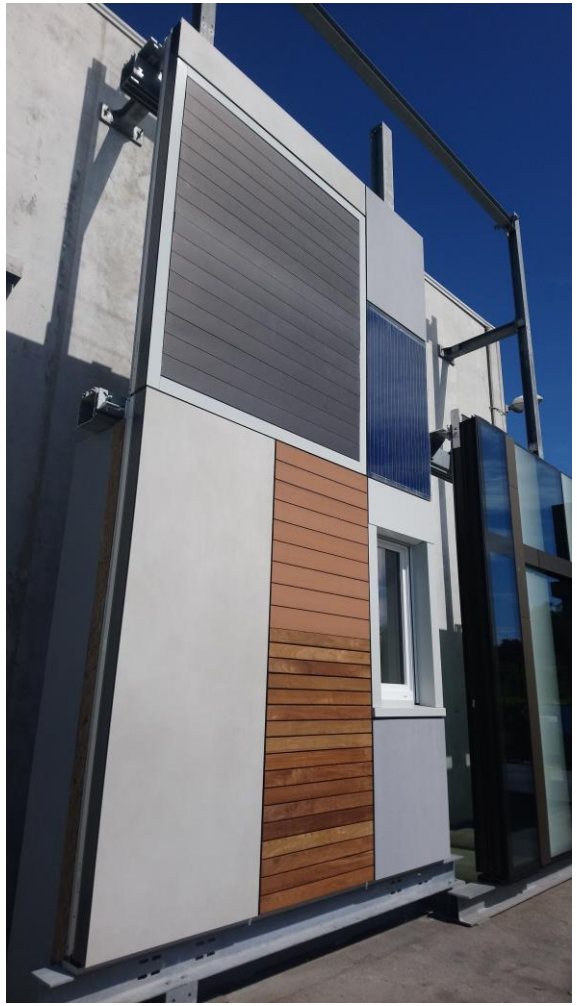
RenoZEB Project in a nutshell

Accelerating nearly zero energy renovation for buildings and neighbourhoods

- **Main project goal**: unlocking the nZEB renovation market and and develop a new systemic approach to retrofitting that will include innovative components, processes and decision-making methodologies to guide all value-chain actors in the nZEB building renovation process
- **Start date**: 01/10/2017
- **End date**: 31/09/2021
- **Project Coordinator**:
- **EU funding**: € 6 822 601,50

Are you ready for a live poll?

RenoZEB solutions – “Plug and play” facade



The main element developed within RenoZEB is an **industrialized Plug-and-Play ventilated facade system** able to integrate different technological elements:

- Prefabricated window module and roller shutter
- Multifunctional insulation boards
- Ventilation units with heat recovery
- Building Integrated Photovoltaics (BIPV) and batteries
- Building Integrated Solar Thermal Systems (BIST)
- Intelligent façade controller (integrated sensors and façade controller)
- Mini Heat Pumps
- ….

