The new building regulation plan schema in the town of Castelbuono (Sicily): the experience of FACTOR20- LIFE+ project

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ABSTRACT

The LIFE+ Programme is the European Union's funding instrument for the environment. The general objective of LIFE+ is to contribute to the implementation, updating and development of EU environmental policy and legislation by co-financing pilot or demonstration projects with European added value. In the framework of LIFE+, the project "Forwarding demonstrative ACTions On a Regional and local scale (FACTOR20) to reach EU targets of the European Plan 20/20/20" was founded by European Commission. FACTOR20 is aimed to define a set of tools to support the planning of regional and national policies for the reduction of greenhouse gas emissions and for the reduction of energy consumption.
The knowledge of the existing building allow to quantify energy consumption of an urban area and to highlight what are the main energy problems on which to intervene. One of these tools is the definition of a new building regulation schema that identifies the best practices to improve the energy efficiency, to reduce the GHG emissions and to promote the use of RES. The authors, in order to assess the applicability and the effectiveness of some key actions proposed in the new building regulation plan schema, have performed a detailed dynamic analysis of energy consumptions related to typical building structures strongly representative of Sicilian context. The simulations, carried out by using TRNSYS17, have permitted to assess the actual energy consumptions and then to compare the new energy performances induced by the application of some key retrofit actions. In this way it was possible to identify which retrofit action is more convenient from the point of view of energy and environmental; also the designer have an indication to the designer on the priorities of retrofit actions.

KEYWORDS

Energy efficiency, building regulation, Kyoto protocol, FACTOR20, retrofit actions, dynamic simulation.

INTRODUCTION

The most important fraction of energy consumption in the European Union is due to the residential building sectors. A strategic plan aimed to energy saving coming from local authorities, could take advantage of a closer relationship with its citizens and territory. The building stock of Sicilian towns is characterised by several different types of buildings that now are inadequate to achieve the minimum of energy performance ruled by the European Union. A detailed knowledge about the energy effects that different retrofitting solutions induce on building stock, could represent a useful decision support tool to help local authorities in defining more effective policy actions. This approach should permit to draft new guidelines for building regulations that takes into account also greenhouse gases (GHG) emissions linked to the building-plant systems. Under this perspective, the residential sector could be at the same time an important "consumer" but also a strategic "actor".

Based on these considerations, a LIFE+ Environment Policy and Governance project was funded by European Commission. The "Forwarding demonstrative ACTions On a Regional and local scale to reach EU targets of the European Plan 20/20/20" (FACTOR20) is aimed to define a set of tools to support the planning of regional and national policies for the reduction of greenhouse gas emissions, the reduction of energy consumption and dissemination of renewable energy sources (RES). One of these tools is the definition of a new building regulation schema that identifies the best practices to improve the energy efficiency, to reduce the GHG emissions and to promote the use of RES.

The authors, have carried out a detailed dynamic energy analysis by using TRNSYS17, applying some key actions to typical building structures strongly representative of Sicilian context.

The obtained results allow highlighting the priorities of the retrofit actions, allowing the local authorities to choose the best policies to increase the energy efficiency. Moreover, extending the results to the entire city territory, it is possible to quantify the overall energy savings potential.

In detail in this work, it was analysed the built heritage of the town of Castelbuono identifying three representative residential buildings of the building context: a single Family House, a Townhouse and a Multy-family house. The thermo physical analysis of the plant-building system of these constructions allow evaluating the global energy efficiency and the extension of these results to the entire urban area can help the municipality to encourage citizens on the correct retrofit action depending on the type of building.

MICROCLIMATIC AND ENVIRONMENTAL CONTEXT

Castelbuono is a little Sicilian town in the province of Palermo, located at 423 m above sea level, on the slopes of the hill Milocca. The town is part of Madonie Park belonging to the altitude zone of the Coastal Mountains. Castelbuono has a mild Mediterranean climate with cold and wet winters and warm summers. In winter, the average temperature is between 10° to 12° C and rarely falls to 0 °C (Fig.1); snow and fog are not extremely rare. The rains (Fig.2), which are mainly concentrated in the months of October and March, are generally moderate or intense. During the summer the average temperature varies between 25 and 28°C, the global solar radiation is between 600-800 W/m^2 (Fig.3), the average humidity is about 70%; the mean wind speed is about 3 m/s.

