NOVEMBER 30, 2024 | 8TH AIEE ENERGY SYMPOSIUM - CURRENT AND FUTURE CHALLENGES TO ENERGY SECURITY

Decarbonization through electrification of public historic buildings: the case study of National Gallery of Modern and Contemporary Art in Rome

Francesco Castellani

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Abstract

A 100 years old italian museum became an energy efficiency case-study in public historical buildings

- The EU framework sets specific targets in energy efficiency in public and private buildings to reach the main goals of the FF55 strategy; the most important principle to be followed is Efficiency First. The buildings sector accounts for an important share of energy consumption and carbon emissions, for this reason it is fundamental to lower its impact.

- Europe hosts many historic buildings, in which the efficiency works could be more difficult and expensive than in standard buildings because of the many constraints. It is important to develop specific strategies to handle these cases because they are a lot and they account for an important share of the total buildings, in Europe and especially in Italy.

- This work provides the methodology adopted to decarbonize through electrification the National Gallery of Modern and Contemporary Art in Rome, an historic building working as a museum. This is the most important part of the integrated approach followed by the museum under the direction of Cristiana Collu; this path started in 2017, efficiency works were made in 2021 and from 2022 the National Gallery is a net-zero museum hosted in a historic building. The payback period of the works is less than 2 years with 2022 energy prices.

- The monitoring of energy consumption of the first year after the works (2022) shows interesting findings: the new electricity consumption has been lower than the previous one, thanks to the efficiency of the new systems: electrification does not necessarily mean to increase the electric consumption.

The case study of the National Gallery of Modern and Contemporary Art

From 2022 this museum, hosted in a historic building, achieved net-zero emissions.

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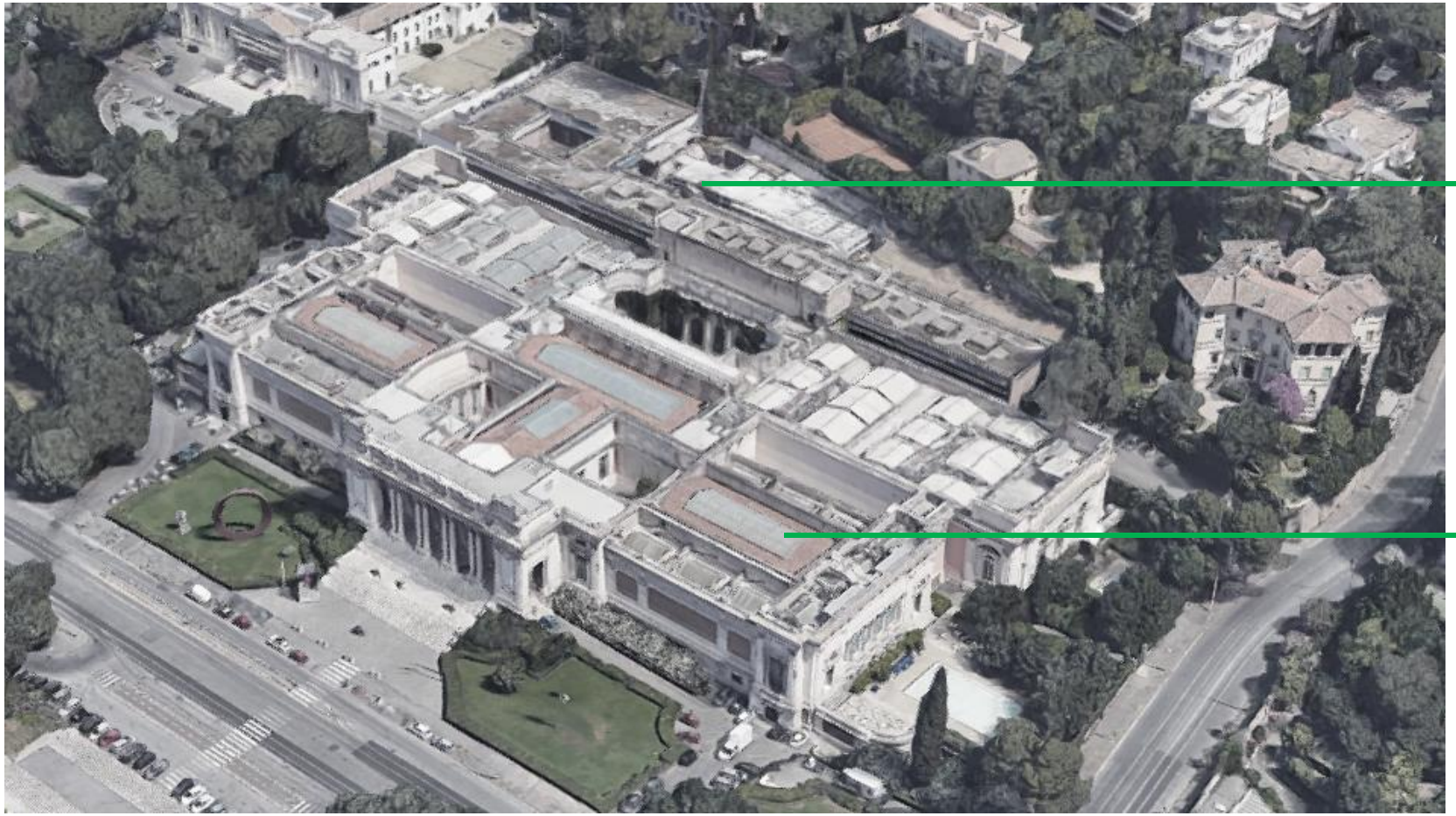
The largest Italian modern and contemporary art collection

One of the most important museum in Rome



Cosenza building

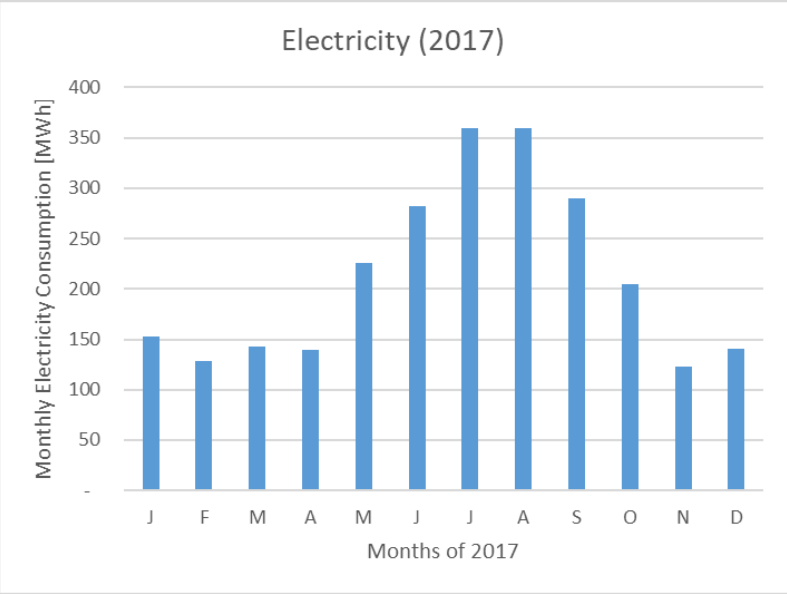
1973-1987 (not completed)
designed by Luigi Cosenza
~35,000 m^3
currently not used, under renovation

