UNIVERSITY ENERGY MASTER PLAN

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

For some time, this university has taken on the important task of combating gender stereotypes through raising awareness of this issue. In accordance with the Gender visibility guidelines for the University of Bologna's institutional communications, approved in 2020, we have aimed to explicitly use the feminine in Italian, or to use neutral wording when possible, in the original University Energy Plan written in Italian. Gender neutral language is also used in this English translation to include all members of the university community.
When only the masculine is used in Italian, for reasons related to fluidity or design limitations, it is used in an inclusive manner that refers to all people within the university community.

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INTRODUCTION

This Energy Master Plan – the first ever in the history of the University of Bologna – is the result of the intersection of many of the dimensions that characterise this institution as a large, public university, a sentinel of knowledge and values. We look first and foremost to our sense of social responsibility, which requires us to not only have the greater good at heart during the daily operation of our institution, but also to set an example for others, encouraging collective behaviours through our actions. Secondly, we rely upon our technical and scientific skills, which allow us to process and implement original solutions to original problems. Finally, we have a duty to adopt a perspective that views the University of Bologna as a lasting institution, including both its centuries-old history and its innovative future, going beyond the activities of a single period or a single university administration.

The energy crisis is one of the most complex and urgent problems facing humanity today. To ignore this situation, and remain passive as a result, would be unethical and scientifically short-sighted. The climate crisis, pollution, environmental degradation, loss of biodiversity and even inequalities and wars are, directly and indirectly, consequences of the patterns of our energy consumption.

Our teaching, scientific and administrative activities are carried out over an area of more than one million square metres. In absolute terms, the energy these activities require is constantly increasing, and this is an indirect sign of the growth and success of the University of Bologna. But this increase requires increasingly informed, aware and responsible energy management strategies in order to control and limit not only expenditures, but also greenhouse gas emissions.

The Energy Master Plan of the University of Bologna defines the intervention strategies needed to promote an efficient use of energy and increase the social, economic and environmental sustainability of our activities. The university community can find above all an explanation of the university's current energy situation in this document: a university still reliant on fossil fuels (natural gas in particular), thermal energy produced from district heating networks and electricity drawn from the local grid, with a limited portion of self-generated solar energy (3% in 2022).

Starting from this baseline, the Energy Master Plan describes a series of scenarios that attempt to predict the evolution of energy consumption in the short and medium term, and it indicates the direction in which the university should move forward, pursuing a reduction in greenhouse gas emissions, increased use of renewable resources and higher levels of energy efficiency.

Based on the directions provided in the European Green Deal and the "Fit for 55%" programme, the Energy Master Plan identifies actions to implement in the near future. Among these actions is the installation of new solar panels to enable the university to produce 17% of the electricity it consumes by 2030; a relamping campaign that will increase the efficiency of lighting systems in university buildings; the creation of a remote control network for the entire thermal energy system of the university; the elimination of remaining boilers powered with heating oil or fuel oil.

Finally, with the declaration of a desire to pursue a clear university policy of energy efficiency in the short and medium term, the Energy Master Plan aims to stimulate new synergies with local public administrations and involve private collaborators in the funding of individual measures. In other words, the university would like to render itself an "open laboratory" to host new, experimental systems, but also for innovative awareness-raising activities regarding themes tied to energy and the environment.

Nonetheless, beyond the implementation of the technical interventions described in this document, the success of the Energy Master Plan will require the meaningful involvement of the entire university community. Professors, technical and administrative staff and the student population must see themselves as part of a shared initiative focused on reducing energy waste thanks to responsible individual behaviours when using spaces, equipment and machinery. This shared initiative must be fuelled by an ongoing collaboration aimed at identifying problematic situations and stimulating improvements.

Today, as members of a farsighted and innovative community, we are called to accept this task. We must remember that we have the power to decide our future today, with the knowledge that the decisions we make are the root of the future of coming generations, which will grow from the contributions each and every one of us offer.

