Building Archetypes for Urban Building Energy Modelling

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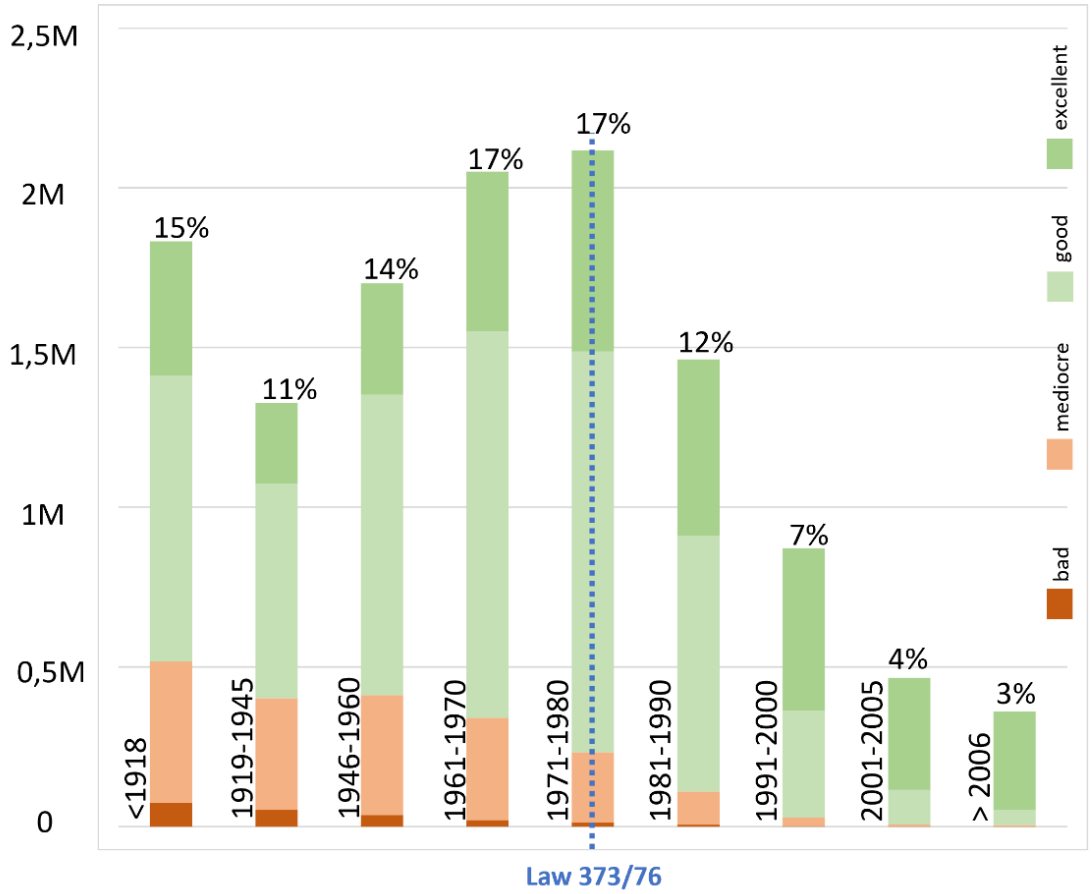
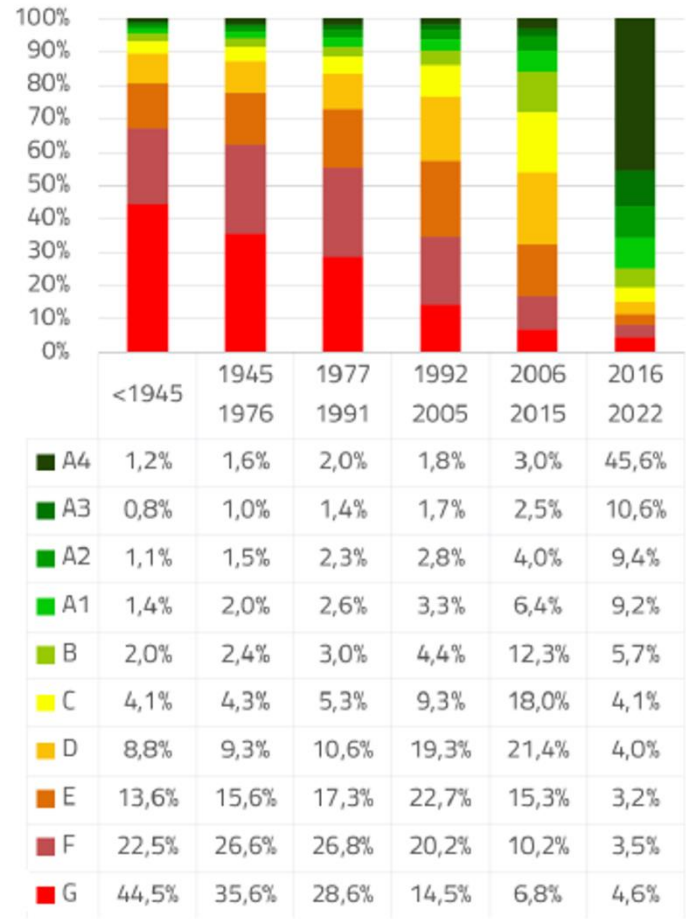
Energy Performance of Italian building stock

Residential Building Stock - State of Conservation by Period of Construction (ISTAT, 2011)