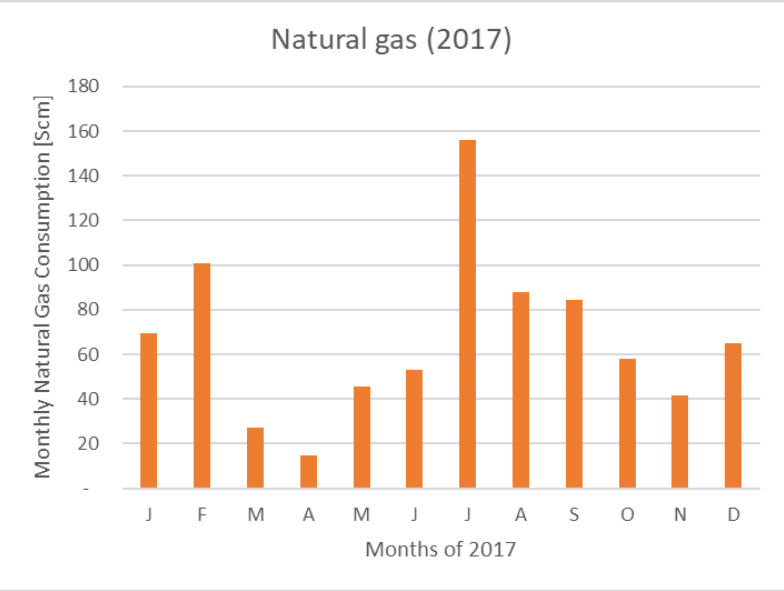
Bazzani building

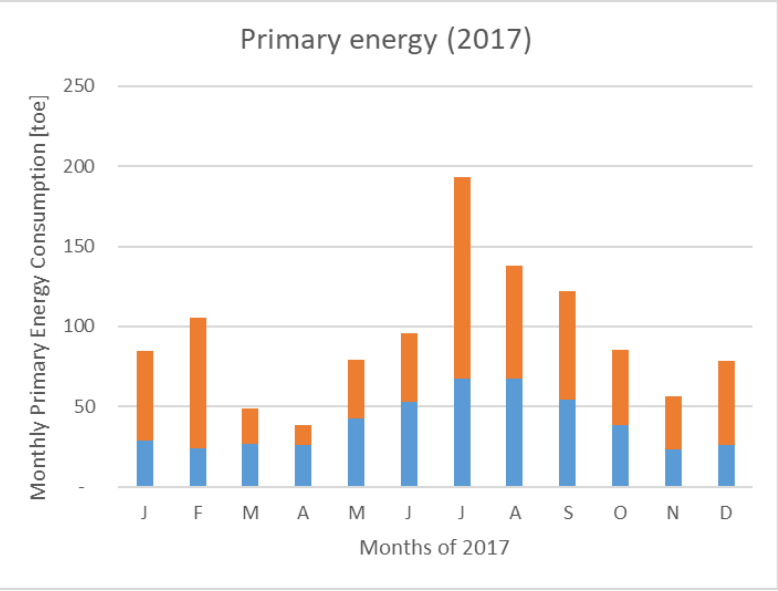
1911-1933
designed by Cesare Bazzani
~15,000 m^2, ~120,000 m^3
55 exposition rooms
1,100 art works
>200,000 visitors/year

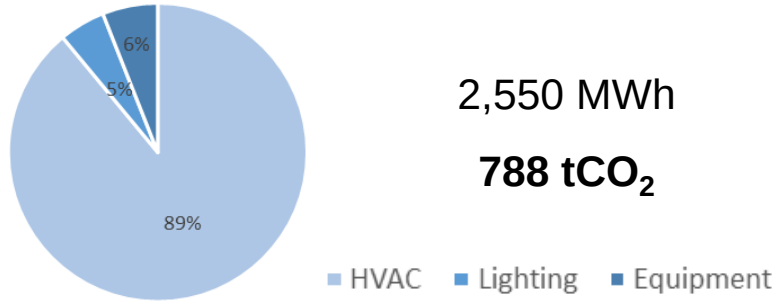
2017 baseline: when everything started

«The butler did it»: as usual in buildings, energy audit showed that the higher energy user was HVAC



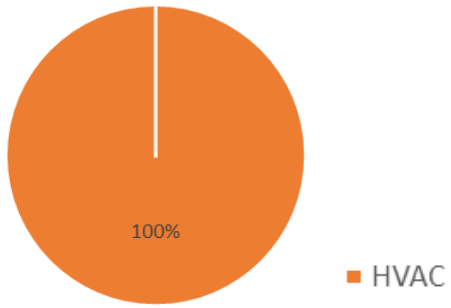






2,550 MWh

788 tCO_2



803 Scm

1,580 tCO_2

1,125 toe

2,368 tCO_2

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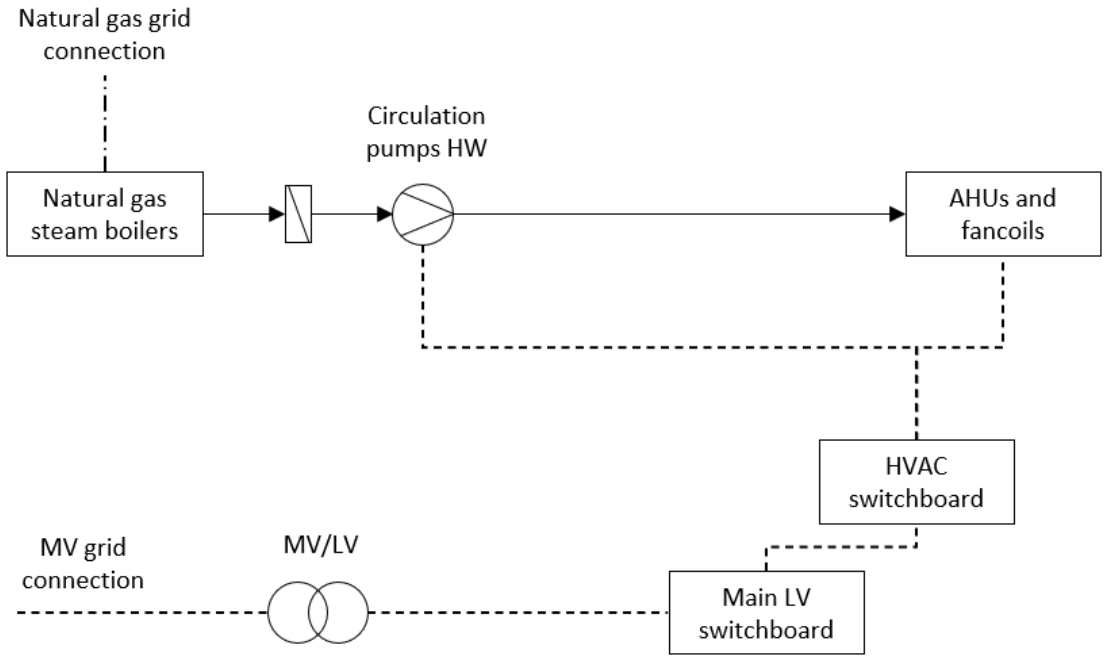
2017 baseline: winter HVAC