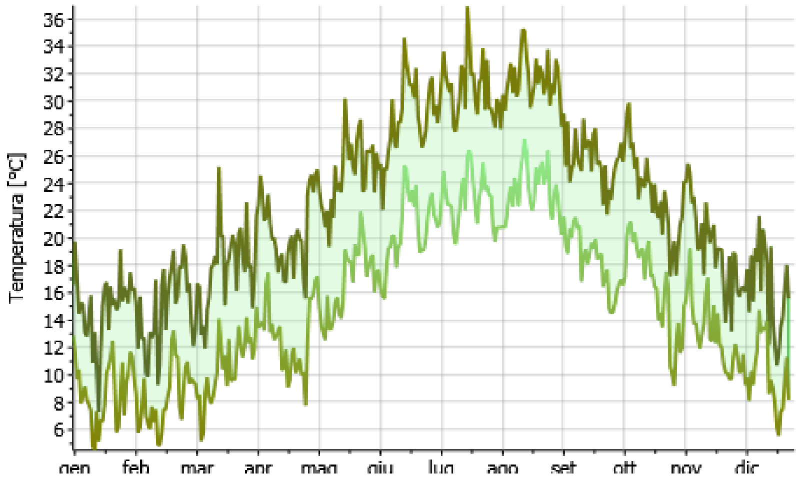

Figure 1. Air temperature trend of Castelbuono

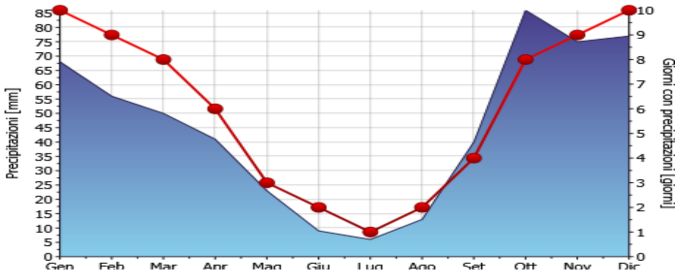

Figure 2. Rains trend of Castelbuono

In accordance with the current Italian regulations laws [1-2], Castelbuono falls in the climatic area represented by the “Zona C” with 1321 degree-day (GG=1321). In this climatic area, the operation of thermal plants is allowed for 10 hours per day, from November 15 to March 31.

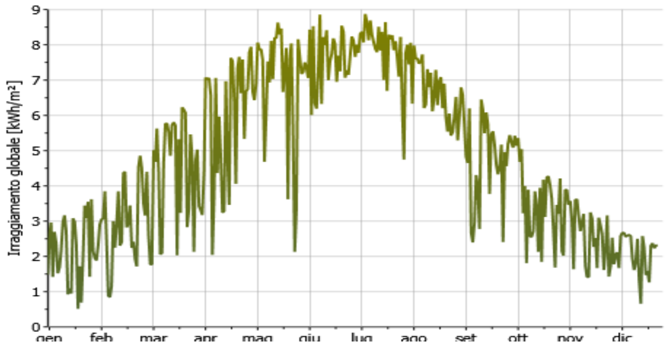

Figure 3. Global solar radiation trend of Castelbuono

The Italians climate data can be determined from the standard UNI 10349 "Heating and cooling of buildings"[3], from the "Climate Profile of Italy" by De Giorgio and ENEA institute, from the indicators of Eurometeo, from the Italian Society of Meteorology; from the “Handbook of Fundamentals” of ASHRAE; the data of NREL, NOAA and Meteonorm software [4]. Figures from 1 to 3 shows the trends of some meteo-climatic parameters of the Castelbuono taken from the international database Meteonorm 7 [5-7].

ANALISYS OF THE ACTUAL BUILDING CONTEXT

Basing on the ”Report of testing activities promoted by Region of Sicily DELIVERABLE-13” it is possible to classify buildings according to their use; the building classification is defined by Presidential Decree 412/93 [1] on the basis of the following Table 1:

Table 1. Building Classification based on DPR 412/93

Category	Description
E.1 (1)	RESIDENTIAL BUILDINGS- continuous employment
E.1 (2)	RESIDENTIAL BUILDINGS -occasional employment
E.1 (3)	BUILDINGS USED to HOTEL, HOSTEL and similar activities
E.2	BUILDINGS USED to OFFICE and similar activities
E.3	HOSPITALS, HOMES CARE, and CLINICAL
E.4	BUILDINGS used for recreational, community or religion and similar
E.5	COMMERCIAL BUILDINGS
E.6	SPORTS BUILDINGS
E.7	SCHOLASTIC BUILDINGS
E.8	INDUSTRIAL BUILDINGS AND CRAFT heated for the comfort of the occupants

In detail, for the town of Castelbuono the following percentages have been identified:

Table 2. Classification of Castelbuono buildings

Category	[%]
E.1 (1)	86.71
Different from E1	5.57
Not used	7.75

In total, the residential buildings are 4,396: only about 1/3 are houses scattered in the outer zones, while 2/3 are built near the centre of the town.

From the structural point of view, taking into account the material used in different historical periods, and also data obtained from the last Italian National Census, it was possible to classify the buildings as:

- Self-supporting Masonry walls: 2,868;
- Reinforced Concrete: 1,010;
- Others: 518,

of which 16.36% in excellent condition, 50.48% in good condition, 29.30% in a poor state and only 3.86% in very poor conditions.

The assessment and calculation of thermo-physical properties of building materials is very important for the overall evaluation of the global energy efficiency; indeed, the conduction heat transmission through the envelope represents the main contribution of total energy balance [8-9].

In order to make a good analysis that represents the existing building heritage of Castelbuono, three sample buildings were selected. According to the above considerations, the following sample buildings were identified:

Sample A: Single Family House

The single family house is designed to accommodate a single family, it is isolated and independent from other building units and usually has a private garden. This type of housing requires a considerable development of roads and services.

Sample B: Townhouse

This typology of house is characterized by adjacent buildings, with a small footprint on multiple floors. The single unit generally has a narrow front that grows in depth and height with several floors. Often presents a garden or a backyard with an internal scale can lead to the upper floors. Generally, it is a mono-family house and this is the typical building construction of Sicilian urban centres.

Sample C: Multi-family house

The Multi-family is a condominium consisting of a building usually free from any side, built on relatively narrow areas, with 2-6 apartments per floor and a variable number of floors, usually 3-6. Characteristic of this type of housing are the internal courtyards. After the Second World War, this housing solution has become widespread in the peripheral areas of large cities, not always with positive results in terms of urban quality. This kind of buildings is typical of the 80’s and it is developed in the area outside the city centre, adjacent to it.