Opaque Unit

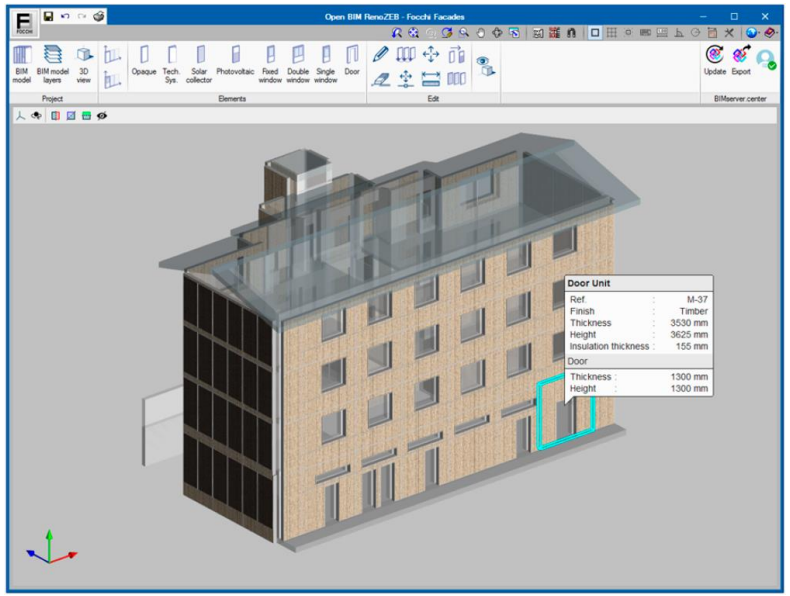
PV Unit

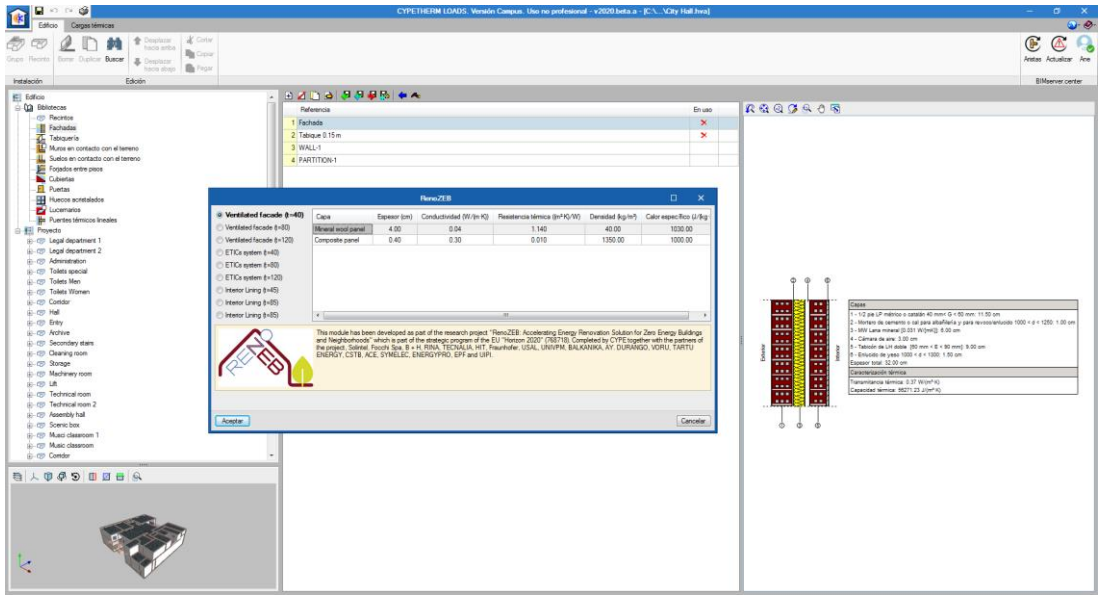
Solar Collector Unit

RenoZEB solutions – Complementary services

In addition to the facade system, the project has developed a several additional services for retrofitting planning based on the RenoZEB facade. Mainly:

- A cloud collaboration platform integrated with a set of decision-making tools, which will support the different actors in the renovation process
- An easy-to-use BIM configurator for RENOZEB solution, for the easy application of RenoZEB modules on existing facades and the definition of models ready to be imported from energy simulation software (Cypetherm)





RenoZEB's ambition - Strengths and weaknesses

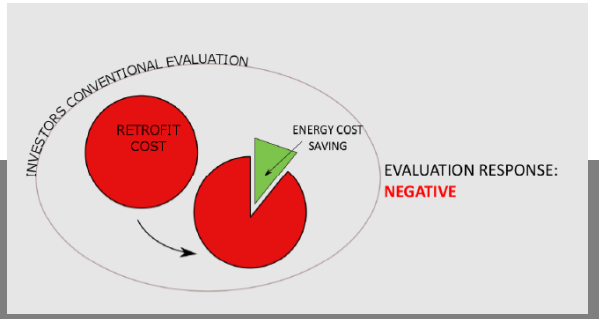
The RenoZEB's goal is to develop a product

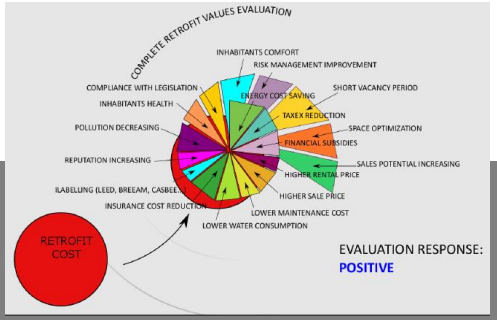
- ✓ (1) enabling the conversion of **existing buildings into NZEB buildings**,
- ✓ (2) **minimizing the user disturbance** and
- ✓ (3) allowing the complete renovation of the envelope, in **the shortest time possible, without interruption of the building's activities**

Compared to traditional solutions, **additional advantages** achieved through the adoption of a **sophisticated industrialized façade system** are:

- **Lower maintenance** costs over time
- Radical revamping of the **aesthetic appearance of the building**
- **Self-production of heat and electricity** (photovoltaic panels and solar collectors applied on the façade)
- Improvement of **internal thermal comfort** through the use of Intelligent façade controller
- **Natural internal cooling** and **better air quality** achieved through integrated ventilation systems

Drawback: higher **implementation costs**





The importance of the Property Value for RenoZEB (but not only)

Typically, an energy refurbishment investment is evaluated by just considering:

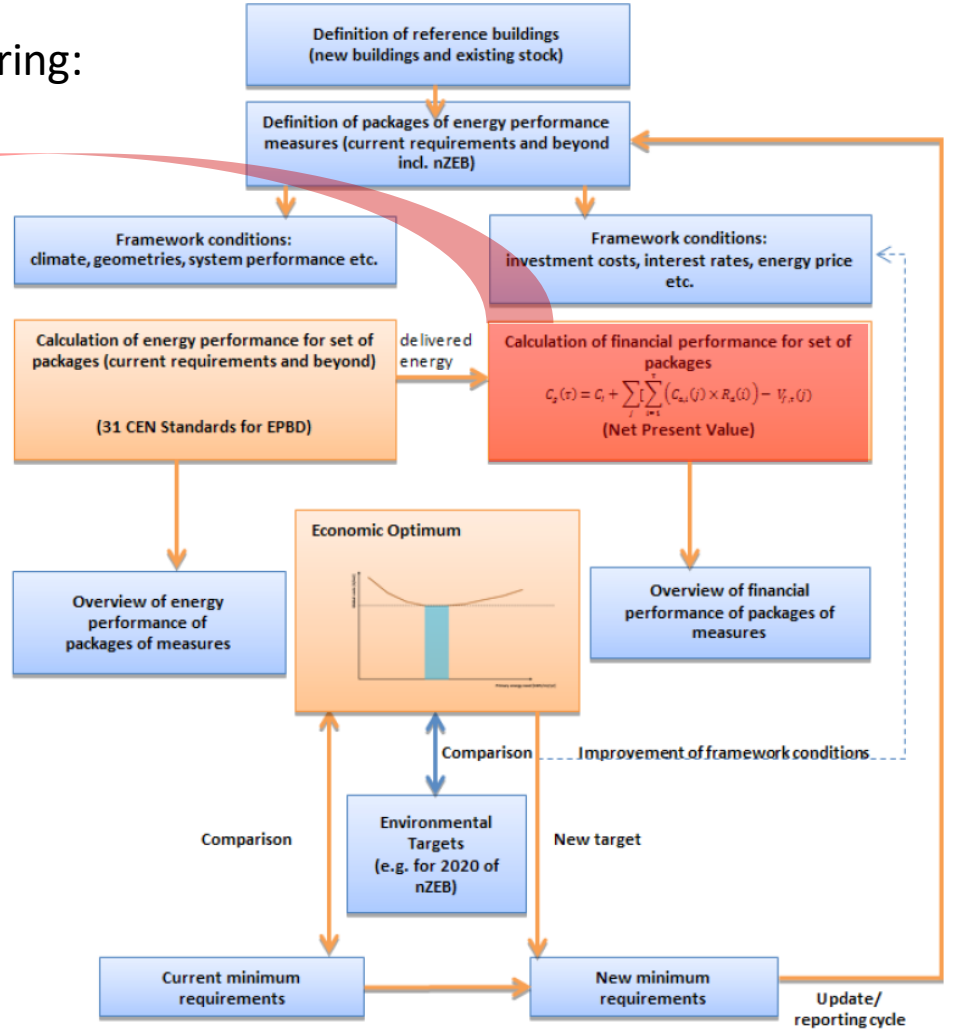
- ✓ (1) The energy benefits (savings)
- ✓ (2) Tax benefits (if there are any).