From steam to hot water for AHUs and fancoils: is it worth?



Winter season

- AHUs and fancoils use hot water obtained by steam produced by gas boilers
- High temperatures, high energy waste
- High electricity consumption in circulation pumps

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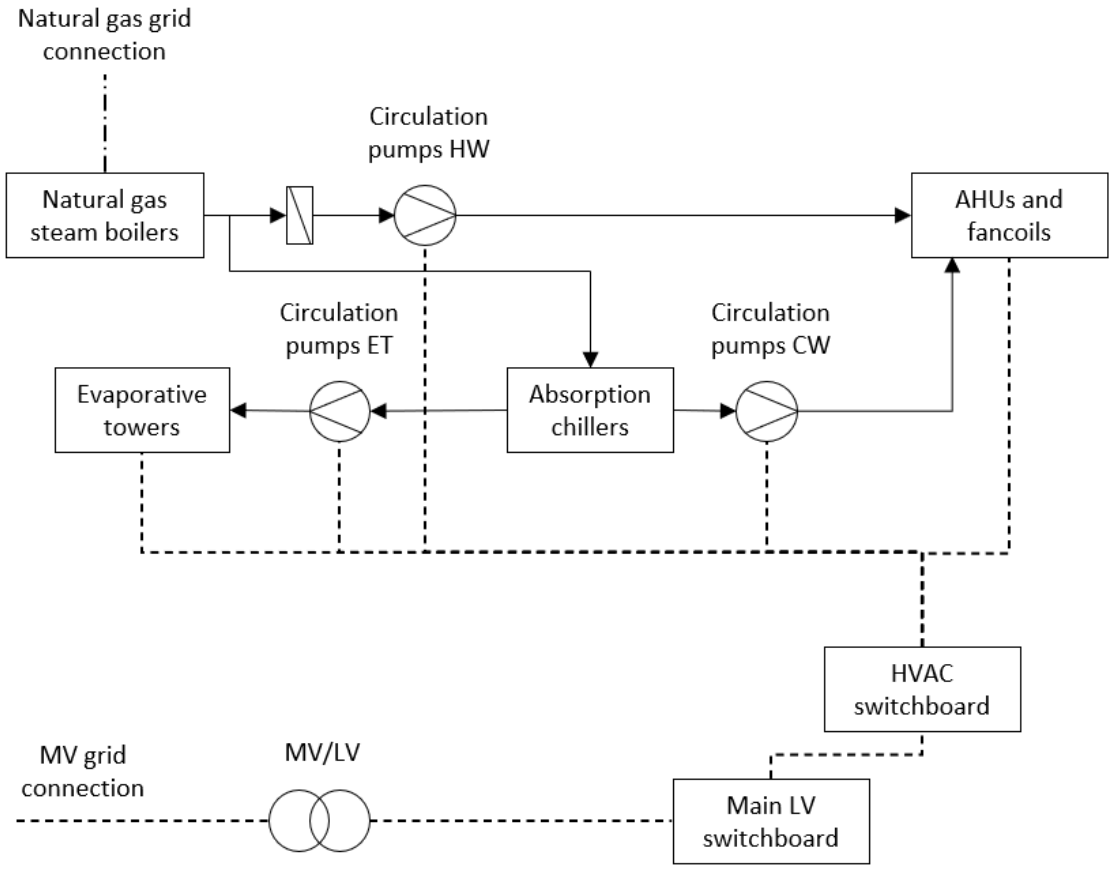
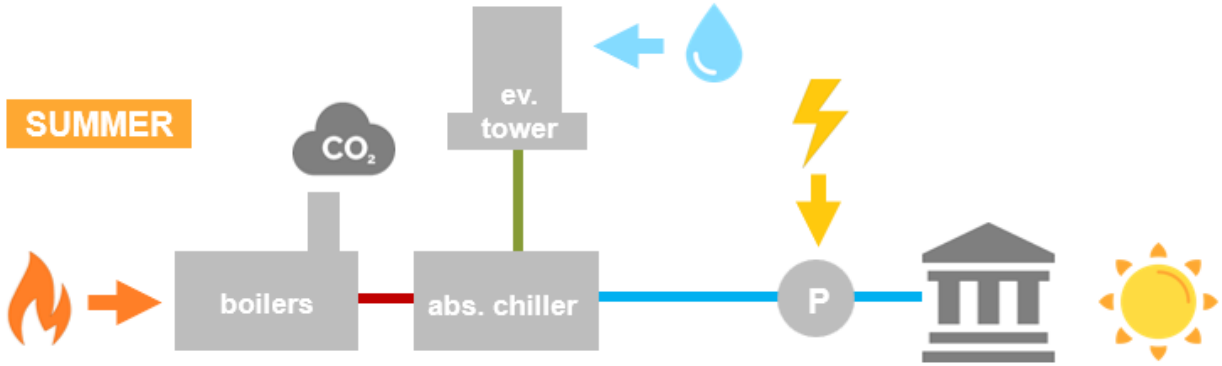
2017 baseline: summer HVAC

Highest consumption of natural gas during… summer!



