Decarbonization of residential thermal consumption

Project Summary

July 2024

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Current context and objectives

Current context

European context	The EU Directive (EPBD) stipulates that the **average primary energy consumption** of the entire residential building stock must **decrease** by **16% compared to 2020** levels **by 2030**
Italian context	The **Italian PNIEC** outlines the development of policies aimed at **decarbonizing the residential sector**, promoting **energy efficiency** and the **electrification of final energy consumption**, with the goal of reducing the sector's consumption by 17% by 2030 (compared to 2021 levels)
Challenges of electrification	The electrification of the residential sector entails **technical, social and economic challenges**, requiring the **analysis** of the **specific characteristics of each housing context** to provide technologically feasible and affordable solutions for consumers

Objective of the study:

Identify viable decarbonization solutions for the Italian residential sector considering the housing, socio-demographic and economic situation

Methodology

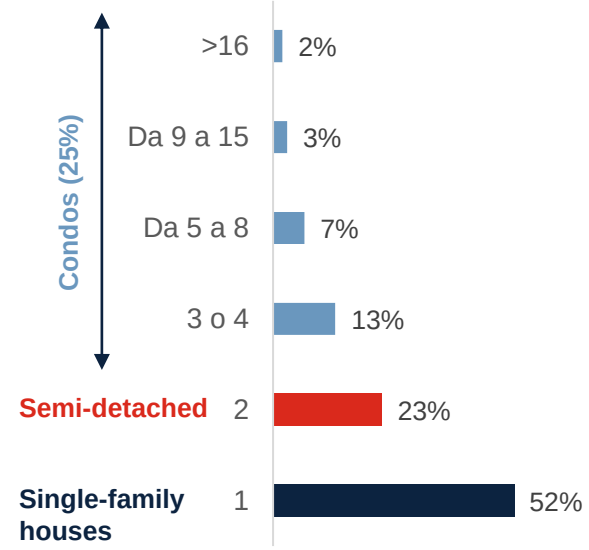
- Analysis of the **characteristics** and **conditions** of the **Italian housing stock**, with a focus on heating systems and current energy performance
- Analysis of the **socio-demographic characteristics** of the Italian population highlighting age, income and financial resources
- Analysis of the **installers' supply chain to assess its capacity** to handle a growing demand for heat pump installations
- **Technical and economic evaluation** of the **different technologies** aimed at highlighting technical performance and economic competitiveness
- Assess the **actual readiness** of the national context for the **technological switch** and identify **potential development scenarios** for achieving efficiency and decarbonization goals

In Italy, apartments in condominiums are the most common housing solution and there is a notable age of the residential stock with over 70% exceeding 45 years

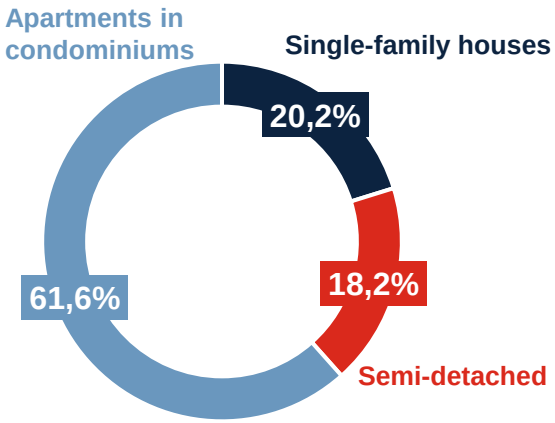
Number of dwellings per building

12 mln of *residential buildings*

Dwellings by building

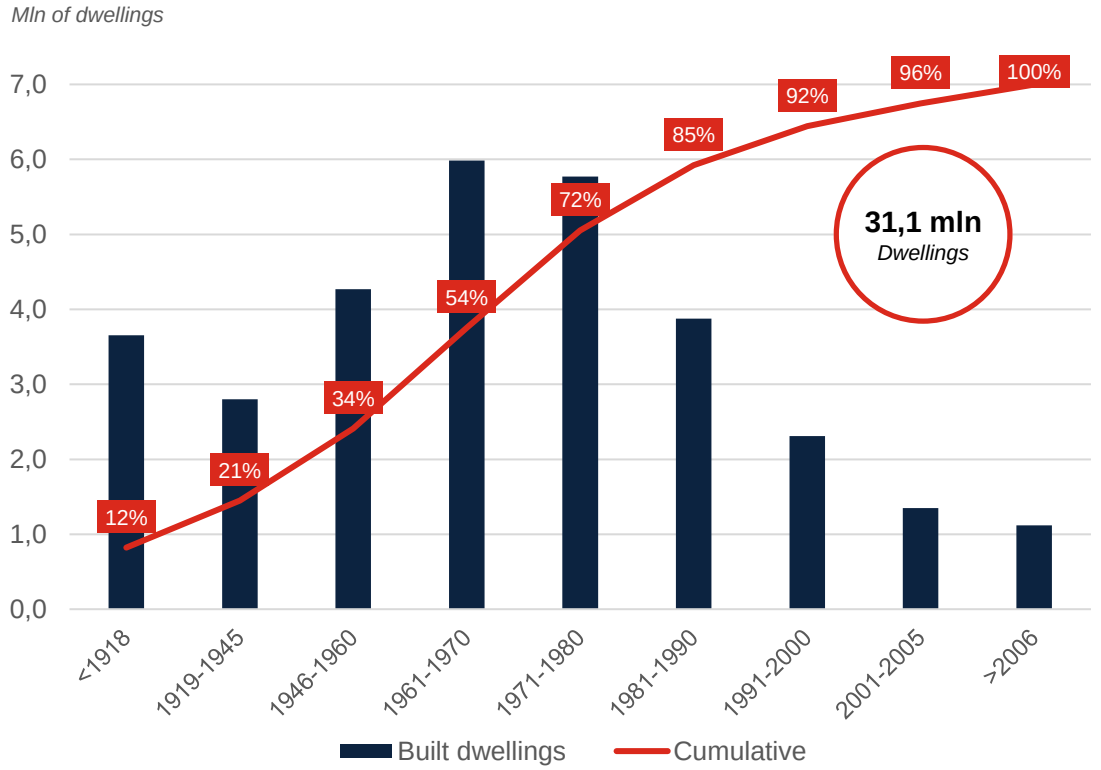


31,1 mln *dwellings*



- **Single-family houses** account for **52% of residential buildings,** however, they represent only **20% of total dwellings**
- **Over 60% of the total dwellings** are situated in **condominiums**, although they represent only 25% of buildings

Dwellings by construction period



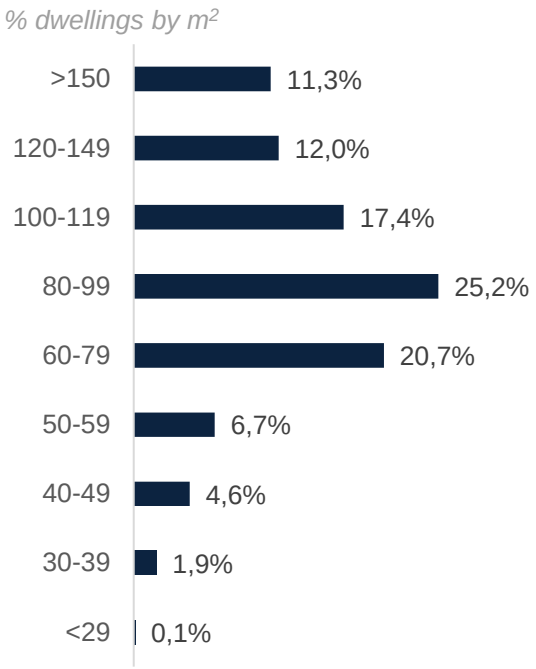
- The Italian housing stock shows a notable age with **over 70% of houses built before 1980** and an **average age** of dwellings that **exceeds 45 years**
- Houses built **after 2000** represent **only 8%** of the total dwellings

Sources: CRESME, TABULA-EPISCOPE, Studio DESTEC, ISTAT

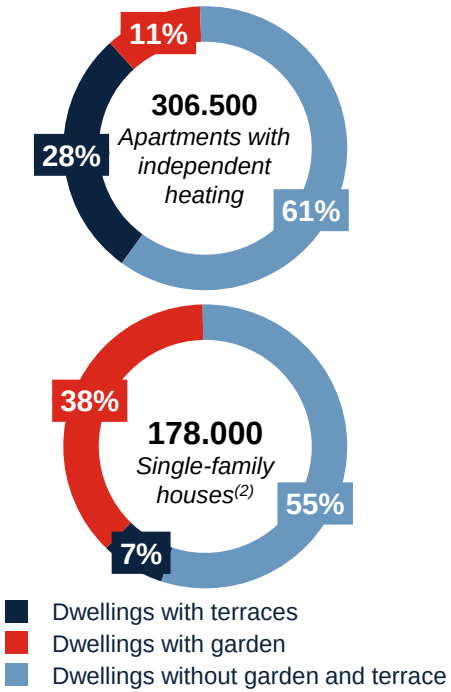
The average dwelling's surface is between 60-100 m² and there is a limited availability of outdoor spaces, about 30% of the dwellings are considered unoccupied or for uncertain use

Housing size and availability of outdoor spaces

Size of the Italian dwellings



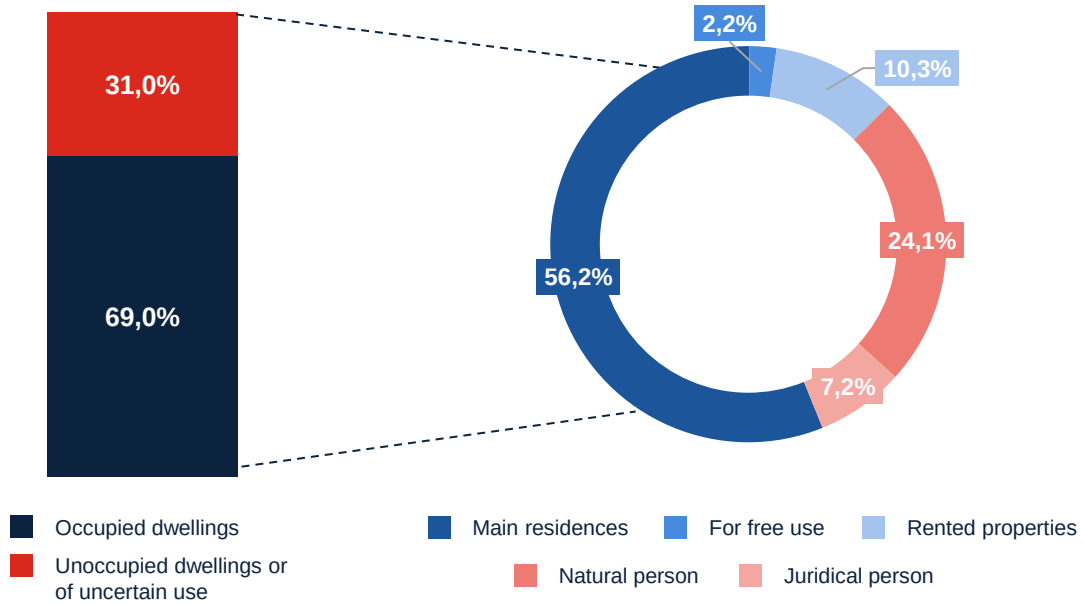
Availability of outdoor spaces emerging from the analysis of the real estate market(1)



