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DECEMBER, 3-6 2024
BENEVENTO, ITALY

FROM NZEB TO HZEB: HYDROGEN-BASED TECHNOLOGIES FOR GREEN TRANSITION OF BUILT ENVIRONMENTS

December 4th, 2024

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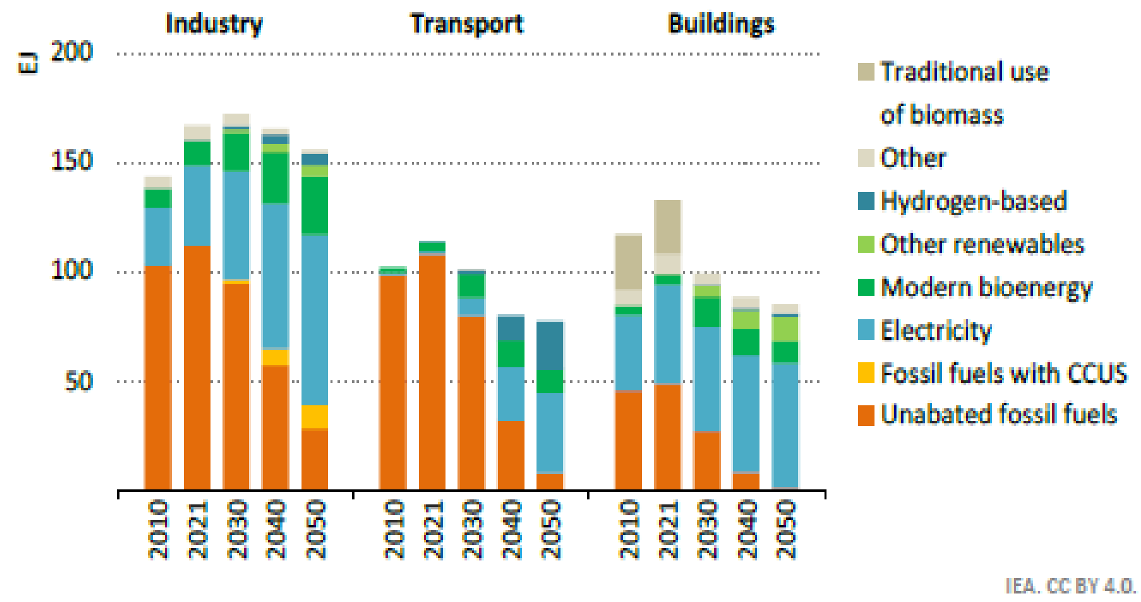
Net zero emission scenario - 2050

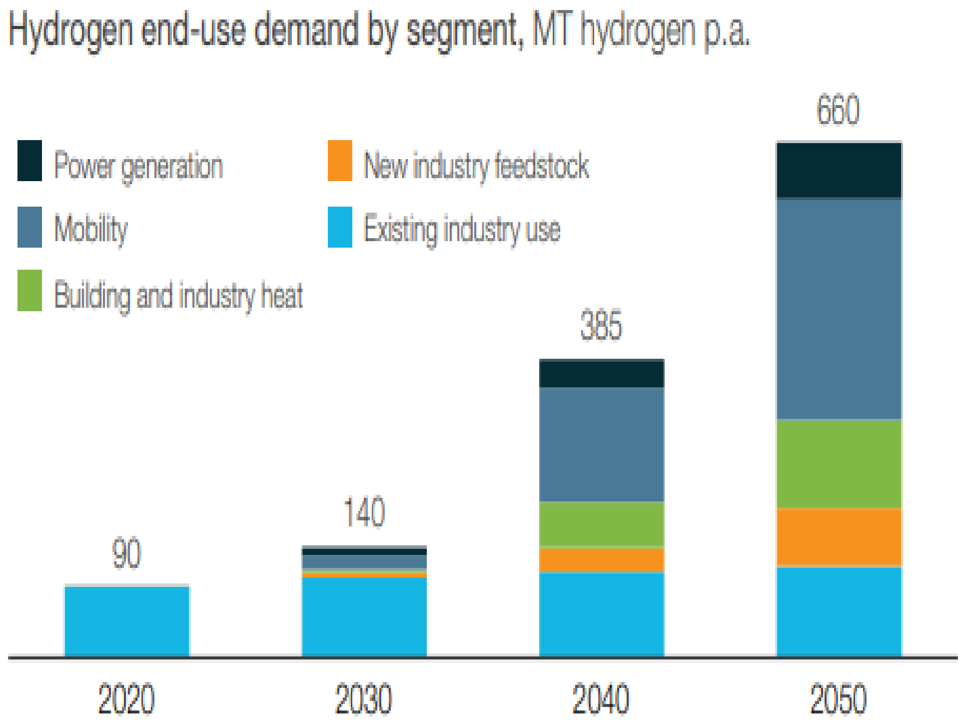
IEA, 2022



End-use sectors come to be dominated by electricity, which provides more than half of total final consumption by 2050

Note: Other renewables include solar thermal and geothermal used directly in end-use sectors.

The pipeline of hydrogen projects is continuing to grow, but actual deployment is lagging



Hydrogen Council, McKinsey & Company

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DA NZEB AD HZEB: Hydrogen Zero Emission Building

O P E N I N G
07 luglio 2022 ore 13.00

Via San Pasquale - Complesso ex iPAI - Università degli Studi del Sannio - Benevento

stress

SolydEra

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BNZEB: il nearly Zero Energy Building di Benevento

The building has been designed for being **a best practice of a new way of living**, by reducing - as much as possible - energy needs, energy demand of active energy systems and by converting the entire request by means of renewable sources located on-site.

SMARTCASE (2014-2016) – "Innovative solutions for the optimization of multi-functional primary energy consumption and indoor living conditions in the Building System" – Italian project, financed by Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR).

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Design approach

The adopted approach followed these steps:

1. Methodology of analysis
2. Investigation of climatic condition;
3. Definition of architectural design, thermal envelope and airtightness;
4. Selection of HVAC system and efficient lighting layout and appliances;
5. Maximization of renewable energy potential;
6. optimization of home design for human comfort and load reduction.

Gross floor area (m^2)	71
Gross Heated Volume (m^3)	300
Surface to Volume ratio S/V	1.04
Windows / Wall Ratio	26%