$$C_g(\tau, r) = I_0 + \sum_{i=1}^{\tau} \frac{CF(i)}{(i+r)^i} = I_0 + \sum_{i=1}^{\tau} CF(i) \cdot R_d(i)$$

$$R_d(i) = (1+r)^{-1}$$

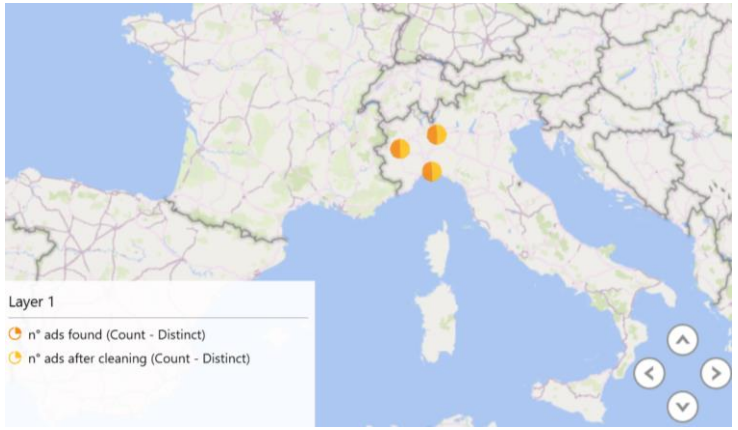
Where:

- Cg is the global cost
- τ is the appropriate period over which cash flows are considered
- r is the discount rate
- I_0 is the initial investment cost for the energy efficiency measures
- $CF(i)$ are the cash flows at the i-th year and **include the Property Value Increase due to RenoZEB** at the end of the calculation period
- $Rd(i)$ is the discount factor for year i based on discount rate r to be calculated



Are you ready for a live poll?

The Hedonic Price Criterion – Property Value assessment

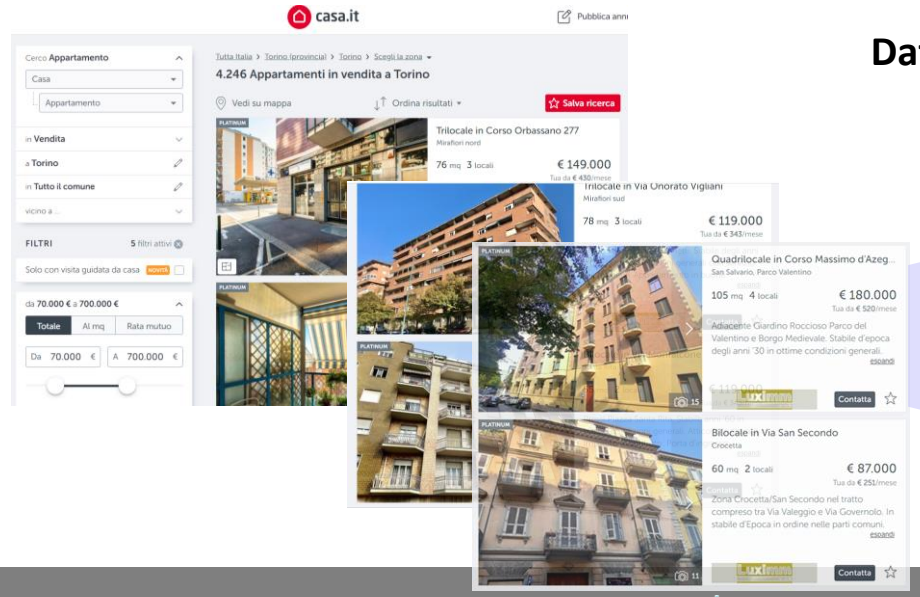


Methodology

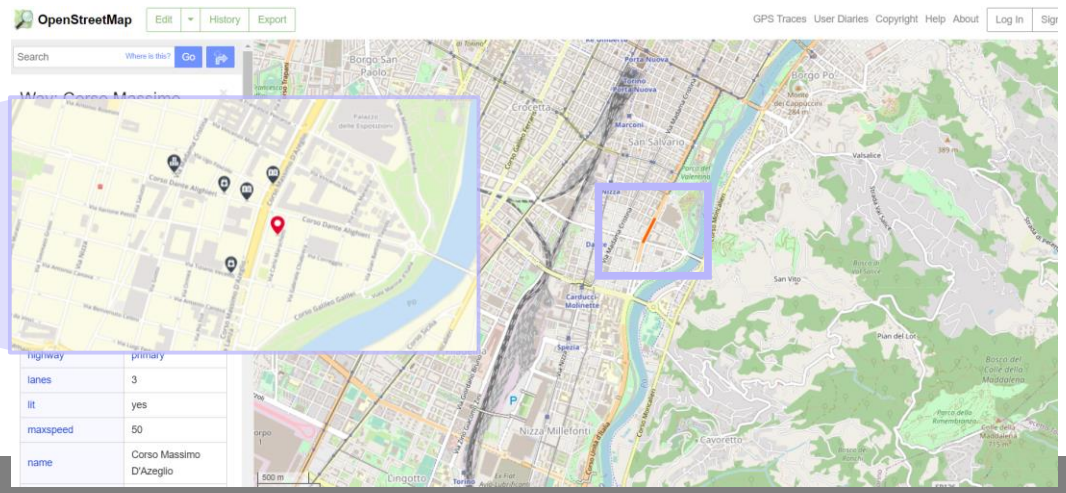
$$\ln\left(\frac{P}{SQM}\right) = c + \sum_{i=1}^{n} X_i \beta_i + \sum_{j=1}^{m} Y_j \beta_j + \varepsilon$$

