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POLITECNICO DI TORINO

Dipartimento Energia ''Galileo Ferraris''

Tradition and innovation: nZEB hi-tech houses. A case study in Matera (Italy)

Authors:

Mutani, Guglielmina
Todeschi, Valeria
Perfetto, Jose
La Macchia, Francesco

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Introduction

- To promote **smart and sustainable cities**, the Europe's society and economy must be based on **renewable resources and energy efficiency**
- The EU energy efficiency policy for buildings and the **Energy Performance Building Directive** have been introduced **the concept of nZEB**

  → a building that has a **very high-energy performance** and **very low amount of energy required** should be covered to a very significant extent from renewable sources

- In line wit the EPBD, in Italy the Ministerial Decree n. 6 of 26th June 2015 (DM 26/6/2015) introduced '**Minimum building requirements**' to promote the **nearly zero-energy buildings**

Thermal transmittance requirements

Climatic zone	U_e	U_{roof}	U_{ground}	U_w	U_{op}	g_{gl}
	W/m²/K					-
A-B	0.43	0.35	0.44	3.00	0.8	0.35
C	0.34	0.33	0.38	2.20		
D	0.29	0.26	0.29	1.80		
E	0.26	0.22	0.26	1.40		
F	0.24	0.20	0.24	1.10		

Aim of the work

- To respect the laws that impose on the buildings a very important role is the **infill**, the **thickness of the wall**, but also **the different materials used and their precise sequence order**.
- This work presents a project of **hi-tech and super-green 'nZEB casale' in Matera** in the south of Italy

- The **use of renewable energy sources** to cover the heating and cooling consumption and electricity respects the limits of law
- This work presents also an **environmental protocol to be applied to nZEBs** in order to take into account the other benefits of these constructions, as well as the energy benefits

  → the **100% zero-impact residential complex has obtained the '*Edifici a Consumo Zero*' (Ec0) environmental protocol**, which guarantees the truthfulness and consistency of the environmental and energy characteristics of the structure

Case Study: from 'Casale' to nZEB

- The project presented in this work concerns **the renovation of a medieval 'casale'**, that is a group of rural houses for residential use
- Between the 15th and 18th centuries, the surviving 'casale' evolved into urban centers, becoming **aggregates of dwellings** consisting of agricultural residences, second homes and villas

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Case Study: from 'Casale' to nZEB

- Six 'casale' have been renovated using an **innovative masonry** with high energy performance for low energy consumption buildings and a **high level of well-being in residential buildings**

- The constructive solution identify **six independent buildings** characterized by the same architectural, artistic, and landscape style, as well as for the structural and plant characteristics

Description of the masonry

- **High-energy performance masonry** has been used → **seven layers** necessary to achieve energy performance requirements
- The total thickness of the masonry is **56 cm**
- The **P55 wall** –designed by Antonio Pepe– guarantees the **separation of the internal air temperature from the external air**, but also the separation of **the relative humidity**
- The use of local and certified materials → **Tuff is a local natural material** of the Matera territory
- Excellent winter and summer energy performance reaching **the best energy class A4**

Opaque envelope: WALL

Layer description	Value
Internal adductance	-
Lime and gypsum plaster	10 mm
Tuff	150 mm
Rock wool	200 mm
Horizontal air layer	20 mm
Tuff	**150 mm**
Lime and gypsum plaster	10 mm
External adductance	-
Thermal characteristics	**Value**
Thermal transmittance	0.147 W/m^2/K (limit 0.29)
Periodic thermal transmittance	0.01 W/m^2/K (limit 0.10)
Attenuation or decrement factor	0.04 -
Time shift	19.70 h

Transparent envelope: GLAZING

Thermal characteristics	Value
Thermal transmittance of glazing U_g	1.000 W/m^2/K
Thermal transmittance of frame U_f	1.300 W/m^2/K
Total solar transmittance g_{gl}	0.35 - (limit 0.35)
Thermal transmittance of window U_w	1.229 W/m^2/K