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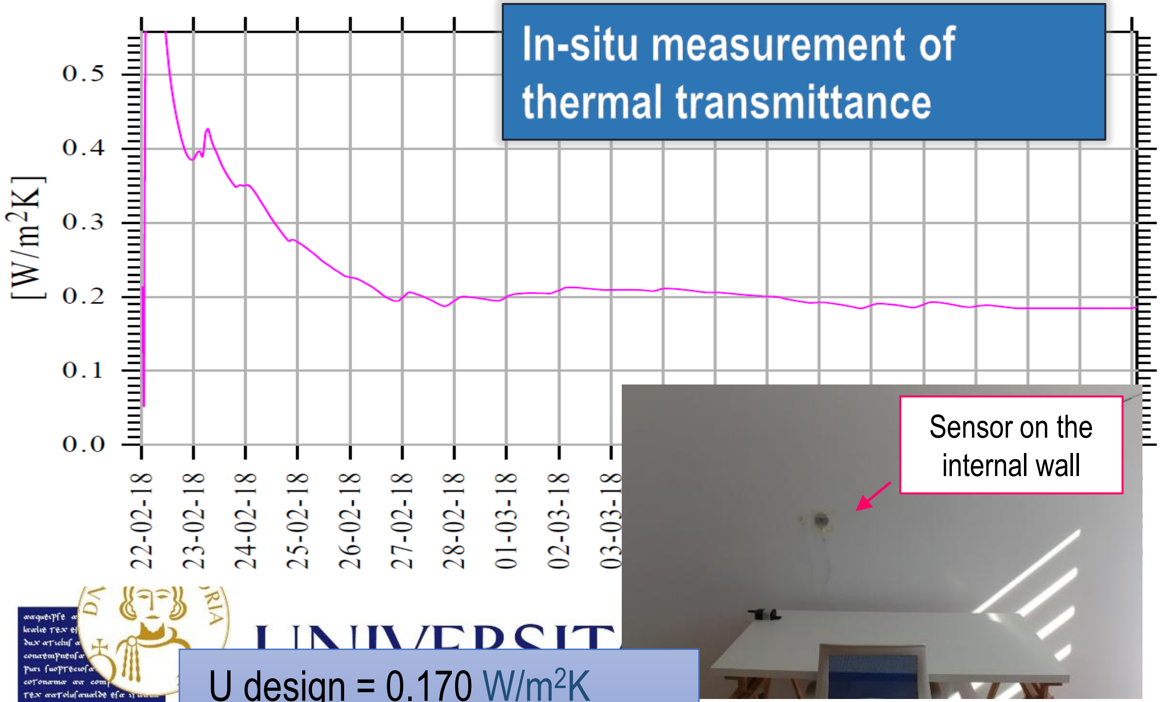
Building envelope

	s [m]	λ [W/(mK)]	ρ [kg/m³]	c [J/(kgK)]
External walls s_{tot} = 0.337 m				
Internal clay plaster	0.01	0.91	1200	1960
Clay panel	0.022	0.353	1600	1100
Wood fiber thermal insulation	0.05	0.038	55	2100
X-Lam	0.095	0.13	500	1600
Wood fiber thermal insulation	0.14	0.04	130	2100
External plaster	0.02	0.90	1000	1800

In-situ measurement of thermal transmittance



U design = 0.170 W/m^{2}K
U measured = 0.186 W/m^{2}K

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Building envelope

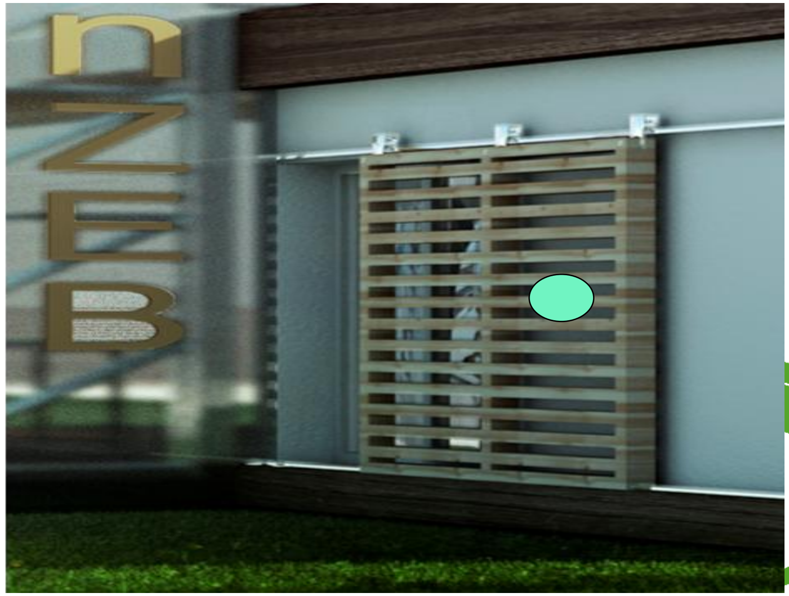
Internal walls s_{tot} = 0.259 m				
Internal plaster	0.01	0.91	1200	1960
Clay panel	0.022	0.353	1600	1100
Air	0.05	R = 0.11 (m²K) /W		
X-Lam	0.095	0.13	500	1600
Air	0.05	R = 0.11 (m²K) /W		
Clay panel	0.022	0.353	1600	1100
Internal plaster	0.01	0.91	1200	1960
Thermal transmittance = 0.789 W/m²K				
Roof covering s_{tot} = 0.498 m				
Bituminous membrane	0.008	0.13	800	2100
Leveling screen	0.06	0.129	380	1000
Insulating layer	0.10	0.041	2100	145
Vapor barrier	0.0001	0.400	427	1800
X-Lam	0.12	0.130	500	1800
Internal plaster	0.01	0.91	1200	1960
Air	0.19	R = 0.17 (m²K) /W		
Plasterboard	0.01	0.072	480	1380
Thermal transmittance = 0.229 W/m²K				

Two layers of glass plus a suspended heat-mirror film with argon gas-filled air space and PVC frame (U_W≈1.5 W/m^2 K)

Smart window

(U_W≈0.85 W/m^2 K)