Building Energy Performance by Period of Construction

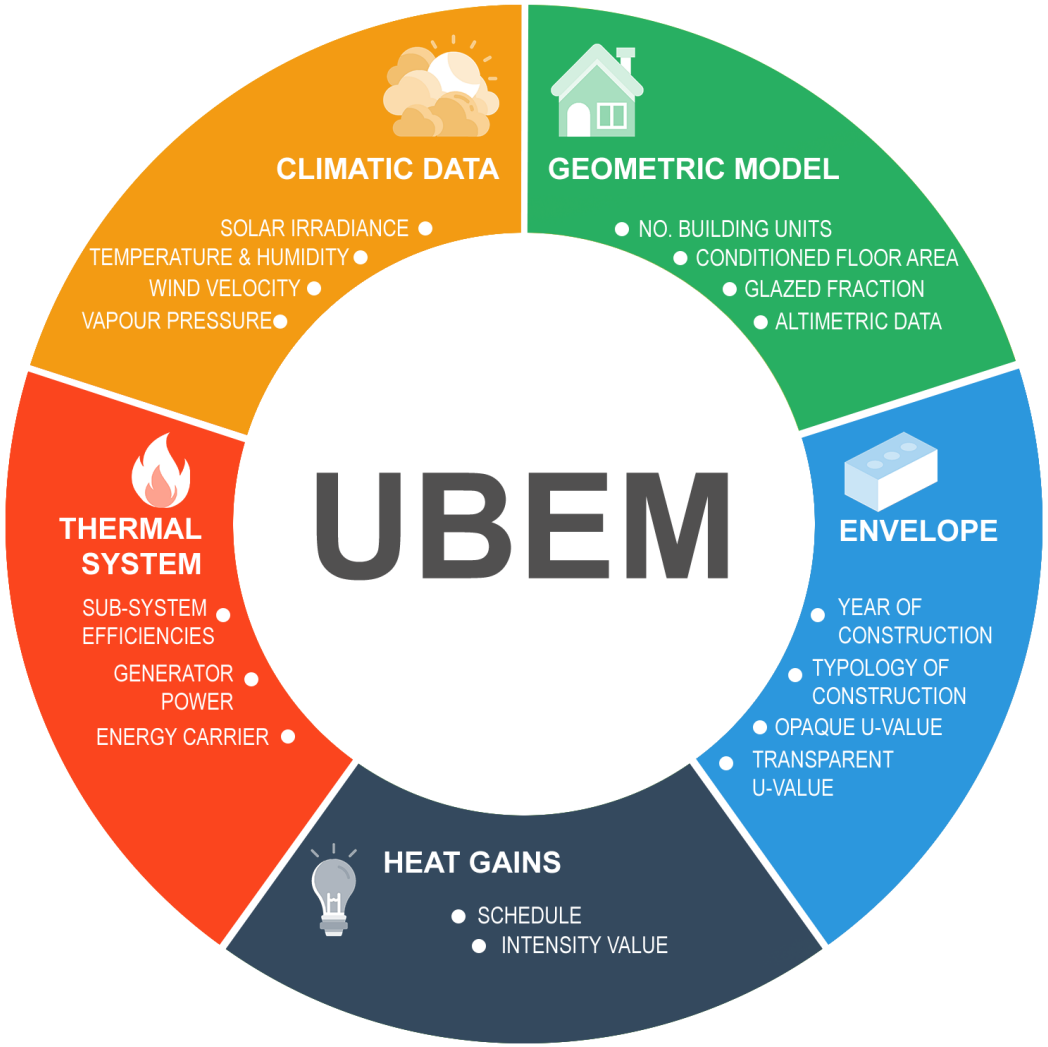


	<1945	1945 1976	1977 1991	1992 2005	2006 2015	2016 2022
A4	1,2%	1,6%	2,0%	1,8%	3,0%	45,6%
A3	0,8%	1,0%	1,4%	1,7%	2,5%	10,6%
A2	1,1%	1,5%	2,3%	2,8%	4,0%	9,4%
A1	1,4%	2,0%	2,6%	3,3%	6,4%	9,2%
B	2,0%	2,4%	3,0%	4,4%	12,3%	5,7%
C	4,1%	4,3%	5,3%	9,3%	18,0%	4,1%
D	8,8%	9,3%	10,6%	19,3%	21,4%	4,0%
E	13,6%	15,6%	17,3%	22,7%	15,3%	3,2%
F	22,5%	26,6%	26,8%	20,2%	10,2%	3,5%
G	44,5%	35,6%	28,6%	14,5%	6,8%	4,6%

Source: ENEA & CTI. (2023). Rapporto annuale sulla certificazione energetica degli edifici- Annualità 2023. p. 29. ISBN 978-88-8286-448-4.

Urban Building Energy Modelling (UBEM)

- **UBEM** for the **large-scale energy** and **environmental performance assessment**.
- UBEM as a **support tool** for **public administrations**, energy agencies, and urban planners **to encourage** the development of **national building renovation plans**.



How to develop a UBEM?

Very detailed model

Accurate results

Time consuming

Lack of data

High amount of real buildings to be assessed!

Need of expert modellers

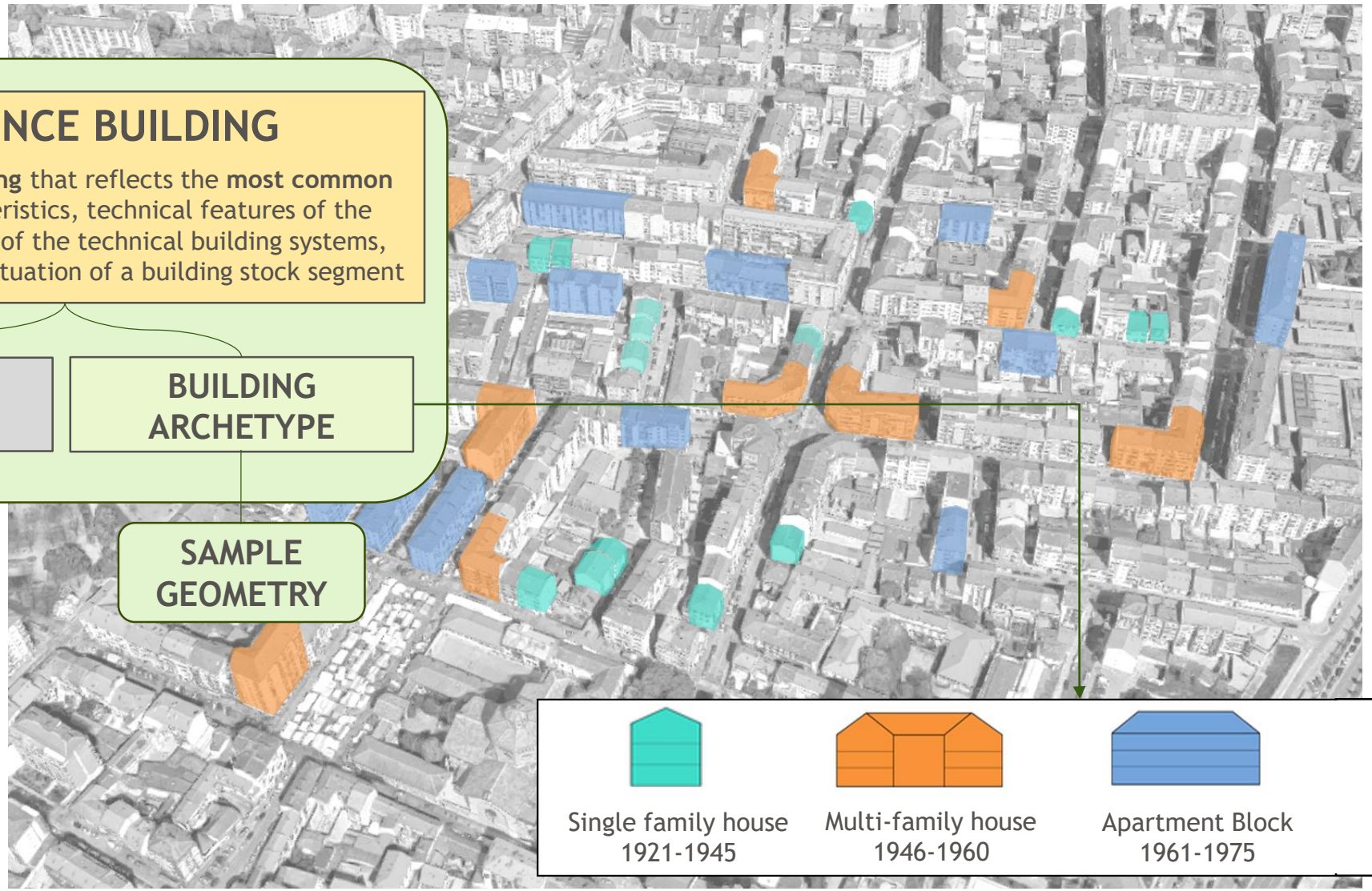
Tools not easily exploitable

Not flexible model

Source: Google Maps

Reference building approach

EXAMPLE



REFERENCE BUILDING

Representative building that reflects the **most common** geometrical characteristics, technical features of the building envelope and of the technical building systems, providing the average situation of a building stock segment