Geometrical characteristics

- The shape of the new nZEB is:
  - → in the style of **old light-colored buildings**
  - → **compact**
  - → **with solar shading elements to reduce the summer thermal loads**
- The residential complex was designed for **six families** (about 24 inhabitants)
- The building is integrated with renewable energy systems: **heat pumps**, **photovoltaic** (PV) **panels and solar thermal** (ST) **collectors**

Characteristics	Design data
Gross volume	1,645 m^3
Heated volume	1,200 m^3
Heat loos surface	921 m^2
Net floor area	400 m^2
Surface-to-volume ratio (S/V)	0.55 m^2/m^3

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Technological systems

- The technological system consists of a **reversible air/water heat pump** (HP) **for heating, cooling and domestic hot water** (DHW) with a single high efficiency system
- The thermal distribution system by radiation is of the **hot/cold radiant floor type**
- The temperature control system is **proportional integral derivative (PID) for each room**
- The **production of DHW** was design by an **electric air/water HP** and integrated by 10 m^2 of **high-efficiency ST collectors** (vacuum tube)
- For the **production of electricity**, **PV panels** in multi-crystalline silicon have been installed
- A **controlled mechanical ventilation** (CMV) **system with heat recovery** has been installed, which allows optimal air hygiene and a **reduction of ventilation losses by about 90 %**

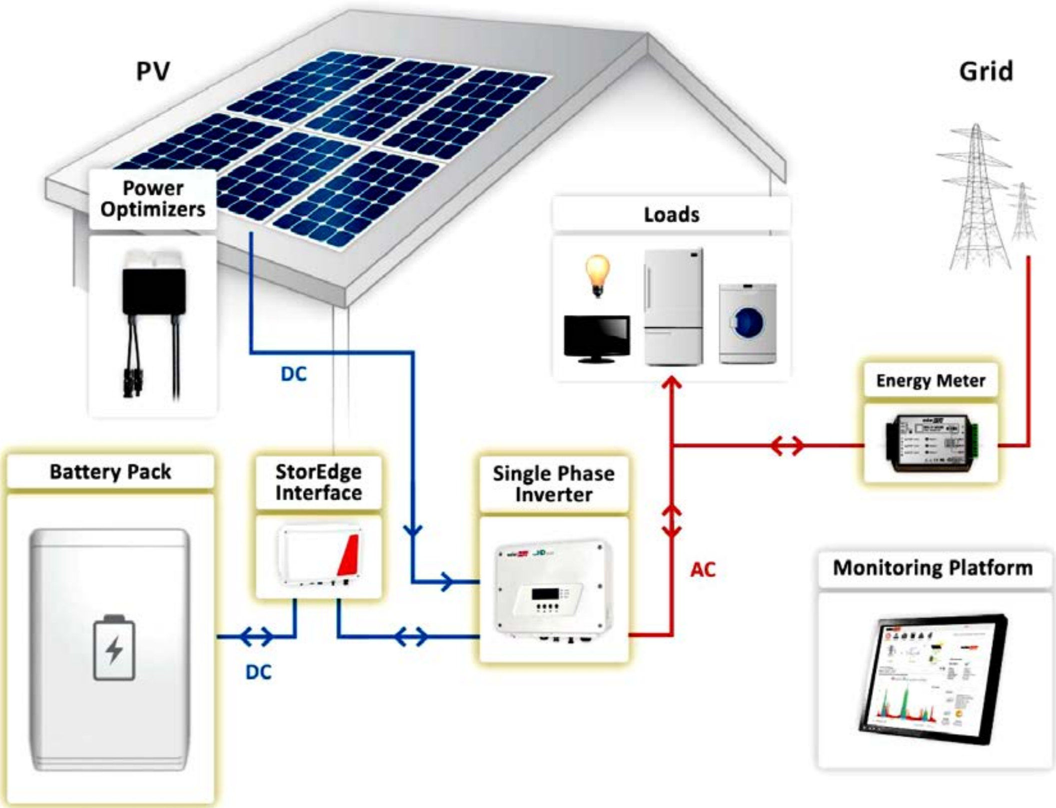
Technological systems and solar energy technologies