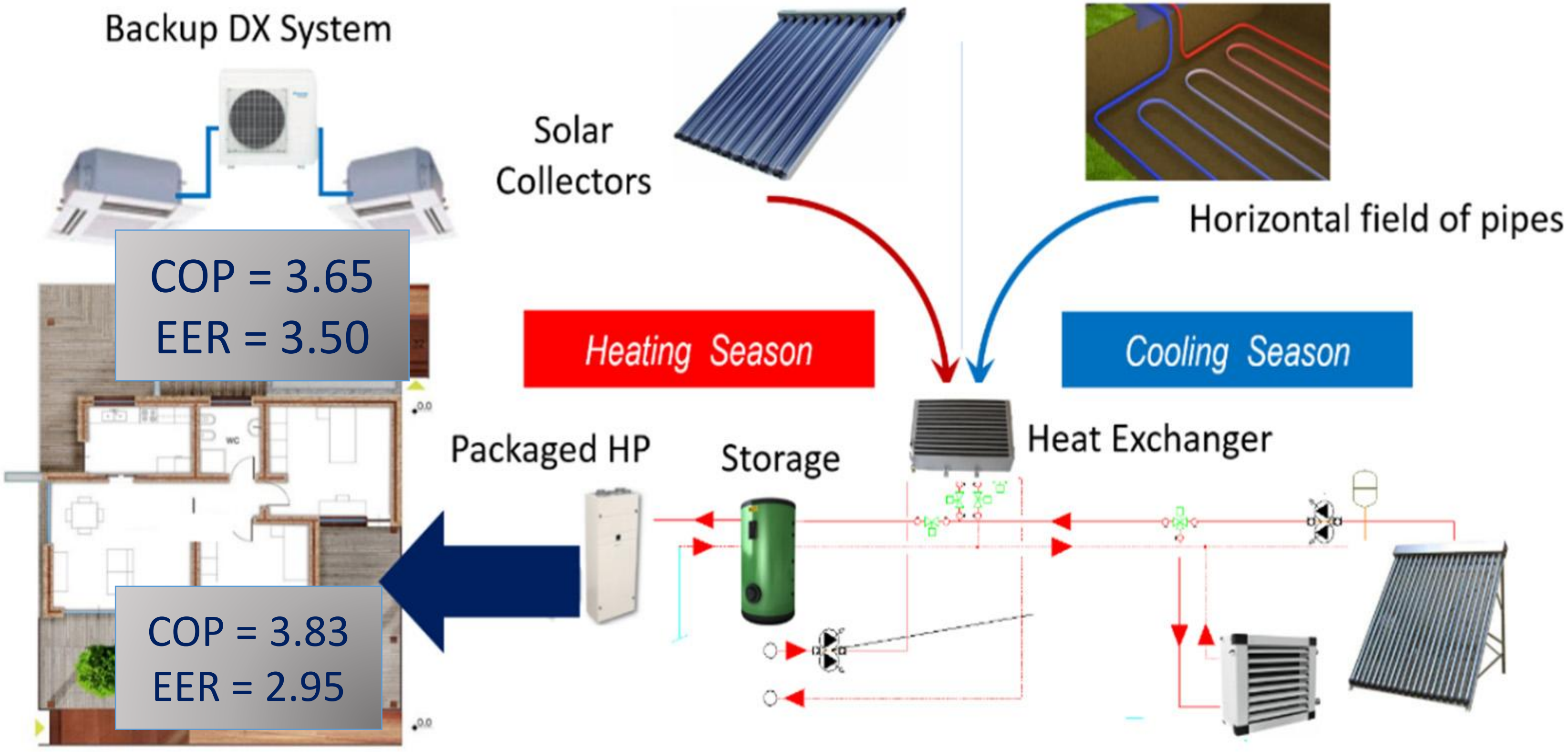
Shading system



Indoor microclimatic control

The indoor microclimatic control, in both heating and cooling, is achieved by means of a **packaged system**, and **a backup DX multi-split**, for contrasting the peak of summer heat wave.

More in detail, an air-to-air heat pump provides mechanical ventilation, with warm air in winter, cold air in summer.
*The packaged unit is equipped with an active **thermo-dynamic heat recovery**.*



There is an interaction between the external heat exchanger (condenser in summer, evaporator in winter) with the exhaust air, in order to increase the coefficient of performance / energy efficiency ratio of the system.

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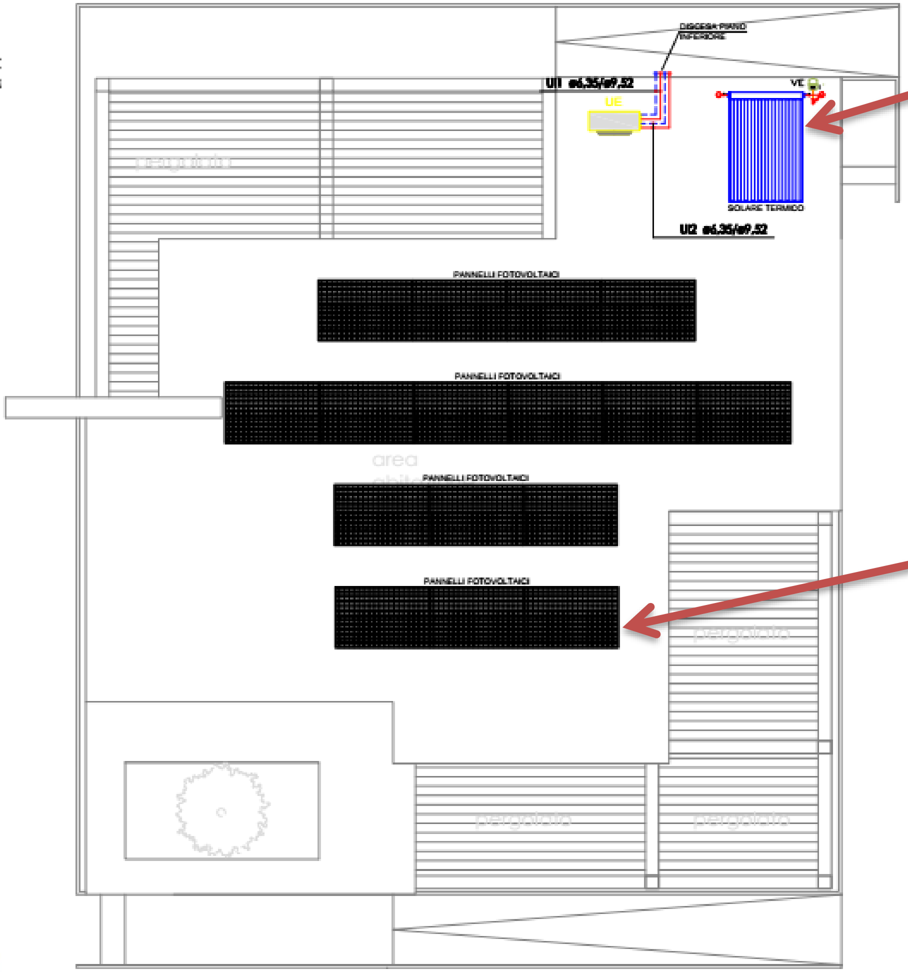
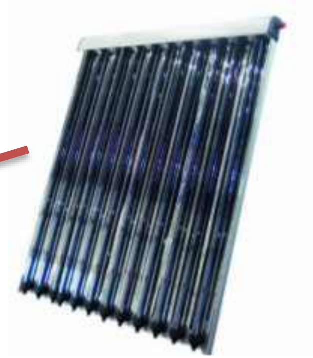
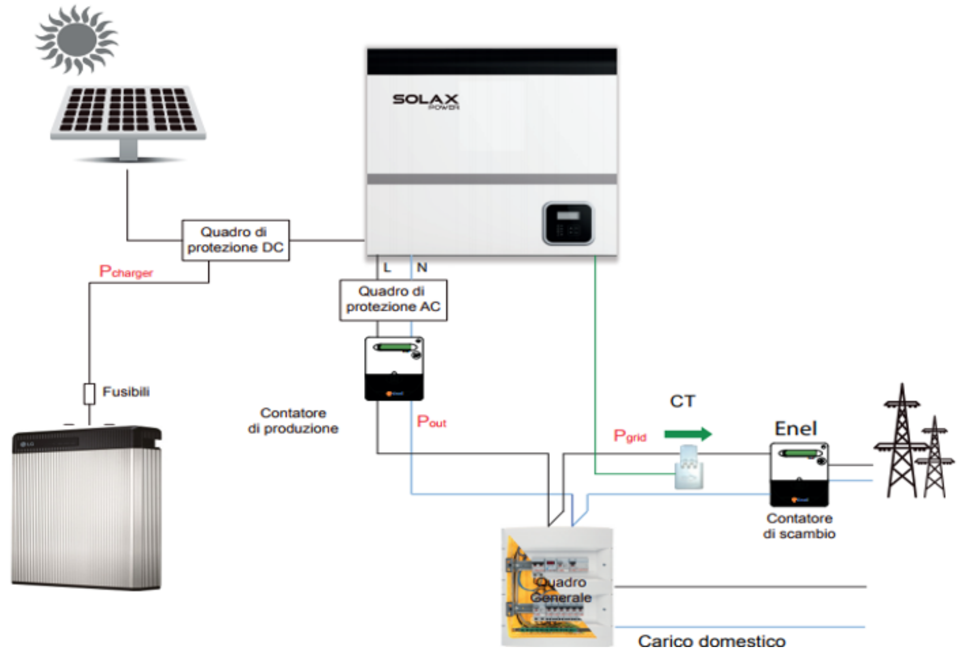
Renewable energy sources





Solar collectors *(2.16 m^2)*



The photovoltaic system:

- 5.3 kWp (in total)
- Monocrystalline silicon
- Azimuth Angle: 0˚
- Tilt angle: 5˚
- Electric storage: 6.5 kWh

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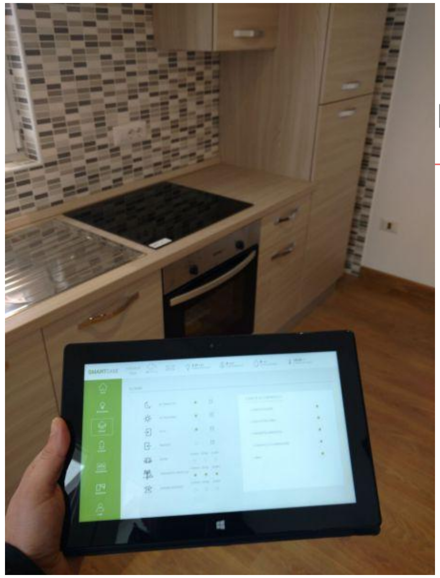
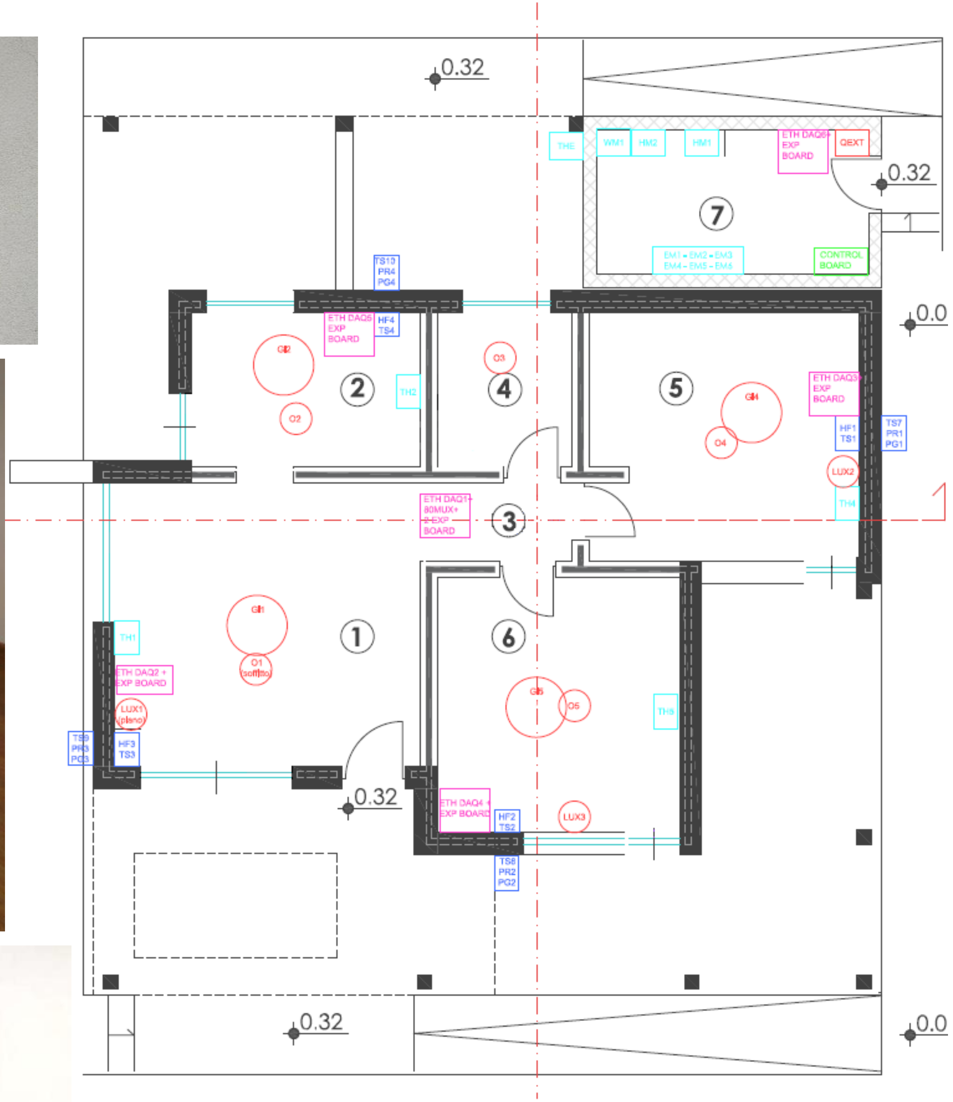
MONITORING SYSTEM

	n°	Sensor
Technical room	6	Meters for electric energy
	2	Meters from solar collectors and from geothermal source
	1	Domestic hot water volume and energy demand
Outdoor	1	External temperature
	1	-wind speed and direction - air temperature -relative humidity -barometric pressure -global solar radiation
	1	External concentration of CO_2 and VOC
	5	Solar radiation
	5	Longwave infrared radiation and sky and equivalent ground temperature
Indoor	4	Internal light
	5	Air temperature and relative humidity
	5	Presence and light level
	4	Concentration of CO_2 and VOC
	10	Surface temperature
	4	Heat flux sensor
	1	Globe thermometer





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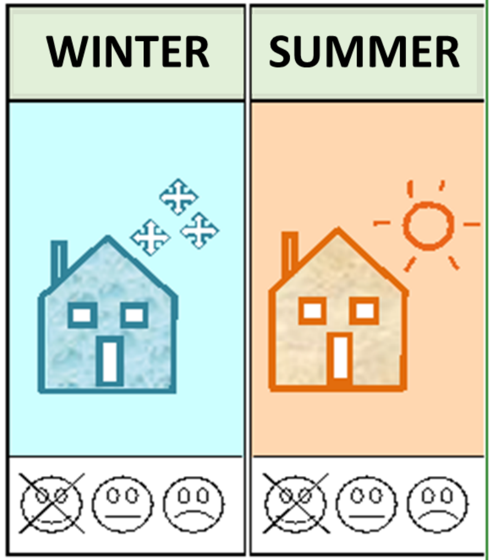
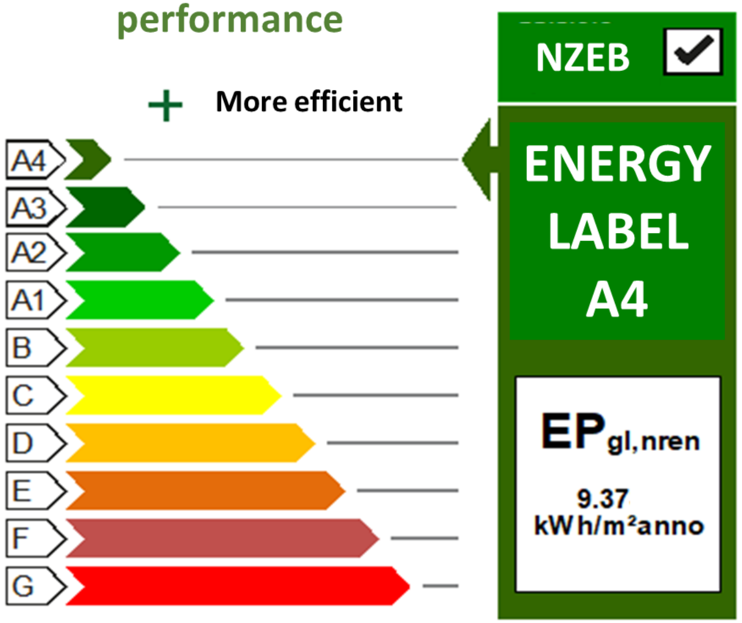
BNZEB: Zero Energy Building di Benevento

DM 26/06/2015 + D. Lgl. 28/2011 s.m.i.