Thermo-physical evaluation

To properly analyse the energy requirements of existing buildings, three buildings that actually exist in Castelbuono, representing the three above identified categories, have been chosen,. Thanks to the documents provided by the technical office of Castelbuono, the following buildings have been identified:

- ✓ Sample A : a single house family located in Contrada Vinzeria;
- ✓ Sample B: a building for residential site in Via Abruzzi 51-53, located in the centre of the town;
- ✓ Sample C: a residential complex located in via Geraci.

For each building, all thermo-physically characteristics of the enclosures, the heating/cooling and DHW systems present, the type of lighting, estimating the thermal and electrical consumptions have been analysed.

<u>*Sample A:*</u> The building representing Sample A it was built in 2007 and it is a single family house in a ground floor, with a basement unheated used as deposit.

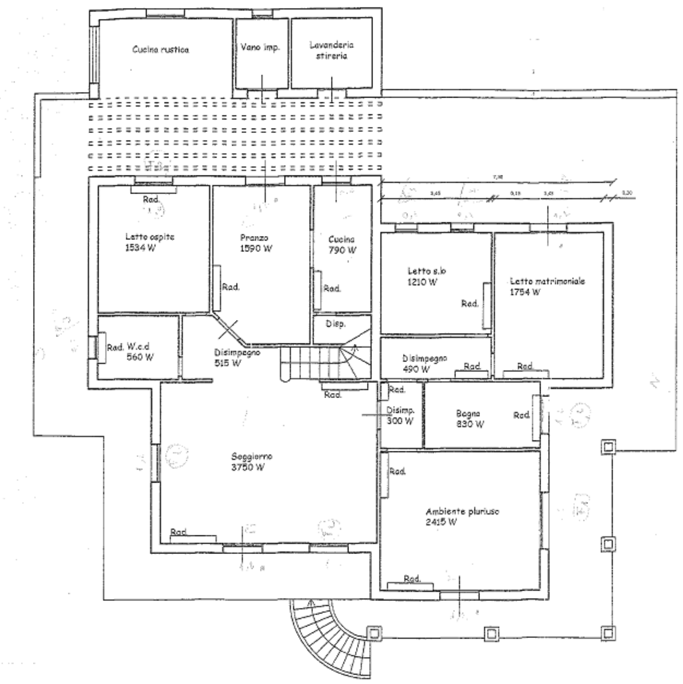

Figure 4. Plan of Sample A (not in scale)

From the structural point of view, the Sample A has a reinforced concrete. It is surrounded by a portico and has a pitched roof with red tiles.
The ground floor, for residential use, consisting of: 1 lounge, n. 3 bedrooms, n. 1 living room, n.1 kitchen, n.3 hall, n. 1 bathroom, n. 1 toilet and an internal staircase connecting the floor to the deposit, for a total are surface of about 156 m^2.
The height is 2.7 m for a total heated volume of 617.2 m^3; the basement is devoid of any type of plant and is in contact with approximately 50% of the upper surface of the ground floor. The remaining floor is a technical unheated room.
By the documentation provided by the technical department of the City of Castelbuono was possible to identify the stratigraphy of the outside vertical walls. As regards the other envelope surfaces (coverage and inter- slab) in the absence of data, were assumed two stratigraphy that comply the transmittance legal limits values U_{lim} in 2007. In detail, the thermo- physical characteristics of the envelopes surfaces are:

Table 3. Transmittance of the opaque envelope of Sample A

Surface	U [W/m²K]	U_{lim} [W/m²K]
External vertical Wall	0.361	0.54
Coverage	0.53	0.55
Internal floor	0.542	0.55

In all apartments aluminium windows with thermal break double-glazed (4-6-4) with aluminium shutters are installed. According to UNI 10077-1 [10], UNI 6946 [11], and [12-13] the following thermo-physical parameters were calculated:

- ✓ transmittance of the glass: U_g = 3 W/m^2K;
- ✓ transmittance of the frame: U_f = 2.8 W/m^2K;
- ✓ coefficient of thermal linear transmission: ψ = 0.08 W/m^2K;

Because all windows are fitted with shutters, it was necessary to evaluate the additional resistance, according to the UNI 10077-1 Standard; the value of thermal resistance for aluminium shutters is 0.02 m^2K/W. For each type of frame the respective U_w transmittance values has been determined:

Table 4. Thermo-physical and geometry properties of Windows (Sample A)

Types	Description	Number	Width [m]	Heigh [m]	U_w
F1	two-wing window	1	1.8	1.5	2.98
F2	two-wing window	4	1.2	1.5	2.99
F3	one-wing window	3	0.7	1.5	3.06
PF1	Door window-two-wing	4	1.2	2.4	2.98
PF2	Door window-one-wing	1	0.9	2.4	3.03
PF3	Door window-four-wing	1	2.4	2.4	2.95

These values of transmittances are all within the legal limit in 2007 (U_w =3.3 W/m^2K).
In the apartment, there is an autonomous heating plant with two 24 kW heaters radiators in all rooms.
The thermal plant was built with horizontal distribution and insulated copper pipe embedded in the floor. The plant is controlled by an ON/OFF room thermostat adaptable for different

areas. For each room the power provided by the radiating elements for a total of 15,378W was estimated.

Furthermore, the following electrical loads have been estimated: n. 1 refrigerator; n. 1 washing machine, n.1 dishwasher, 5W/m^2 of lighting with incandescent lamps, n. 1 PC, n. 3 TVs, n. 1 electric oven; a family of four people occupies the building.

Sample B: is a residential building sited in Via Abruzzi 51-53, located in the centre of Castelbuono. It is a typical construction of nineteenth-century with mono-functional volumes from ground to roof. The building has a body of 13 m x 5 m with the access from Via Abruzzi and borders on three sides to two floors (ground floor and first floor) and on two sides to a floor (second floor). As it can be seen from the floor plans, the building consists of a ground floor, a first floor, a second floor with a little attic.