Characteristics	Design data
Emission system	Radiant floor
HP power	5.2 kW
Type of HP	A-W
COP	3.8
EER	3.5
Temperature control system	PID
CMV efficiency with heat recovery	89.4 %
N. of air changes per hour	0.3 vol/h
ST collectors' area	10.2 m^2
Solar radiation on ST collectors	16,325 kWh
ST annual production	4,683 kWh
Annual heating consumption	4,300 kWh
Annual cooling consumption	12,000 kWh
Annual DHW consumption	5,000 kWh
Total annual consumption	16,700 kWh
PV panels	10 kWp
PV annual production	13,000 kWh
Annual electrical consumption	4,500 kWh

Technological systems

- There is a **storage system** with:
  - → an '**energy meter**' to accumulate electricity
  - → an '**energy manager**' for intelligent control of energy-consuming appliances
  - → a '**my-reserve battery**' to use solar energy in nighttime
- The entire system is managed remotely through the **home automation management**
- The systems can be controlled and managed using a **touch device**

The nZEB house functional features scheme: self-construction technology



Energy Performance Indices

- The **high performance of the building** and of the **machine**, and the **design choices**, guarantee coverage of all needs through the production of energy through renewable sources
- **The energy performance indices** for heating and cooling seasons, for the production of domestic hot water, for ventilation and lighting **have been verified**

Index	Value (limit)
Heat transfer coefficient – H_T	0.33 W/m²/K (0.58)
Transparent equivalent area - $A_{sol,est}$ / $A_{sup,utile}$	0.01 (0.03)
Energy performance for heating - $EP_{H,nd}$	14.76 kWh/m² (23.59)
Energy performance for cooling - $EP_{C,nd}$	31.91 kWh/m² (61.72)
Global energy performance - $EP_{gl,tot}$	30.38 kWh/m² (72.96)
Energy efficiency of heating system - h_H	0.98 (0.62)
Energy efficiency of DHW system -h_W	0.93 (0.41)