Where:

- P/SQM is the asking selling price per unit area
- **X** is a set of i physical INTERNAL characteristics of the building and the apartment (architectural variables)
- **Y** is a set of j EXTERNAL characteristics related to the context where the apartment is located (special variables)
- **β**s are the coefficients for each of the variables expressed as unit price semi-elasticities
- **ε** is the error term



Database built by merging data from ***Casa.it*** and ***OpenStreetMap***



The Hedonic Price Criterion – Property Value assessment

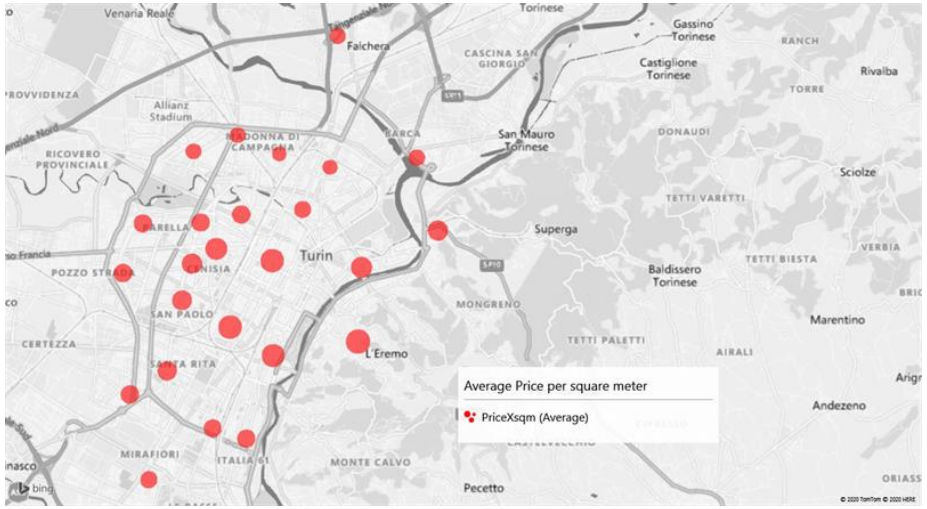
Data

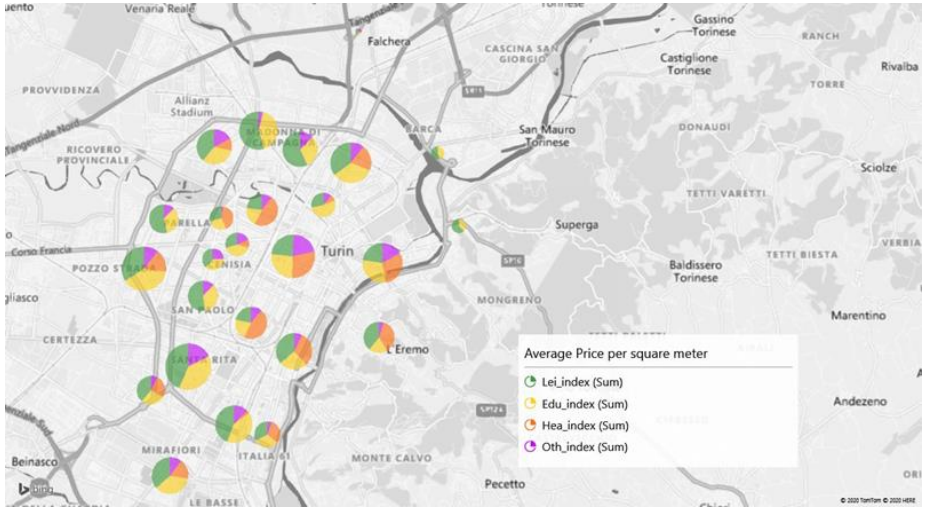
Database for the city of Turin (Northern Italy)

