International Conference on Applied Energy 2020
Dec. 1 - Dec. 10, 2020, Bangkok / Virtual
Paper ID: 0506

Green investments in buildings after the COVID-19 pandemic: the case of Italy

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ABSTRACT

COVID-19 pandemic brought economic crisis, also in the building sector, with an increase of energy consumption in the residential sub-sector due to the more intensive use. The strategic plans put in place by the European Union to face this crisis look to environmental sustainability, by identifying the building as a key sector. In Italy, it has been offered a tax deduction of 110% (divided into 5 annual quotas) aimed at promoting energy efficiency measures for existing buildings, also for fulfilling the new requirements of the Directive EU 844/2018. This investigation aims to analyse - from energy, environmental and economic points of view - this new funding program. It will be shown how it leads to prefer energy efficiency measures characterized by the best energy performance, and not by the best cost/benefit ratio.

Keywords: Public funding, Energy retrofits, Building simulation, Feasibility study, COVID-19, Energy label.

1. INTRODUCTION

Energy efficiency of buildings is a key factor of the international policy actions, in order to favor the transition to a green society [1]. In areas characterized by an increasing development of the construction sector (e.g., China), mandatory building standards alone can trig the development of high energy performance buildings (e.g., nZEB standard) [2]. On the other hand, in countries with a low rate of new constructions (European Union EU), and with most of existing buildings built without mandatory performance requirements, financial support could be the only thrust for final users to invest in energy efficiency [3,4].

According to the International Energy Agency, the COVID-19 pandemic brought an increase of energy consumption in the residential sub-sector due to restrictions to free mobility, extended lockdown, spread of teleworking and e-Learning. In 2020, in the United States, the energy demand increased by 6-8% compared with the previous year. On the other hand, the economic crisis due to the pandemic heavily impacted the construction activities and related sectors, which employ around 10% of the global workforce [5]. To face this crisis, with high risks of loss of jobs, EU has put in place strategies and investments for doubling the annual energy renovation rates over the next ten years, reducing the greenhouse gas emissions and creating up to 160 000 additional jobs in the construction sector by 2030 [6]. In this frame, the Italian government, starting from May 2020, increased the tax deduction rate to 110%, for energy efficiency measures (EEMs) in building. This work analyzes - under energy, economic and environmental points of view - the actions of the Italian Government, by means of a deep study referred to a residential building.

2. INCENTIVE MECHANISMS

Before the COVID-19 pandemic, in Italy, the financial support to specific EEMs in private buildings consisted of a tax reduction from 50 to 85% over 10 years (called "Eco-bonus"). In special cases, also 90% could be achieved. In May 2020, the so called "Recovery Decree" [7], converted in law 77 on July 2020, concerning social policies to face the COVID-19 emergency, increased the tax deduction rate to 110% for expenses incurred from July 2020 to the end of December 2021, to support the building sector renovation. It is the so-called "Super-

Selection and peer-review under responsibility of the scientific committee of the 12th Int. Conf. on Applied Energy (ICAE2020).

bonus". The tax reduction is for investments aimed at EEMs for multi-family buildings and individual homes.
The tax reduction of 110% is recognized if at least one of the main EEMs, called "driving measures" is applied:

- Driving 1: thermal insulation of building envelope with an incidence ≥ 25% of the total heat transfer surface (i.e., the building envelope area), by means of insulation materials complying with minimum environmental criteria [8];
- Driving 2 and 3: replacement of heating systems with (i) condensing boiler; (ii) heat pump; (iii) hybrid system; (iv) micro-cogeneration system; (v) solar collectors; (vi) biomass boiler; (vii) district heating, if specific performance criteria are met. Driving 2 is the replacement of the generator, Driving 3 considers also other improvements of the whole heating system (terminals, distribution, new regulation).

The maximum expense is 50'000 € and 20'000 € for individual real estate units, respectively for the first and second driving measures. An improvement of at least two energy classes must be achieved; when this is impossible, the best class (i.e., the A4) must be obtained. Other EEMs (such as window replacement, solar shields, PV system, devices for home automation and so on) called "driven measures", if applied jointly with at least one of the "driving measures", can also benefit of the tax deduction of 110%. It is possible also to carry out two "driving measures" simultaneously in the same building. In addition to the tax deduction, it is also possible to transfer credit to suppliers or other active parties or even to obtain (if the construction company agrees) an equal direct discount of the costs; in this case, the construction company becomes the owner of the credit.