Summer season

- Natural gas mostly used during summer
- AHUs and fancoils use chilled water produced by absorption chillers, powered by steam produced by gas boilers
- High electricity consumption in circulation pumps



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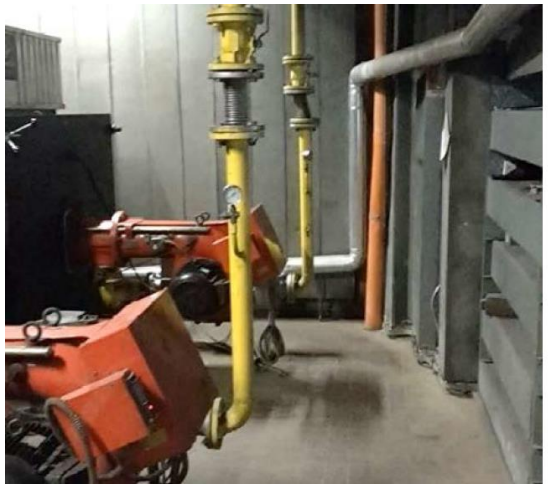
Efficiency works: new heating&cooling system

Dismission of the natural gas heating&cooling system for a new electrical heat pumps system

From fossil fuel…



Existing (built in 1997):

- 3 natural gas boilers (heating)
- 2 water-lithium bromide (LiBr) vapor absorption refrigerators (cooling)

…to renewable energy

New (activated in 2022):

- 4 air-water heat pumps (heating&cooling)
- Inverter controlled electric motors (auxiliary systems)

…powered from July 2022 by renewable electricity with GO

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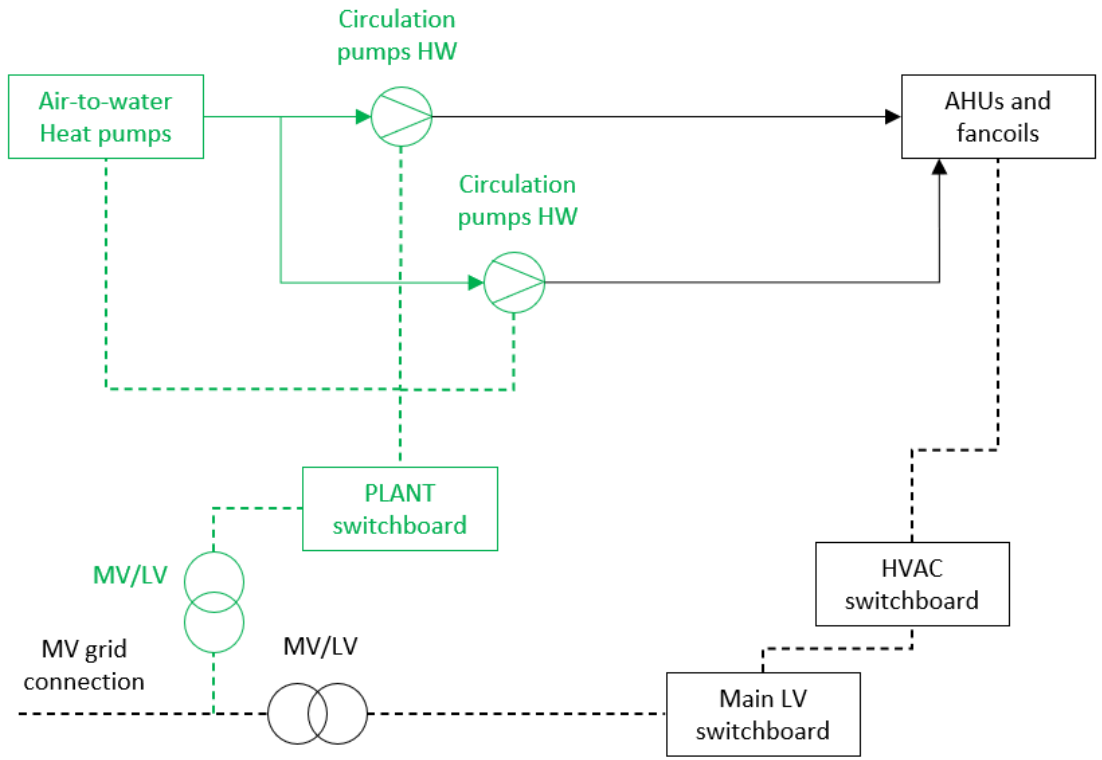
2022 netZero: winter HVAC

Full electric heating, with aerothermal renewable energy



Winter season

- AHUs and fancoils use hot water (at the requested temperature) produced by reversible air/water heat pumps
- Lower temperatures (no more steam), lower energy waste
- No more natural gas, only electricity

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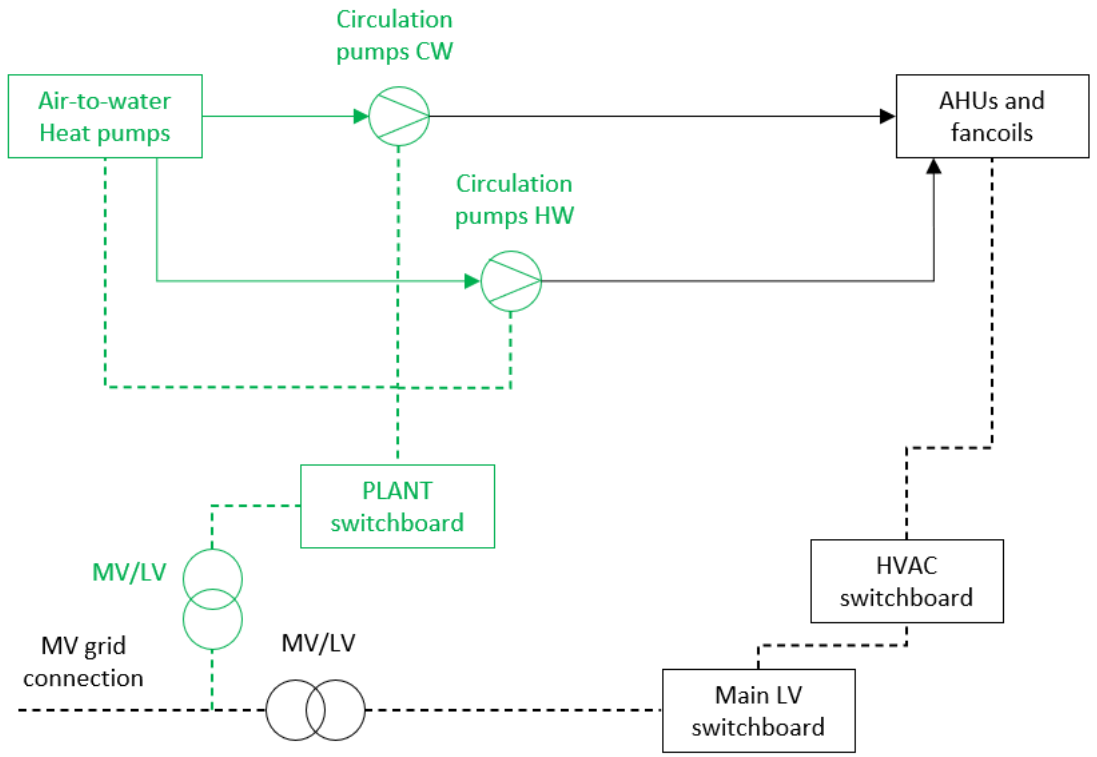
2022 netZero: summer HVAC