Initial dataset: 6039 ads.
Dataset after cleaning: 2100 ads

Table - DataFrame

Index	Annuncio	Indirizzo	Zona	one_ai	Link	Prezzo	Log_price	Metri_quadr	og_pricexsqr	PriceXsqm	Log_sqm	Locali	Bagni	Balcone	N_piano	vg_mq_loca	Cantina	Condizioni	Anno_di_costruzione	iscaldamento_autonom	Constr_period
0	Trilocale in…	Via Venaria 52	aurora	App…	htt…	65000	11.0821	60	6.98779	1083.33	4.09434	3	1	1	4	20	1	Bad	1960	0	Postwar
1	Appartamento…	Corso Brescia 62	aurora	VEN…	htt…	520000	13.1616	196	7.88347	2653.06	5.27811	5	3	0	1	39.2	1	Excellent	2019	0	Newest
2	Trilocale in…	Corso Brescia 62	aurora	VEN…	htt…	245000	12.409	80	8.02699	3062.5	4.38203	3	1	1	2	26.67	1	Excellent	2018	1	Newest
3	Bilocale in …	Via Bra 5	aurora	VIA…	htt…	75000	11.2252	50	7.31322	1500	3.91202	2	1	1	2	25	1	Acceptable	2007	1	Early2000
5	Trilocale in…	Via Gianfra…	aurora	L'a…	htt…	189000	12.1495	91	7.63864	2076.92	4.51086	3	1	1	4	30.33	1	Acceptable	1970	0	70s&80s
10	Trilocale in…	Via Varese 1	aurora	Il …	htt…	88000	11.3851	75	7.0676	1173.33	4.31749	3	1	1	4	25	1	Excellent	1960	1	Postwar
11	Bilocale in …	Via Cremona 27	aurora	Pro…	htt…	79000	11.2772	60	7.18286	1316.67	4.09434	2	1	1	7	30	1	Excellent	1965	0	Postwar
14	Trilocale in…	Corso Vigevano	aurora	In …	htt…	54000	10.8967	75	6.57925	720	4.31749	3	1	1	2	25	0	Acceptable	1950	1	Postwar
15	Quadrilocale…	Lungo Dora Napoli	aurora	In …	htt…	155000	11.9512	123	7.13899	1260.16	4.81218	4	2	1	2	30.75	0	Excellent	1900	1	Vintage
17	Appartamento…	Corso Giulio Cesare 44	aurora	App…	htt…	160000	11.9829	140	7.04129	1142.86	4.94164	5	1	1	5	28	1	Excellent	1950	0	Postwar
19	Trilocale in…	Via Rivarolo 15	aurora	VEN…	htt…	149000	11.9117	85	7.46905	1752.94	4.44265	3	1	1	4	28.33	1	Acceptable	1951	1	Postwar
21	Appartamento…	Via Clement…	aurora	VEN…	htt…	199000	12.2011	125	7.37275	1592	4.82831	5	1	1	2	25	1	Acceptable	1936	1	Vintage
22	Trilocale in…	corso XI Febbraio 31	aurora	VEN…	htt…	109000	11.5991	80	7.21708	1362.5	4.38203	3	1	1	2	26.67	1	Bad	1934	0	Vintage
26	Bilocale in …	Via Frances…	aurora	Tor…	htt…	55000	10.9151	50	7.00307	1100	3.91202	2	1	1	2	25	1	Acceptable	1931	0	Vintage
29	Trilocale in…	Lungo Dora Agrigento 75	aurora	In …	htt…	90000	11.4076	75	7.09008	1200	4.31749	3	1	1	4	25	1	Acceptable	1970	1	70s&80s
31	Trilocale in…	Via Alessan…	aurora	A p…	htt…	160000	11.9829	87	7.51702	1839.08	4.46591	3	1	0	5	29	0	Excellent	1970	0	70s&80s
37	Bilocale in …	Largo Brescia 47	aurora	€ 6…	htt…	69000	11.1419	35	7.58651	1971.43	3.55535	2	1	0	2	17.5	0	Acceptable	1970	0	70s&80s
38	Trilocale in…	Via Cremona 1	aurora	In …	htt…	115000	11.6527	75	7.3352	1533.33	4.31749	3	1	1	4	25	1	Acceptable	1960	0	Postwar
39	Bilocale in …	via bergamo 6	aurora	Via…	htt…	84000	11.3386	50	7.42655	1680	3.91202	2	1	1	2	25	1	Acceptable	1960	0	Postwar
44	Quadrilocale…	Via Clement…	aurora	VE…	htt…	190000	12.1548	120	7.36729	1583.33	4.78749	4	1	1	6	30	1	Acceptable	1935	0	Vintage
45	Bilocale in …	Via Varese 1	aurora	AC …	htt…	49000	10.7996	46	6.97094	1065.22	3.82864	2	1	1	4	23	1	Acceptable	1965	0	Postwar
54	Trilocale in…	Via Pinerolo 41	aurora	Rif…	htt…	79000	11.2772	85	6.83455	929.41	4.44265	3	1	1	6	28.33	1	Acceptable	1965	0	Postwar
56	Trilocale in…	corso brescia 6	aurora	Cor…	htt…	55000	10.9151	70	6.66659	785.71	4.2485	3	1	1	5	23.33	1	Acceptable	1940	1	Vintage



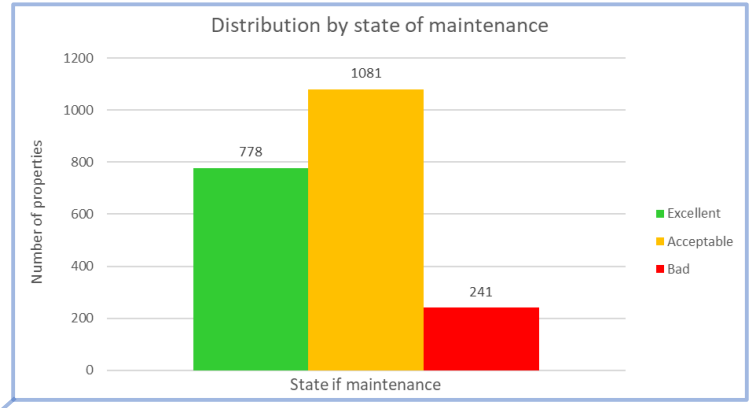


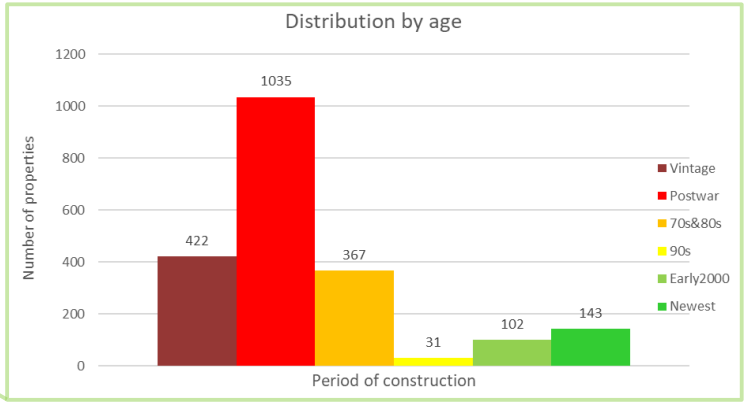
The Hedonic Price Criterion – Property Value assessment