3. CASE STUDY AND METHOD

The building chosen for the analysis is a single-family house of the 1980s, located in Italy. It develops on three levels: a semi-basement floor (i.e., the garage) and two floors above the ground, with a usable floor area of 200 m^2 and a surface to volume ratio of 0.71 m^{-1}. In order to define a case study representative of one national building typology, the TABULA WebTool has been used [9]. The building envelope has a structural frame in reinforced concrete, hollow masonry blocks, floor and roof slabs of mixed reinforced concrete and hollow bricks. The windows are double glazed, air gap and wooden frame. There are not shading systems and the total solar factor (g_{tot}) is 0.75. Table 1 infers all thermal transmittance values. Production of heating and domestic hot water is provided by a standard gas boiler.

Table 1 Thermal transmittance of building elements

Building element	U-value [W/m²K]
Wall	0.74
Pitched roof	1.20
Floor	0.95
Glass (windows)	2.80
Frame (windows)	1.60

Efficiencies of generation and distribution subsystem are low (0.73 and 0.86, respectively). In-rooms hot water radiators are installed and the indoor temperature control is centralized for the whole building. There is no mechanical cooling. The energy performance of the building has been performed with a semi-stationary calculation method (Italian standard UNI/TS 11300), by using a standard (asset) energy rating.

It was chosen to place the building in three different Italian cities (Naples, Ancona and Turin), representative of the three most frequent climatic zones: C, 1034 HDD; D, 1688 HDD; and E, 2617 HDD (baseline 20°C). These cities are positioned in the south, in the center and in the north of Italy, respectively, in order to carry out the analysis of the application of tax reduction for the various climatic contexts and building markets.

The EEMs concerned two macro-categories, following the two main "driving measures":

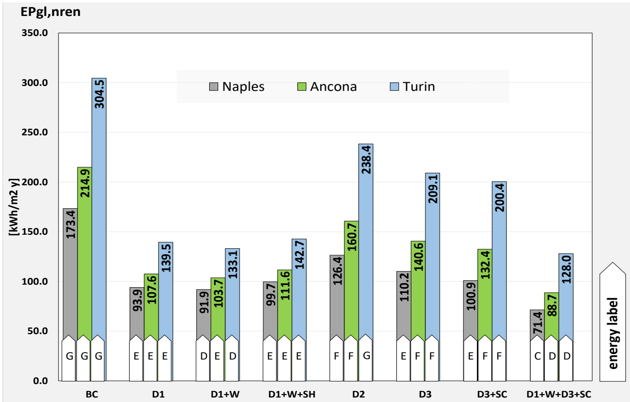
- measures on building envelope: ETICS insulation of walls and roof slab, in addition to the replacement of windows and solar shading installation;
- replacement of the heat generator or refurbishment of the entire system (generation, distribution, regulation and emission) in addition to the integration of a solar thermal system.

In all cases, the thermo-physical thresholds required by law, different among the climate zones, have been fulfilled. Table 2 summarizes both "driving" and "driven" Energy Efficiency Measures (EEMs), with their short name too, and the total investment costs (materials and installation) that are within the cost limits. Note that U_g and U_f are the thermal transmittances of glass and frame respectively, $\eta_{(LHV)}$ and $\eta_{(HHV)}$ are boiler efficiency at rated conditions, by considering the Lower Heating Value and the Higher Heating Value, respectively.

4. RESULTS AND DISCUSSIONS

For the building in the base (i.e., the current) configuration (BC) and for all EEMs, in Fig. 1 are shown:

- the global non-renewable energy performance index, $EP_{gl,nren}$ and the Energy label;
- the percentage difference (Δ) compared to the BC for what concerns $EP_{gl,nren}$ and CO_2 emissions.



		BC	D1	D1+W	D1+W+SH	D2	D3	D3+SC	D1+W+D3+SC
$\Delta EP_{gl,nren}$	Naples		-46%	-47%	-42%	-27%	-36%	-42%	-59%
	Ancona		-50%	-52%	-48%	-25%	-35%	-38%	-59%
	Turin		-54%	-56%	-53%	-22%	-31%	-34%	-58%
ΔCO_2	Naples		-46%	-47%	-42%	-26%	-36%	-41%	-58%
	Ancona		-50%	-52%	-48%	-25%	-34%	-38%	-58%
	Turin		-54%	-56%	-53%	-21%	-31%	-34%	-58%
			ENVELOPE EEMs			HEATING SYSTEM EEMs			

Fig 1 Energy and enviromental results

In the BC, the maximum values of both indices ($EP_{gl,nren}$ and CO_2 emissions) are achieved in Turin (57.2 kg CO_2/m^2y), followed by Ancona (40.4 kg CO_2/m^2y) and Naples (32.6 kg CO_2/m^2y). This trend follows the one of heating need, of course, since the primary energy demand is essentially due to the needs of heating and DHW, as there is no cooling.