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Energy Performance Indices

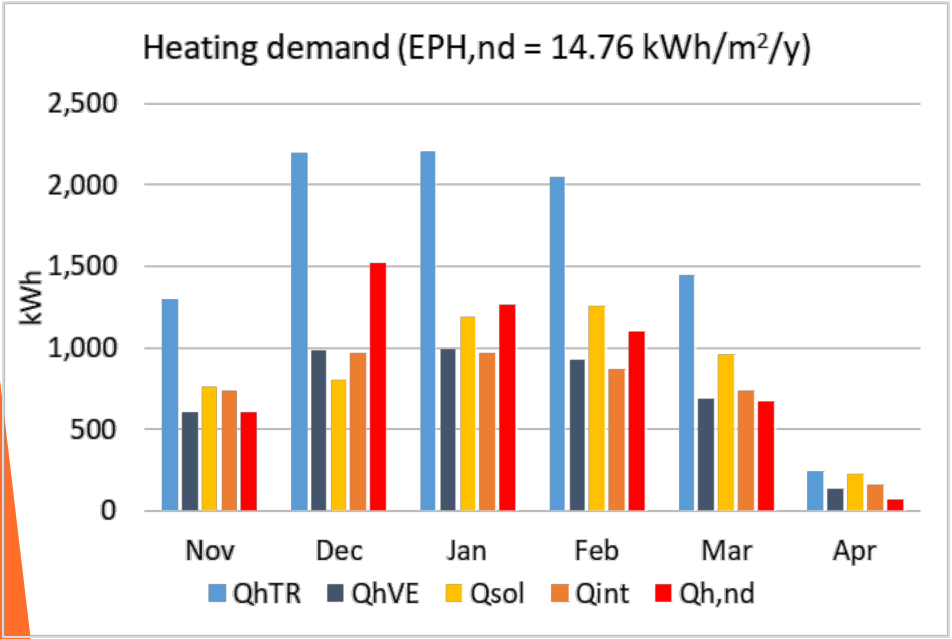
The **heat gains due to:**

- the solar heat Q_{sol}
- the internal heat Q_{int}

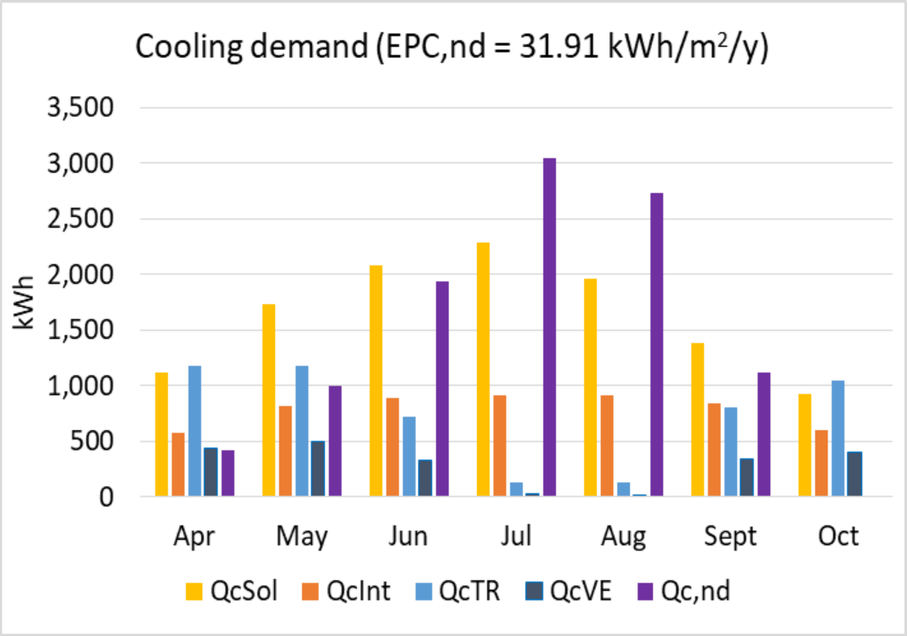
The heat losses due to:

- the transmission Q_{TR}
- the ventilation Q_{VE}

Heating demand with monthly detail and heat transfer components



Cooling demand with monthly detail and heat transfer components



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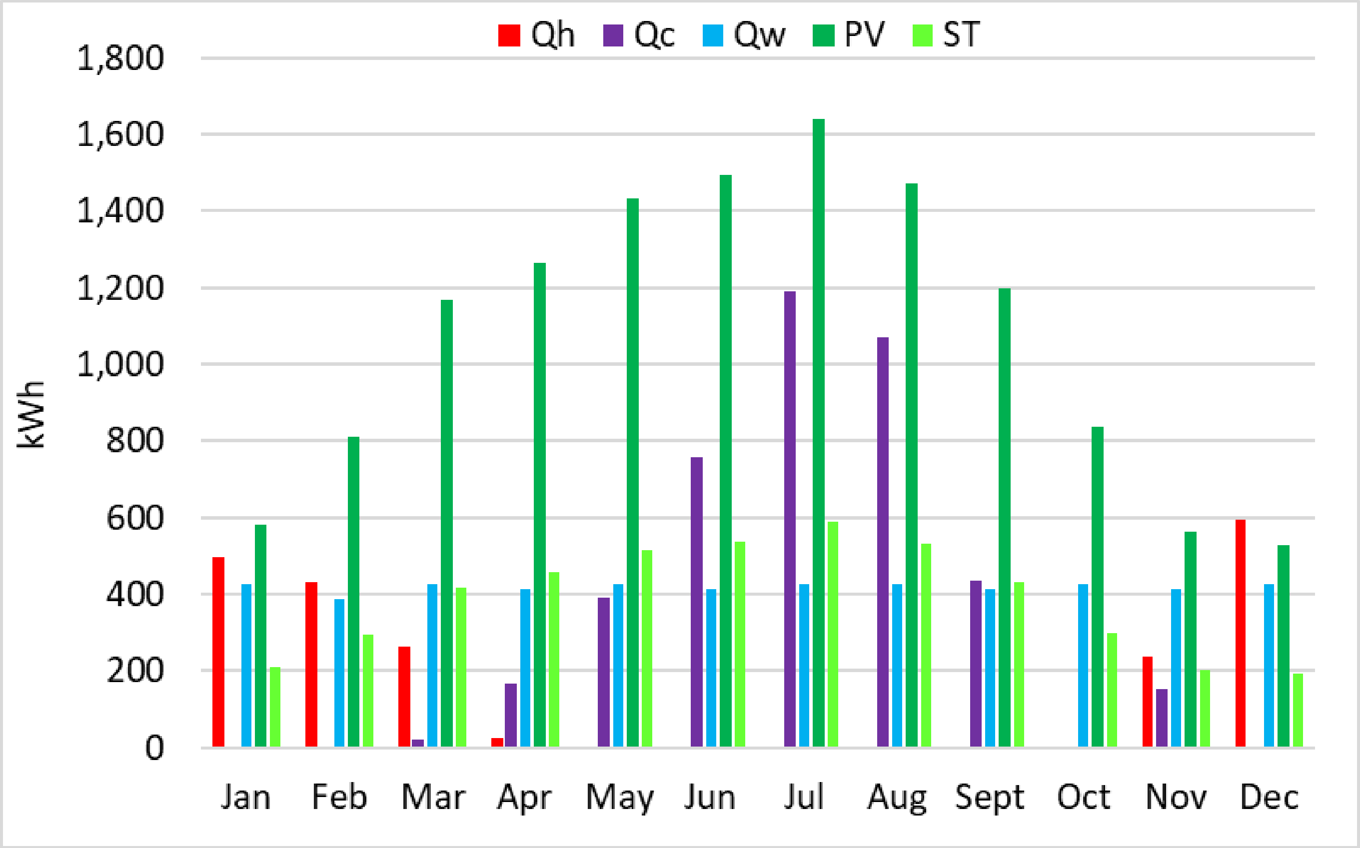
Energy Performance Indices