REAL BUILDING

BUILDING ARCHETYPE

REAL GEOMETRY

SAMPLE GEOMETRY

Archetypes

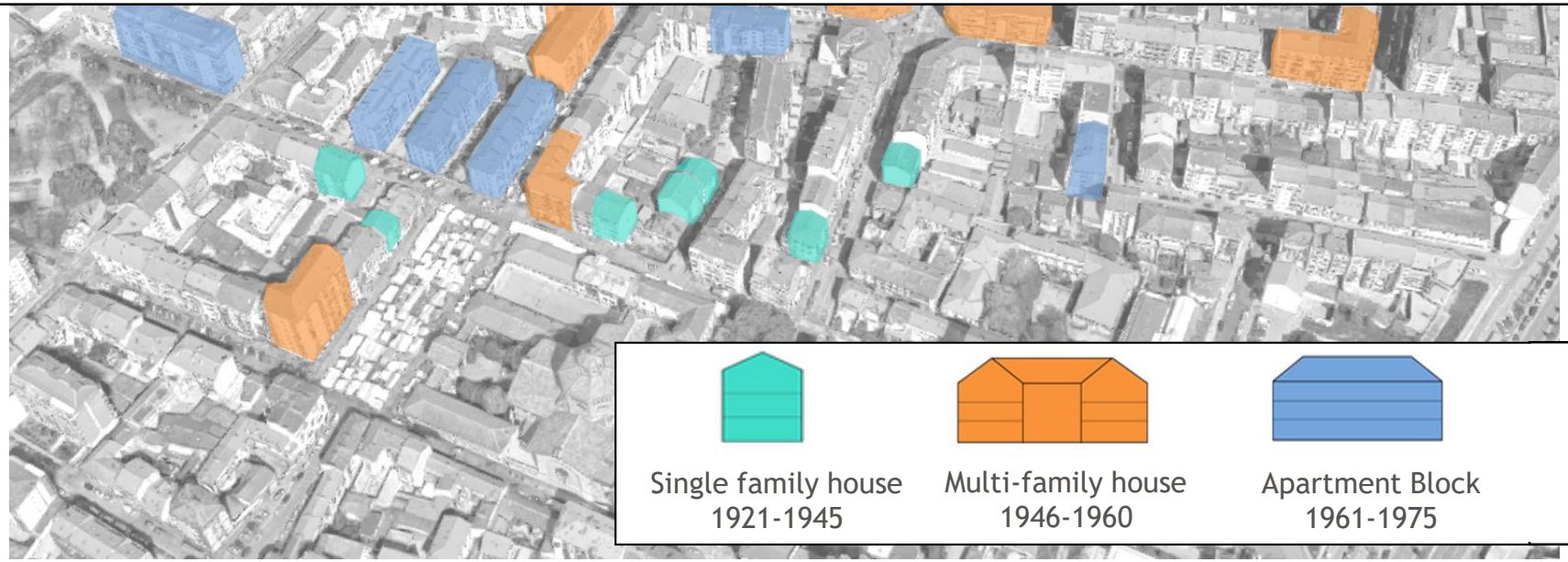
Single family house 1921-1945	Multi-family house 1946-1960	Apartment Block 1961-1975	.....

Source: Google Maps

Bottom-up UBEM using archetypes

EXAMPLE

Building-type energy intensity **X** Numerical consistency of real buildings → Building stock energy performance (baseline and future scenarios)



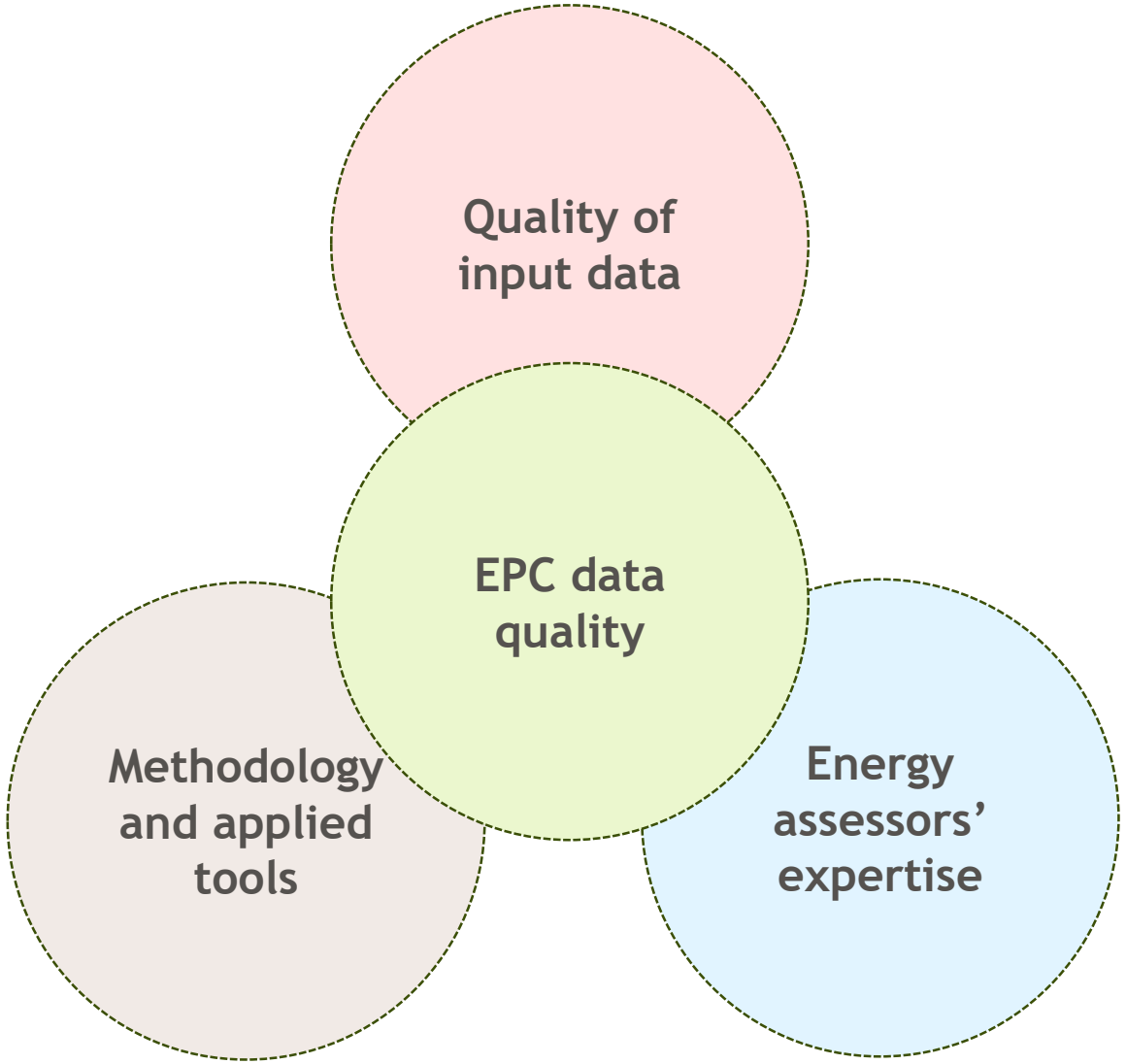
Archetypes

Single family house 1921-1945	Multi-family house 1946-1960	Apartment Block 1961-1975	.....