- Nearly **60%** of the **dwellings** are under 100 m² in size
- Dwellings in **classes** with a **surface of 60-79 m² and 80-99 m²** are the **most common** in the country with an overall share of **46%**
- Almost **60%** of the **apartments with independent heating do not have a private garden or terrace**(1), the lack of outdoor spaces limits technological alternatives for heating systems(3)

Housing occupancy status - 2020

% of dwellings



- **Permanently occupied dwellings** account for **70%,** while the remaining **30%** is designated for **non-permanent of uncertain use**
- Properties used as **main residences** account for about **56%** of the **housing stock**
- The **willingness to invest** in decarbonization solutions will be **lower** for **secondary dwellings** (e.g. second homes, rented properties)

Sources: CRESME, TABULA-EPISCOPE, Studio DESTEC, database ISTAT, Agenzia delle Entrate – Gli immobili in Italia (2023)

(1) The availability of a suitable space to install heat pumps was verified based on an analysis performed on a sample of 484,500 homes with independent heating,

(2) Includes detached houses, cottages and townhouses

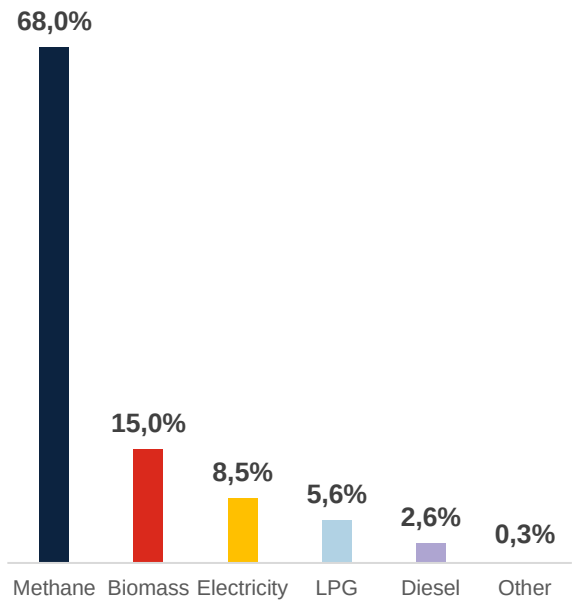
(3) In the case of central heating, which may not be convertible to heat pumps due to space restrictions

Natural gas fuel, independent heating and radiators are the most frequent technical solutions, moreover, DHW is often produced by the heating systems themselves

Heating systems

Prevailing heating system

% of dwellings



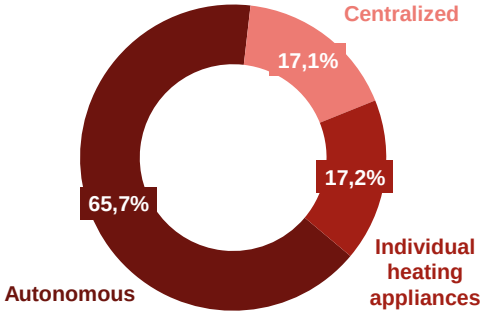
Heat Transfer System

% of dwellings in the sample

91,7%
radiators(1)

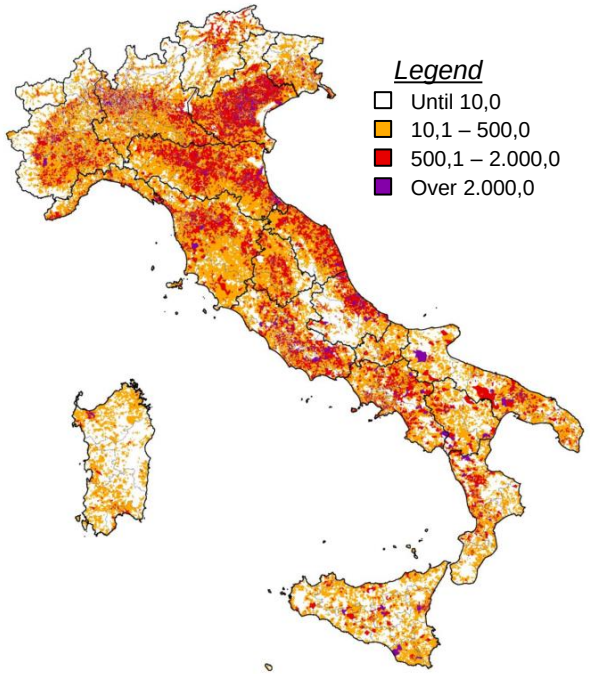
Heat Distribution System

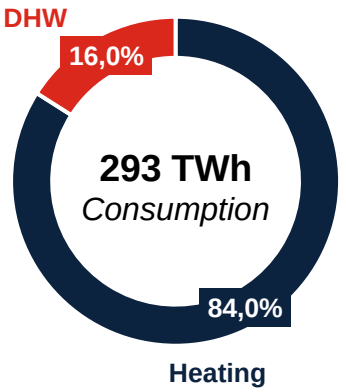
% of dwellings



Residential heating and DHW need and consumption – 2018

MWh





In **69%** of instances, domestic hot water is generated directly by the heating system

- **Natural gas** is the **heating source** for almost **70%** of **households**
- **Independent heating** is the most frequent heat distribution system (**66%**)
- **Radiators** emerge as the **main heat transfer system** (**92%**)
- Approximately **69%** of the **heating systems** are utilized to generate **domestic hot water** (**DHW**)

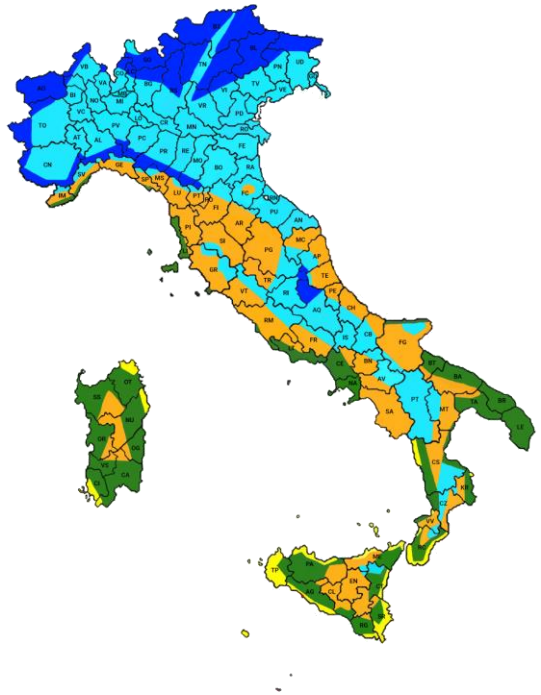
- **Heating** is the **predominant consumption** component in the **residential sector**, with an **84%** share over a total consumption of approximately **293 TWh**
- **Consumption** is mostly located in the **North**, with **Lombardy**, **Piedmont** and **Veneto** (**41% of total consumption**) emerging as the most energy-intensive regions

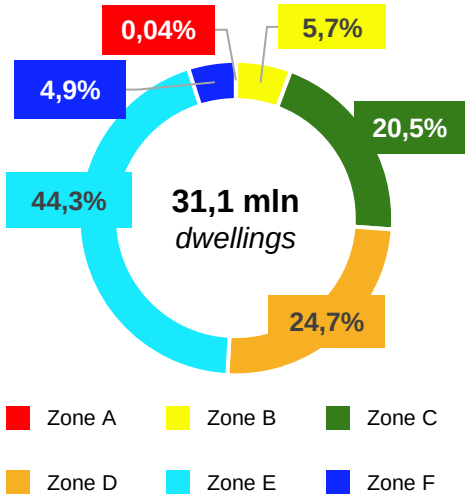
Sources: CRESME, TABULA-EPISCOPE, Studio DESTEC, database ISTAT, Valutazione del potenziale nazionale e regionale del riscaldamento efficiente (GSE, 2021)
(1) Systems designed to operate at high flow temperatures, typical of gas boilers

Over 50% of dwellings are situated in cold areas with over 2.100 degree-days, moreover, 50% of homes belong to the worst energy classes (F – G)

Breakdown of the residential housing stock by climate zone

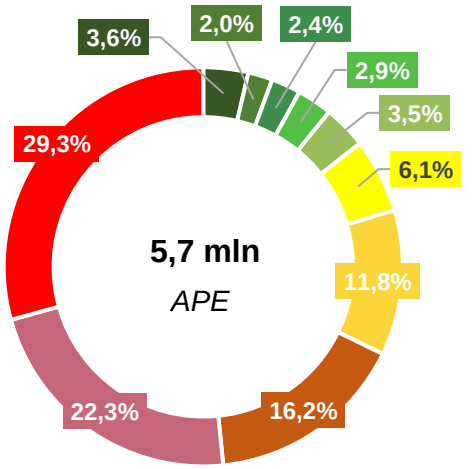
Mln of dwellings





Energy classes[1] on a national basis

% of dwellings



18,2% *Relevance of the certified sample on the total number of residential dwellings*

Energy class	Specific consumption (kWh/m^2)
A4	$EP_{gl,nren} \leq 0,4$
A3	$0,4 < EP_{gl,nren} \leq 0,6$
A2	$0,6 < EP_{gl,nren} \leq 0,8$
A1	$0,8 < EP_{gl,nren} \leq 1,0$
B	$1,0 < EP_{gl,nren} \leq 1,2$
C	$1,2 < EP_{gl,nren} \leq 1,5$
D	$1,5 < EP_{gl,nren} \leq 2,0$
E	$2,0 < EP_{gl,nren} \leq 2,6$
F	$2,6 < EP_{gl,nren} \leq 3,5$
G	$EP_{gl,nren} > 3,5$

The values from the Energy Performance Certificate (APE) appear overestimated compared to the real consumption values due to the actual usage conditions and energy performance calculation algorithms

- **50%** of dwellings are situated in **climatic zones** experiencing **more than 2,100 degree-days** per year (**zones E – F**), characterized by a **greater number** of **operating hours** for heating systems
- Homes in **medium-temperate zones** (**zones C – D**) account for almost **45%**

- In the analyzed sample, **80%** of the **dwellings** have an **energy class lower than or equal to D,** where **50%** belongs to the **worst energy classes** (**F-G**)
- For the residential sector, the **EPBD Directive** anticipates a **16% reduction** in the **average primary energy consumption by 2030**, compared to 2020 values (**55%** achievable through the **renovation of 43%** of the **buildings** with the **worst performance**)