Table 2 EEMs put in place

EEM code		EEM description	EEM performance	EEM costs
D1 Driving 1 (ETICS)		Wall insulation		
	Naples	thickness 0.08 m	U= 0.27 W/m²K	16'785 €
	Ancona	thickness 0.09 m	U= 0.25 W/m²K	18'012 €
	Turin	thickness 0.11 m	U= 0.22 W/m²K	18'484 €
		Roof insulation		
	Naples	thickness 0.10 m	U= 0.26 W/m²K	8'643 €
	Ancona	thickness 0.13 m	U= 0.21 W/m²K	9'066 €
	Turin	thickness 0.15 m	U= 0.19 W/m²K	9'173 €
W windows replacement		Triple low-emission glass with Argon	U_g=0.90 W/m²K	1'748 € (Naples) 1'795 € (Ancona) 3'285 € (Turin)
		Aluminium frame with thermal break	U_f=1.10 W/m²K	8'573 € (Naples) 9'331 € (Ancona) 12'871 € (Turin)
SH Shading system		External white blinds	g_{tot} = 0.35	5'120 € (Naples) 5'133 € (Ancona) 5'149 € (Turin)
D2 Driving 2		Condensing boiler	$\eta_{(LHV)}$= 97.5 % (80-60°C)	2'527 € (Naples) 2'552 €(Ancona) 2'692 € (Turin)
D3 Driving 3		Condensing boiler	$\eta_{(HHV)}$= 104.8 % (50-30°C)	16'095 € (Naples) 16'605 €(Ancona) 16'912 € (Turin)
		Fan-coils and single room regulation. Insulation of DHW tank		
SC solar collector		Glazed collectors, 45° south facing, net area of 6.6 m²		8'646€ (Naples) 8'920€ (Ancona) 8'965 € (Turin)

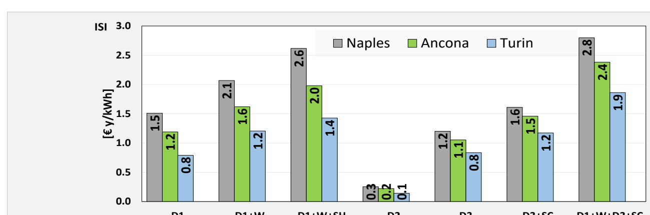
By considering only EEMs applied to the building envelope, in accordance with the 110% tax reduction requirements, all cases achieved the improvement of two energy classes and thus are worthy of the benefit.

From energy and environmental points of view, the most suitable EEM package is D1+W. Compared to the latter case, the application of the shading system is pejorative, since - without the evaluation of summer energy performance - it is possible to quantify only the penalties that the SH causes in winter and not the summer benefit. The calculation of the cooling need showed that the thermal insulation of the envelope brings an increase (with respect to the BC) of cooling need of about 46% in Naples and 68% in Turin. On the other hand, D1+W+SH shows a reduction of the cooling of about 64% in Naples, 59% in Ancona and 56% in Turin.

By analyzing only the EEMs applied to the heating system, in this case, not all interventions are sufficient to obtain the improvement of two energy classes. For Turin, the D2 does not guarantee any improvement in the energy label. This is essentially due to the fact that D2 involves only the replacement of the boiler, which has to operate with the existing radiators, and so with a heat transfer fluid at high temperature. In these operating conditions, there are no energy benefits deriving from the application of a condensing boiler. Within this area, the intervention D3+SC is the best one. Really, in Ancona and Turin, this is not sufficient to obtain the "jump" of two energy classes. To obtain even better energy performance, the generation sub-system should be replaced by a different type of plant (e.g., a heat pump).

Finally, combined EEMs on envelope and systems have been applied, by considering the best one of both macro-areas (D1+W+D3+SC). In this case, the maximum reduction of $EP_{gl,nren}$ and CO_2 emissions is achieved.

Fig. 2 shows economic issues of the various EEMs.



