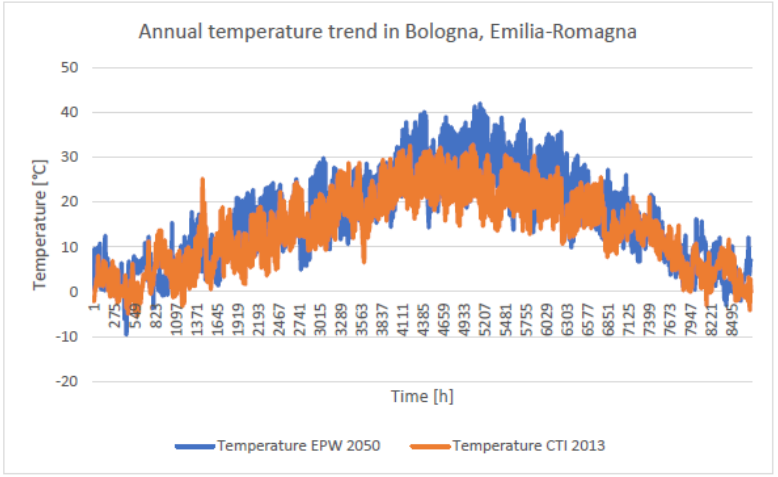




[source: Electricity Maps, 2023]

# Expected results

## Impact of climate change



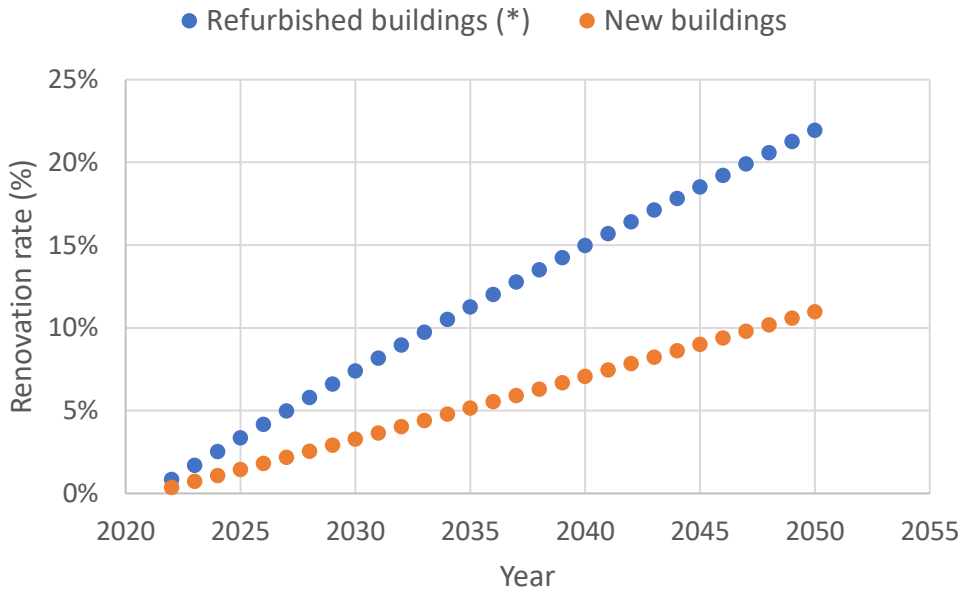




ure 4.7: Annual trend of external temperature in Bologna, Emilia-Romagna, of 2013 and 2050 climatic data.

[source: Gaudino F., 2023]

# Expected results

## Impact of energy retrofit policies




(*) source: STREPIN – STrategia per la Riqualificazione Energetica del Parco Immobiliare Nazionale, 2020

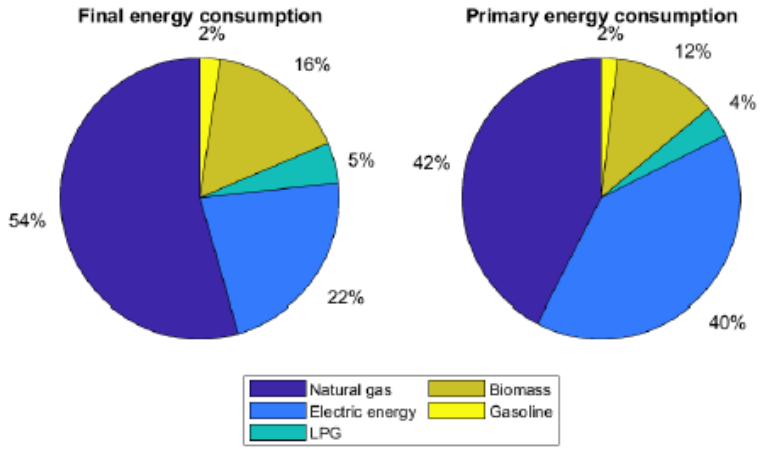



Figure 4.8: Share of energy vector on final and primary energy consumption for the scenario of building envelopes and heating systems retrofits.