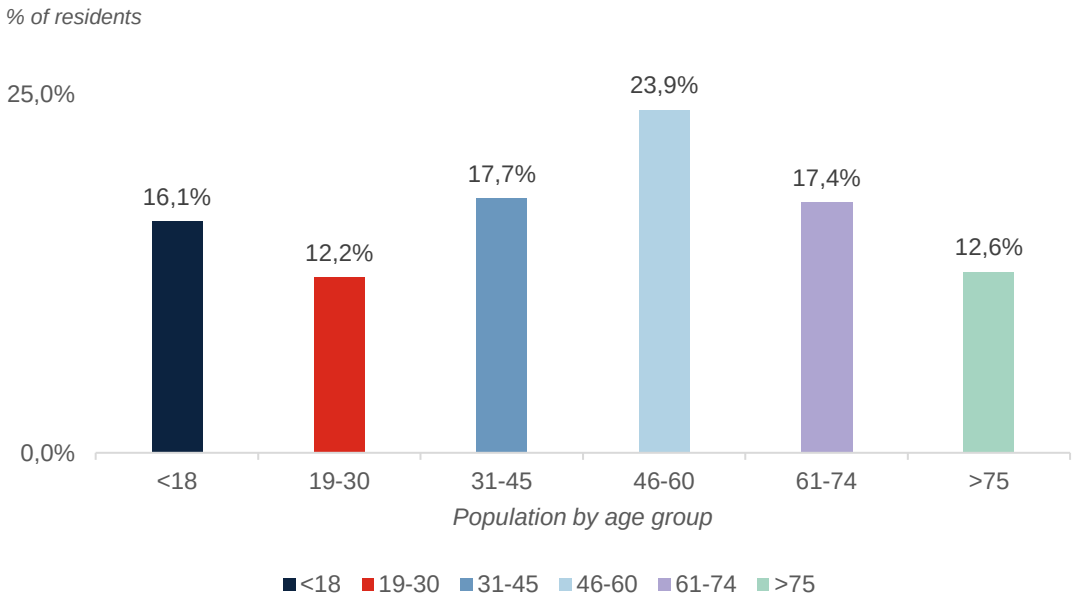
Sources: portale SIAPE-ENEA, Rapporto annuale sulla certificazione energetica degli edifici 2023 (ENEA), D.M. 6 agosto 1994 – Allegato A, Art. 4 del Decreto 16 Aprile 2013

[1] Defined with the Global Energy Performance Index in the non-renewable component (Epgl,nren). It constitutes information on the thermal insulation of the building and the energy dissipated

In Italy, the aging rate is significant, as over 30% of the population is aged over 60 years old, 58% of Italians live in owned properties, owned largely by elder people

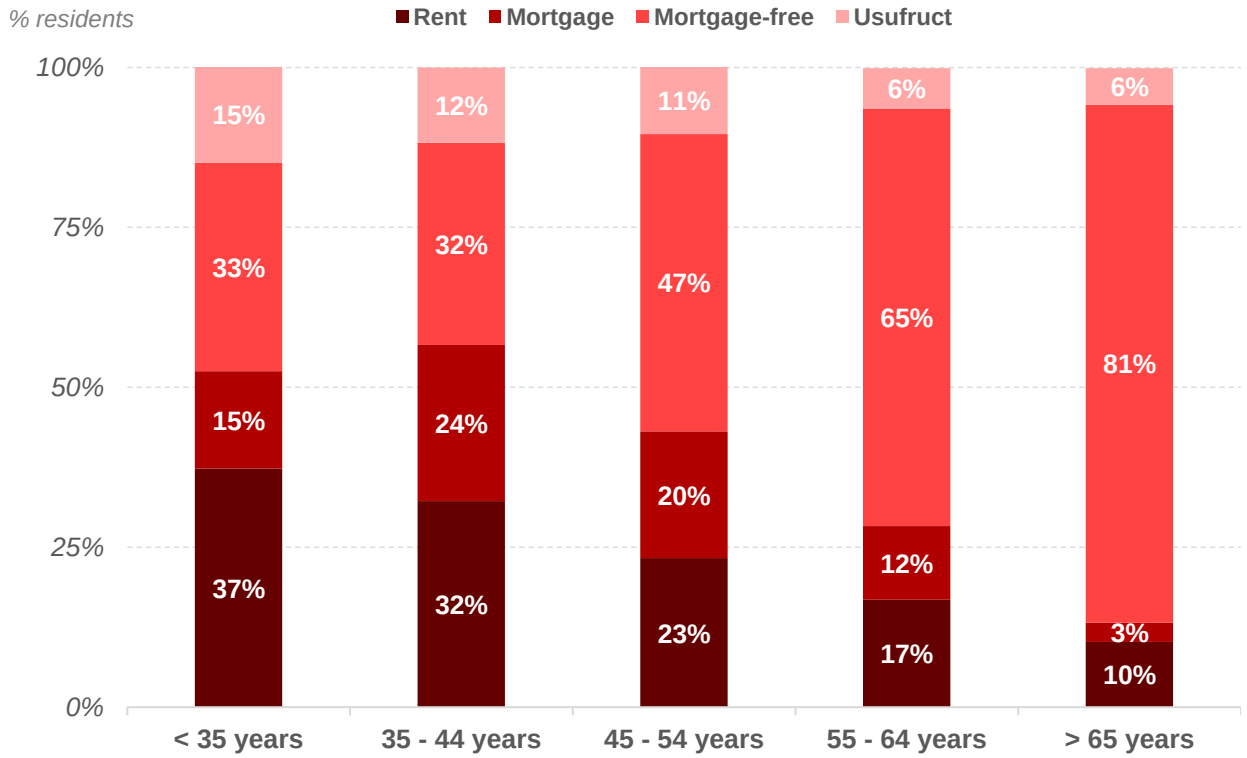
Resident population by age group - 2022

59 million residents on the national territory
-7,9% population decline expected between 2022 and 2050



- The population **aged between 46 and 60** is the **most significant** nationwide, comprising **24%**
- However, **Over-60 residents** represent **more than 30% of the population**
- The **demographic projections** predict a **decline of 7,9%** during the period **2022-2050**, reaching **54,4 million** inhabitants by the end of the same period

Property ownership by age group(1)

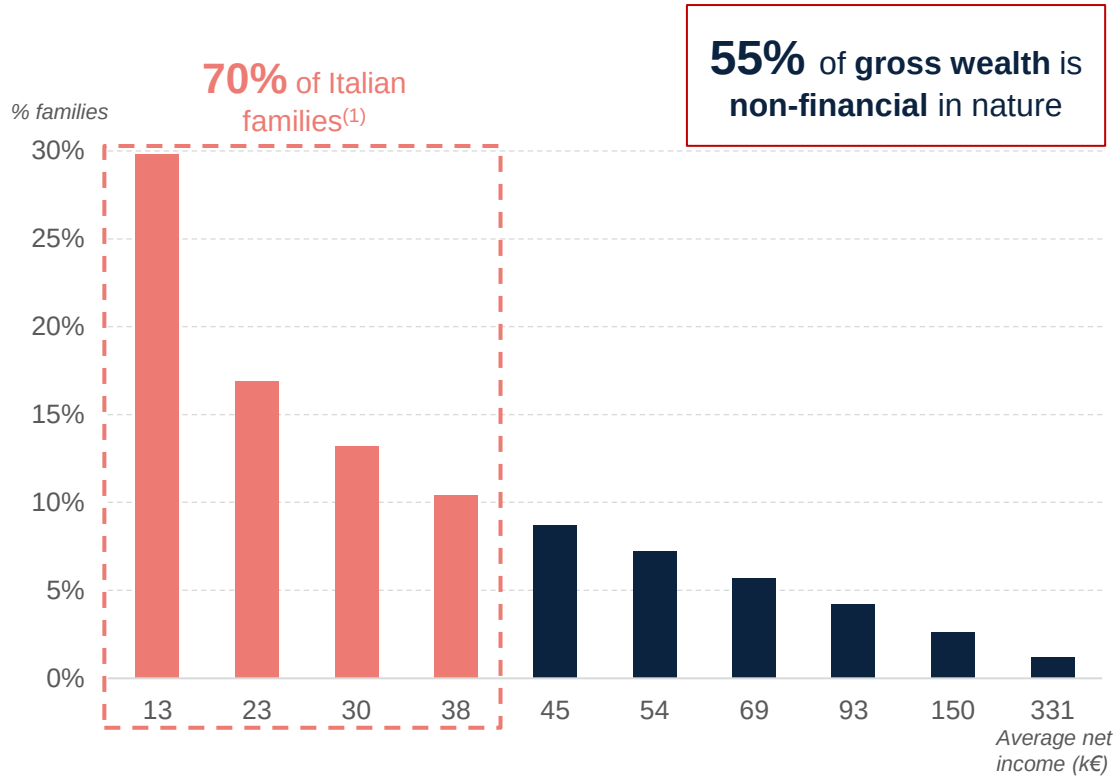


- **81%** of the **Over-65 individuals** live in their **own house without paying a mortgage,** while **only 10%** live in **rented accommodation**
- **Renting** emerges as the **dominant solution** in the **younger age groups**, with over **37%** of the **Under 35s** and **32%** of the population between **35 and 44 years old**
- Citizens **aged between 35 and 54** have the **highest shares** of residents living in **owned homes** for which they are **still paying a mortgage**

Sources: ISTAT, Ministero dell'Economia e Finanza
(1) Age of the main income earner

Out of 24,6 million families, 70% have an average income insufficient to afford a heat pump, with a net income of 40.000 € it would be necessary to invest all the annual savings

Average net incomes and shares of families by tenths of income – 2020



- Out of a total of **24,6 million families**, there is a **prevalence** of households consisting of **1 or 2 members** (**58%**)
- Among **Italian households**, almost **70%** have a **net average income below 40.000 €**
- Only **14%** of households have a **net average income** of more than **68.000 €**
- The **average household wealth** is highly **polarized**, where **most families** possess **below-average values**

Families with sufficient economic capacity to invest in heat pumps

Hypothesis	
Costs	In the **absence of incentives** and **external financing**, an **average investment** between **10.000 – 15.000 €** is required for **purchasing** and **installing** a **heat pump**
Average family expenditure	In 2022, there was an **average household expenditure** of **2.625 € per month**, about **31.500 € per year**

Minimum net income required	*Share of households without availability*
40.000 €	**70%**

In this **edge scenario**, the **investment** in **heat pumps** would equal to **100%** of the **annual savings**

- The **average total cost** for **heat pump** installation is estimated to range between **10.000 and 15.000€**
- Nationally, the **average annual expenditure** amounts to approximately **31.500 €**
- Only **30%** of **households** have **sufficient financial resources** to install a heat pump

Sources: ISTAT, Banca d'Italia
(1)Out of a total of 24,6 million families (ISTAT 2011)