Full electric cooling, with aerothermal renewable energy



Summer season

- AHUs and fancoils use chilled water (at the requested temperature) produced by reversible air/water heat pumps
- Direct production (no more steam powered absorption chiller), lower energy waste
- No more natural gas, only electricity

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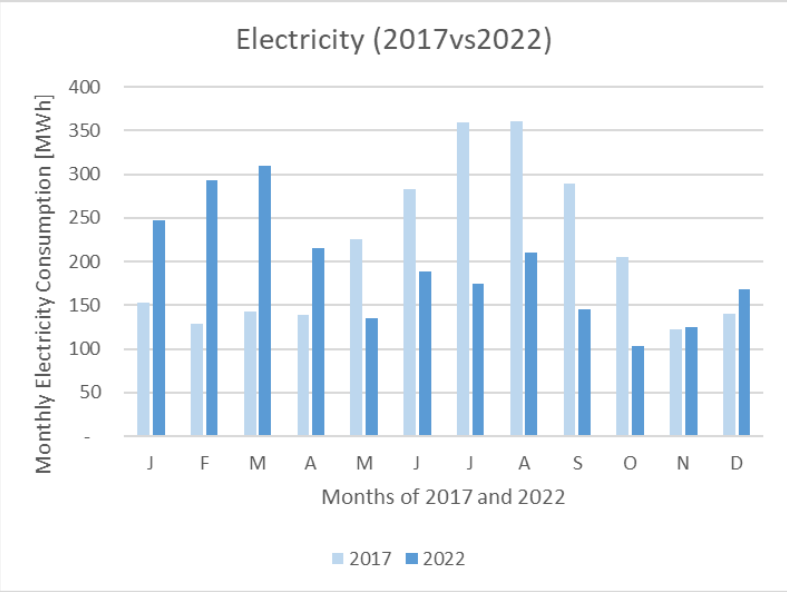
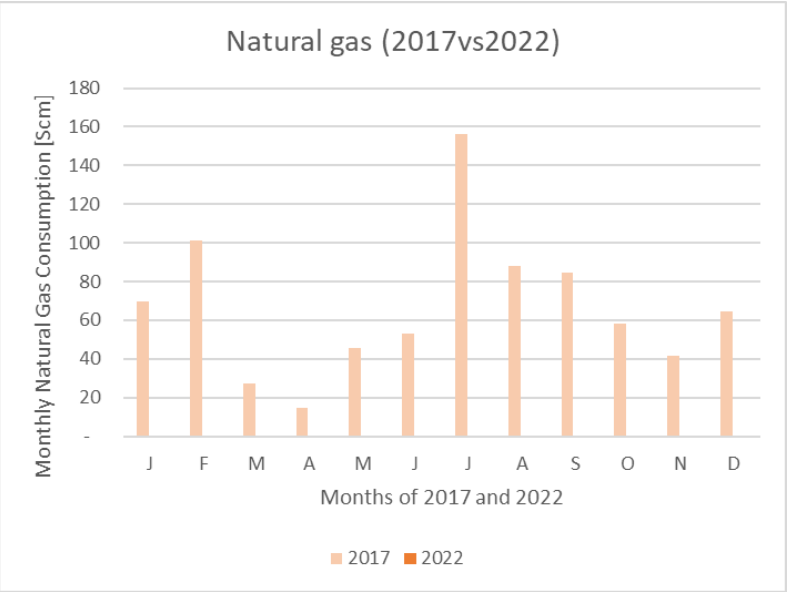
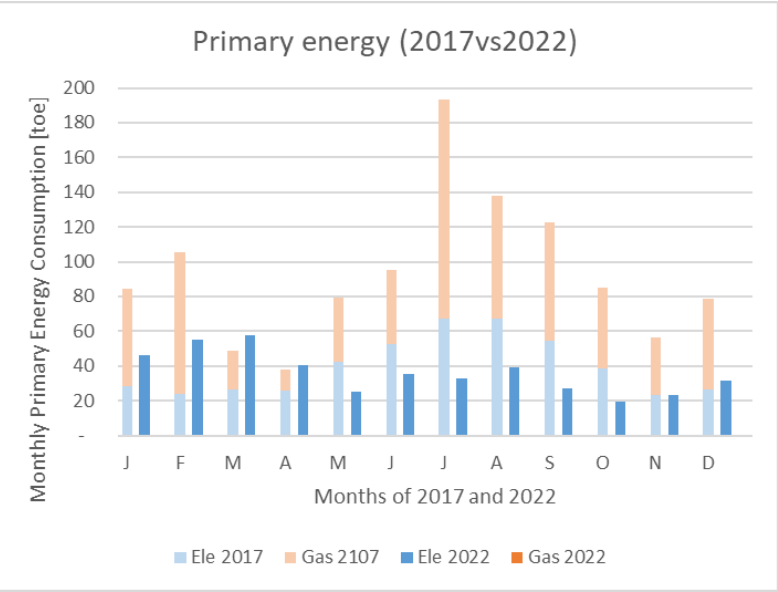
2022 netZero vs 2017 baseline: final results

-61% in primary energy consumption, -82% in carbon emissions (could have been -100%...)