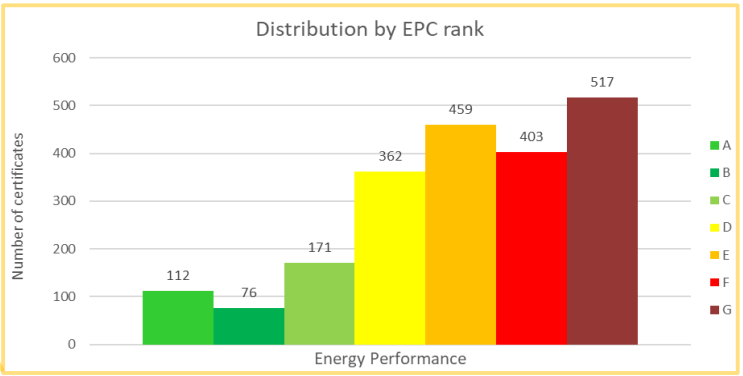
Data

	Variable	Type of variable	N	Min	Max	Average	Std. Dev.
Structural characteristics of dwelling and buildings	Price (Euro)	O	2100	30,000 €	1,980,000 €	181,876 €	179,337 €
	Unit Price (Euro/sq.m)	O	2100	465 €	7,009 €	1,786 €	860 €
	Area (Sq.m)	O	2100	15	446	92	46
	Number of rooms	O	2100	1	15	3	1
	Number of bathrooms	O	2100	1	4	1	1
	Level of the apartment in the building	O	2100	1	13	4	2
	Ratio Area/n° of rooms (Sq.m)	O	2100	13	59	27	5
	Elevator (dummy)	D	2100	0	1	70%	46%
	Balcony (dummy)	D	2100	0	1	90%	31%
	Terrace (dummy)	D	2100	0	1	89%	32%
	State (Categorical)	C	2100				
	Year of construction	O	2100	1900	2019	1960	27
	Construction period (Categorical)	C	2100				
	Independent heating (dummy)	D	2100	0	1	42%	49%
	Energy category (Categorical)	C	2100				
	Garden (dummy)	D	2100	0	1	21%	41%
	Air conditioner (dummy)	D	2100	0	1	15%	36%
	Garage (dummy)	D	2100	0	1	17%	38%
	Park space (dummy)	D	2100	0	1	7%	26%
	Terrace (dummy)	D	2100	0	1	15%	35%
	Pool (dummy)	D	2100	0	1	0%	6%

	Variable	Type of variable	N	Min	Max	Average	Std. Dev.
Characteristics of the urban context	Neighborhood	C					
	Educational Index	O	2100	0	0.75	35%	18%
	Health Index	O	2100	0	1	19%	39%
	Culture and Transport Index	O	2100	0	0.71	13%	14%
	Leisure Index	O	2100	0	0.75	40%	18%





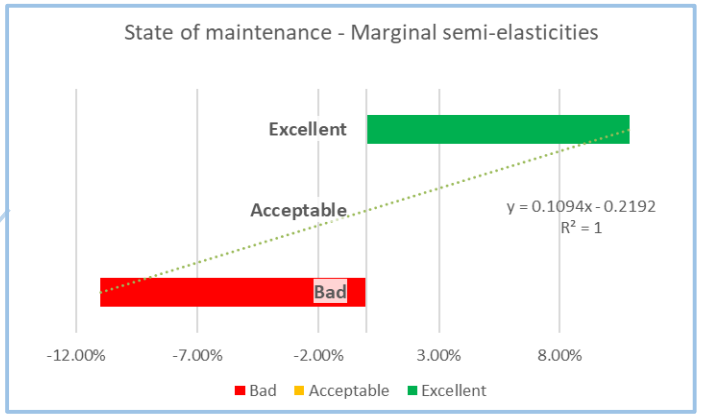


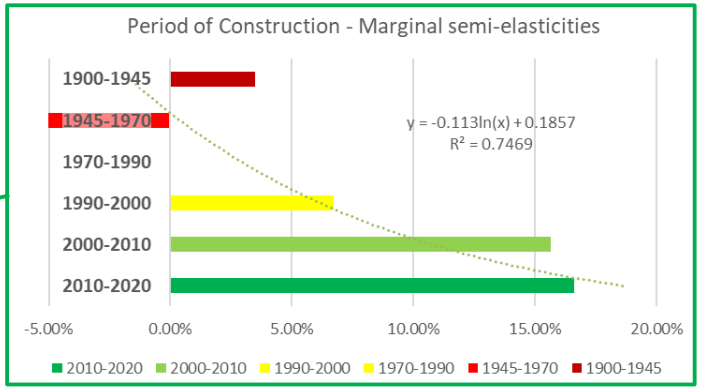
The Hedonic Price Criterion – Property Value assessment