Characterization of the main domestic heat generation technologies

		Energy input	Average efficiency in zone E[1]	DHW Tank[2]	Dimensions	Pros	Cons
Boilers	Oil boiler		88% - 90%	✓	~ 0,6 m³ + Diesel tank	• Limited CapEx	• Involves high emissions (greater than natural gas and LPG), reducible through renewable fuels
	Gas boiler		95% - 97%	✗	~ 0,1 – 0,2 m³	• Instantaneous heat production for DHW • Limited CapEx	• CO_2 emissions, which can be reduced through renewable fuels
	LPG boiler		95% - 97%[5]	✗	~ 0,1 – 0,2 m³ + LPG tank	• Instantaneous heat production for DHW • Limited CapEx	• Involves emissions, which can be reduced through renewable fuels
Heat Pumps[3]	Air – water heat pump		240%	✓	~ 0,4 – 0,6 m³ + Technical Room	• Low CO_2 emissions • High declared efficiency (COP), to be checked depending on weather conditions	• Compatibility with heat transfer systems • Significant dimensions • Lower performance in cold climates • High CapEx
	Gas heat pump		160%	✓	~ 0,4 – 0,6 m³ + Technical Room	• Suitable for cold climates • Good overall efficiency	• Significant dimensions • Not applicable in all cases • High CapEx
Hybrid	Gas boiler and heat pump		170%	✗	~ 0,1 – 0,2 m³ ~ 0,4 – 0,6 m³[4]	• Instantaneous heat production for DHW • Good overall efficiency • Flexibility guaranteed by the boiler even at low temperatures	• High CapEx

Legend

Energy input:

- Liquid fuels Bio-fuels
- Methane Biomethane
- LPG / Bio-LPG rDME
- Hydrogen
- Electricity

Dimensions:

- Low
- Medium
- High

Sources: DEA, Market Scouting – Ariston, Vaillant, Riello, Daikin

(1) Performance was evaluated in the form of efficiency; in the case of gas boilers, the Higher Heating Value for condensing boilers is considered; in the case of the heat pumps, the COP is considered

(2) DHW tank type size: 250 L for apartments of 80-90 m² for 2/3 people per family

(3) Introduction of natural refrigerants: the heat load dissipated is lower than current refrigerants; for the same heat load, the outdoor unit needs to be oversized

(4) Considering the dimensions for an air-to-water heat pump and a gas boiler

(5) Performance calculated on LPG and bio-LPG blends, but it is possible to evaluate additional scenarios related to the distribution of renewable dimethyl ether (rDME) blends (drop-ins) aimed at reducing the carbon footprint of the product

For heat pump installation, the entire process, from inspection to testing, requires much longer time compared to boilers, and results in significant housing disruptions

Main steps for heat pump installation

Phase	Description	Timing	Housing discomfort
Initial inspection	**Specialized technician** verifies **technical compatibility** and evaluates the **energy requirements**	1-2 weeks since the first contact	
Design & Quotation	**Sizing** of the **system** according to specific needs and definition of the **possible price**	1-2 weeks since initial inspection	
Heat pump order and delivery	Following the agreement on the estimate, the **heat pump** is **ordered**, the **availability** of which **may vary**	2-4 weeks	
Site Preparation	**Preparation** of the dwelling for the heat pump installation through **construction works**	2-5 days	
Installation	Heat pump installation, **electrical and plumbing connections**	1-8 days	
Testing and commissioning	Test the **correct functioning** of the system	1-2 days	

The entire process takes an average of **12 weeks** with **peaks** of up to **7 months**

- Overall, the whole **process** is **long** and **complex**, and it involves **multiple professional figures**, including installers, electricians and plumbers
- **At the end of the process**, **additional interventions** may be required to restore the house (including whitewashing and cleaning) which may result in **further delays and inconveniences**

Average installation times for different technologies

- On average, **heat pumps take longer** to install **than gas boilers**
- In addition to installation period, it is necessary to consider the **timing and complexities** related to **designing the system**
- Each installation requires an average of **two installers** and **one electrician**

Sources: Il mercato dell'installazione degli impianti negli edifici in Italia 2020-2022 (CRESME), Heating and Cooling Installer Study (HaCIS), BEUC – The European consumer organization

(1) It includes companies involved in the installation and construction of installations: electrical and electronic, plumbing, heating and air conditioning, other construction and installation works, public utility works for the transport of fluids, for public utilities for electricity and telecommunications

The analyzed case studies represent the main characteristics of the existing Italian residential stock that requires energy improvement interventions

		Dwelling type	Climatic zone	Current heating technology	Heat distribution system	Heat transfer system	Energy Class	Technology solutions analysed				
								Gas boiler	Heat pump	Oil boiler	LPG boiler	Hybrid systems
Selected case studies	**Case 1: Urban Apartment** *(centralized)*	Condominium apartment	E	Gas boiler (non-condensing)	Centralized	Radiator	G	✓	✓			✓
	Case 2: Urban Apartment *(autonomous)*	Condominium apartment	E	Gas boiler (non-condensing)	Autonomous	Radiator	G	✓	✓			✓
	Case 3: Single-family *(on-grid)*	Detached house	E	Gas boiler (non-condensing)	Autonomous	Radiator	G	✓	✓			✓
	Case 4: Single-family *(off-grid)*	Detached house	E	LPG boiler (non-condensing)	Autonomous	Radiator	G		✓	✓	✓	✓

General assumptions:

- The analysis involves the development of an assessment of the Total Cost of Ownership (TCO) of the different alternatives under consideration, highlighting the emerging impact for each cost component
- The investment is assumed to involve the replacement of existing technology that has reached the end of its useful life
- The cash flow discount factor is 3%
- The investment duration is assumed to be 14 years (from 2025 to 2039); where the useful life of the technology is longer, a terminal value has been introduced
- Incentives are not considered to support the analyzed cases
- Standard consumption (from APE) has been adjusted to real consumption (referred to year 2021[(2)]) that considers the actual usage conditions of the analyzed buildings

Technical assumptions:

- In climate zone E, an average SCOP of 2.2 (from experimental studies[(1)]) was considered for air-to-water heat pumps coupled with radiators
- For heat pump solutions, the DHW storage system is also considered in the investment
- Biomass solutions for single-family contexts are not considered given the high emissions of particulate, matter subject to regional constraints, and given the possible priority of district heating networks in mountain contexts
- To simulate the use of renewable fuels at the residential level, it is hypothesized that there is the possibility of purchasing Guarantees of Origin (GO)

(1) La pompa di calore – Una soluzione efficiente e sostenibile (RSE, 2018); Misura delle prestazioni in campo di una pompa di calore di grande taglia (ENEA, 2018)
(2) Representative year of the historical series, not influenced by extraordinary events (Russian-Ukrainian conflict or particularly hot winters) – Source: State of services (ARERA, 2022)

In urban contexts with centralized heating, the natural gas boiler is the most competitive solution, even with the use of renewable gases

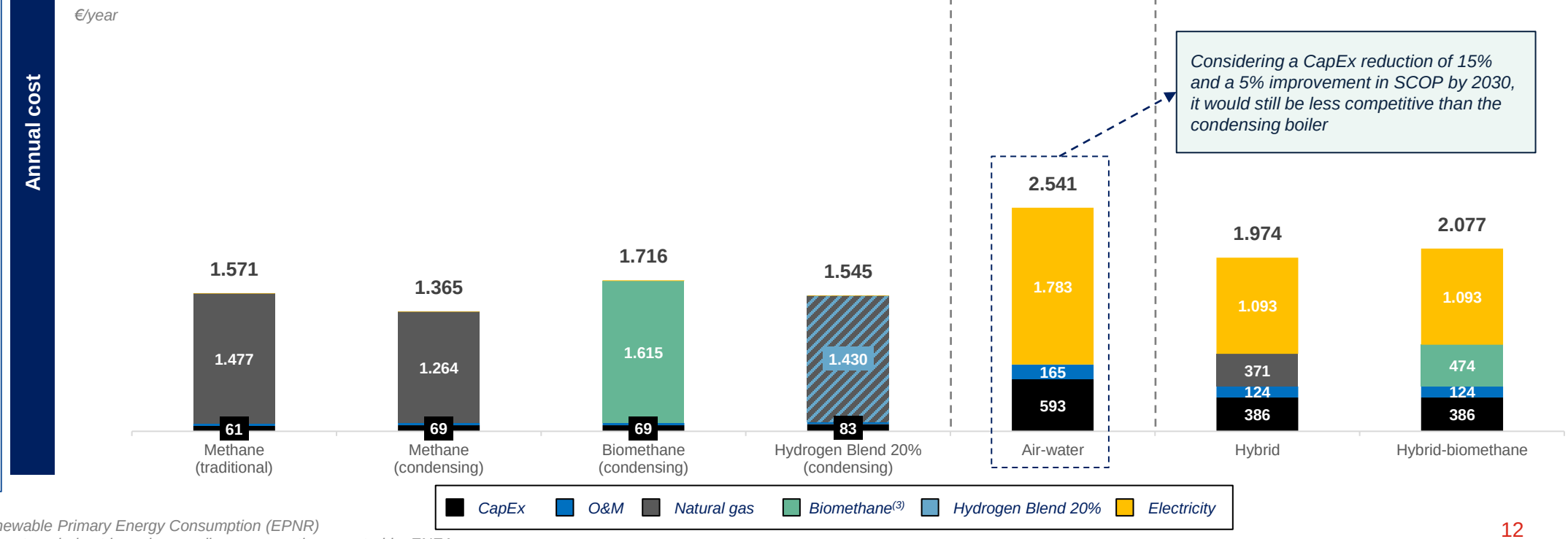
Case 1: Urban apartment with centralized heating

2025 | 14 years

INPUT

- Climatic zone: *E*
- Energy Class: *G*
- Type of accommodation: *Condominium*
- Heating: *Centralized*
- Surface: *80 m²*
- Heating requirement: *10.080 kWh$_{th}$/year*
- DHW requirement: *2.049 kWh$_{th}$/year*

	Gas boiler				Heat pump	Hybrid	
CapEx (k€)	1,0	1,1	1,1	1,4	8,7	5,6	5,6
EPNR (1) (MWh/y)	14,8	12,6	0,03	11,8	9,2	9,4	5,7
Emissions (kgCO$_2$/y)	2.913	2.493	3	2.320	809	1.227	496
Estimated Class Upgrade(2)	G	G	A	F	E	E	C



(1) Non-Renewable Primary Energy Consumption (EPNR)
(2) Assessment carried out based on median consumption reported by ENEA
(3) In the case of using commercial GOs (Guarantees of Origin)

For apartments with independent heating systems, gas boilers remain cost-effective and offer the potential emission reduction through renewable gases