@2017		@2022
2,550 MWh	→	2,314 MWh
788 tCO_2		**407 tCO_2 ***

@2017		@2022
803 Scm	→	0 Scm
1,580 tCO_2		**0 tCO_2**

@2017		@2022
1,125 toe	→	433 toe (-61%)
2,368 tCO_2		**407 tCO_2 (-82%) ***

* Renewable electricity with guarantee of origin purchased from Q3@2022

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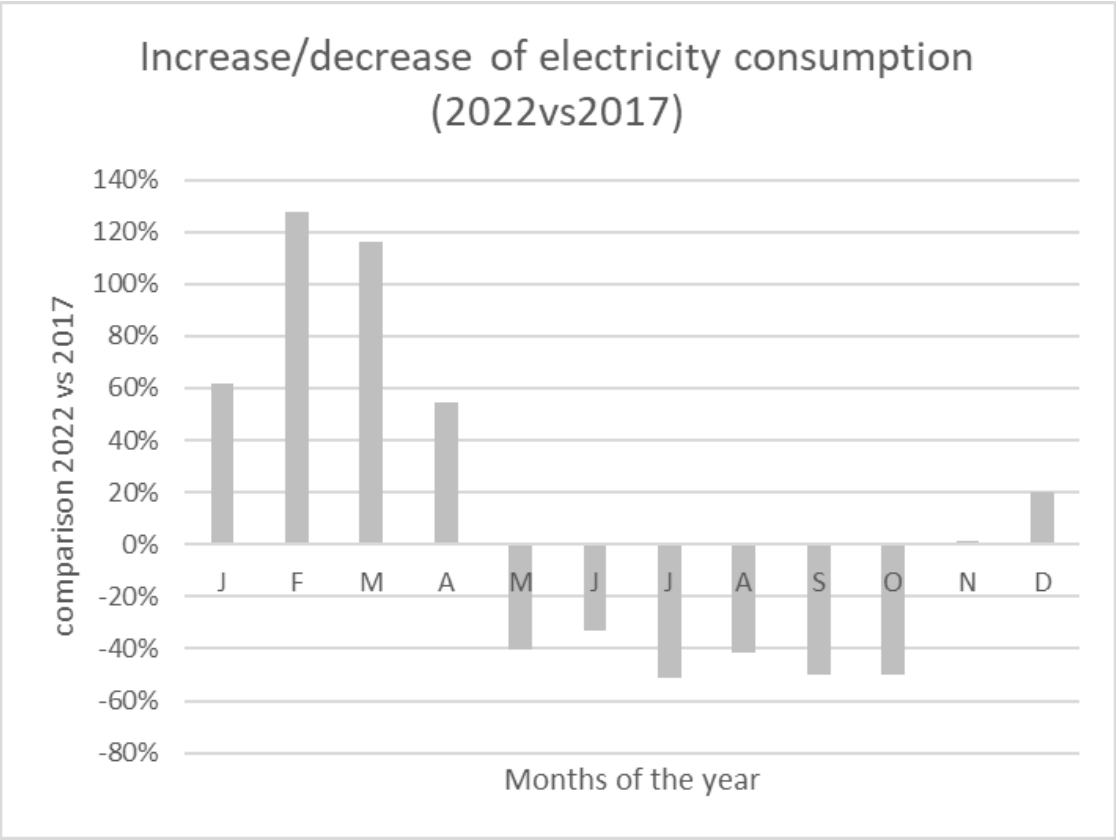
2022 netZero vs 2017 baseline: electricity consumptions

Electrification doesn’t meen increasing of electricity consumptions, sometimes.



- The monthly electricity consumption in 2017 and 2022 is different
- The winter electricity consumption in 2022 is higher than the 2017, because the entire heating load is transferred from natural gas to electric air/water heat pumps
- The summer electricity consumption in 2022 is lower than the 2017, because even if the entire cooling load is transferred from natural gas powered absorption chillers to electric air/water heat pumps, the old circulation pumps for cooling water (evaporative towers) consumed more than the new heat pumps.

@2017		@2022
2,550 kWh	→	2,314 kWh **(-9%)**

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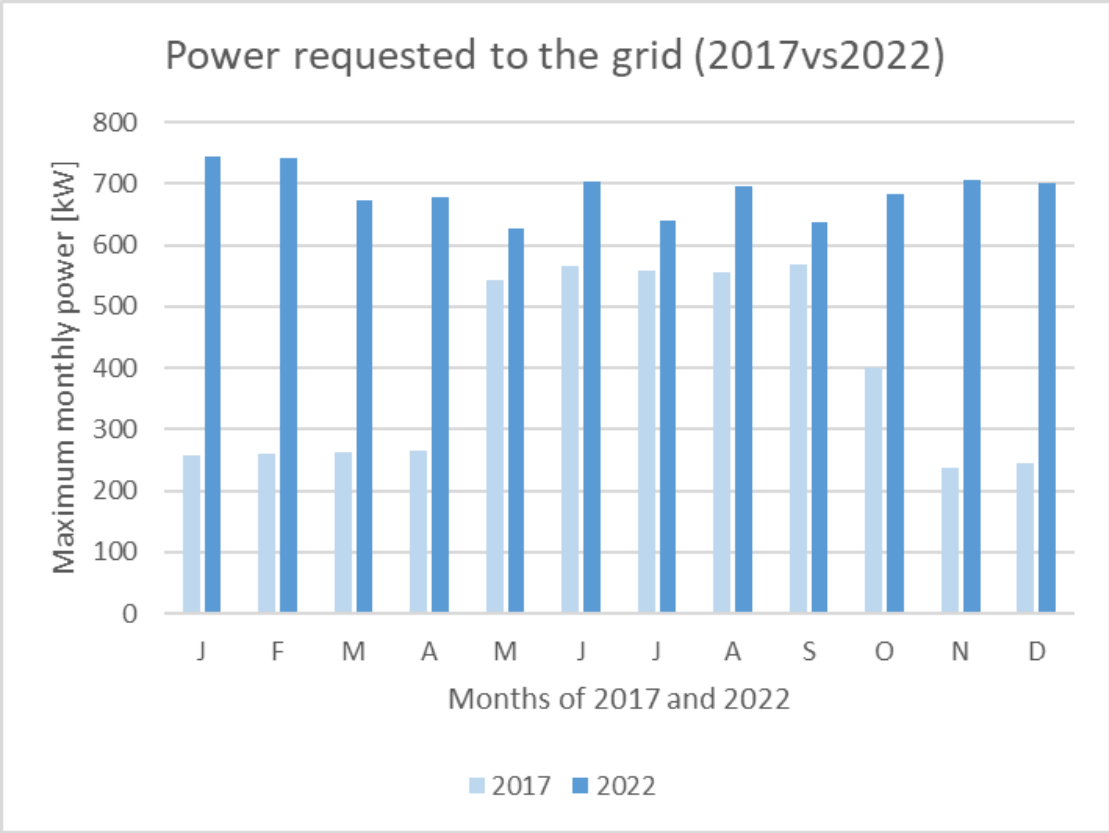
2022 netZero vs 2017 baseline: maximum power requested to the grid

From seasonal variations to a flat profile.



- The 2017 chart shows clearly the activation, during summer season, of the powerful circulation pumps for cooling water in the evaporative towers: in 2017 the summer maximum monthly power is almost double of the winter power.
- The 2022 chart shows that the load is slightly higher than 2017 but the maximum monthly power is almost flat during the year, linked to the size of the heat pumps and circulation pumps: in 2022 no more heavy seasonal variations in loads.