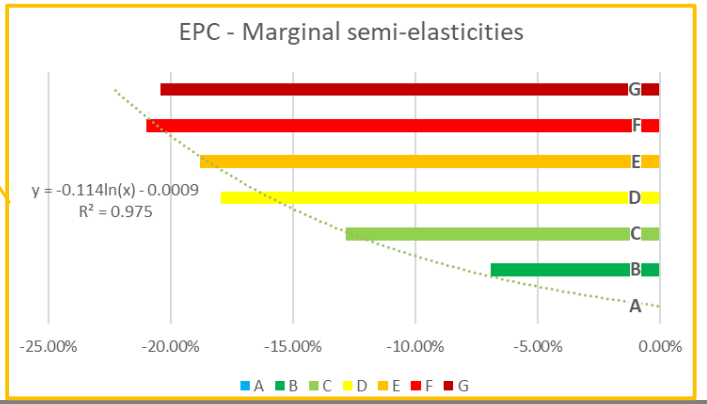
Results

$$\beta_s \rightarrow \ln\left(\frac{P}{SQM}\right) = c + \sum_{i=1}^{n} X_i\beta_i + \sum_{j=1}^{m} Y_j\beta_j + \varepsilon$$

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	7.3823	0.098	75.624	0.000	7.191	7.574
Classe_energetica[T.B]	-0.0718	0.042	-1.721	0.085	-0.153	0.010
Classe_energetica[T.C]	-0.1376	0.043	-3.205	0.001	-0.222	-0.053
Classe_energetica[T.D]	-0.1983	0.042	-4.773	0.000	-0.280	-0.117
Classe_energetica[T.E]	-0.2087	0.042	-5.022	0.000	-0.290	-0.127
Classe_energetica[T.F]	-0.2358	0.042	-5.599	0.000	-0.318	-0.153
Classe_energetica[T.G]	-0.2283	0.042	-5.475	0.000	-0.310	-0.147
Aria_Condizionata[T.1]	0.0689	0.017	4.124	0.000	0.036	0.102
Riscaldamento_autonomo[T.1]	-0.0400	0.013	-3.032	0.002	-0.066	-0.014
Condizioni[T.Bad]	-0.1100	0.019	-5.724	0.000	-0.148	-0.072
Condizioni[T.Excellent]	0.1088	0.014	7.961	0.000	0.082	0.136
Constr_period[T.90s]	0.0670	0.051	1.321	0.187	-0.032	0.166
Constr_period[T.Early2000]	0.1562	0.033	4.702	0.000	0.091	0.221
Constr_period[T.Newest]	0.1661	0.041	4.031	0.000	0.085	0.247
Constr_period[T.Postwar]	-0.0525	0.017	-3.067	0.002	-0.086	-0.019
Constr_period[T.Vintage]	0.0348	0.022	1.555	0.120	-0.009	0.079
Box[T.1]	0.0356	0.017	2.048	0.041	0.002	0.070
Posti_auto[T.1]	0.0612	0.025	2.496	0.013	0.013	0.109
Terrazzo[T.1]	0.0595	0.019	3.199	0.001	0.023	0.096
Balcone[T.1]	-0.0159	0.020	-0.793	0.428	-0.055	0.023
Cantina[T.1]	-0.0426	0.019	-2.260	0.024	-0.079	-0.006
Ascensore[T.1]	0.1771	0.015	12.084	0.000	0.148	0.206
Giardino[T.1]	-0.0067	0.016	-0.413	0.680	-0.039	0.025
Zona[T.barriera-milano]	-0.1137	0.041	-2.772	0.006	-0.194	-0.033
⋮						
Zona[T.vanchiglia-vanchiglietta]	0.4559	0.046	9.818	0.000	0.365	0.547
Log_sqm	-0.0271	0.021	-1.310	0.190	-0.068	0.013
N_piano	0.0021	0.003	0.683	0.495	-0.004	0.008
Avg_mq_locale	-0.0086	0.001	-8.243	0.000	-0.011	-0.007
Bagni	0.1187	0.016	7.490	0.000	0.088	0.150
Edu_index	0.1264	0.041	3.098	0.002	0.046	0.206
Hea_index	0.0398	0.017	2.329	0.020	0.006	0.073
Oth_index	0.2335	0.051	4.616	0.000	0.134	0.333
Lei index	-0.0098	0.036	-0.270	0.788	-0.081	0.061







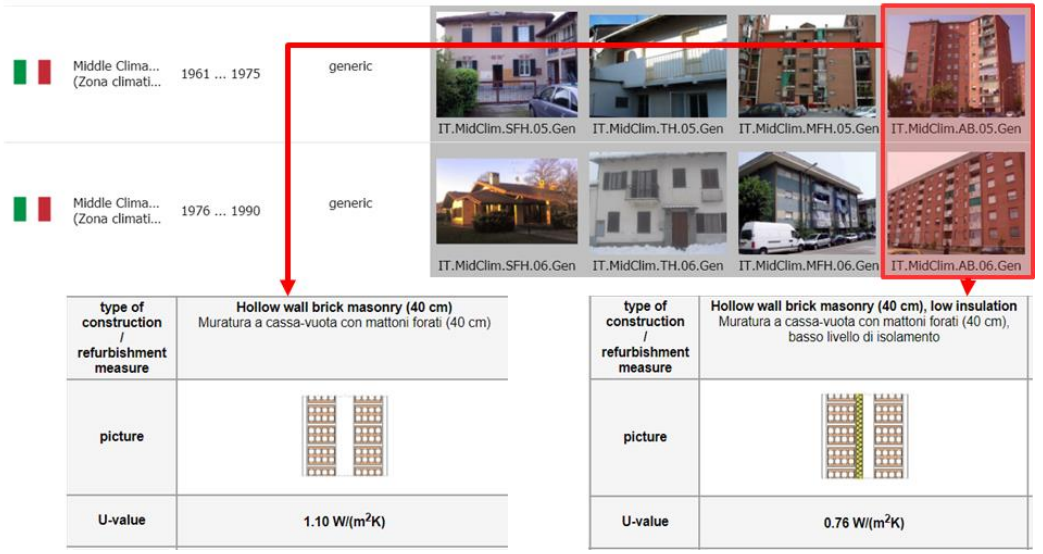
RenoZEB's impact on Property Value

$$\ln\left(\frac{P}{SQM}\right) = c + \sum_{i=1}^{n} X_i\beta_i + \sum_{j=1}^{m} Y_j\beta_j + \varepsilon \rightarrow X_s,\ Y_s?$$

Intervention scenarios and the reference building

- TYPICAL Intervention: Facades only → minimize the level of intrusiveness for people living in the apartment
- FULL Intervention: façade renewal is a driver for the refurbishment of interior spaces → maximize property value increase

- With a 100 sqm surface area and 5 rooms (arbitrary choice)
- Apartment block
- With poor energy performance (G category)
- Built between 1950 and 1990
- Without air conditioning system
- In a poor state of maintenance
- Characterized by a frame construction typology, with external hollow walls brick masonry.