Envelope energy performance



Building global energy performance



Reference: comparable building would have the following classification

If new

A1 (162.45)

Renewable energy for domestic hot water	98 %
Renewable energy for heating, cooling and domestic hot water	91 %

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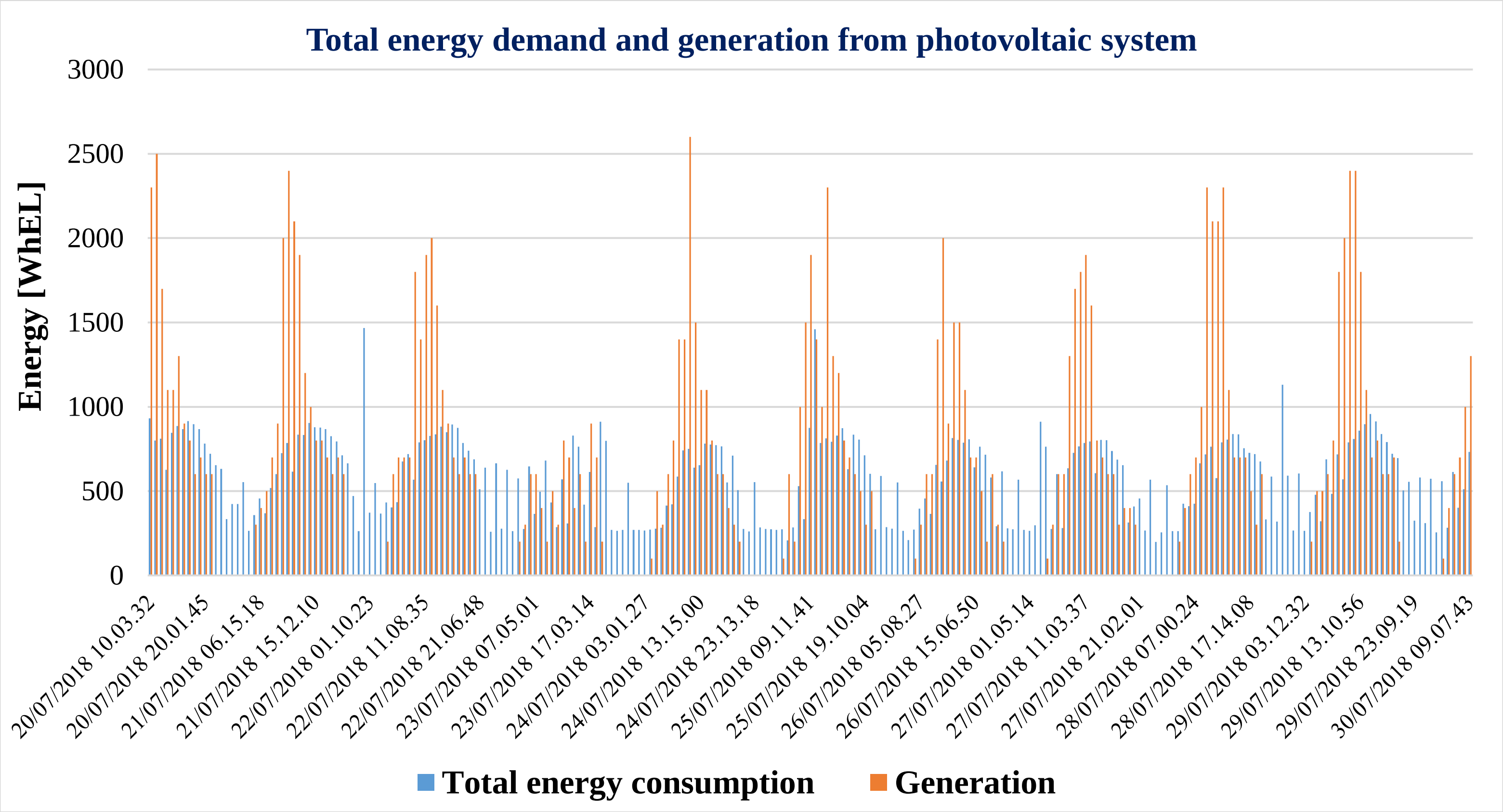
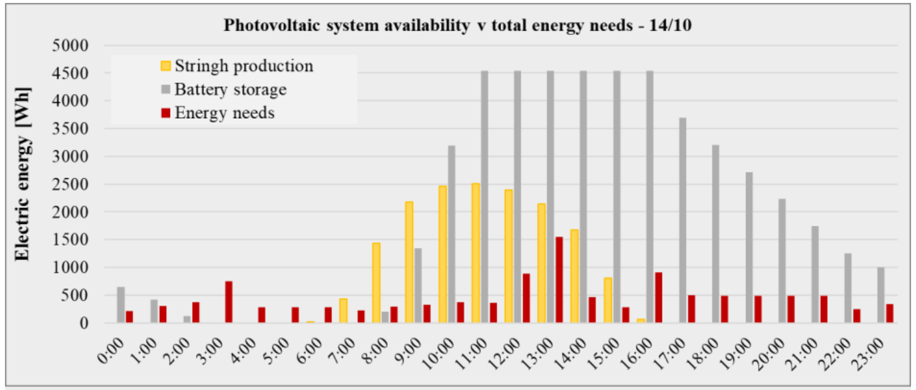
SOME MONITORING RESULTS:

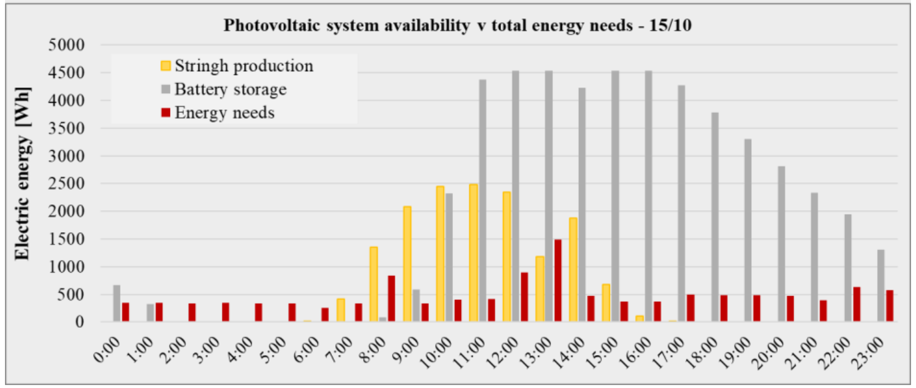
from 20 to 30 July 2018

Monitoring results (10 days):
Total PV generation = 159 kWh
Total building requirement = 140 kWh



Autumntime (Oct 2019)





	14th Oct	15th Oct
$F_{loadmatc}$	89.9 %	88.3 %
RenEl	93.4 %	92.3 %
PV	155.0 %	131.7 %

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H-ZEB – Hydrogen Zero Emission Building