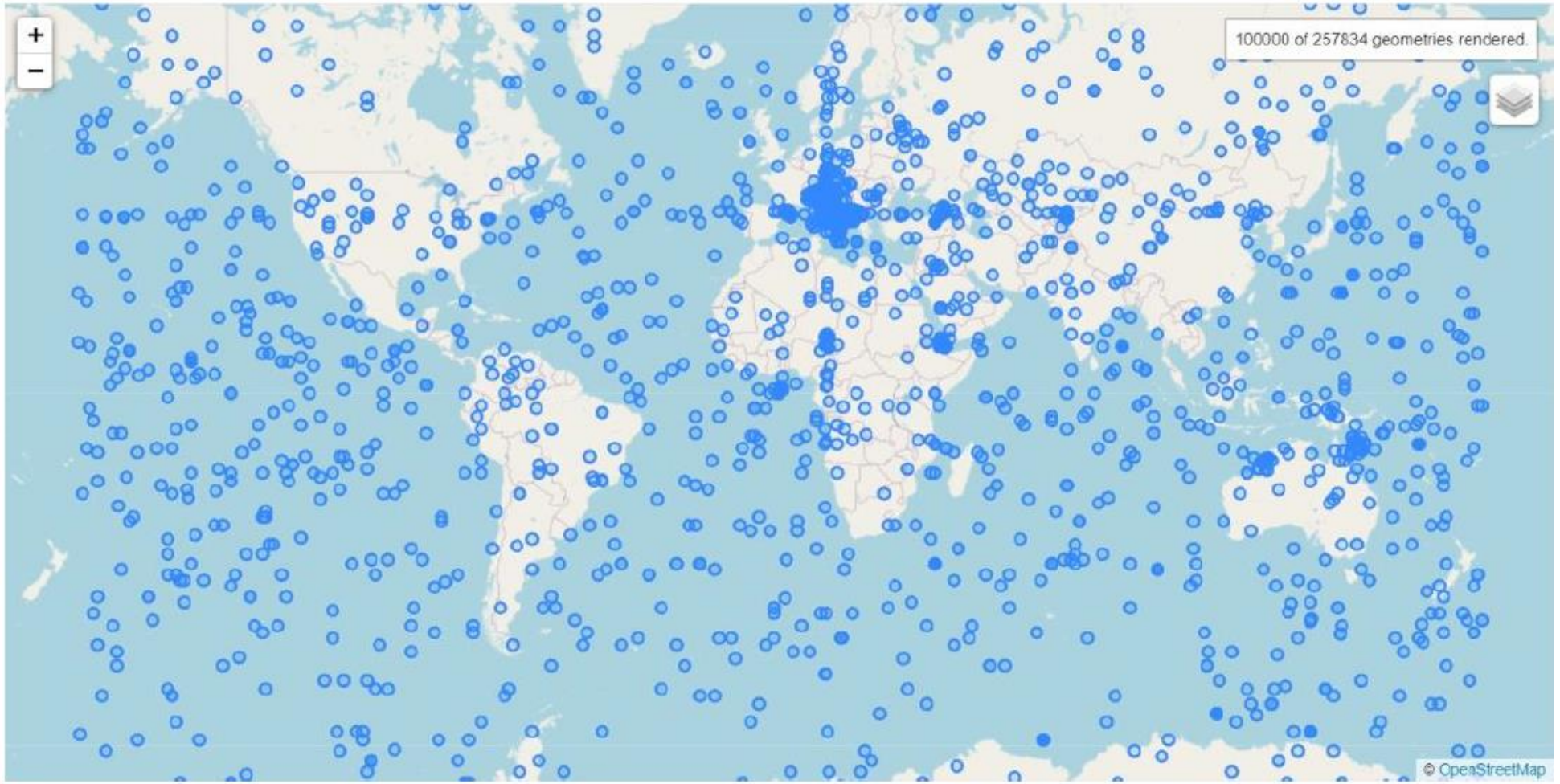
Source: Google Maps

Energy Performance Certificate (EPC) as a data source

Data quality issue



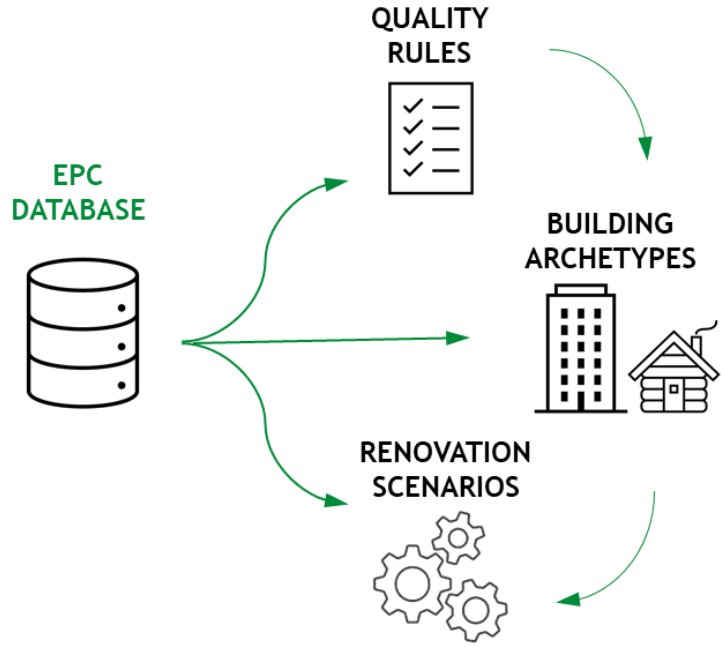
Why is data quality important?