Giovanni Molari
Rector, Alma Mater Studiorum – Università di Bologna

1. ENERGY BALANCE SHEET OF THE UNIVERSITY

The University of Bologna manages an estate with a total of 287 buildings, with an overall area of more than one million square metres. The majority of buildings (204) are situated within the Metropolitan City of Bologna, while 21 buildings are located on the Ravenna Campus, 20 on the Cesena Campus, 24 on the Forlì Campus, 17 on the Rimini Campus and one in Fano.

Figure 1.1 – Geographic distribution of the University of Bologna's building stock (Source: University Data Warehouse).

From 2015 to 2020 total surface in use increased by 18.63%, while in 2021 it decreased due to some closures and a policy of rationalised use of university spaces (Table 1.1).

Table 1.1. - Buildings used by University of Bologna staff and students (2015-2022).

		2015	2016	2017	2018	2019	2020	2021	2022
SPACES									
Total surface area	m^2	964,186	971,768	979,633	969,191	1,016,325	1,143,841	1,070,661	1,031,022
PEOPLE									
Professors		2,781	2,782	2,721	2,743	2,802	2,854	3,002	3,76
Technical and Administrative Staff		3,072	3,021	2,965	2,926	2,963	2,942	3,008	3,151
Students		81,174	81,988	82,882	84,331	84,659	84,626	86,326	89,580

The energy balance sheet of the university plays a significant role in terms of expenditure, consumption, emissions and environmental and social impact; the university has an environmental impact of over 14,000 toe (Tonne of Oil Equivalent) each year, with an energy expenditure of €15 million in 2021, which grew to over €21 million in 2022 due to the international crisis that limited market availability of a main energy source (Table 1.2).
The university's annual consumption of primary energy makes it one of the major energy consumers in the Emilia-Romagna Region, and as such our institution must assume a sense of responsibility and a foresight that are commensurate with our role.

Table 1.2. - Primary energy consumption of the University of Bologna (2015-2022) expressed in toe (1 toe = 11,630 kWh, MISE Memo dated 18/12/2014 conversion factors, Italian Federation for Energy Efficiency (FIRE) conversion factors).

	2015	2016	2017	2018	2019	2020	2021	2022
Electricity	8,201	6,823	7,904	7,962	7,990	6,778	7,615	7,961
Natural gas	2,864	2,878	3,236	2,956	2,658	2,493	3,061	2,675
Heating oil	260	166	221	246	209	146	80	62
Fuel oil	-	-	-	109	103	113	123	126
District heating (TLR)	2,250	2,190	2,853	3,089	2,767	2,776	3,583	3,237
Total consumption	**13,575**	**12,058**	**14,215**	**14,362**	**13,727**	**12,305**	**14,461**	**14,062**

Figure 1.2 shows the breakdown of the University of Bologna's primary energy consumption by energy source: the percentage of self-generated electricity is equal to 3.2% of electricity consumption (2015-2022 average), corresponding to 2% of primary energy consumption; the percentage of consumption of thermal energy from the district heating network is equal to 21% of annual primary energy consumption.