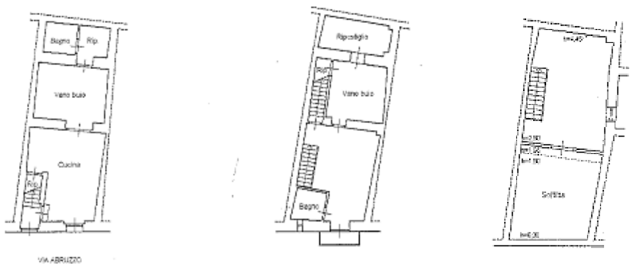

Figure 5. Plan of Sample B (not in scale)

The ground floor and the first floor borders with Abruzzo Street. The entire surface was redone with mortar of lime in light colors. The staircase is internal to the building and is developed from the ground floor to the second floor.

From the structural point of view, the building was consolidated in 2004 and it is characterized by a load-bearing masonry variable with height:

1. Ground and first floor: continuous Masonry with shapeless stone;
2. Second floor and attic: continuous masonry with bricks.

During the consolidation phase, the entire masonry has been reclaimed by a hydraulic injection of lime mortar at low pressure. In detail, the envelope surfaces characteristic are illustrated in the following tables:

Table 5. Transmittance of the opaque envelope of Sample B

Surface	U [W/m^2K]	U_{lim} [W/m^2K]
External vertical Wall (ground and 1° floor)	0.906	0.54
External vertical Wall (2° floor)	0.917	0.54
Coverage	0.429	0.55
Ground floor	0.314	0.55

In the building, there are wooden windows with single glazing and shutters. According to UNI 10077-1 [10], UNI 6946 [11], and [12-13] the following thermo-physical parameters were calculated:

- ✓ Glass transmittance: U_g = 5.8 W/m^2K;

- ✓ Frame transmittance: $U_f = 2$ W/m^{2}K;
- ✓ coefficient of thermal linear transmission: $\Psi = 0$ W/m^{2}K;
- ✓ additional resistance of wooden shutters: $\Delta R = 0.20$ m^{2}K /W;

for each type of frame the respective value of transmittance U_w was calculated.

Table 6. Thermo-physical and geometry properties of Windows (Sample B)

Types	Description	Number	Width [m]	Heigh [m]	U_w
F1	one-wing window	1	0.4	0.5	1.93
F2	two-wing window	1	0.8	1.5	2.36
PF1	Door-window two-wing	2	1.2	2.4	2.36
PF2	Door-window two-wing	1	1	2.4	2.30

In this building, there is no heating and cooling facilities; for this reason in the first analysis, it is assumed that the heating and the domestic hot water (DHW) productions are guaranteed by electrical equipment, such as stoves and boilers. In the sample B the following electrical loads have been supposed: 1 refrigerator; n. 1 washing machine, 1 dishwasher, 5W/m^2 of incandescent lighting lamps, 1 PC, n. 2 TVs, 1 electric oven. It is assumed that there is a family composed by two people.

Sample C: The sample C is a residential complex sited in the Geraci Street. The building was built in 2001, and is a residential condominium with four apartments, two business areas and two attics. More in detail, there are two apartments on the first floor and two apartments on the second floor, in the ground floor there are the two business areas.

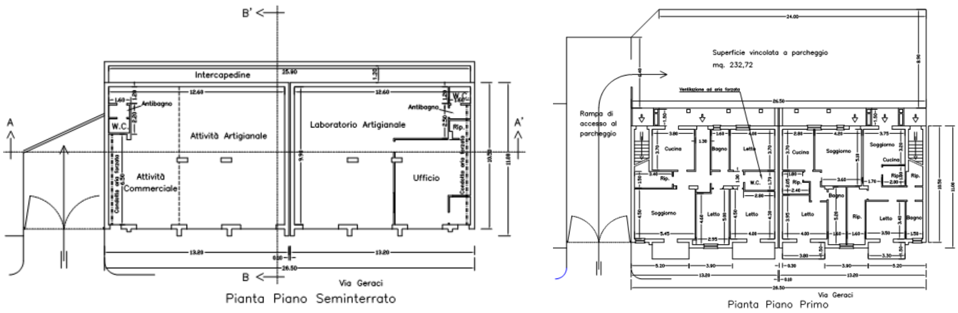

Figure 6. Plan of Sample C (ground and 1thfloor)

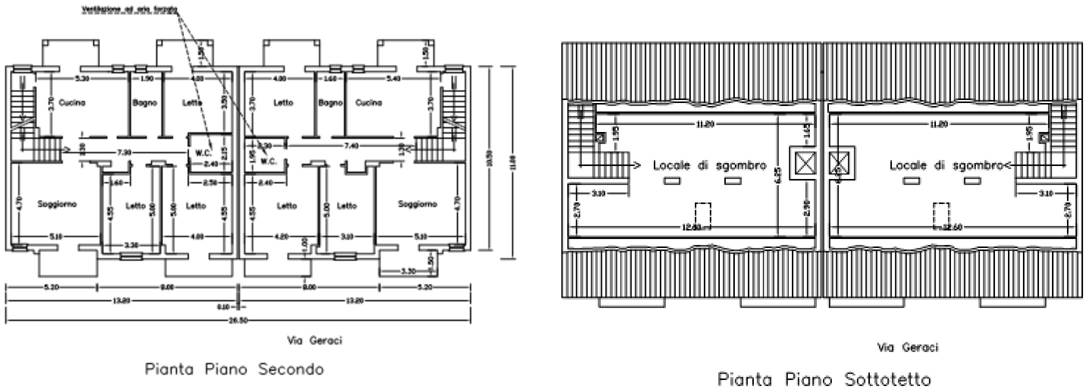

Figure 7. Plan of Sample C (2^{nd} floor and attic)