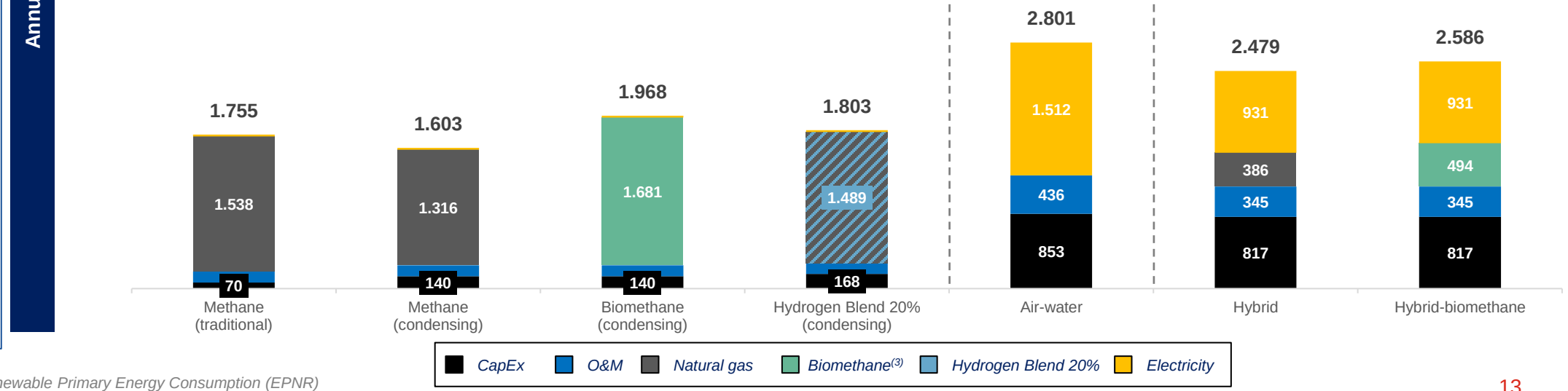
Case 2: Urban apartment with independent heating

2025 | 14 years

INPUT

- Climatic zone: *E*
- Energy Class: *G*
- Type of accommodation: *Condominium*
- Heating: *Autonomous*
- Surface: *80 m²*
- Heating requirement: *10.080 kWh_{th}/year*
- DHW Requirement: *2.049 kWh_{th}/year*

	Gas boiler				Heat pump	Hybrid	
CapEx (k€)	1,0	2,0	2,0	2,5	10,9	10,4	10,4
EPNR (1) (MWh/y)	15,4	13,2	0,1	12,3	7,8	8,7	4,8
Emissions ($kgCO_2$/y)	3.040	2.603	10	2.422	686	1.184	422
Estimated Class Upgrade(2)	G	G	A	F	D	E	C



(1) *Non-Renewable Primary Energy Consumption (EPNR)*
(2) *Assessment carried out based on median consumption reported by ENEA*
(3) *In the case of using commercial GOs (Guarantees of Origin)*

In single-family homes connected to the gas grid, boilers are still the most cost-effective solution and enable emission reductions through renewable gases

Case 3: On-grid single-family

2025 | 14 years

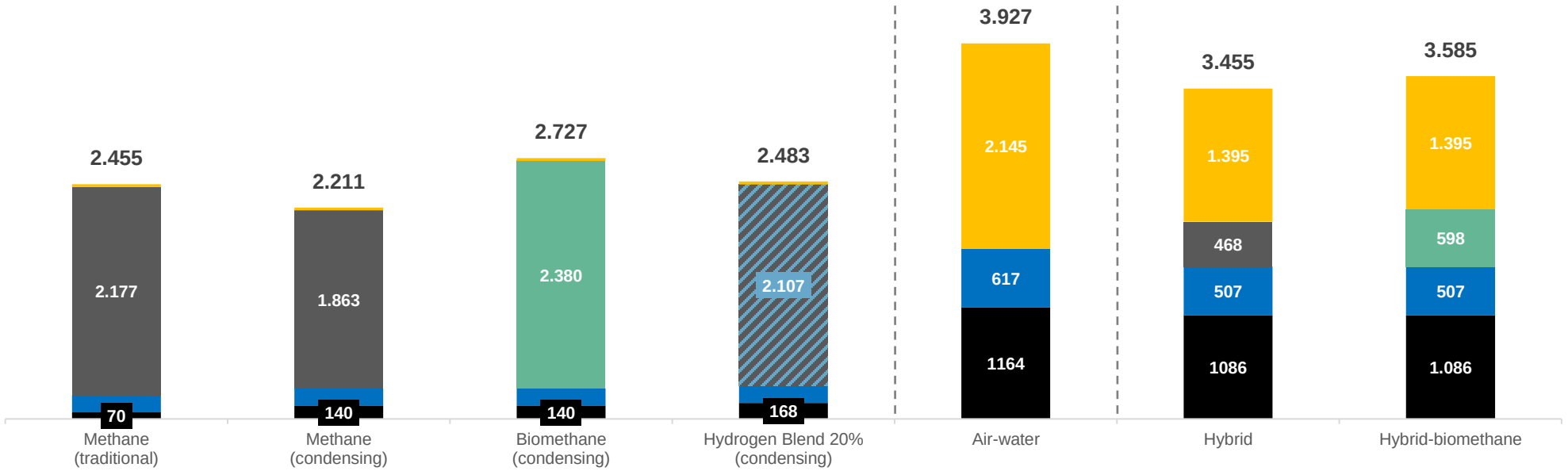
INPUT

- **Climatic zone**: *E*
- **Energy Class**: *G*
- **Type of accommodation**: *Single-family*
- **Heating**: *Autonomous*
- **Surface**: *120 m²*
- **Heating requirement**: *15.120 kWh$_{th}$/year*
- **DHW Requirement**: *2.049 kWh$_{th}$/year*

	Gas boiler				Heat pump	Hybrid	
CapEx (k€)	1,0	2,0	2,0	2,5	14,8	13,8	13,8
EPNR (1) (MWh/y)	21,9	18,7	0,2	17,4	11,1	11,9	7,2
Emissions (kgCO$_2$/y)	4.304	3.684	14	3.428	974	1.556	633
Estimated Class Upgrade(2)	G	G	A	F	D	E	C

Annual cost

€/year



(1) *Non-Renewable Primary Energy Consumption (EPNR)*
(2) *Assessment carried out based on median consumption reported by ENEA*
(3) *In the case of using commercial GOs (Guarantees of Origin)*

In off-grid contexts, the heat pumps are less competitive than the LPG boilers, which remain the most economically efficient solution

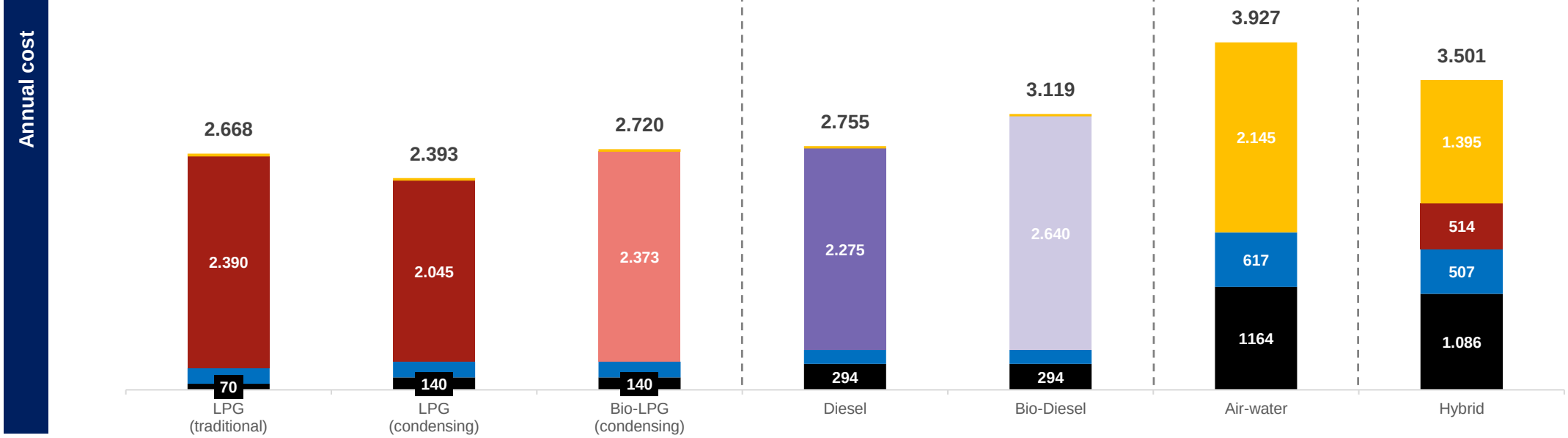
Case 4: Off-grid single-family

2025 | 14 years

INPUT

- **Climatic zone**: *E*
- **Energy Class**: *G*
- **Type of accommodation**: *Single-family*
- **Heating**: *Autonomous*
- **Surface**: *120 m²*
- **Heating requirement**: *15.120 kWh$_{th}$/year*
- **DHW Requirement**: *2.049 kWh$_{th}$/year*

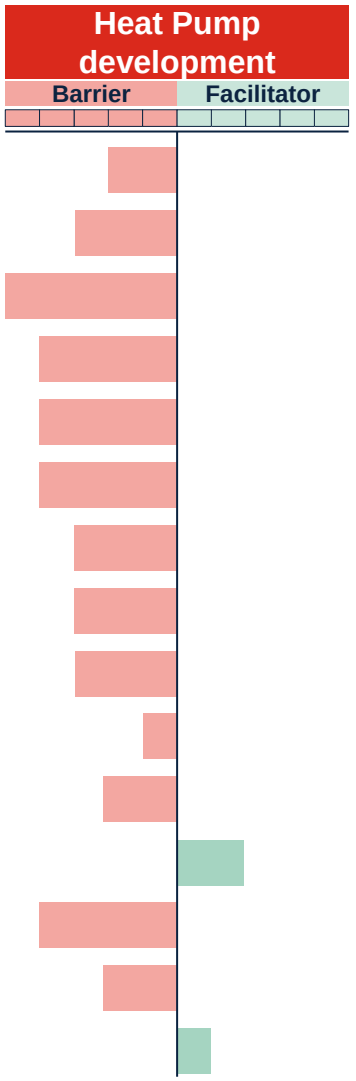
	Gas boiler			Oil boiler		Heat pump	Hybrid
CapEx (k€)	1,0	2,0	2,0	4,3	4,3	14,8	13,8
EPNR [1] (MWh/y)	21,9	18,7	0,2	20,1	0,1	11,1	11,9
Emissions (kgCO$_2$/y)	4.898	4.193	14	5.493	14	974	1.684
Estimated Class Upgrade[2]	G	G	A	G	A	D	E



[1] Non-Renewable Primary Energy Consumption (EPNR)
[2] Assessment carried out based on median consumption reported by ENEA
[3] In the case of using commercial GOs (Guarantees of Origin)

Even under the most favorable conditions in terms of income and building structure, the barriers to the development of heat pumps outweigh facilitating factors