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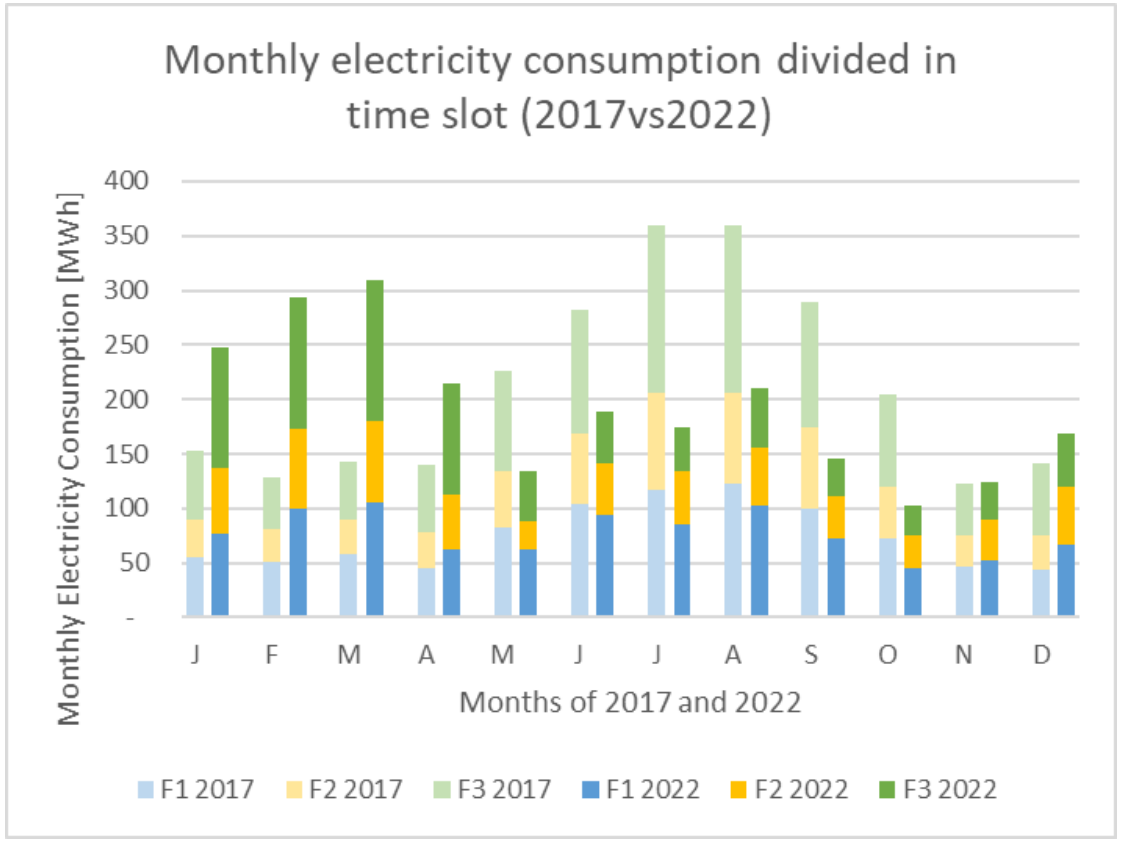
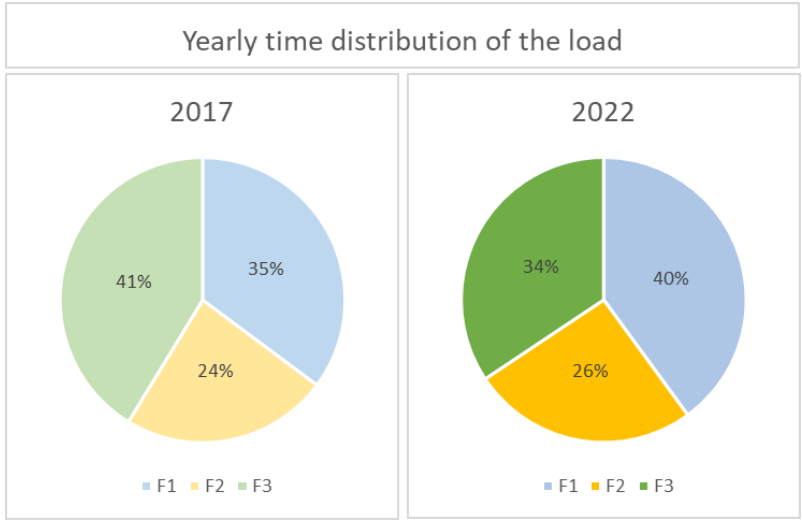
2022 netZero vs 2017 baseline: electricity consumption in time slots

Users profile is consumption profile, this is the rule.



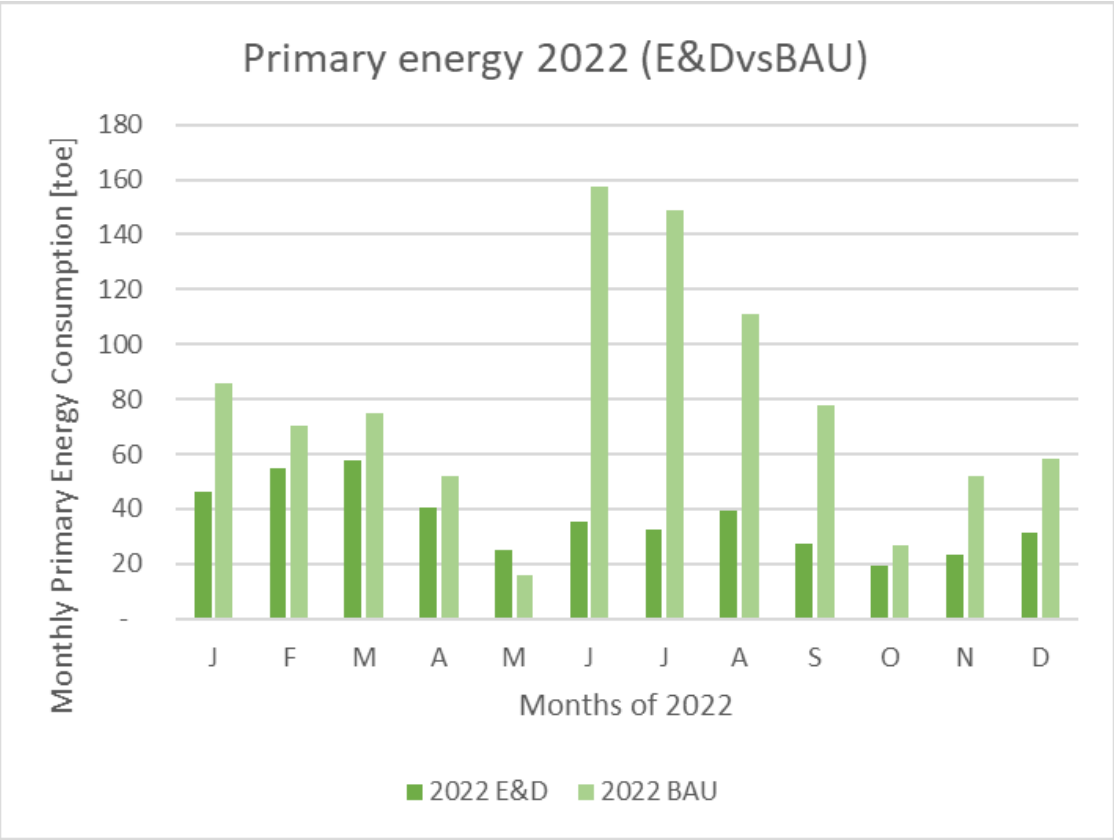
- The monthly energy consumption in 2022 is sometimes higher (winter) sometimes lower (summer) but the time distribution is almost the same.
- The user profile (opening hours, etc.) determines the time distribution.