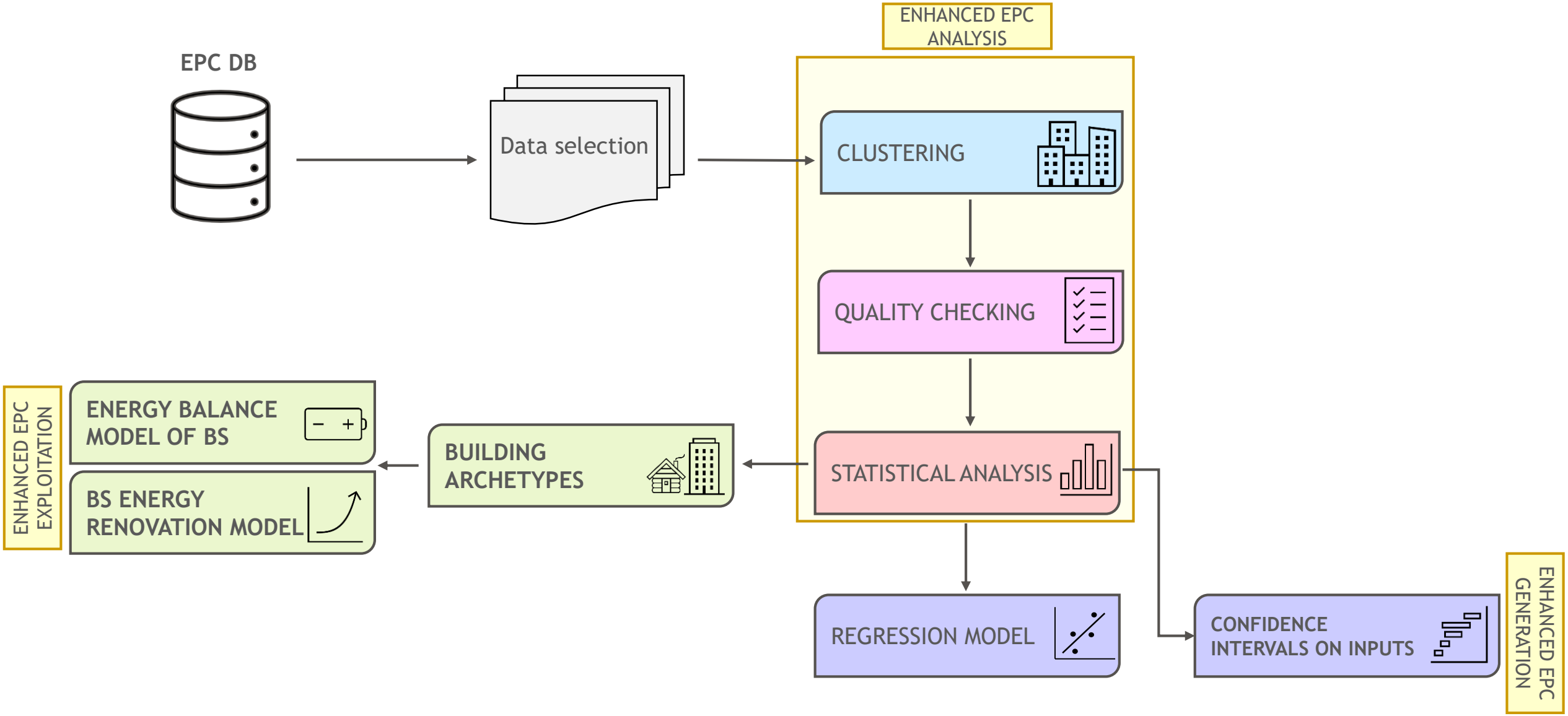
Source: ENEA & CTI. (2023). Rapporto annuale sulla certificazione energetica degli edifici- Annualità 2023. p. 69. ISBN 978-88-8286-448-4.

TIMEPAC objectives

- To **check** and **improve quality** of the EPC data,
- to exploit the EPCs to carry out **energy balances** of the building stock using **representative buildings** (archetypes), and
- to provide **targeted stakeholders** with a methodology to perform reliable **refurbishment scenario** analyses of their building stocks.