Topic	Considerations for Heat Pump Installation
Housing Mapping	**Notable age** – Prevalence of buildings with **high dispersions**, the **heat pump is not sufficient** for the **required class upgrade**
	Centralized systems – In **apartment buildings** with **centralized heating**, interventions require **unanimous consent**
	Spaces – **Space limitations** for outdoor unit installation
Socio-demographic	**Income** – **Lack of financial resources** for a large part of the population to invest in heat pumps
	Age of population – An aging population **less inclined to embrace change and invest** in energy efficiency solutions
	High upfront costs – The significant initial investment **discourages people to invest**
Technical feasibility	**Climatic zone** – **Decline in performance in cold climates,** with increased consumption and thermal discomfort
	System coupling – **Poor adaptability** of **radiators** to **low-temperature systems**
	Electrical grid – Need for significant **upgrades** to **increase available power** in the event of widespread adoption of heat pumps
Supply chain	**Installers** – Currently, **the supply chain of installers is not sufficiently trained** for large-scale installation of heat pumps
	Customer experience – Particularly **long periods** from inspection to installation, with a relevant impact on the living comfort
	Potential cost reduction – **Booming technology** with potential to **reduce supply costs**
TCO	**TCO** – **Heat pumps** have significantly **higher CapEx** (**30% of TCO**) compared to condensing boilers
	Operating Costs - **Significant maintenance and repair costs in the event of breakdowns**
	Emissions – Low emissions using RES, despite the **time lag between thermal consumption and RES production**



Out of 10,3 million dwellings in classes F – G, the heat pump would be technically feasible in 5,9 million, the share reduces to 1,76 million when considering factors related to income

STEP 1 - Out of **31,1 million**, only dwellings **outside historic centers and permanently occupied** (**19,3 million**) were considered, since the **EPBD Directive** requires interventions in homes **occupied** for **at least 4 months** a year

STEP 2 – Dwellings in **energy classes A – E** (**9 million**) were **excluded** and only those in **F and G** (**10,3 million**) were considered, as they require priority interventions

STEP 3 - Out of **10,3 million remaining** dwellings, those in climate **zones F and E** with **more** than **2.800 degree-days** (**0,7 million**) were **excluded**

STEP 4 – Over the **remaining 9,6 million** homes, those **without outdoor spaces** (**3,7 million**) were **excluded** due to technical and environmental constraints

STEP 5 – Out of the **remaining 5,9 million dwellings**, the share of **families** with an **average annual income below € 40,000** (**70,3%**) was excluded, as their **financial capacity** is **insufficient** to cover the investments

National Housing Stock
31,1 mln dwellings

Unoccupied dwellings and in historic centres
(11,8 mln dwellings)

Occupied dwellings
(19,3 mln dwellings)

Energy classes A – E
(9,0 mln dwellings)

Energy classes F – G
(10,3 mln dwellings)

Zones F and E (DD >2.800)
(0,7 mln dwellings)

Zones A, B, C, D, E (DD <2.800)
(9,6 mln dwellings)

Dwellings with centralized systems
(1,6 mln dwellings)

Dwellings with insufficient space
(3,7 mln dwellings)

Dwellings with autonomous systems
(4,3 mln dwellings)

~1,76 mln
~10,6% dwellings in classes F and G are potentially addressable by heat pumps

Insufficient income
(70,3%$_{families}$)

Adequate income
(29,7%$_{families}$)

The final number of heat pumps may be lower due to
- Older people generally showing less readiness for change
- Technical constraints arising from the combined use of radiators
- Technical and administrative constraints for centralized condominiums (also considering the availability of district heating networks [1])

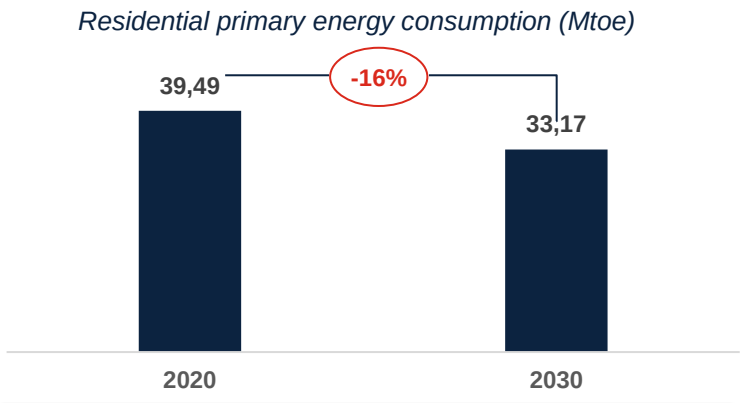
Homes excluded from methodological step

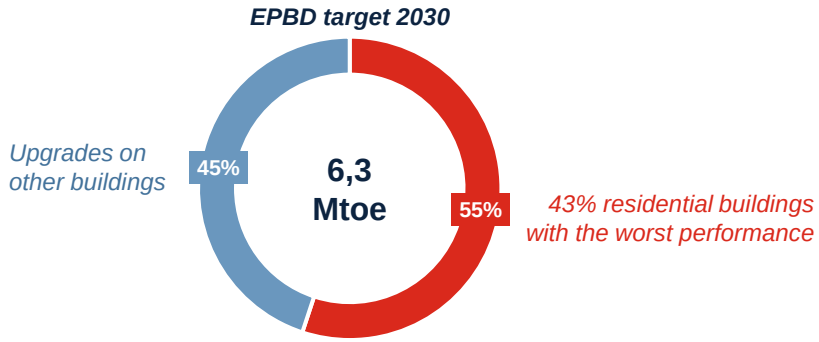
[1] According to a study conducted by AIRU, in a scenario of minimum cost for the system, by 2030 district heating could cover 18% of total demand (mainly centralized condominiums)

Replacing traditional boilers with efficient condensing systems could achieve almost 40% of the EPBD target in terms of primary energy reduction

EPBD Directive

Residential primary energy consumption– EPBD Directive





55% of the **decrease** in **average primary energy consumption** must be achieved by improving the performance of **43%** of the **residential buildings** with the **worst efficiency. By 2035,** the Directive aims for an **additional reduction of 20-22% in primary energy consumption** compared to **2020**

Results and considerations

*Approximately **12 mln traditional gas boilers** are estimated to be installed (1)*

Replacement scenarios	Replaced systems	Inv. required	Primary energy saving(2)	Bn€/Mtoe	Timing
Scenario 1 - Condensing boilers	12,0 mln	24,0 bn	2,3 Mtoe	10,6	
Scenario 2 – Hybrid*	3,6 mln	30,3 bn	0,6 Mtoe	54,7	
Scenario 3 – Electrical heat pumps	1,8 mln	17,6 bn	0,5 Mtoe	35,2	
Scenario 4 – Condensing boilers and heat pumps (in different buildings)	12,0 mln *(1,8 mln heat pumps)*	38,1 bn	2,4 Mtoe	15,7	

**In the scenario of replacement with hybrid systems, the share of households with insufficient income (70% in analogy with the heat pumps) was excluded due to high CapEx*

- The scenario with **only condensing boilers** is the **best solution** in terms of **investment/savings ratio** (10,6 € billion/Mtoe)
- A **mixed replacement** with **condensing boilers and heat pumps**, up to the limit of the calculated attackable share (1,76 million), would result in **greater primary energy savings** despite a **higher investment** (+ 59%)

(1)The standard APE consumption have been recalculated on real consumption, which considers the actual usage conditions of buildings (12.000 kWh th/year for a house of 80 m²)
(2) Ambient energy is not considered in the calculation of primary energy as assumed by the European guidelines; the trajectory of decrease in the en. factor was considered according to PNRR provisions

Implementation timelines: Short Medium Long

Main findings

- The age of the buildings, which results in **limited thermal insulation**, along with the **predominance of dwellings in condominiums** with **independent heating and limited outdoor spaces**, presents technical challenges for heat pump installation
- Across the country, there is a **significant presence of dwellings located in historic centers** (approximately **3,1 million**), while the **occupancy rate stands at 70%**
- The **real consumption assessment** revealed **lower values** than the ones certified by the APE, indicating a need to reconcile consumption data

- In Italy, **the average age is particularly high,** elder individuals register higher incomes and hold the largest share of owned properties
- The **wealth distribution among households** is extremely **polarized**, with **70%** having an **average net income below 40.000 € per year**
- Socio-economic conditions (**income**, **education** and **financial resources**) **constrain** the **willingness to invest** in alternative technologies aimed at reducing emissions, which often require a significant initial investment

- Nearly **94%** of the **companies** engaged in **heating systems installation** are **small** (**0-9 employees**), their **limited specialization** in **heat pumps** installation **hinders** the **widespread adoption** of the technology
- The **entire process**, from **planning** to **actual commissioning of heat pumps**, requires **more time compared to boilers**, averaging **12 weeks** with **peaks** extending **up to 7 months**
- **Heat pumps installation** may involve **expensive construction work**, generating considerable **inconvenience** and **increasing** the **upfront costs**

- The **TCO** analysis shows that **condensing boilers** represent the **most competitive solution**, while the adoption of renewable gases may significantly reduce emissions
- **Heat pumps** emerge as **less competitive**, whereas **hybrid solutions** present a viable alternative to **contain** both **costs** (compared to heat pumps) and **emissions**
- **The use of mixtures** containing **renewable fuels** allows for the **utilization of existing technologies while simultaneously reducing emissions**
- Replacing a **traditional gas boiler with a condensing boiler** could bring **savings** in terms of annual costs (approx. -14%) despite a modest CapEx increase

- **Electrification is not always technically feasible**, moreover, **socio-demographic factors** and **financial constraints** may pose significant **obstacles**
- While heat pumps using renewable energy could reduce emissions, they **frequently operate** when **renewable energy sources are not available**, resulting in **greater reliance on fossil electricity from the grid**
- Out of the 16,6 million dwellings in classes F and G, heat pumps are a technically feasible solution for only 5,9 million; however, this number drops to approx. 1,76 million when household income factors are considered

- Compared to 2020, the **EPBD Directive** mandates a **16% reduction in average residential primary energy consumption by 2030** (**- 6,3 Mtoe**), where **55%** of this reduction must come from improvements in **43%** of the **worst-performing residential buildings**
- Scenarios that involve **adopting condensing boilers** in the existing housing stock would enable **significant primary energy savings at a lower cost** and in **less time** compared to scenarios focused on extensive electrification

Final recommendations

Pursuing the principle of technological neutrality

- **Prioritize efficiency and decarbonization solutions** based on **technological neutrality** rather than unconditionally pursuing electrification
- **Renewable gas-fueled boilers** and **hybrid solutions** present a viable alternative for **reducing consumption** and **emissions** while **minimizing the impact on existing buildings**
- Promote the **development of decarbonization technology production chains** to **reduce initial investments** and enhance accessibility to these solutions
- **Enhancing skills across the installer supply chain** is crucial to support the development of more sophisticated systems and improve the customer experience

Promoting the penetration of renewable fuels

- Encouraging the use of renewable fuels facilitates the decarbonization of residential thermal consumption **without expensive insulation upgrades** or **substantial technical changes** for users
- Using renewable gases enables the utilization of existing infrastructures while **minimizing the need for substantial investments in upgrades or new infrastructures**
- To **promote** the use of **renewable gases in the residential sector**, it is essential to establish a **system** for allocating **Guarantees of Origin (GOs)** applicable to building consumption
- **Integrating renewable fuels** into the grid facilitates the **development of gas-electricity *sector coupling***, which enables the conversion of excess renewable energy production (over-generation) into hydrogen (or alternative fuels), thereby avoiding *curtailment* and improving the overall efficiency of the energy system