Energy consumption, PV panels and ST collectors production with monthly detail



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Environmental Protocol for nZEBs

- The **environmental protocol applied to nZEBs** has the purpose of guaranteeing the management of processes in the direction of **environmental sustainability**
- The **LEED and ITACA protocols**, which inspire the task of certifying the environmental sustainability of the building interventions in question, are both based on a rating system divided into macro-areas to be assigned a score
- The protocol presented here **'*Edifici a Consumo Zero*' (Ec0)** represents the integration between the morpho-typological characteristics of the building and the constructive-environmental aspects
- The vision of sustainability considers the eco-sustainable building, the bioclimatic architecture, and the bio-architecture whose objectives are:
  - → A sustainable relationship with the environment
  - → A design and building activity based on energy saving
  - → A healthy use of technologies and natural materials

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Environmental Protocol for nZEBs

The **Ec0 Protocol** is represented by **six key criteria**:

1. **Location on the ground**: the geographical and topological location
2. **Formal Structuring**: form, orientation, solar paths
3. **Design report in harmony with the characteristics of the outdoor spaces**: integration with the surroundings
4. **Planimetric articulation**: internal distribution and intended use of the spaces
5. **Choice of materials, preferably local**: ecological nature of the building
6. **Plant engineering based on energy transformation from renewable sources**: i.e. solar systems and an attention to emerging technologies

Example of Environmental Protocol for nZEBs 'Casale'

Requirements	Points from 1 to 5
1. Location: Context	4
2. Sustainable Design – Program	5
3. Energy and Atmosphere – Project	4
4. Conservation of water, materials and resources – Project	4
5. Internal environmental quality – Project	3
6. Innovation and performance verification processes - Execution & Monitoring	ongoing

Conclusions and future works

- In accordance with European and National Directives, **in Italy from January 2021, all new buildings or reconstructed buildings must become nZEBs**
- The Italian regions have been encouraging the implementation of nZEB
  - → **their amount in Italy did not reach the 0.03 % in 2018**
  - → but there is an **nZEB Italian observatory to collect good practices and verify the threshold values on energy performances** of these buildings in the various regions
- This work have been presented a project by **nZEB just realized (2019) in Matera for residential buildings** with high energy performance that also use local materials such as tuff and other local certificated materials
- The **excellent energy and environmental performance** is also reflected in **the environmental protocol score** presented
- The high performance of these buildings **have a cost that is about +20% compared to a standard building that will be repaid in a few years given the increasing cost of energy**