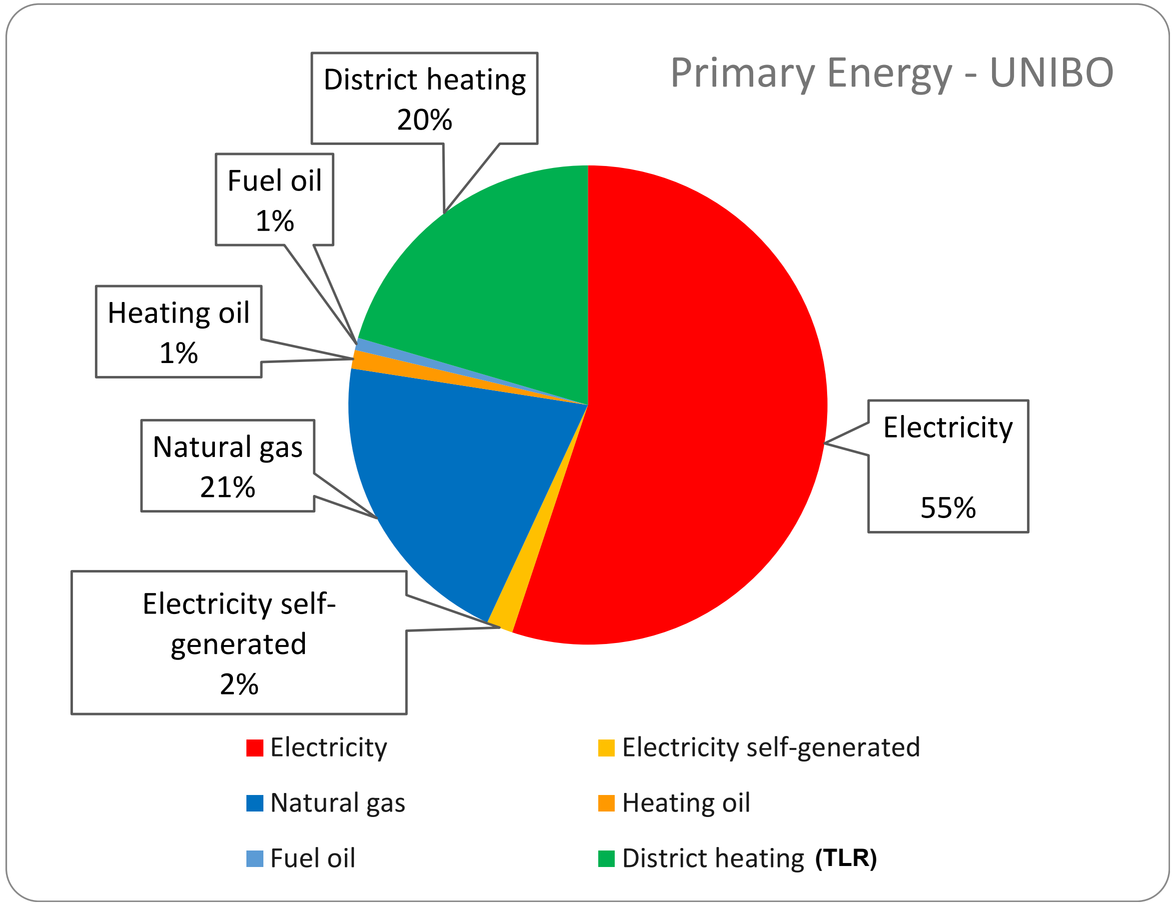


Figure 1.2. Breakdown of annual primary energy consumption of the University of Bologna by energy source (2015-2022 average).

An examination of trends in energy consumption (and the related costs) in the period indicated is included below, divided by end use: electricity (indicating the percentage of self-generated energy) and thermal energy (further divided into each energy source: methane, heating oil, fuel oil and thermal energy from the district heating network).1.

1.1 ELECTRICITY CONSUMPTION AND PRODUCTION

Electricity consumption was stable between 42 and 44 GWh/year from 2015 to 2022 (Table 1.3). In 2020, electricity consumption, like consumption of all energy sources, was lower than previous years due to the COVID-19 emergency, in part due to a restructuring of equipment use periods and turning off equipment whenever possible. 2021 saw an increase in consumption due to the gradual return to in-person activities for the entire academic community; in addition, new didactic activities began at the ex-ENAV Academy site in Forlì, buildings in the Navile District became partially operational and the student residence in the ex-Red Cross building in Bologna became fully operational.

Table 1.3 – Electricity consumption, production and costs (2015-2022).

		2015	2016	2017	2018	2019	2020	2021	2022
Consumption	MWh_el	43,856	36,488	42,270	42,577	42,727	36,244	40,721	42,572
Costs	€	9,620,135	9,308,582	7,638,326	7,646,887	9,228,379	7,187,654	6,961,918	9,251,694
PV production	kWh_el	1,380,292	1,343,958	1,426,186	1,294,574	1,312,262	1,347,267	1,258,260	1,241,485

Beyond the return to in-person activities, the increase in electricity consumption in 2022 was also caused by a summer that was hotter and longer than usual, which required prolonged use of cooling systems. Furthermore, a significant increase in consumption was also recorded for the Navile District, where didactic activities, as well as administrative offices, gradually began making use of the newly opened locations.