RenoZEB's impact on Property Value

Up to 39 % in case of TYPICAL Intervention

Mapping of the RenoZEB multiple benefits on adopted hedonic price criterion

Variable	Coefficent
Intercept	7.382292
ENERGY_CATEGORY[T.B]	-0.071751
ENERGY_CATEGORY[T.C]	-0.137625
ENERGY_CATEGORY[T.D]	-0.198273
ENERGY_CATEGORY[T.E]	-0.208685
ENERGY_CATEGORY[T.F]	-0.235822
ENERGY_CATEGORY[T.G]	-0.228333
Air Conditioning System[T.1]	0.068893
Heating System[T.1]	-0.040042
Condizions[T.Bad]	-0.109989
Condizions[T.Excellent]	0.108765
Constr_period[T.90s]	0.066985
Constr_period[T.Early2000]	0.156181
Constr_period[T.Newest]	0.166136
Constr_period[T.Postwar]	-0.052548
Constr_period[T.Vintage]	0.034795
Box[T.1]	0.035582
Park space[T.1]	0.061217
Terrace[T.1]	0.059516
Balcony[T.1]	-0.015853
Basament [T.1]	-0.042555
Elevator [T.1]	0.177056
Garden [T.1]	-0.006732
Log_sqm	-0.027149
N° floor	0.002148
Avg_mq_locale	-0.008598
Bathrooms	0.118726
Edu_index	0.126401
Hea_index	0.039753
Oth_index	0.233500
Lei_index	-0.009750

RenoZEB benefits	Affected by the intervention ? TYPICAL Intervention	FULL Intervention
Energy Performance	Yes	Yes
Air Quality	Yes	Yes
Comfort	Yes	Yes
Aesthetic impact of the building	Yes	Yes
Air Conditioning	Yes	Yes
Better state of mainenance	Only external	Yes
Increase of total floor Area	No	Yes
Internal conditions	No	Yes

	TYPICAL Intervention	FULL Intervention
Energy Performance	A/C	A
Air-Conditioning system	Yes	Yes
State of maintenance	n.a.	Excellent
Construction Period	2000-2020 (50%)	2000-2020 (90%)
Total floor Area	n.a.	+4 sqm

Context -->	Medium-quality neighbourhood		
Intervention Scenario -->	Reference Scenario	FULL Intervention	TYPICAL Intervention
Total Sqm	100	104	100
N° of Rooms	5	5	5
Price per sqm	1,784 €	3,578 €	2,482 €
Price	178,432 €	372,160 €	248,154 €
Price per sqm - difference Pre/Post		1,794 €	697 €
Total Price - difference Pre/Post		193,727 €	69,721 €

Variable	Coefficent			
Intercept	7.382292	1	1	1
ENERGY_CATEGORY[T.B]	-0.071751	0	0	1
ENERGY_CATEGORY[T.C]	-0.137625	0	0	0
ENERGY_CATEGORY[T.D]	-0.198273	0	0	0
ENERGY_CATEGORY[T.E]	-0.208685	0	a 0	0
ENERGY_CATEGORY[T.F]	-0.235822	0	0	0
ENERGY_CATEGORY[T.G]	-0.228333	1	0	0
Air Conditioning System[T.1]	0.068893	0	b 1	1
Heating System[T.1]	-0.040042	1	1	1
Condizions[T.Bad]	-0.109989	1	0	1
Condizions[T.Excellent]	0.108765	0	1	0
Constr_period[T.90s]	0.066985	0	0	0
Constr_period[T.Early2000]	0.156181	0	0.9	0.5
Constr_period[T.Newest]	0.166136	0	c 0	0
Constr_period[T.Postwar]	-0.052548	1	0.1	0.5
Constr_period[T.Vintage]	0.034795	0	0	0
Box[T.1]	0.035582	0	0	0
Park space[T.1]	0.061217	1	1	1
Terrace[T.1]	0.059516	0	0	0
Balcony[T.1]	-0.015853	1	1	1
Basament [T.1]	-0.042555	1	1	1
Elevator [T.1]	0.177056	1	1	1
Garden [T.1]	-0.006732	0	0	0
Log_sqm	-0.027149	4.6052	4.6444	4.6052
N° floor	0.002148	2	2	2
Avg_mq_locale	-0.008598	20	20.8	20
Bathrooms	0.118726	1	1	1
Edu_index	0.126401	0.75	0.75	0.75
Hea_index	0.039753	1	1	1
Oth_index	0.233500	0.5	0.5	0.5
Lei_index	-0.009750	0.5	0.5	0.5

X_s, Y_s

Next steps and future developments

1. Develop **more precise hedonic models**, reducing multicollinearity and heteroskedasticity
2. **Cross-reference data from multiple Real Estate ads sites** to build stronger databases
3. **Monitor ads over time** to detect other information (e.g. **Time elapsed between publication and sale**)
4. Develop **collaborations with Real Estate agencies** in order to obtain more complete and reliable databases
5. **Make the most of the potential of OpenStreetMap**, developing algorithms allowing to collect information more accurately

Thank you for your attention

Project Website:

https://renozeb.eu/

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