			D1	D1+W	D1+W+SH	D2	D3	D3+SC	D1+W+D3+SC
Naples	SC1	NPV_{20}	17'160 €	17'684€	16'045€	NA	13'350€	15'294€	21'676€
		DPB	5 y	5 y	5 y	NA	4 y	5 y	5
	SC2	NPV_{20}	2'386€	- 3'087€	- 7'701€	8'352€	6'058€	4'084€	-5'731€
		DPB	17 y	> 20 y	> 20 y	4 y	10 y	14 y	> 20
	SC3	NPV_{20}	- 8'459€	- 18'334€	- 25'132€	6'950€	- 2'866€	- 9'634€	-39'270€
		DPB	> 20 y	> 20 y	> 20 y	5 y	> 20 y	> 20 y	> 20
Ancona	SC1	NPV_{20}	23'137€	24'049€	22'389€	NA	NA	NA	27'045€
		DPB	4 y	5 y	5 y	NA	NA	NA	5
	SC2	NPV_{20}	7'404€	1'851€	- 2'792€	9'773€	8'167€	5'823€	-1'830€
		DPB	13 y	18 y	> 20 y	4 y	10 y	12 y	> 20
	SC3	NPV_{20}	- 4'146€	- 14'444€	- 21'276€	8'358€	- 1'040€	- 8'330€	-37'165€
		DPB	> 20 y	> 20 y	> 20 y	4 y	> 20 y	> 20 y	> 20
Turin	SC1	NPV_{20}	35'463€	36'937€	34'928€	NA	NA	NA	37'780€
		DPB	4 y	4 y	5 y	NA	NA	NA	5
	SC2	NPV_{20}	19'394€	11'480€	6'480€	12'105€	12'502€	10'241€	6'205€
		DPB	9 y	13 y	16 y	3 y	8 y	10 y	16
	SC3	NPV_{20}	7'598€	- 7'207€	- 14'403€	10'613€	3'124€	- 4'107€	-32'436€
		DPB	15 y	> 20 y	> 20 y	4 y	16 y	> 20 y	> 20

Fig 2 Main results of the feasibility study

In particular, the bars show the ISI (Investment/Saving Index), and thus the ratio between "the investment cost" and the "annual primary non-renewable energy saving". In the table, the Net Present Value (NPV_{20}) (lifespan of 20 years) and the discounted pay-back period (DPB) with a discount rate of 3% are reported. Reference prices are 0.19 €/kWh and 0.67 €/Sm^3 for electricity and natural gas, respectively [10]. By simplifying, tax reduction considers three possible scenarios (SC):

- SC1: 110% tax saving, over 5 years based on the new "Super-bonus" incentive mechanism;
- SC2: tax saving of 50-65% in 10 years based on the previous "Eco-bonus" incentive, here simplified (50% for envelope EEMs and 65% for heating system EEMs).

No incentives are considered in the SC3. The acronym NA means that the tax reduction is "not applicable" because the improvement of two energy classes is not achieved. By analyzing the ISI, the EEM that ensures the lowest value (i.e., the best one) is D2, and thus replacement of the boiler, in all cities. This EEM is also the one that brings the shortest DPB, both for tax reduction SC1 or SC2 and without funding incentives (SC3). In this latter SC, all other EEMs have a DPB higher than 15 years. On the other hand, by considering the profitability of the energy retrofit on the basis of the NPV_{20}, for all cities, it was found that, if SC1 is applied, the most profitable EEM is a combined package involving envelope and heating system (D1+W+D3+SC), followed by the EEMs concerning the envelope alone (D1+W), and thus those ones that bring the greater energy saving. If SC2 is applied, the most profitable EEM is again D2, and thus the replacement of the boiler (except for Turin).

5. CONCLUSIONS

The paper has investigated, under energy, environmental and economic points of view, the new funding incentives of the Italian Government, following the COVID-19 emergency, in comparison with the previous funding measures for energy retrofit. With a benefit of 110% of the investment cost, the energy efficiency measures that would be chosen from an energy point of view (i.e., insulation of opaque building envelope, replacement of windows and heating system) is also the most economically profitable, having a NPV_{20} equal to € 21'700 for Naples, € 27'000 for Ancona and € 37'800 in Turin, with an energy-saving and avoided CO_2 emissions of about 60%, by considering a single-family building of about 200 m^2. With the application of the previous incentive mechanism (tax deduction between 50 and 65%), or in case of absence of incentive, the more convenient choice is the cheaper one (that is also the less efficient) and thus the mere replacement of old gas boilers. It has been highlighted that the best energy and environmental performance is achieved if retrofits involve the whole building-HVAC system. The Italian funding system leads to prefer EEMs characterized by the best energy performance and not by the best cost/benefit ratio. This allows economic advantages for building owners and environmental benefits for all. The new funding program is complex and fiscally articulated and this can be a barrier: a wide re-organization of professionals and construction companies is required.

ACKNOWLEDGEMENTS

The study is supported by the Italian PRIN Project "SUSTAIN/ABLE" - SimultaneoUs STructural And energetIc reNovAtion of BuiLdings through innovativE solutions", ERC Sector PE8, ID 20174RTL7W_007.

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