The pv electricity self-consumed by the university was produced by solar PV fields installed on the roofs of university buildings covering a total surface area of 9,340 m2, which were purchased by the University in December 2022. Today, the University of Bologna has at its disposal a total of 1.4 MWp installed on the roofs of the Engineering and Veterinary Sciences Departments in Ozzano and the Agricultural Sciences and Physics Departments in Bologna. These installations provide the main contribution to the current amount of energy generated by the university, as indicated in Table 1.3.

The amount of electricity currently produced via PV panels covers roughly 3% of the university's annual consumption of electricity (which increased to a maximum of 3.7% in 2020, due to the reduction in electricity consumption during lockdown).

1.2 THERMAL ENERGY CONSUMPTION

The university's average annual consumption of natural gas fluctuated between 3 and 4 million Sm³ from 2015 to 2022, while consumption of heating oil and fuel oil steadily decreased (Table 1.4). In contrast, in 2019 consumption decreased as a result of a milder winter, despite the activation of a heating system in the new location of the Cesena Campus (ex-sugar mill).In 2020 thermal energy consumption saw a sharp decrease during the pandemic; this also allowed for a re-

Table 1.4 – Thermal energy consumption and costs (2015-2022).

Thermal energy consumption and cost		2015	2016	2017	2018	2019	2020	2021	2022
NATURAL GAS									
Consumption	Sm^3	3,671,390	3,690,022	4,148,279	3,789,213	3,407,179	3,195,816	3,924,110	3,429,647
Costs	€	2,196,171	3,579,489	2,673,795	2,614,319	2,528,281	2,106,718	2,674,152	3,549,915
HEATING OIL									
Consumption	Ton	255	163	217	241	205	143	78	61
Costs	€	313,572	219,584	262,279	307,408	264,277	164,107	95,438	100,913
FUEL OIL									
Consumption	Ton	-	-	-	108	102	112	122	125
Costs	€	-	-	-	153,330	143,653	156,575	162,198	202,087
DISTRICT HEATING									
Consumption	kWh_th	21,842,789	21,266,621	27,700,171	29,994,781	26,867,555	26,949,714	34,786,674	31,428,710
Costs	€	3,734,804	4,214,164	4,196,405	4,735,071	4,273,976	3,622,391	5,317,123	8,863,269

structuring of equipment use wherever possible. Furthermore, in the centre of the Bologna Campus, known as the "cittadella universitaria", the decommissioning process of five operational heating systems that use heating oil began in October 2020, to be replaced with a district heating network, connection which resulted in a fall in requests for heating oil starting that same month; this decrease became increasingly evident in the two years that followed. In terms of use of the district heating network, 2020 witnessed a slight increase in consumption compared to the previous year, as the teaching facilities for the Engineering and Architecture programmes at the Cesena Campus became fully operational a year after they were opened in 2019. Furthermore, four new district heating connectionsbecame operational that same year (three in the Filippo Re District, one in the Zamboni District).

In 2021, following the gradual return to in-person activities and the establishment of new teaching activities in Forlì and the Navile District, consumption for all energy sources was higher than the previous year. It should also be noted that the increase in energy consumption for heating systems in 2021 is due to the specific measures adopted to prevent COVID-19 infection, following the instructions from the Italian National Health Institute (equipment fully functioning 24/7 without air recirculation, increased the expenses for forced ventilation of spaces, longer periods of operation than normal). Lastly, in 2022 energy consumption for all sources used for winter heating decreased due to the weather (milder winter), as well as a growing attention to equipment use, thanks to a specific energy saving policy and greater community awareness.