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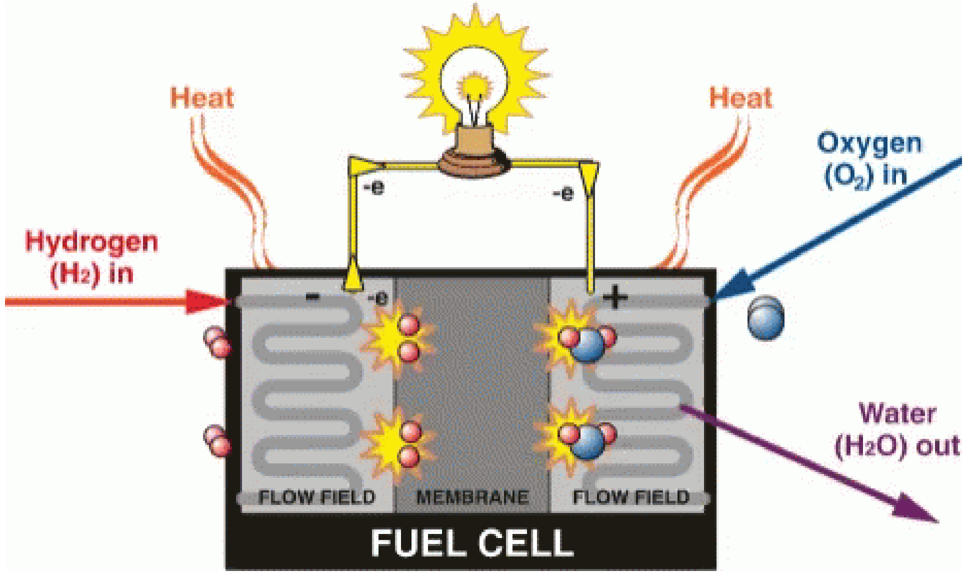
FUEL CELL



A **fuel cell** is an electrochemical cell that converts the chemical energy of a fuel (often hydrogen) and an oxidizing agent (often oxygen) into electricity through a pair of redox reactions.

Solid oxide fuel cells (SOFCs) use a solid material, most commonly a ceramic material called yttria-stabilized zirconia (YSZ), as the electrolyte. They require high operating temperatures.

Oxygen gas is fed through the cathode, where it absorbs electrons to create oxygen ions. The oxygen ions then travel through the electrolyte to react with hydrogen gas at the anode. The reaction at the anode produces electricity and water as by-products.

FUEL CELL

SolydEra

BluegenHydro BG-15
SOFC fueled by hydrogen
Operative temperature a 700÷750° C

Hydronic circuit for heat recovery

Fireplace connected to the outside

Electric power cable

Fuel Cell

Pipe for hydrogen supply

Output

Electric power: 0.2÷1.2 kW_{el},
(nominal value 1.0 kW_{el})
230 V AC ± 10 %, 50 Hz single phase

Thermal power: until 0.86 kW with return temperature of 30°C and 1.0 kW_{el}

Input

Pressure of hydrogen 15÷25 mbar
(flow ≈ 12 l/min a 1.0 kW_{el})

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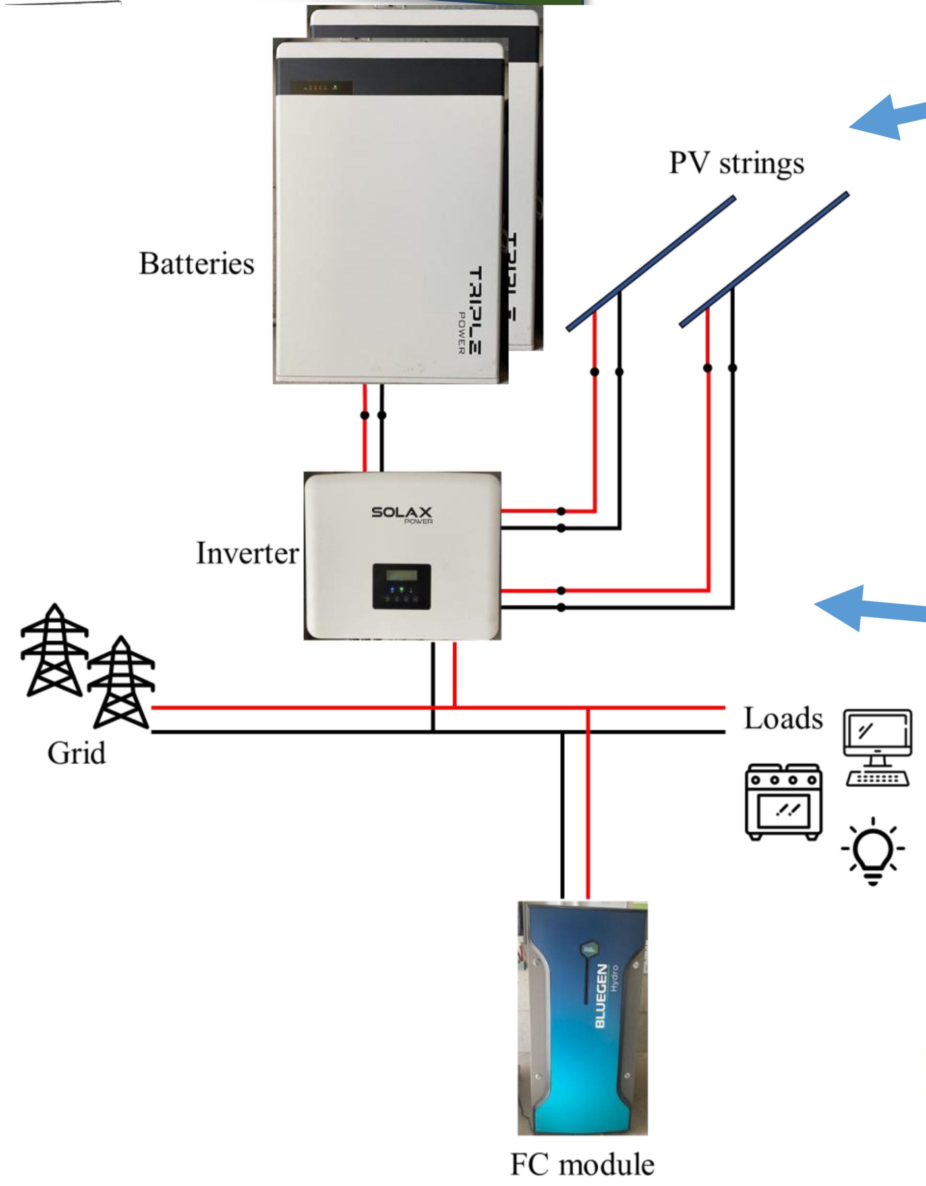
INTEGRATION OF THE FUEL CELL INTO THE ELECTRICAL SYSTEM