[source: Gaudino F., 2023]

# Expected results

## Impact of user habits

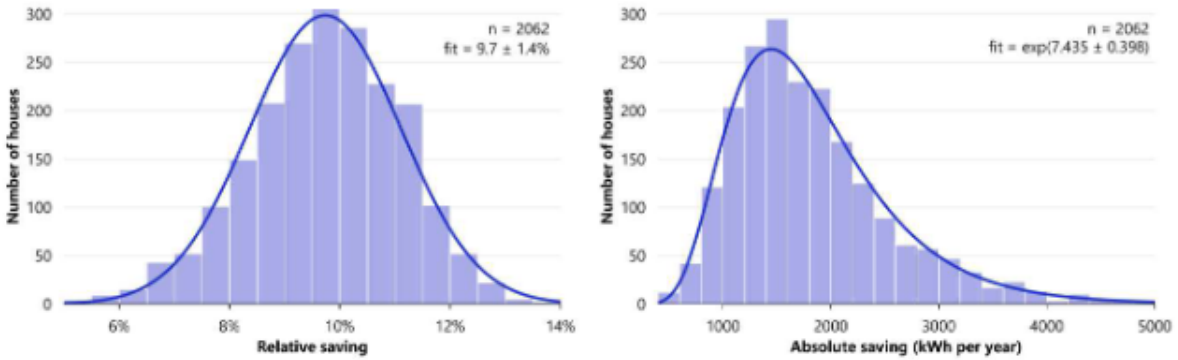
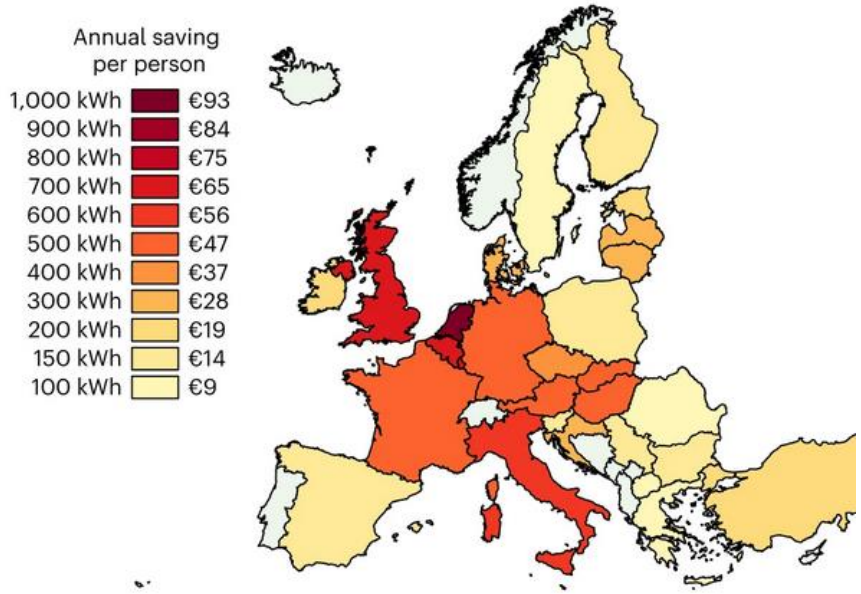



*Figure 5: The impact of turning down the thermostat by 1°C in individual houses. Top panel shows the change in daily gas consumption over one year (2009–10) in a randomly selected British house. Bottom panels show the gas saving across the whole population of houses with gas metering in the EDRP dataset [36], relative to total gas consumption in each house (bottom left) and in absolute terms (bottom right).*




[source: Staffel et al , Nature Energy, 2023]

# Thank you for your attention!

Contact

jacopo.vivian@unipd.it