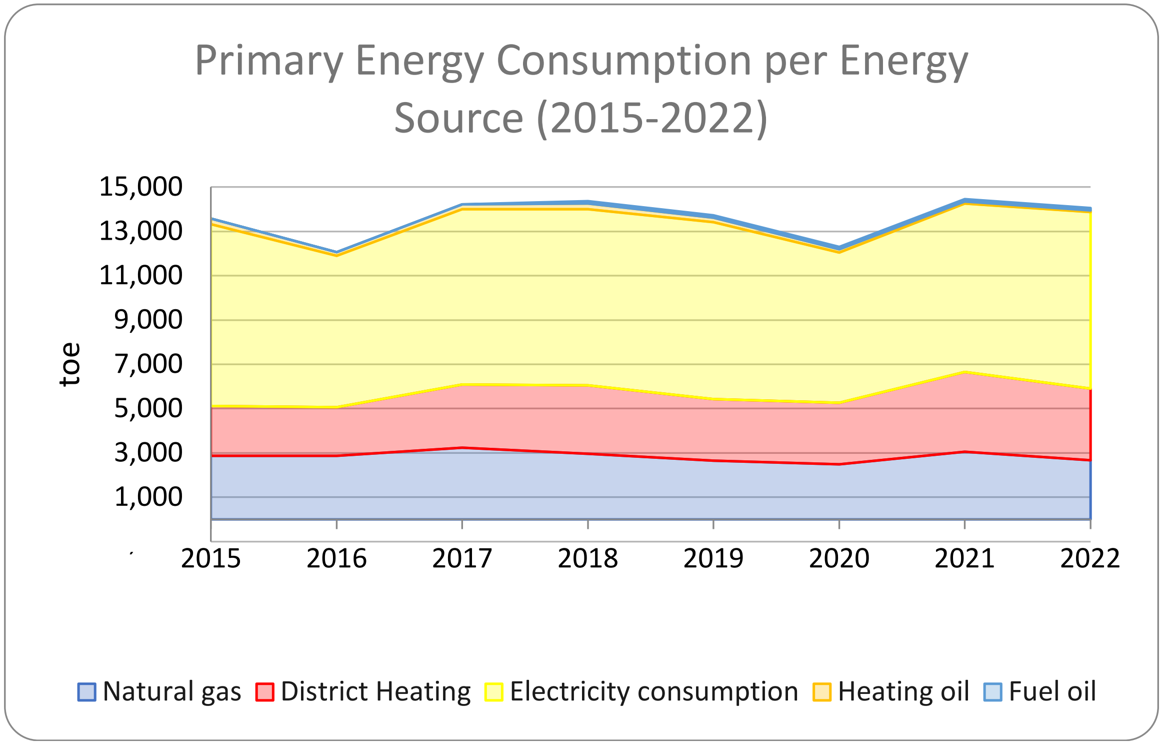


Figure 1.3. - Trends in primary energy consumption per energy source (2015-2022).

1.3 AVERAGE DAILY CONSUMPTION AND AVERAGE DAILY ENERGY CHARGES

An analysis of the average daily consumption of the university for each main energy source, with separate values calculated for the summer (April-September) and winter (October-March) (Table 1.5), reveals that the average daily energy charges of the university in 2022 was equal to €74,165/day during the winter and €41,938/day in the summer (with respective increases of 35% and 18% compared to the winter and summer of 2019). Thermal energy is also consumed via the district heating network (TLR in Table 1.5) in the summer, used for bathroom water heaters at some sites, to power the post-heating batteries of the Air Handling Units and to power the absorption chiller used for refrigeration at the Food and Agricultural Sciences and Technologies Department in Bologna. A single building, the main building of the DIFA Physics Department on Viale Berti Pichat, is connected to Hera's district cooling network (TLF in Table 1.5).

Table 1.5 – Average daily consumption per energy source and average daily expenditure in summer and winter for water and energy supply.