The Sample C building has a reinforced concrete structure. From the main façade in Geraci Street, West exposure, the building looks like as a building with three floors; on the opposite, East exposure, the building has only two floors.
On the ground floor, there are two the business areas each about 132 m^2. The first and the second floors for residential use, are composed of two apartments per floor, each one consisting of: n. 1 living room, n. 1 room kitchen, n. 3 bed rooms, n. 1 bath, n. 1 toilet, n. 1 utility room, for a usable area of 116 m^2 on the first floor and approximately 112 m^2 on the second floor. The staircases (about 6.15 m^2 on the first floor and 9.81 m^2 on the second floor) are outside and adjacent to the apartments. The height of the two inter- floors used in residential is equal to 2.7 m while the height of the ground floor is 3.10 m.

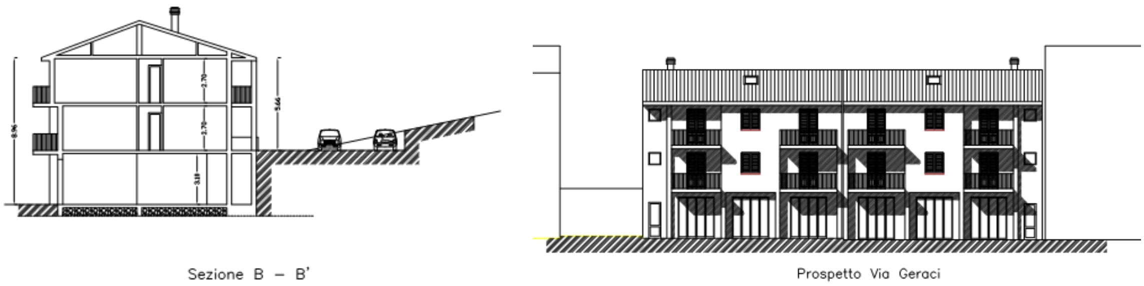

Figure 8. Main section and elevation of Sample C

By the documentation provided by the manufacturer, it was possible to identify the type of bricks used for the construction of the vertical walls. For the other envelope surfaces the following stratigraphy typically of the period of the built up were assumed.
The building is equipped with aluminium frames without thermal break with 4-9-4 glass and green aluminium shutters. According to UNI 10077-1 [10], UNI 6946 [11], and [12-13] the following thermo-physical parameters were calculated:

- ✓ Glass transmittance: U_g = 2.8 W/m^2K;
- ✓ Frame transmittance: U_f = 7 W/m^2K;
- ✓ coefficient of thermal linear transmission: Ψ = 0.02 W/m^2K;

- ✓ additional resistance of aluminium shutters: $\Delta R = 0.20$ m^2K /W;

for each type of frame was calculated the respective value of transmittance U_w and the different orientation.

Table 7. Thermo-physical and geometry properties of Windows (Sample C)

Types	Description	Number	Width [m]	Heigh [m]	U_w
F1	one-wing Window	6	0.7	1.4	4.13
F2	two-wing Window	6	1.3	1.4	4.06
F3	one-wing little Window	6	0.85	1	4.13
PF1	two-wing Door-Window	14	1.2	2.3	3.98

Each apartment is equipped with an independent heating system with radiators and a natural gas heater of about 24 kW. The single plant is controlled by an ON / OFF manual room thermostat. Considering that each flat has an internal height of 2.7 m, the climate of Castelbuono recommended about 30 W/m^3 and that a single radiant element, for a temperature difference of about 50 °C (plate-to-air), has a heat output of 196 W.
Also, in the ground floor, dedicated to commercial activities, are installed four heat pumps of 5.2 kW for heating power and 4.5 kW for cooling power (COP = 3.7).
In the sample C the following electrical loads have been estimated: n. 1 refrigerator; n. 1 washing machine, n. 1 dishwasher, 5W/ m^2 incandescent lamps lighting; n. 1 PC, n. 2 TVs, n. 1 electric oven. It is assumed that four people occupy each apartment.

THERMAL PERFORMANCE AND ENERGY CONSUMPTION

Dynamic Simulation

The thermal analysis is used to assess the distribution of thermal heating and cooling loads for each single thermal zone. For this reason, according to the actual conditions, to the employment and use, to the orientation, and to the ratios of the glass/opaque surface, any buildings were divided into several homogeneous thermal zones. The correct identification of the thermal zones allows a rational description of the complex building-plant. In detail, the following thermal zones have been identified.

Sample A

Zone 1. = Living area;
Zone 2. = Sleeping area;
Zone 3. = Basement floor (garage);
Zone 4. = Technical vacuum.

Sample B

Zone 1. = Ground floor and the first floor;
Zone 2. = Second floor and attic.

Sample C

Zone 1. = Basement floor;
Zone 2. = First and second floor;
Zone 3. = Under roof.

This approach has permitted to develop three models that describe the dynamic thermal behaviour of the building under any environmental conditions; the used software is TRNSYS.16 [14].
TRNSYS is one of the most diffused software for modelling the energy behaviour of a building. To test, to design and to simulate the complex building-plant system, including the

control strategies, and several alternative energy systems (wind, solar, photovoltaic, hydrogen systems), etc, the software is used.