The photovoltaic system:
5.3 kWp (in total)
Electric storage: 11.6 kWh

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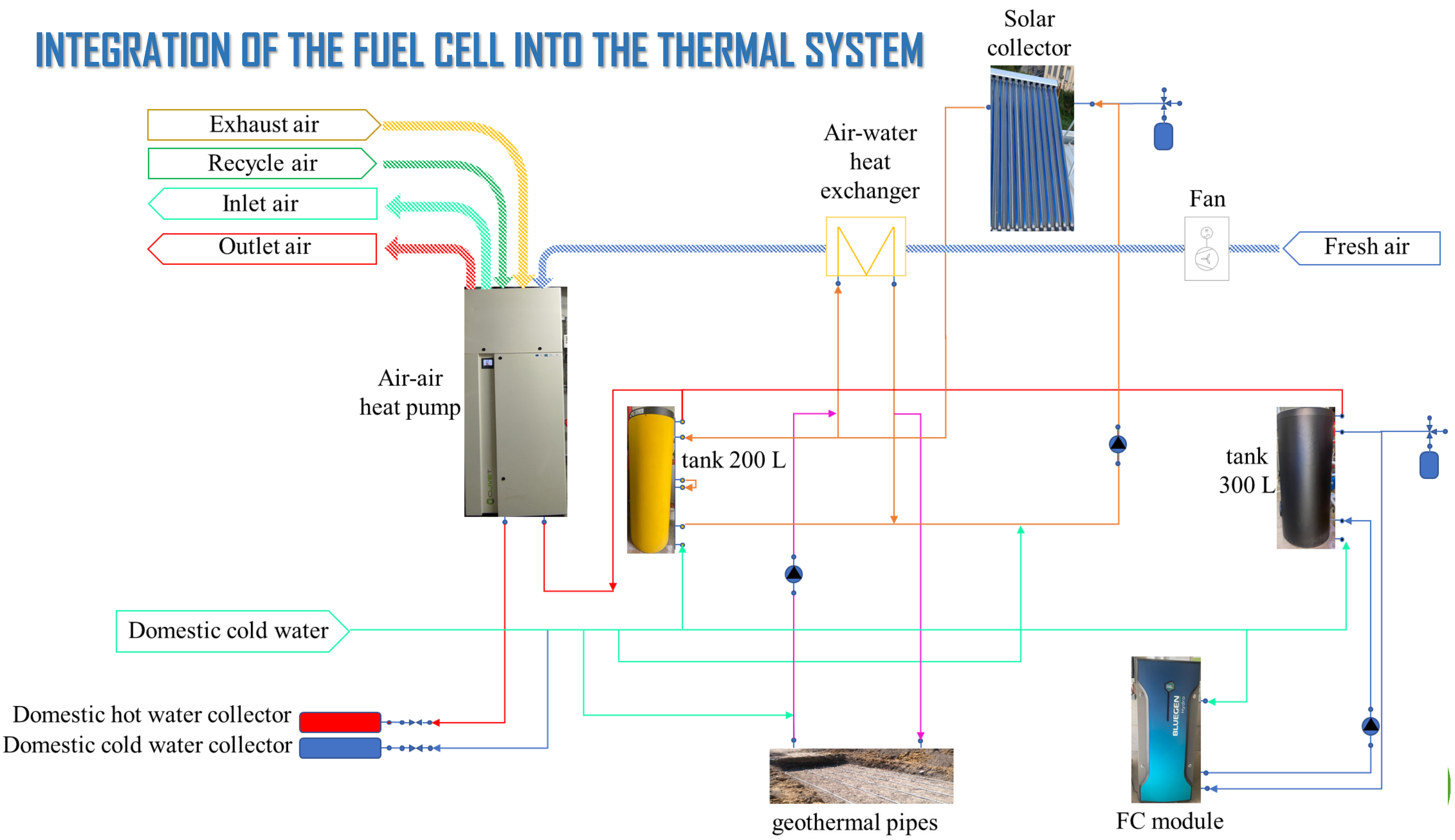
INTEGRATION OF THE FUEL CELL INTO THE THERMAL SYSTEM



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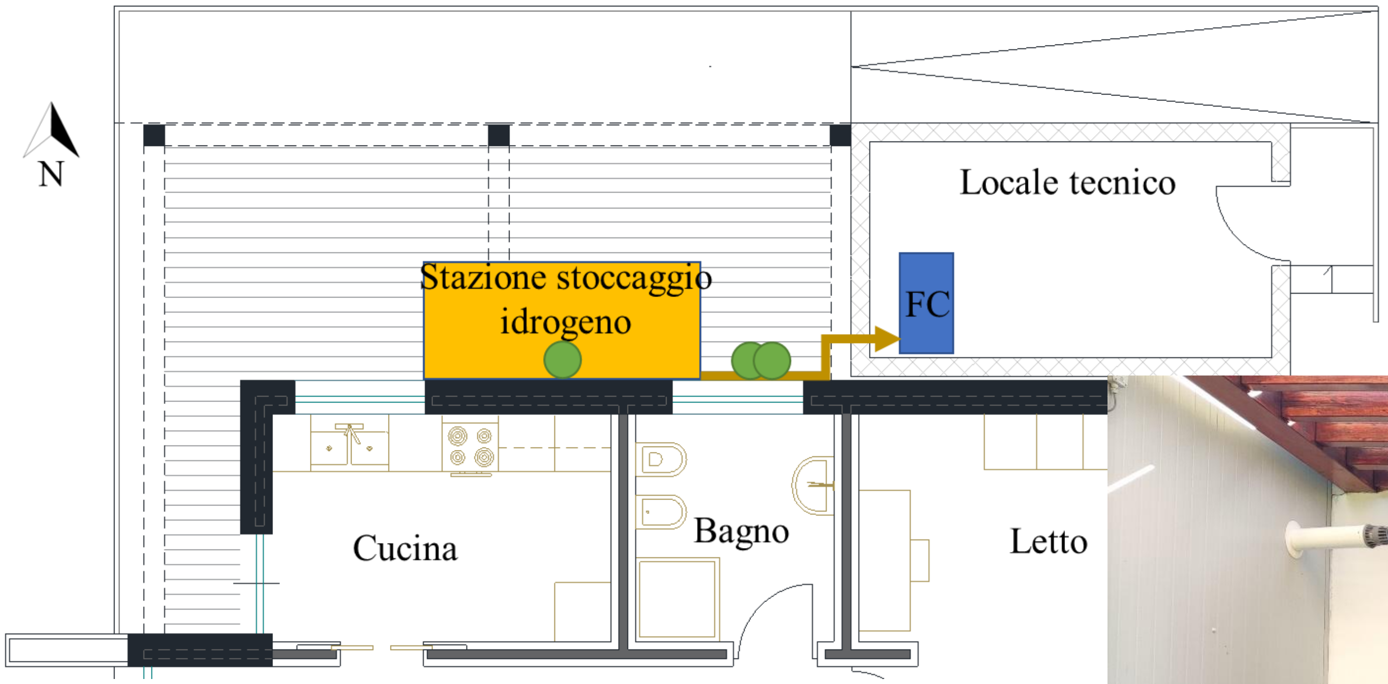
HYDROGEN STORAGE STATION