	Daily consumption			Energy costs 2022		Daily energy charges 2022		
	unit	winter	summer	unit	value	unit	winter	summer
EE	MWhe/d	101.97	121.56	€/MWhe	217.30	€/d	22,157.70	26,414.21
NATURAL GAS	Sm^3/d	15,685.00	939.02	$€/Sm^3$	1.04	€/d	16,235.54	971.98
TLR	MWh/d	112.12	29.48	€/MWh	282.00	€/d	31,618.75	8,314.46
HEATING OIL	litres/d	743.94	48.39	€/litres	1.42	€/d	1,057.13	68.76
FUEL OIL	kg/d	447.29	90.52	€/kg	1.61	€/d	721.84	146.07
TLF	MWhf/d	-	7.13	€/MWhf	463.78	€/d		3,305.50
WATER	m^3/d	763.29	873.31	$€/m^3$	3.11	€/d	2,374.86	2,717.19
						TOT (€/d)	**74,165.83**	**41,938.17**

1.4 EQUIVALENT EMISSIONS OF CO_2 LINKED WITH THE CONSUMPTION OF VARIOUS ENERGY SOURCES

Annual equivalent emissions of CO_2 generated by university energy consumption (Table 1.6) are above 31,000 tonnes of CO_2 per year (excluding 2020 due to measures adopted to address the pandemic). This value has been relatively stable over the years thanks to efficiency improvement interventions on old equipment and the installation of high-efficiency equipment in new university locations.

More than half of the university's CO_2 emissions are from electric energy consumption. Equivalent emissions from systems connected to the district heating network were equal to those of natural gas, due to the increase in the district heating network connections that were planned for the 2019-2026 period.

Table 1.6 – Equivalent emissions of CO_2 per energy source and emission index (2015-2022).

ELECTRICITY		2015	2016	2017	2018	2019	2020	2021	2022
Emissions	tCO_2	18,998	15,807	18,311	18,445	18,509	15,701	17,640	18,442

THERMAL ENERGY		2015	2016	2017	2018	2019	2020	2021	2022
Natural gas									
Emissions	tCO_2	6,998	7,034	7,907	7,223	6,494	6,092	7,480	6,537
Heating oil									
Emissions	tCO_2	744	476	634	704	598	417	228	178
Fuel oil									
Consumption	tCO_2	-	-	-	335	316	347	378	388
District heating									
Emissions	tCO_2	4,364	4,249	5,534	5,993	5,368	5,385	6,950	6,279

		2015	2016	2017	2018	2019	2020	2021	2022
Total consumption	toe	13,575	12,058	14,215	14,362	13,727	12,305	14,461	14,062
Total emissions	tCO2	31,105	27,565	32,386	32,699	31,287	27,942	32,676	31,825
Emission index	tCO2/toe	2.29	2.29	2.28	2.28	2.28	2.27	2.26	2.26

In conclusion, the energy balance sheet of the university highlights the following data:

- primary energy consumption is equally divided among thermal energy (44%) and electricity (56%);
- in 2022, the percentage of primary energy consumption from use of the district heating network (21%) was the same as that of natural gas (21%);
- daily energy charges in winter is double than in summer;
- electric energy consumption is maximum in summer months;
- in light of reduced use of fuel oil and heating oil for building heating (2.2% of total primary energy consumption of the university), it is possible to plan a timely elimination of these high-impact energy sources;
- the emission index of the university (expressed in tCO2/toe) is typical of systems that primarily consume thermal energy produced by fossil fuels and electricity from the local grid.

2. ENERGY SUPPLY CONTRACTS

The liberalisation of the electricity and natural gas markets has allowed users to choose among various electricity suppliers and offers.

Italian universities, like all public administrations, are required to use the suppliers indicated in the Consip S.p.A. framework agreement (Legislative Decree 95/2012 converted to Law 135/2012 and Law 228/2012), and for purchases that are below the community threshold, they are required to use the Electronic Marketplace of the Public Administration (MePA) managed by Consip, or to use other e-procurement instruments, including those made available by regional central purchasing bodies. Using the Consip system, it is possible to purchase energy through the agreements that are periodically stipulated based on bidding contests that are distributed through a series of regional subdivisions.

As the university has long been attentive to the rationalisation of supply processes, it purchases electricity, natural gas and heating oil through the active agreements promoted by the national central purchasing body Consip, as well as through the regional body Intercent-ER, which in some years has allowed energy to be purchased at a lower price compared to market values.

The university occasionally makes use of the Energy Service Contract (Legislative Decree 115/2008, and subsequent amendments).