Hours	Mon to Fri	Sat	Sun
7:00 8:00	F2	F2	F3
8:00 19:00	F1	F2	F3
19:00 23:00	F2	F2	F3
23:00 07:00	F3	F3	F3

2022 netZero vs 2022 BAU: the final comparison

The comparison 2022 netZero vs 2017 baseline was not fully representative of the impact of the decarbonization



2022 netZero (so called E&D, Efficient and Decarbonized) is compared with 2022 BAU (Business As Usual)

Methodology

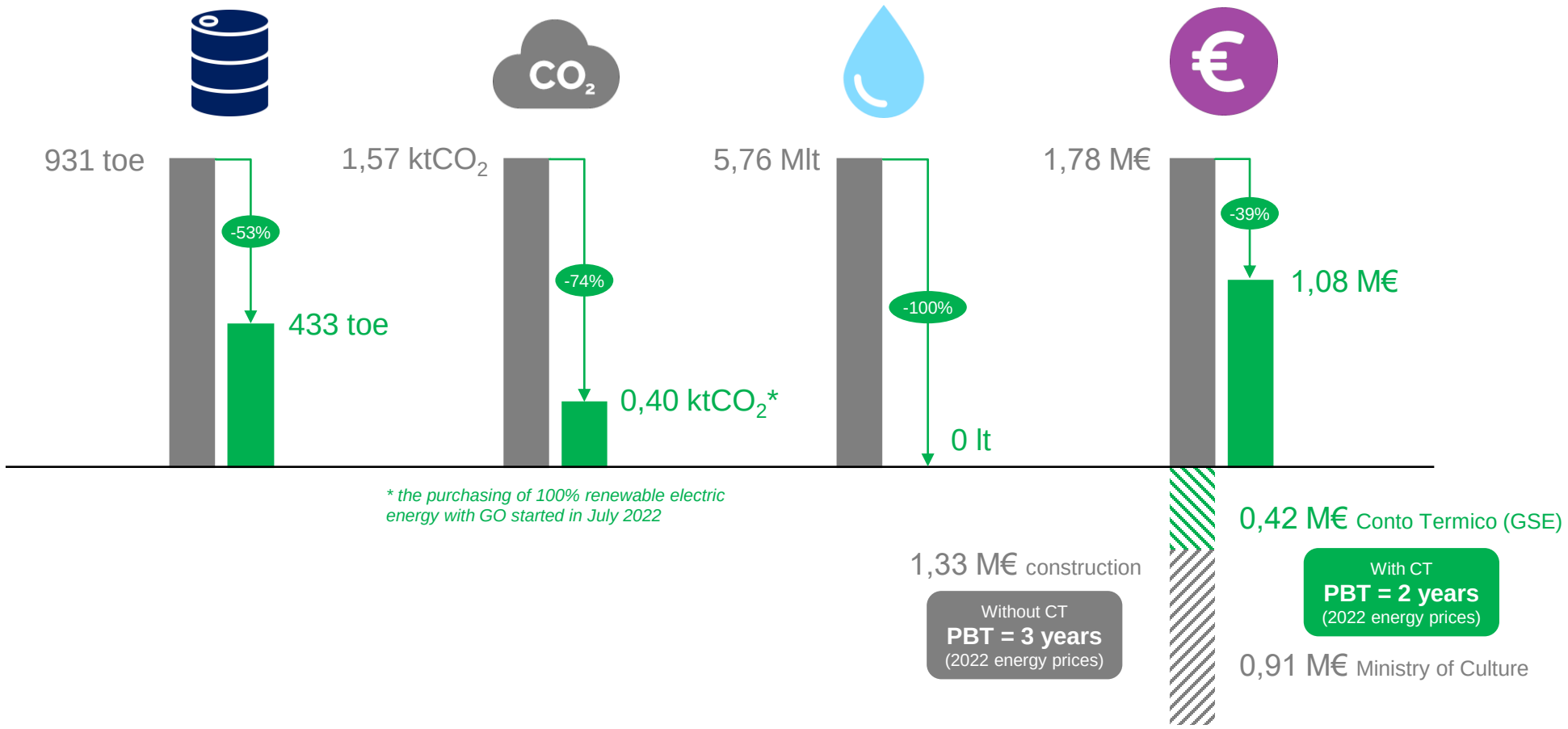
- **2022 E&D**: measured energy consumption of 2022, netZero museum, new heating and cooling plant, full electric
- **2022 BAU**: simulated energy consumption of 2022 (meteo data, users profile, etc.), old heating and cooling plant (natural gas powered)

@2022 BAU		@2022 E&D
931 toe	→	433 toe (-54%)
1,572 tCO_2		**407 tCO_2 (-74%) ***

* Renewable electricity with guarantee of origin purchased from Q3@2022

2022 netZero vs 2022 BAU: the final comparison

Important results in reduction of primary energy, carbon emission, water consumption and energy cost



A 100 years old italian museum became an energy efficiency case-study

Decarbonization through electrification of the National Gallery of Modern Art in Rome led to important findings

- The National Gallery became a net Zero Energy Building in 2022, thanks to the decarbonization through electrification of its heating and cooling plant and the purchase of renewable electricity with Guarantee of Origin.
- The substitution of the old natural gas-powered plant with a new full electric air/water heat pumps plant led in 2022 to a reduction of -61% in primary energy consumption and -82% in carbon emissions of the museum, if compared with the value of 2017.
- From an electrical point of view, the decarbonization through electrification led to a light decrease of the electricity consumption (-9% 2022 vs 2017), a strong change in the maximum load profile (from variable seasonal profile in 2017, to flat profile in 2022) and the same substantial distribution of the consumption during the day: electrification does not necessarily mean to increase the electric consumption and enable the building to manage the energy demand.
- The comparison between the real 2022 and the simulated 2022 BAU scenario leads to the same results: -54% in primary energy consumption and -74% in carbon emissions of the museum: the efficiency and decarbonization strategy is effective and represents a best practice for the historic building sector.
- Considering the high prices of energy in 2022 and the incentive “Conto Termico” achieved by the museum, the first-year savings of 780k€ lead to a payback period of just 2 years (instead of 5-6): decarbonization through electrification is economically sustainable.

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