Prioritize cost/benefit ratio

- **Condensing boilers** are the **most cost-effective solution** for reducing energy consumption in the national housing stock, offering lower TCO and maximizing primary energy reduction compared to equivalent investments
- Installing **condensing boilers minimizes** the **impact** on **existing buildings** and guarantees **shorter construction times**

Thank you

Glossario

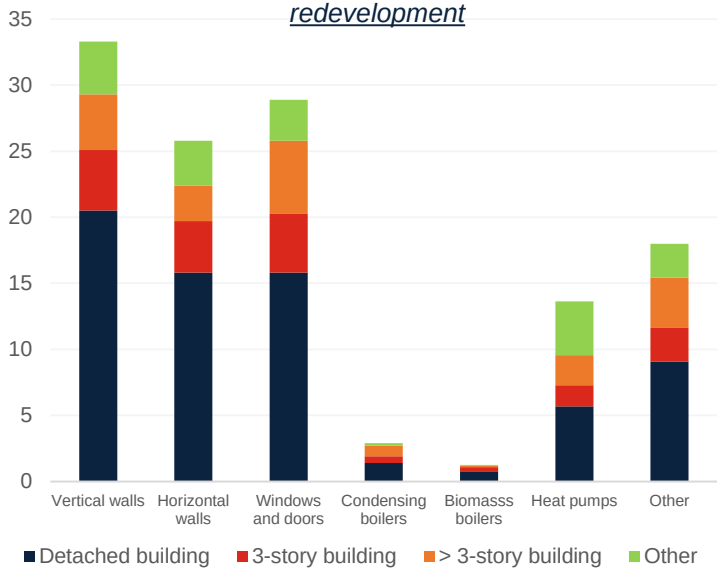
Terminology	Definition
EPBD Directive	*Energy Performance of Buildings Directive*, directive aimed at improving the energy efficiency of European buildings
PNIEC	Integrated National Energy and Climate Plan, a document drawn up by each Member State of the European Union in which national objectives and measures for the energy transition are established
TCO	*Total Cost of Ownership,* calculation method that includes all costs associated with the purchase, use and replacement of a good or service during its life cycle
DHW	Domestic Hot Water
APE	Energy Performance Certificate, is an official document that describes the energy characteristics of a building or a real estate unit
COP	*Coefficient of Performance*, is an efficiency index used to evaluate the performance of cooling and heating devices (heat pumps)
RES	Renewable Energy Source
ETS	*Emission Trading System*, environmental policy instrument used to reduce greenhouse gas emissions
LCOtE	*Levelized Cost of Thermal Energy*, measure to assess the overall cost of energy production of a plant over its useful life

To achieve the EU targets by 2030, approximately € 320 billion would be needed solely for reducing the energy consumption of the worst-performing residential buildings (~16 million)

Energy class upgrade cost

The estimated cost[1] for an **upgrade** from **energy class G** to **energy class A** is between **75.000 €** and **115.000 €** for **single-family houses**, and between **400.000 € and 600.000 €** for **condominiums** (ref: building with 4 floors, containing 16 apartments of 80 m² each)

Investments [M€] with Ecobonus (year 2022) for total redevelopment



- The **average price differential** between a **house** in **classes A1-A4** and in **G** is about **25%** with equivalent characteristics. Heterogeneous differential between provinces and can **vary between 7 and 35%**

Superbonus – Interventions and costs

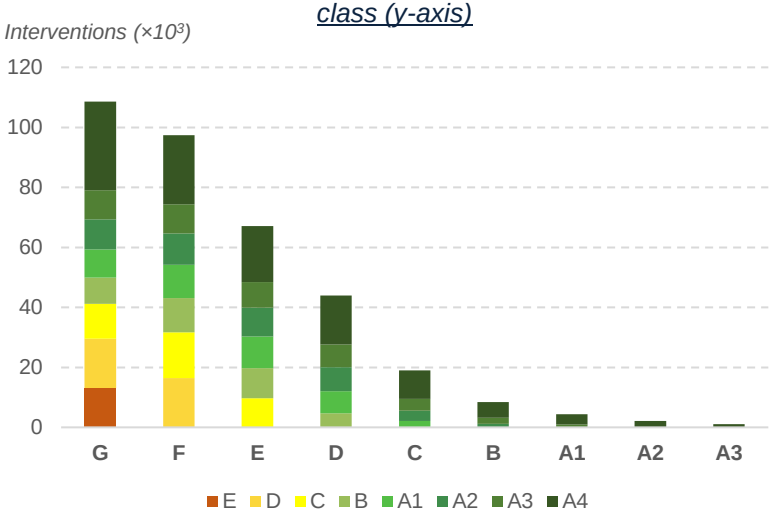
62 bn €[2]
Investments

305.588
Interventions on single-family units

46.508
Interventions on condominium units

0,8 Mtoe/y
Energy saving

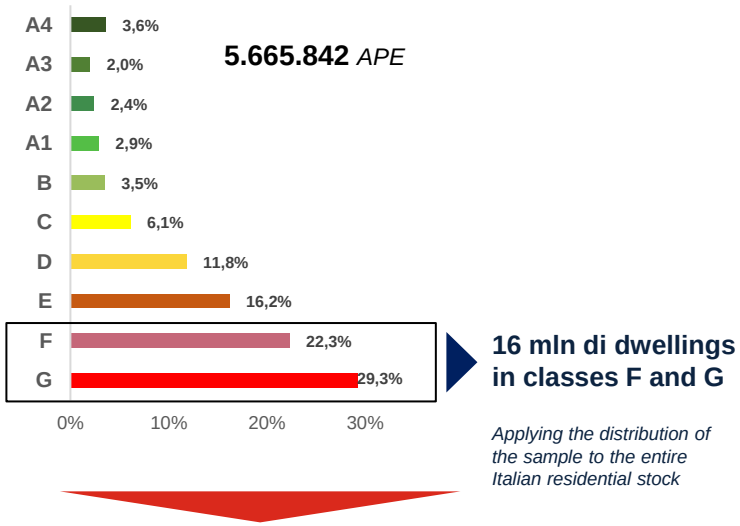
Energy class upgrades: starting class (x-axis) and final class (y-axis)



- Out of **352.101 energy class upgrades**, **67%** reached **at least class A1**
- Only **2% of condominiums and 15% of single-family buildings** have **reached class A, starting from class G**

Residential sector target by 2030

The EU Directive (EPBD) provides that the **average primary energy consumption** of the entire residential building stock must **decrease by 16%**, compared to 2020 values, by **2030**. **55% of the decline** in average primary energy consumption must be achieved through the **renovation of 43% of the worst-performing residential buildings**



- Considering a **minimum expenditure of 10.000 €** (*for a heat pump*[3]) and a **maximum expenditure** of **30.000 €** (*insulation and/or window frames*), per home, the **financial impact** (on 16 million homes) of the EPBD directive would amount to **between 160 and 480 € billion** [4]

Sources: Rapporto Annuale sulle Detrazioni Fiscali (ENEA, 2023), Il miglioramento dell'efficienza energetica delle abitazioni in Italia: lo stato dell'arte e alcune considerazioni per gli interventi pubblici (Banca d'Italia, 2024)

[1] The estimated costs exclude any regularization fees

[2] Total investment in Superbonus as of 31/12/2022; it is estimated that the Superbonus has cost €114 billion to date (ENEA)

[3] The cost of the technology does not include the additional costs related to construction work

[4] The simplified calculation is based on the use of average values

Condensing boilers with window frames are the fastest and least expensive alternative to reach the EPBD target

*It is assumed that the **minimum target** of the **EPBD Directive** (**-6,3 Mtoe**) will be achieved in **4 scenarios**, starting with the **replacement** of **traditional gas boilers** (**12 mln**)*
***Technologies alone do not reach the EPBD target**, it is necessary to introduce **mixed solutions** with **insulation** systems*

		CapEx[1] (€)	Energy saving expense (€/MWh)	Primary energy savings[3]	Scenario 1: Condensing boilers and window frames			Scenario 2: Hybrid systems and window frames			Scenario 3: Window frames and building insulation			Scenario 4: Heat pumps[2] and building insulation		
					Dwellings mln	Savings Mtoe	Cost Bn €	Dwellings mln	Savings Mtoe	Cost Bn €	Dwellings mln	Savings Mtoe	Cost Bn €	Dwellings mln	Savings Mtoe	Cost Bn €
Technologies	Condensing gas boiler	2.000	913	14%	-	-	-	-	-	-	-	-	-	-	-	-
	Hybrid	8.500	4.705	12%	-	-	-	-	-	-	-	-	-	-	-	-
	Air – water heat pump	10.000	3.030	22%	-	-	-	-	-	-	-	-	-	-	-	-
Insulation	Window frames	8.500	3.733	15%	12,1	2,0	102,9	14,1	2,4	120,0	9,1	1,5	77,4	-	-	-
	Building insulation	40.000	6.587	40%	-	-	-	-	-	-	9,1	4,8	364,3	9,7	5,1	389,3
Technology & insulation	Cond. boiler & window frames	10.500	2.537	27%	12,0	4,3	126,0	-	-	-	-	-	-	-	-	-
	Hybrid & window frames	17.000	4.459	25%	-	-	-	12,0	3,9	204,0	-	-	-	-	-	-
	Heat pump & insulation	50.000	6.209	53%	-	-	-	-	-	-	-	-	-	1,8	1,2	88,0
	Total				24,1	6,3	**228,9**	26,1	6,3	**324,0**	9,1	6,3	**441,7**	11,5	6,3	**477,3**
	Timing															
	Specific cost *[Bn€/Mtoe]*					**36,3**			**51,4**			**70,1**			**75,8**	

[1] *The interventions on window frames aim to achieve the target of the EPBD standard (6,3 Mtoe)*
[2] *The maximum number of heat pumps previously identified (1,76 million) was considered, although achieving it completely may pose significant challenges*
[3] *The savings are calculated compared to the consumption of the traditional gas boiler*

Implementation timelines:
Short *Medium* *Long*

Consumption for domestic heating from energy certification (APE) derives from standardized calculations and appears to be overestimated compared to real consumption

Real vs standard consumption

Introduction to the problem

The **consumption data** for domestic heating **deriving from the energy certification** refer to **standardized calculations**, aimed at comparing different properties for the purposes of energy certification.