Alongside these suppliers, thermal energy is also supplied by the district heating network that covers the energy needs of various buildings in Bologna and Imola, as well as on the Forlì, Cesena and Rimini campuses.

2.1 ELECTRICITY

From 2018 to 2022, the university purchased approximately 42 GWh/year.

The number of active connections vary each year based on how many temporary connections are necessary for construction sites and research projects, as well as the need for permanent connections in new locations or when existing locations are repurposed. In 2022 the university had 175 active connections throughout the territory, 174 in the Emilia-Romagna Region and one in the Marche Region (Fano Marine Center). As the active connections are spread among different geographic areas, electricity is purchased from two suppliers chosen via active agreements with two separate supply contracts.

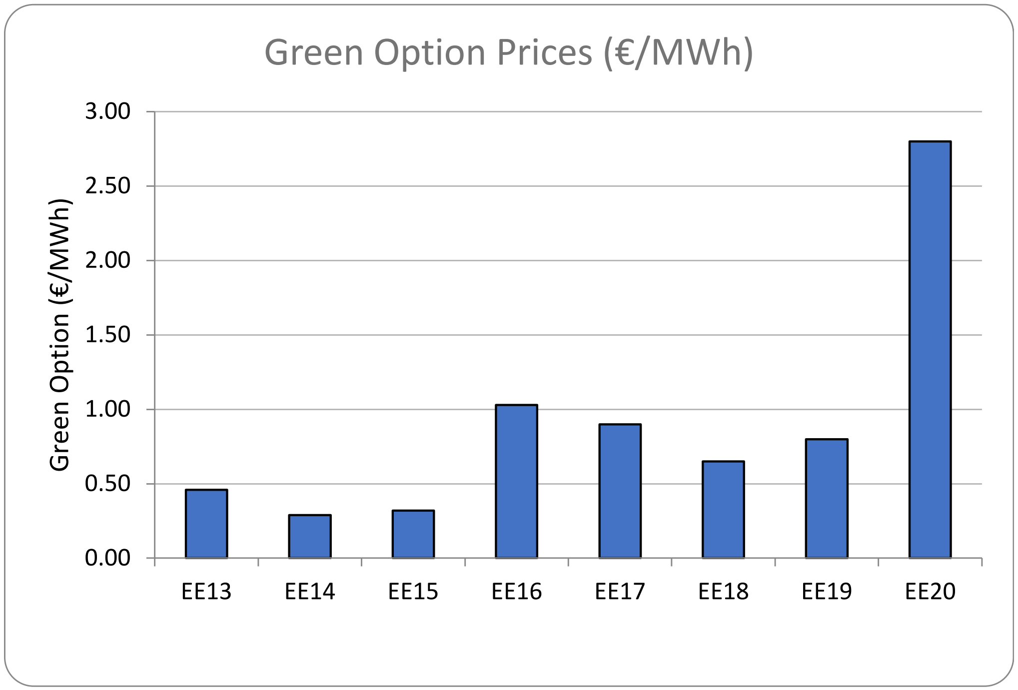


Figure 2.1 – Trends in the cost of the Green Option (certified 100% renewable electricity) in Consip agreements from 2015 (Energia Elettrica EE13) to 2022 (Energia Elettrica EE20).

The university chose its electricity supplier through the Consip agreement in 2019, 2020 and 2022, and used the Intercent-ER agreement in 2018 and 2021. This choice was guided by an evaluation of the best price offered, supplier reputation and any additional services proposed (summary invoicing, dedicated call centre and single point of reference for the agreement).

The purchase process is carried out in October of each year; the starting date of supply is 1 January and the contract is generally valid for one year, with an end date of 31 December.
In accordance with the Strategic Plan of the university, and in particular with objectives 48 ("Reducing energy consumption and promoting energy efficiency in buildings") and 50 ("Adopting an efficient environmental management model, including as part of a circular economy"), the university purchases electricity, when possible, generated entirely from renewable resources (Green Option); moreover, it favours fixed-price agreements to have certainty regarding costs and remain unaffected by any volatility of market energy prices.