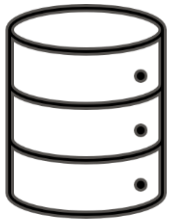


Project work-flow

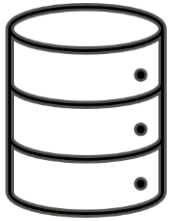


EPC data selection

XML ridotto



XML esteso

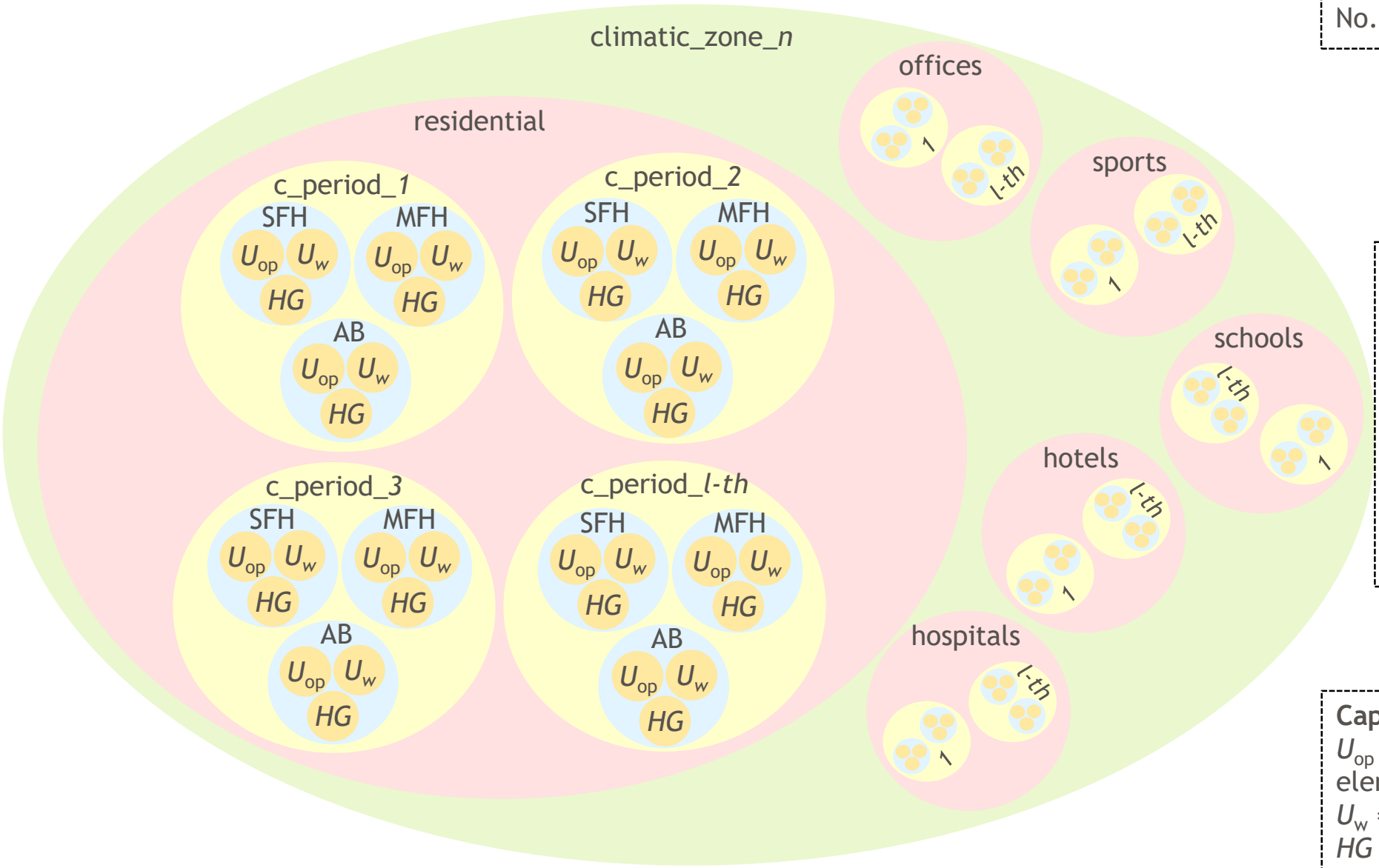


Data needed

Assessed object	Application type	EPC ID code	Building city
Building category	No. of building units	Building typology	Building constructive typology
Year of construction	Year of last renovation	No. of floor	Climatic region
Heating degree days	Compactness ratio	Thermally conditioned floor area	Thermally conditioned gross volume
Thermal envelope area	Mean overall heat transfer coefficient by thermal transmission	Opaque thermal envelope area	Transparent thermal envelope area
Mean *U*-value of the total building envelope	Mean *U*-value of opaque building envelope	Mean *U*-value of transparent building envelope	Energy services
TBS type of generator per energy service	TBS energy carrier per energy service	TBS mean global seasonal efficiency per energy service	TBS subsystems efficiency per heating system
$EP_{H,nd}$	$EP_{C,nd}$	$EP_{W,nd}$	$EP_{H,nren}$
$EP_{C,nren}$	$EP_{W,nren}$	$EP_{gl,nren}$	$EP_{gl,ren}$
$EP_{gl,nren}$ per energy service	Delivered energy per energy carrier	Recommended EEM(s)	$EP_{gl,nren}$ of recommended EEM(s)

EPC data clustering

No. of climatic zones: $n = (1, \ldots, 6)$
No. of intended uses: $m = (1, \ldots, 6)$
No. of constr. periods: $l = (1, \ldots, L)$
No. of bldg size: $o = (1, \ldots, 3)$



Colour caption

- Climatic zone
- Building use
- Construction period
- Building size and shape
- Other parameters

Caption

U_{op} = Thermal trasmittance of the opaque element
U_w = Thermal trasmittance of window
HG = Space heating generator type

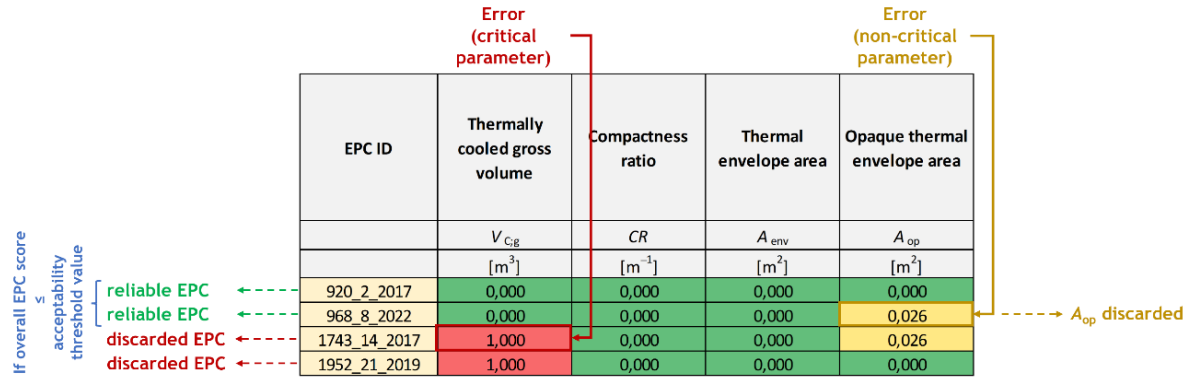
EPC data quality

- The **EPC data quality checking** procedure provides the **score attribution** to parameters and values contained in the energy certificates. For each of the EPC data, a **validity rule** has been associated.

EPC data rules and scores

Data name (Critical parameter*)	Typology of rules	Rule	Respected rule (score)	Unrespected rule (score)
Assessed object	D	string not null	0,000	$1/(n-m)$
Application type	D	string not null	0,000	$1/(n-m)$
EPC ID code*	D	string not null	0,000	1,000
Building city	D	string not null	0,000	$1/(n-m)$
Number of building units	D	string not null *or* integer ≥ 0	0,000	$1/(n-m)$
Building typology	D	string not null	0,000	$1/(n-m)$
Building construction typology	D	string not null	0,000	$1/(n-m)$
Building category	D	string not null	0,000	1,000
Year of construction	D, P	integer > 0	0,000	1,000