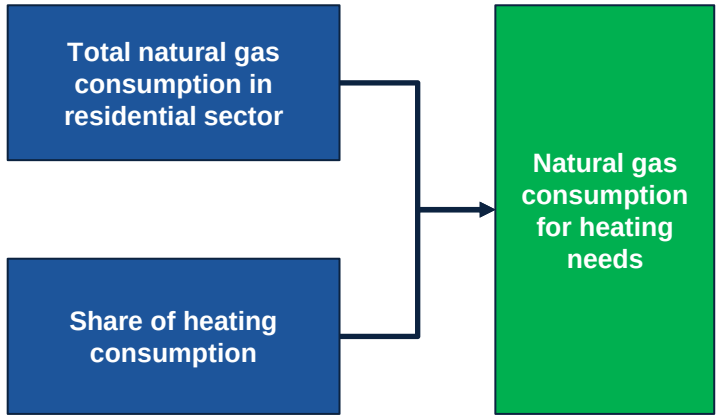
These figures appear to be **vastly overestimated compared to real consumption** and should be reconciled with total national real energy consumption.

Verification methodology

Methodology top-down	vs	Methodology bottom-up
Historical consumption reporting		Standard consumption with APE certification(1)

Top-down methodology

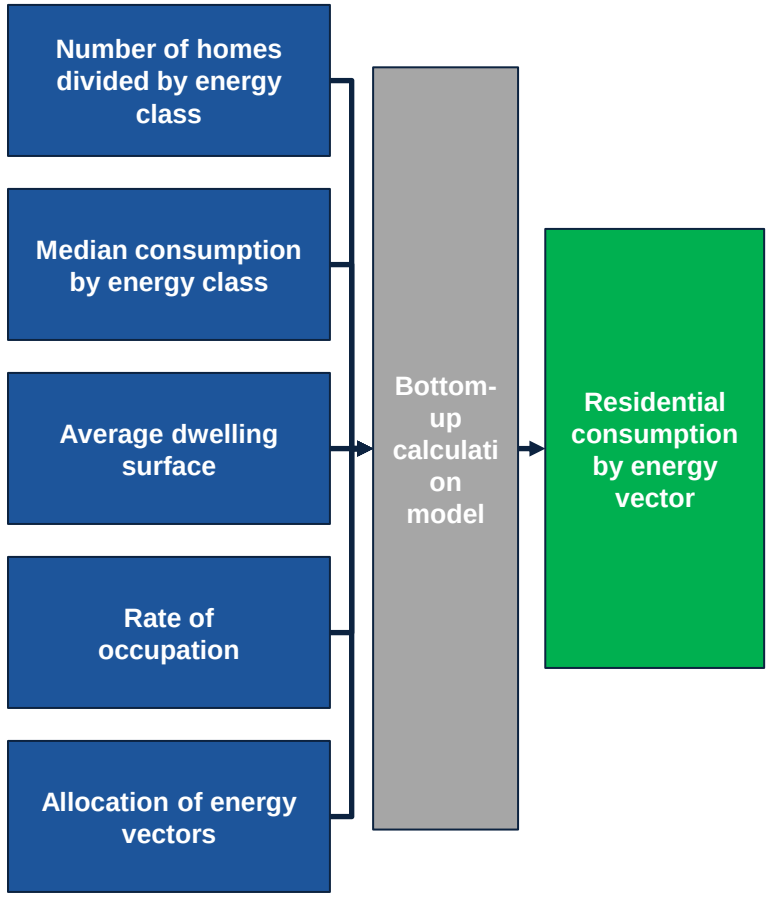
National consumption:



Consumption per dwelling (ARERA):

- **C3** consumption ("Heating, cooking and domestic hot water") amounts to **1.039 m³/year** per apartment, while **C2** ("Cooking and domestic hot water") amounts to **204 m³/year**; therefore, **heating consumption**, satisfied with **natural gas**, can be estimated at approximately **800 m³/year** per apartment (equal to about **95 kWh/m²** assuming a surface of 80 m²).

Bottom-up methodology



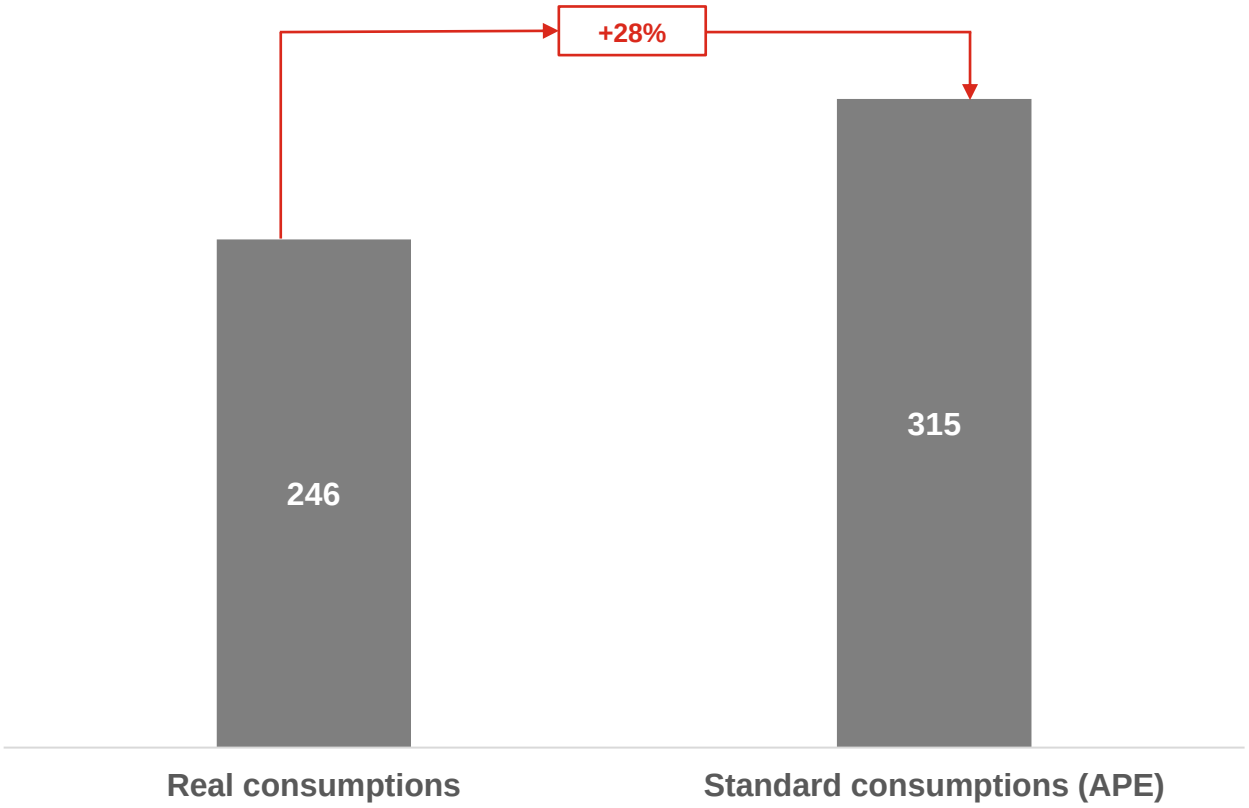
Sources: Stato dei servizi (ARERA, 2022), Sistema Informativo sugli Attestati di Prestazione Energetica (SIAPE - ENEA), Rapporto annuale sulla certificazione energetica degli edifici (ENEA, 2023), Censimento (ISTAT, 2011)

(1) Standardised consumption derives from the SIAPE Portal

Standard consumptions (from APE) have been adjusted to real consumptions, which consider the actual usage of the buildings

Consumption for domestic heating: real(1) vs standard

TWh



- The **overestimation** is mostly due to:
  - real **usage conditions**, which may be different from the standard ones;
  - energy performance **calculation algorithms**;
  - **use of other fuels** (biomass, split) in addition to natural gas in the same residential context
- Factors to be considered:
  - the **occupancy rate** can heavily influence the energy consumption;
  - **individuals' behaviour** can have a significant impact, as demonstrated by the reduction in consumption during the Russian-Ukranian conflict

- To correctly assess the technical and economic competitiveness of the technologies and future scenarios, the study uses the real consumption values instead of the standard values provided by the APE certificates

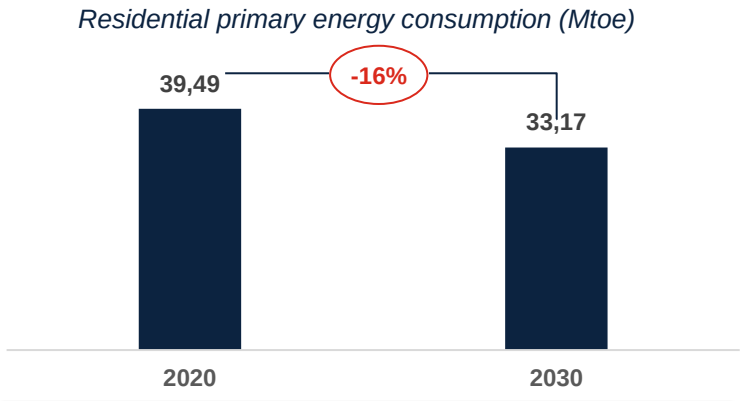
Source: Stato dei servizi (ARERA, 2022)
(1)Referred to the year 2021, representative of the historical series, not influenced by extraordinary events (Russian-Ukrainian conflict or particularly hot winters)

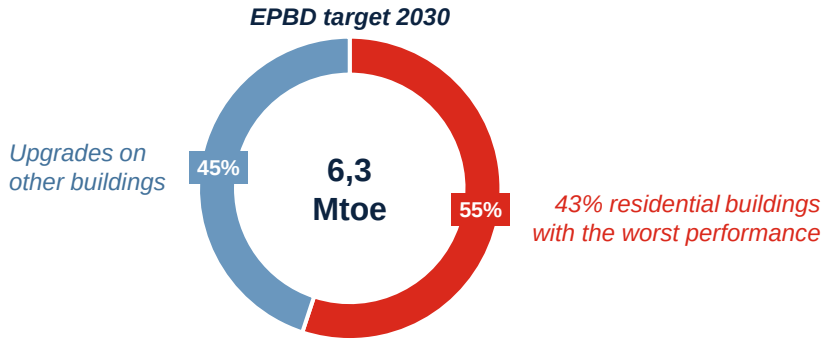
Standard

Replacing the traditional boiler fleet with condensing boilers could achieve approximately 60% of the EPBD target in terms of primary energy reduction

EPBD Directive

Residential primary energy consumption– EPBD Directive





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Scenario 4 – Condensing boilers and heat pumps (in different buildings)	12,0 mln *(1,8 mln heat pumps)*	38,1 bn	3,8 Mtoe	9,9	

**In the scenario of replacement with hybrid systems, the share of households with insufficient income (70% in analogy with the heat pumps) was excluded due to high CapEx*

- The scenario with **only condensing boilers** is the **best solution** in terms of **investment/savings ratio** (6,7 € billion/Mtoe)
- A **mixed replacement** with **condensing boilers and heat pumps**, up to the limit of the calculated attackable share (1,76 million), would result in **greater primary energy savings** despite a **higher investment** (+ 59%)

(1)Reference was made to the standard consumption from APE (19,000 kWh th/year for a house of 80 m²)
(2) Ambient energy is not considered in the calculation of primary energy as assumed by the European guidelines; the trajectory of decrease in the en. factor was considered according to PNRR provisions

Implementation timelines: Short Medium Long