Energy performance of the actual state

For each sample, the heating and cooling thermal energy consumptions and the DHW production have been analysed. The following schema described in Table 8 characterized the consumptions and use of the electrical equipment:

Table 8. Consumption and use of electrical equipment

Types	Electrical Power [W]	use	Thermal gains [W]
refrigerator	200	continuous	180
lighting	5 [W/m^2]	3 h 30 min/day	4.5 [W/m^2]
washing machine	2000	4 washes/week at 60°C	1200
dishwasher	2000	4 washes/week	1800
television	100	4 h/day (without stand by)	90
oven	1000	4 times/week	1000
computer	100	2 h /day	90
refrigerator	200	continuous	180

Results of the status quo

Sample A: Status quo

Simulation	Heating		Cooling		DHW	
kWh	Heat. load	Primary Energy	Cool. Load	Primary Energy		Primary Energy
without use of electrical equipment	6825	7583	0	0	2799	3110
with use of electrical equipment	6139	6921	0	0	2799	3110

On the bases of the heater and plants, it was valuated a global efficiency of 0.9; the electrical consumptions in a year are more of 1972 kWh.

Sample B: Status quo

For this building, without any type of thermal plant, the study was carried out evaluating the heating and cooling load to achieve comfort conditions. The DHW is provided by an electric water boiler of 50 litres.

Simulation	Heating	Cooling	DHW
kWh	Heat. load	Cool. Load	Primary Energy
without use of electrical equipment	8622	185	1061
with use of electrical equipment	8038	341	1061

The estimated value of annual electricity consumption for the use of the equipment is 1,626 kWh, while for the production of DHW was estimated according to the following formula:

$$Q_{HW} = m \cdot c_p \cdot n_p \cdot \Delta T \cdot 365 \qquad (1)$$

Where:

- m is the DHW rate required for a single person (at 50 l / day),
- c_p is the specific heat of water (4186 kJ / kgK),
- n_p is the number of people;
- ΔT is the difference of temperature between the inlet and outlet water (25 °C),
- 365 are the days in a year.

Based on these considerations for Sample B was assessed an annual energy consumption of 1,061 kWh.

Sample C: Status quo

Simulation	Heating		Cooling		DHW	
kWh	Heat. Load (heater+HP)	Primary Energy (heater)	Cool. Load	Primary Energy		Primary Energy
without use of electrical equipment	25138 (17823+7315)	20254	7403	2001	7804	8868
with use of electrical equipment	22519 (15626+6893)	17757	8269	2235	7804	8868

Depending on the heater type and on the type of thermal plant, a global efficiency of 0.88 was evaluated. Concerning the energy consumption, Sample C needs an annual value of 13,710 kWh.

APPLICATION OF SOME KEY ACTIONS, PART OF THE NEW BUILDING REGULATION PLAN

Based on the new building regulation plan of the City of Castelbuono some actions were chosen:
Thematic Area 1: Performance of the building envelope;
Thematic Area 2: Energy Efficiency of Plant;
Thematic Area 3: Renewable Energy Sources.
These key actions were applied to all sample buildings.
Thematic Area 1: Performance of the building; it was decided to evaluate the actions related to:
1.1 Orientation of the building
1.2 Thermal transmittance of opaque envelope components
1.3 Thermal transmittance of transparent components of the enclosure.
1.8 Eco-friendly materials
1.10 Ratio of heat exchanging Surface/ heated Volume (S/V)
In this case, some retrofitting actions that reduce the transmittance values of the opaque and glazed surfaces have been implemented. Furthermore, according to the 1.8 eco-friendly materials sheet, solutions that are efficient and at the same time able to reduce the environmental impact were proposed. The ratio of S/V is calculated as the ratio between the heat exchanging Surface (S) of the building and the heated volume (V). This parameter on the 1.10 sheet it was assessed for each sample.

Thematic Area 2: Energy Efficiency of Equipment; it was chosen to evaluate:
2.1 High efficiency heat pumps
2.3 High efficiency heat pumps
2.5 Efficiency of lighting systems
2:10 Energy Performance Index of buildings [kWh/m^2]
It was assessed the substitution of the actual heating and / or cooling plants with a high-efficiency thermal systems and with an high-efficiency lighting systems. Finally, based on the 2:10 sheet, it was evaluated the primary energy demand before and after retrofit actions. Depending on the S/V factor and the number of Degree Day (DD) it is possible to evaluate the value of Limit Energy Performance for heating EP_{Hlimit}, defined by law [15-16]. The EP_{Hlimit} was compared by the energy performance of the buildings EP_H assessed in the samples.
Thematic Area 3: Renewable Energy Sources, it was decided to evaluate the production of thermal and electric energy from renewable sources, applying the following actions:
3.1.1 Production of domestic DHW with solar panels;
3.1.2 Photovoltaic panels.
Each sheet, and retrofit action, is associated with a score that allows getting monetary incentives.

Application of some actions of thematic area A

In accordance with current legislation for the climate zone C, the limit transmittance values that must be obtained for new buildings construction and / or retrofit action are:

Table 9. Transmittance Zone C (d.lgs. 192/2005)

Climatic Zone C	
Envelope element	U [W/m^2K]
Vertical Wall	0.34
Roof	0.30
Ground Floor	0.40
Window	2.1

Table 10. Annual Primary Energy [kWh/m^2year] for heating (EP_{Hlimit})

S/V	Climatic Zone C	
DD	From 901	To 1400
≤ 0.2	11.5	19.2
≥ 0.9	43.2	61.2

For each building was evaluated the S/V index and the respectively value of Annual Primary Energy. For the Castelbuono town DD= 1321.