EPC data scoring

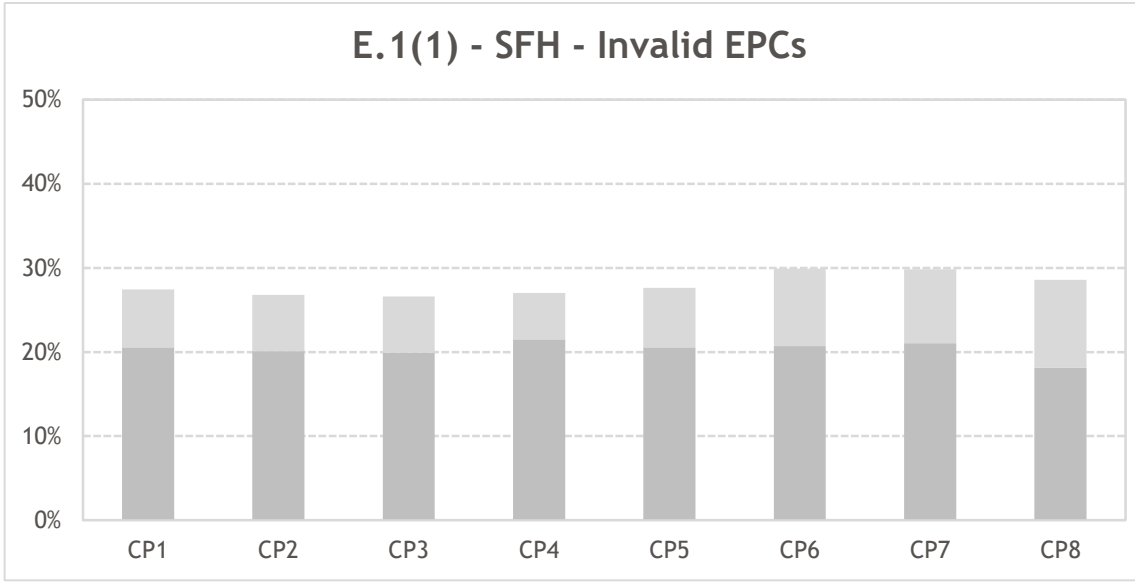


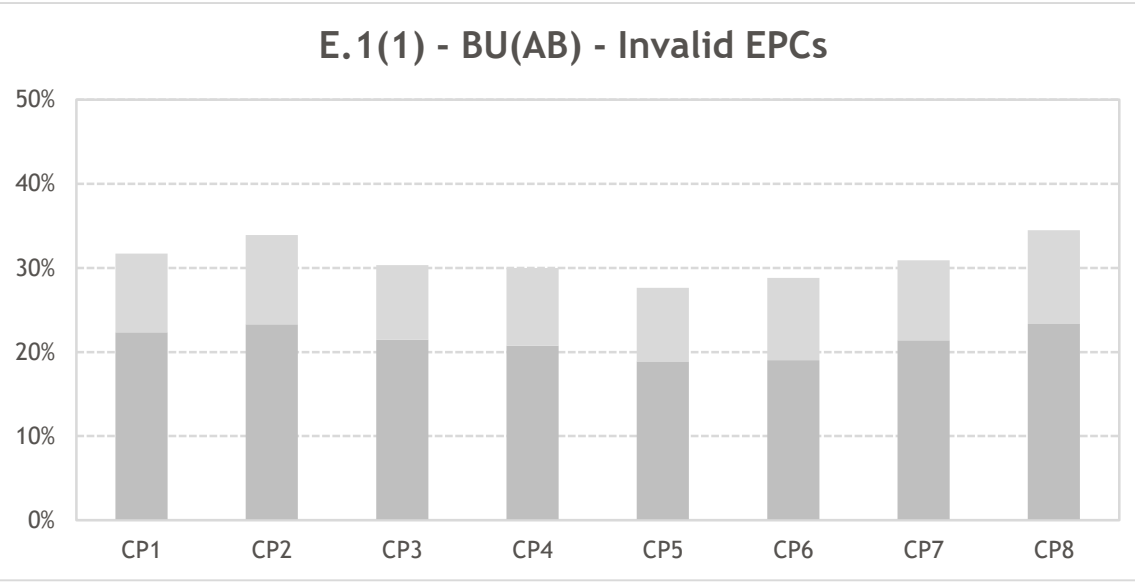
(*) This procedure draws inspiration from the X-tendo project (x-tendo.eu).

EPC data quality

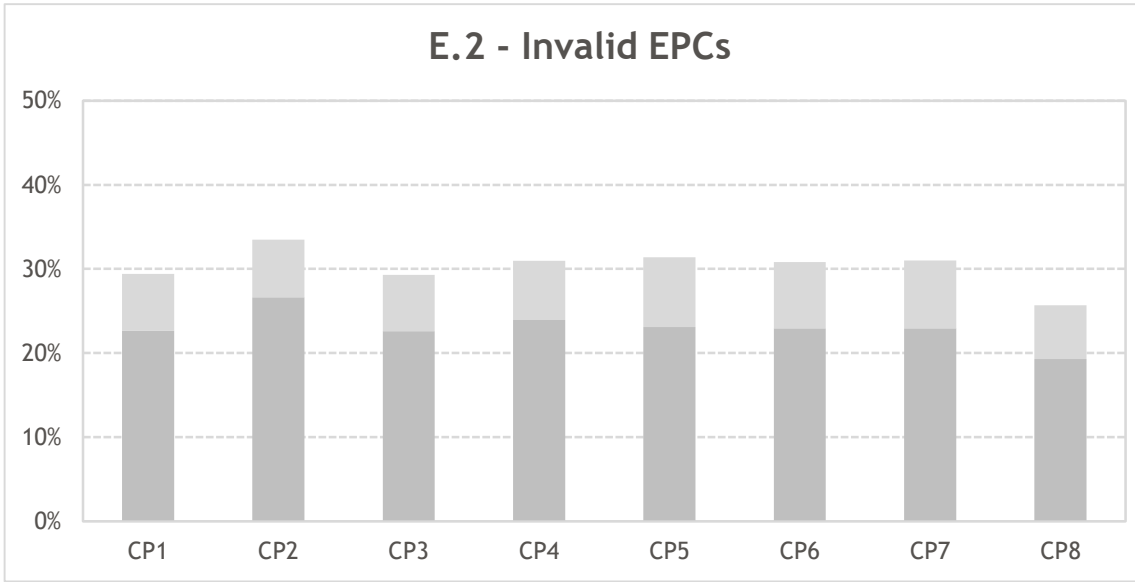
The procedure has been applied to the **Piedmont Region EPC database (SIPEE)**.