Depressurization system
- 200 bar -> 14 bar
- 14 bar -> 4 bar
- 4 bar -> 20 mbar

Hydrogen line

64 Sm³ of green hydrogen

8 cylinders at 200 bar

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MONITORING SYSTEM

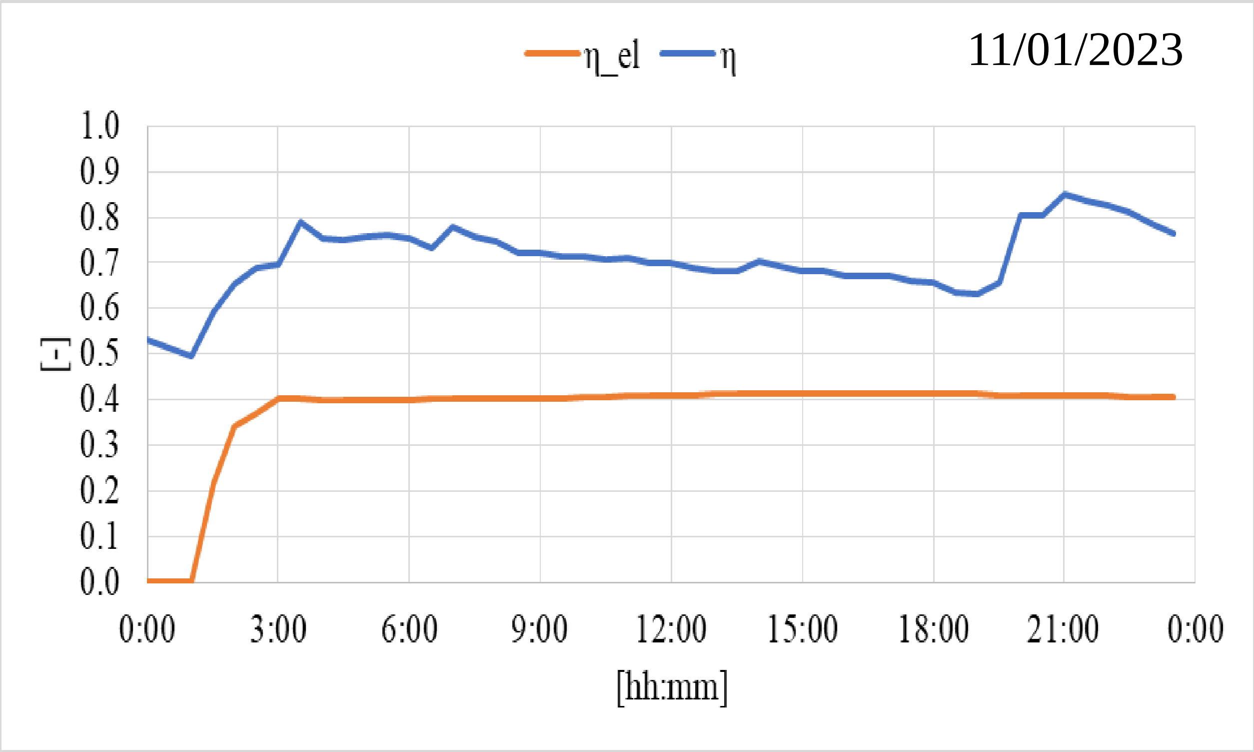
Variable (sensor)	Position	Accurancy
Water temperature (NTC)	Heat recovery flow and return pipes	± 0.5% @ +25÷+85 °C
Volumetric floww (Ultrasuoni)	Heat recovery return pipe	±2%
Water temperature (Pt100)	Tank for heat recovery	± 0.1°C @ 0°C
Electric power (single phase)	FC line	class B (EN50470-1/3)
Air temperature (Pt100)	External garden and inside each room	± 0.1°C @ 0°C
Global solar rafdiation (Termopila)	External garden	<10% day

Monitoring plan:

- HR Power Variation: 100% - 40%;
- Circulation pump operating level (43W, 65W, 80W) ;
- Occupancy profile: maximum, adapted to the user, or none.

$$\eta el = \frac{Pel_{FC}}{(\dot{V}_{H2} \cdot \rho_{H2} \cdot PCS_{H2})}$$

$$\eta = \frac{Pel_{FC} + Pth_{FC}}{(\dot{V}_{H2} \cdot \rho_{H2} \cdot PCS_{H2}) + Pel\_circ}$$



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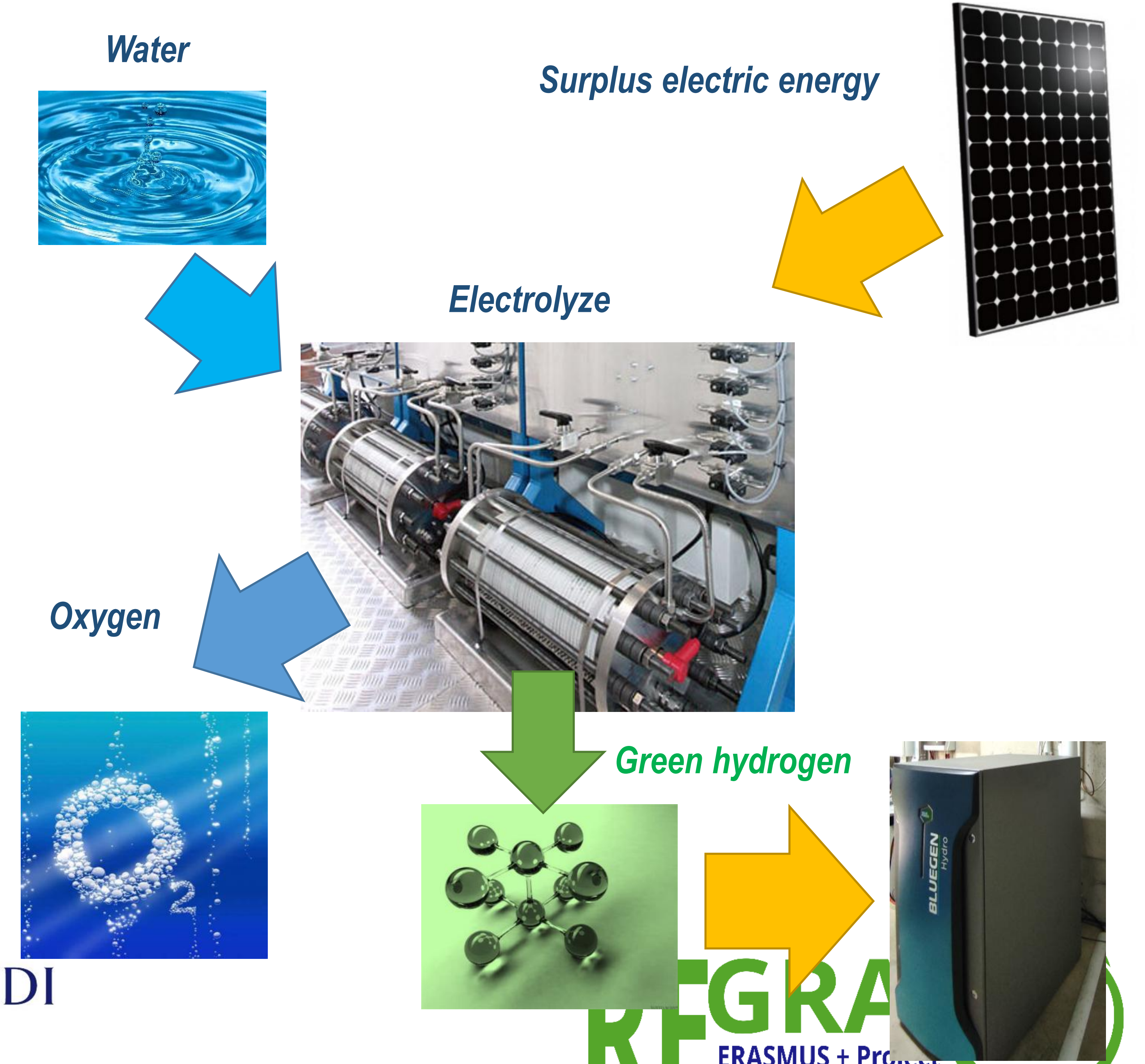

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Edmund Hillary: «Environmental problems are truly social problems, for they begin with people as causes and end with people as victims.»

Thank you

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