Table 11. Annual Primary Energy [kWh/m^2year] for heating (EP_{Hlimit})

		Climatic Zone C	
Sample	S/V [m^{-1}]	EP_{Hlimit} [kWh/m^2year]	Heated floor area [m^2]
A	1.12	58.35	178.37

B	0.32	24.91	173.88
C	0.54	37.59	834.75

To apply the indications of the Area 1, all samples have been simulated improving the envelope surfaces, both opaque and glazed, respecting the legal limit of the thermal transmittance.
Generally, the thermal transmittance of the opaque envelope was improved adding a layer of natural insulating material such as cork or wood fiber. On the contrary, the thermal transmittance of windows has been changed only for the glass in sample A and B with a double-glazed low-emissivity glass; in sample C all windows have been replaced with thermal break aluminum windows with low-emissivity glass. The following Table 12 describes the new thermal hypothesized.

Table 12. New thermal parameters

Sample	Opaque vertical wall	Roof	Ground floor	Windows
		U [W/m^{2}K]		
A	0.264	0.268	0.381	1.5 (glass)
B	0.324 (ground/1°floor) 0.335(2°floor)	0.318	------	1.5 (glass)
C	0.334	0.287	0.40	<1.9

The aftermaths of the new thermal configurations in the following table are collected:

<u>1°Retrofit Simulation</u>

Sample A	Heating		Cooling		DHW	
kWh	Heat. load	Primary Energy	Cool. Load	Primary Energy		Primary Energy
without use of electrical equipment	4628	5142	0	0	2799	3110
with use of electrical equipment	3968	4409	0	0	2799	3110

Sample B	Heating	Cooling	DHW
kWh	Heat. load	Cool. Load	Primary Energy
without use of electrical equipment	6544	125	1061
with use of electrical equipment	5931	294	1061

Sample C	Heating		Cooling		DHW	
kWh	Heat. Load (heater+HP)	Primary Energy (heater)	Cool. Load	Primary Energy		Primary Energy
without use of electrical equipment	21477 (14549+6928)	16533	7688	2078	7804	8868
with use of electrical equipment	18945 (12459+6486)	14158	8623	2331	7804	8868

In terms of EP_H it was obtained:

EP_H	Without electrical equipment	With electrical equipment	EP_{Hlimit}
		[kWh/m^{2}year]	
Sample A	28.83	24.72	58.35
Sample B	37.64	34.12	24.91
Sample C	25.73	22.69	37.59

As it is possible to see, in all cases the application of the retrofit actions permits to obtain a lower values of Annual Primary Energy.

Application of some actions of thematic area 2

It has been assumed to apply some actions of AREA 2 that improve the air conditioning and lighting system performances. These retrofit actions have been proposed only considering the use of electrical equipment, both in the base case (status quo) that in the first retrofit case. In detail, since the A and C samples are characterized by the presence of a heating system with good performance, it has been supposed only the replacement of incandescent lamps with LED devices. In sample B, was supposed the installation of three high efficiency heat pumps (COP=4.19, EER=3.93, P_{nom}=2.15 kW).
The results of simulations are collected in the following table:

2°Retrofit Simulation

Sample A	Heating Load		Electrical consumptions			
kWh	Incandescent light	LED	Total	Light	Total	Light
Status quo	6139	6318	1972	542	1495	65
1°Retrofit simulation	3968	4140				

Sample B	Heating Load				Electrical consumptions			
	Incandescent light		LED		Tot	Light	Tot	Light
kWh	Heat	Cool	Heat	Cool				
Status quo	8038	341	8154	309	2687	301	2422	36
1°Retrofit simulation	5931	294	6055	255				

Sample C	Heating Load						Electrical consumptions			
	Incandescent light			LED			Tot	Light	Tot	Light
kWh	Heat		Cool	Heat		Cool				
Status quo	15626	6893	8269	15815	7124	7970	15788		9492	858
1°Retrofit simulation	12459	6489	8623	12655	6716	8311	16041	7154	9745	

Application of some actions of thematic area 3

For each building, where possible, we have assumed the installation of renewable solar energy systems: solar panel for DHW production and / or solar PV system for the electricity production. For buildings located in the heart of the City, it was not possible to install solar

devices due to national restrictions [17]. For this reason, it was not evaluated the integration of RES in sample B.
The estimated monthly energy production has been evaluated by using the software System Advisor Model (SAM).

3° Retrofit simulation

For both Samples A and C, it was possible to suppose the installation of about 4 m^2 of glazed solar collector and a storage tank capacity of 280 litres. The solar thermal system consisting of 2 flat solar collectors of 2 m^2 each in sample A and 8 flat solar collectors of 2 m^2 each. The solar systems are expected to be installed facing South-East in sample A and facing south-west in sample C.
The estimated monthly production by using SAM is summarized in Table 13:

Table 13. Solar Energy production

	Energy Production [kWh]	
Month	A	C
January	104.	200
February	107	195
March	178	252
April	198	254
May	240	264
June	240	252
July	251	256
August	242	255
September	199	246
October	173	251
November	127	223
December	96	206
Total	2,158	2,860

Generally, in Sample A the solar system is able to cover 77% of the annual needs for the production of DHW. In Sample C the solar system is able to cover about the 30% in winter, and the 40% in summer due to the not proper orientation [18-19].
In Sample A, is was possible to suppose the installation of a 5 kW photovoltaic system. The photovoltaic system has been configured with 16 polycrystalline silicon panels, spread over 2 strings. The system occupies an area of 20 m^2 and is connected to a single inverter.
In Sample C, it was possible to suppose the installation of a 3 kW PV system along North-East prospectus for each apartment. The PV plant occupies an area of 59.7 m^2 and is connected to 4 inverters. The PV system is therefore constituted by 48 panels polycrystalline divided on 6 strings. Energy production is summarised in Table 14:

Table 14. PV Energy production

	Energy Production [kWh]	
Month	A	C
January	240	342
February	264	490
March	412	883
April	475	1210
May	588	1630
June	591	1729
July	641	1819
August	562	1451
September	420	959
October	375	693
November	294	427
December	234	308
Total	5,102	11,945

In Sample A the system covers the entire electricity demand (1972 kWh per year), providing a surplus of energy equal to 3130 kWh per year. In Sample C the system covers the 90% of the electricity demand per year.