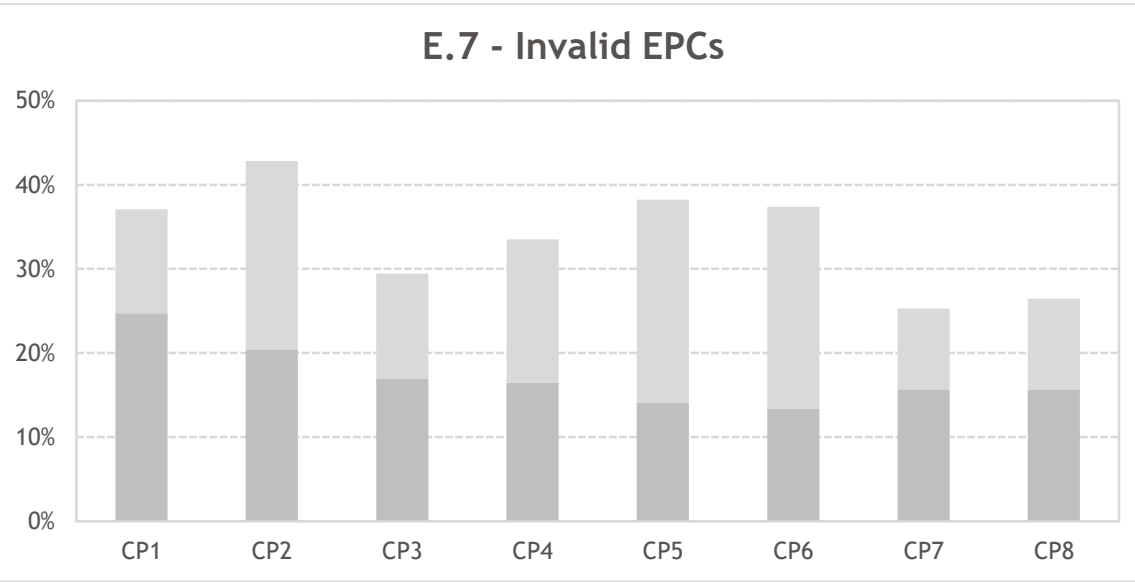
Invalid EPCs due to other rules





Invalid EPCs due to *U*-value rules



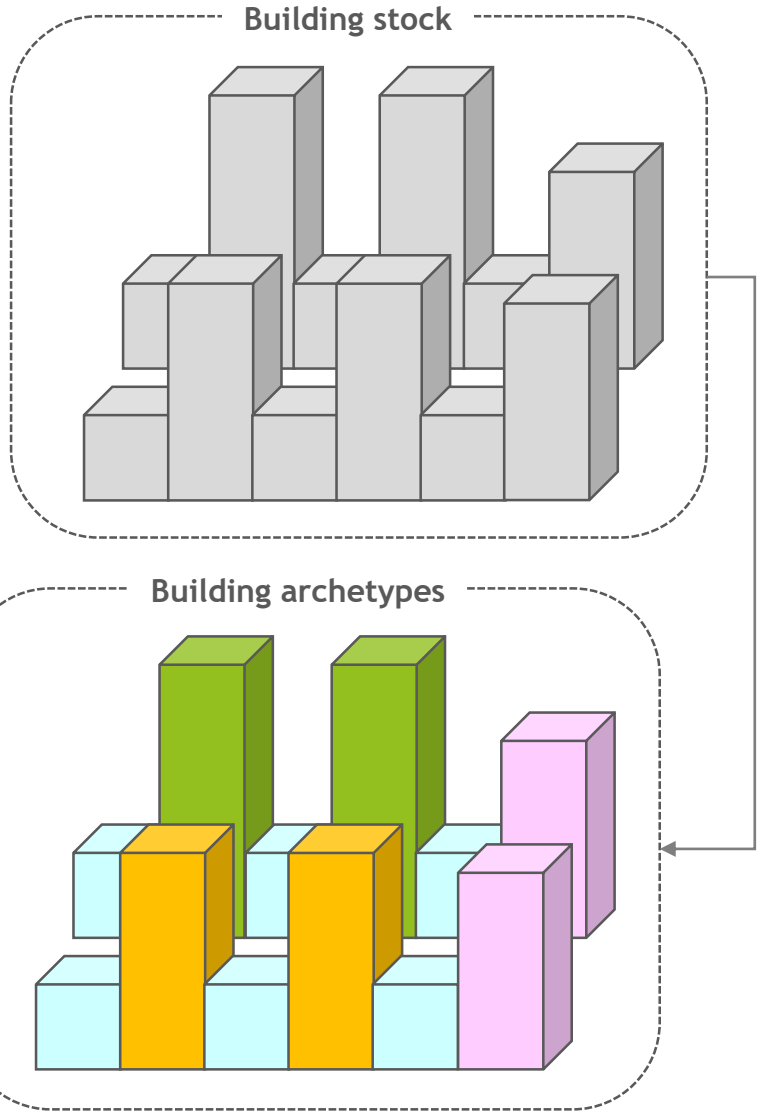


Building archetypes (BAs)

The procedure has been applied to the **Piedmont Region EPC database (SIPEE)**.

Example of BA schema

PIEMONTE REGION EPC DATABASE - E_RES_SINGLE_CP8						
	Data	Symbol	Unit of measure	Median	$(Q_3 - Q_2)$	$(Q_2 - Q_1)$
Geometry	Compactness ratio	CR	m^{-1}	0,788	0,111	0,102
	Thermally heated gross volume	$V_{H;g}$	m^3	534	179	117
	Thermally heated floor area	$A_{H;use;ztc}$	m^2	130	43	28
	Transparent thermal envelope area on thermal envelope area	A_{wi}/A_{env}	%	5%	1%	1%
Envelope	Mean thermal transmittance of opaque building envelope	U_{op}	$W/(m^2 \cdot K)$	0,338	0,244	0,097
	Mean thermal transmittance of transparent building envelope	U_{wi}	$W/(m^2 \cdot K)$	1,570	0,498	0,280
Technical building system	Energy carrier per space heating	Natural gas = 78%; solid biomass = 7%; others = 15% (of the analysed sample)				
	Energy carrier per space cooling	Electricity = 100% (of the analysed sample)				
	Energy carrier per domestic hot water	Natural gas = 72%; electricity = 17%; others = 11% (of the analysed sample)				
	Mean seasonal efficiency of the heating generation sub-system (natural gas)	$\eta_{H;gn}$	–	0,917	0,093	0,127
	Mean seasonal efficiency of the heating generation sub-system (solid biomass)	$\eta_{H;gn}$	–	0,750	0,186	0,290
	Utilisation energy efficiency	$\eta_{H;u}$	–	0,875	0,048	0,065

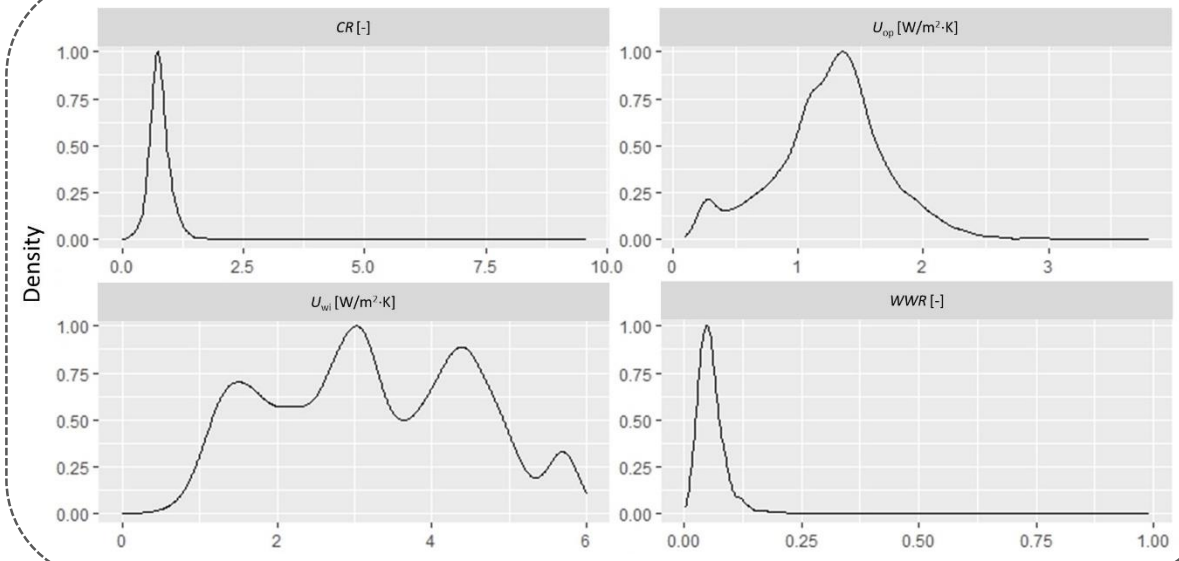


Confidence intervals

The procedure has been applied to the **Piedmont Region EPC database** (**SIPEE**).

- **Plausible values** for the main input data from the regional EPC databases that **affect the energy performance of buildings**.
- Set of controls on EPC input data to increase **reliability** and **representativeness**.

SFH	U_{op} [W/(m²·K)]			U_{wi} [W/(m²·K)]		
	Mean ± SD	95% CI		Mean ± SD	95% CI	
		LL	UL		LL	UL
CP1	1,259 ± 0,45	1,250	1,268	3,234 ± 1,30	3,209	3,260
CP2	1,243 ± 0,45	1,225	1,261	3,209 ± 1,25	3,159	3,258
CP3	1,216 ± 0,44	1,205	1,227	3,170 ± 1,30	3,138	3,203
CP4	1,114 ± 0,45	1,104	1,125	2,960 ± 1,29	2,929	2,991
CP5	1,019 ± 0,42	1,009	1,030	2,872 ± 1,32	2,840	2,905
CP6	0,970 ± 0,38	0,959	0,981	2,678 ± 1,14	2,645	2,712
CP7	0,830 ± 0,33	0,820	0,840	2,390 ± 0,81	2,366	2,415
CP8	0,447 ± 0,30	0,439	0,456	1,749 ± 0,68	1,730	1,769



TIMEPAC The new EPC for Europe

If you would like more information, please visit www.timepac.eu or contact us at

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Thanks for your attention!

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