RESULTS

The analysis of the results shows how to change the state quo of the buildings, allow to obtain different results. Based on the Italian laws in force, in the field of energy certification, it is possible to calculate the energy classes achieved by the buildings.
The energy classes achieved by the status quo of the building are collected in the following table where it is possible to see as only Sample C is characterized by the achievement of the minimum efficient energy class (C energy class); the other examples belong to less energy efficiency classes.

Table 15. Status quo Energy classes of buildings

Sample	**S/V**	**EP_{Hlimit}**	**EP_H**	**Energy Class**
A	1.12	58.35	59.95	*D*
B	0.32	24.91	55.69	*E*
C	0.54	37.59	34.88	*C*

The different retrofit actions permit to improve the global energy efficiency in all cases and to quantify the energy savings in terms of primary energy. For each sample the Building Energy requirements relating to heating and the cooling air conditioning, the electricity consumption relative to current equipment and the production of DHW were evaluated.
These values expressed in kWh / year were calculated for the status quo, in the case of retrofitting of the envelope (Thematic Area 1); in the case of retrofitting of the plant (Thematic Area 2); in the case of simultaneous retrofitting actions; in the case of installation of RES plants (Thematic Area 3).
The primary energy values are evaluated considering:
• the overall performance of the heating and DHW production;
• the coefficients of performance of Heat Pump for heating and cooling mode (COP and EER);

• the energy conversion efficiency of the global Italian energy systems (0.46).
In addition, according to the NIR (National Inventory Report), it was possible to calculate the corresponding (avoided) emissions of climate-changing gases (CO_2) per single primary source. In this way it was possible to assess the following results in Table 16:

Table 16. Summary of Primary Energy Consumption

Sample	Simulation	Consumptions		Total	Saving	CO_2	
		Thermal	Electrical			Issued	Reduction
		[kWh/m^{2}year]	[kWh/m^{2}year]	[kWh/m^{2}year]	[%]	[tCO_2/year]	[%]
A	Status quo	9931	4286	14218	/	3.69	/
	1° Retrofit	7518	4286	11805	16.97	3.21	13.11
	2° Retrofit	7710	3250	10960	22.91	2.83	23.20
B	Status quo	7399	5841	13240	/	5.24	/
	1° Retrofit	6094	5841	11953	9.86	4.73	9.86
	2° Retrofit	4030	5265	9295	29.80	3.68	29.80
C	Status quo	26625	44170	70795	/	22.83	/
	1° Retrofit	23026	44179	67205	5.07	22.11	3.15
	2° Retrofit	23248	30958	54207	23.43	16.92	25.88

In general, the implementation of all considered retrofit measures allows a primary energy savings between 22% and 30%. Regarding CO_2 emissions, the induced avoided emissions varies between 23% and 30%. Comparing the heating primary energy demand to the floor area, it was possible to obtain the respective values of EP_H:

Table 17. Comparison of the EP_H with EP_{Hlimit}

Sample	EP_{Hlimit} [kWh]	1 Retrofit EP_H [kWh]	Energy Class	1+2 Retrofit EP_H [kWh]	Energy Class	1+2+3 Retrofit EP_H [kWh]	Energy Class
A	58.35	28.83	*A*	46.27	*B*	19.76	*A*
B	24.91	37.64	*C*	43.74	*D*	40.93	*C*
C	37.59	25.73	*A*	30.43	*B*	25.78	*B*

Comparing these values with the respective values of EP_{Hlimit} it is possible to state that, applying at the same time all retrofit actions, the Sample B fails to comply with the legal limit. This situation is mostly due to the poor quality of envelope border with other buildings. Concluding, the retrofitting of lighting systems determines a saving of 88%.

CONCLUSION

A reliable assessment of the residential buildings energy performances allows local administrators to have a powerful tool: the division of the entire building stock few classes, taking into account parameters such as age, construction typology, quality of materials, installed equipment, and finally the overall quality of the building energy system, allows to calibrate effective tax and incentive policies that can result in a real energy savings. In this paper was described a study carried out in the district of the town of Castelbuono aimed to identify energy characteristics typical of the urban housing stock. Three main building typologies were identified and subsequently modelled in TRNSYS 17 environment. The results of a one year hourly simulation allowed to assess the real energy performances and furthermore the effectiveness of some retrofitting solutions

The values of energy consumption obtained by an accurate modelling of buildings and installations were compared with the minimum values ruled by the regional laws; in some cases it has been shown that the poor quality of the materials used for the building envelope makes useless or unprofitable the application incentives for renewable energy plants.

The methodology described in the case study of Castelbuono is an example of an analysis model that can be replicated in any other context, and that can represent a valuable decision support tool for local governments to measure the sharpness of tax and incentives policies to improve the energy efficiency the building stock and in order to guide the municipality in the drafting of a modern and efficient building regulation plan.

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