In the Consip agreements between the editions "Energia Elettrica EE13", published in 2015, and "Energia Elettrica EE20", published in 2022, which provide a guarantee of origin of electricity consumed, the average surcharge for 100% renewable energy fluctuated between €0.29 and €2.80/MWh, following the trend of market prices of electricity with a guarantee of origin (Figure 2.1).

The increased cost of the Green Option recorded in 2022, when it rose to €2.80/MWh, is due to distinct market conditions that made the price of electricity generated from renewables particularly volatile. It is not unlikely that the cost of the Green Option will remain high in the face of the projected increase in demand.

2.2 NATURAL GAS

The university purchased approximately 4,000,000 Sm3 of natural gas each year during the 2018-2022 period.
Like with electricity, active connections with the network can vary between years based on how many permanent connections are requested for new locations or when existing locations are repurposed. In 2022 the university had 190 active connections, 189 in the Emilia-Romagna region and one in the Marche region.
Like for electricity supply, the university usually relies on the two suppliers that won the bidding contests held by Consip or Intercent-ER within the relevant regional subdivision.
The supplier was selected by participating in the Consip agreement for the thermal seasons 2017/18, 2018/19, 2019/20 and 2021/22, while the Intercent-ER agreement was used for the 2020/21 and 2022/23 thermal seasons, based on an evaluation of the best price offered, supplier reputation and any additional services offered (summary invoicing, dedicated call centre and single point of reference for the agreement).
The purchase process is carried out in July of each year; the starting date of supply is 1 October and the contract is generally valid for one year, with an end date of 30 September.
The university favours fixed-price agreements to have certainty regarding costs and remain unaffected by any volatility of market gas prices.

2.3 HEATING OIL/FUEL OIL

From 2018 to 2022 the university purchased roughly 150,000 litres/year of heating oil, and it was all purchased from a single supplier through a specific Consip agreement for the entire period.
The university has begun a gradual decommissioning process of remaining heating oil powered boilers since 2018, to be replaced with equipment that is powered with more sustainable energy sources; to date, 5 boilers have been decommissioned and replaced with 5 connections to the district heating network. As of 2022, the university had only 4 active heating systems using heating oil on the Bologna Campus.
The purchase process is carried out each year during the current thermal season (from October to April of the following year); agreements foresee the sending of a new purchase order with the desired product quantity every time resupply is needed. To reduce administrative actions to a minimum, each month the university makes a summary order to cover the supply needs of the various locations that require heating oil. The price of heating oil varies based on the price list published weekly on the central purchasing body portal.
The university purchased roughly 113,000 kg/year of fuel oil from 2018 to 2022. The university has only one building (the ex-Neurology Clinic, Via Foscolo in Bologna) that uses a heating system powered with fuel oil. In 2023, in order to decommission this fuel oil powered heating system, the university signed a six-year contract as part of the Consip agreement “Servizio Integrato Energia SIE 4”, which requires the maintenance provider to fully renovate the heating system and replace the heat generator in 2024.
Fuel oil is purchased directly (quantity below the community threshold) through contracts negotiated using the Electronic Marketplace of Public Administrations (MePA), which is managed by Consip. At least three offers are requested, and a choice is made based on the best price offered thanks to discounts on each kilogram of product.
The price of fuel oil is fixed for the entire duration of the contract, a factor that was confirmed with the supplier during negotiations.

2.4 THERMAL ENERGY FROM DISTRICT HEATING

With the aim of contributing to a reduction of emissions in the city centre, in 1992 the university invested in the use of district heating networks that centrally produce heat, using energy from renewable sources when possible. Today the university has 57 active substations, present on the campuses of Bologna (including Imola), Cesena, Forlì and Rimini. As for district heating supply contracts, it is not possible to take advantage of bidding contests established by central purchasing bodies as existing networks have monopolies in various municipalities. In Bologna, Imola, Forlì and Cesena, district heating is managed by Hera. In Rimini, district heating is managed by SGR. The university has active contracts with both of these suppliers.

On 01/07/2021 the university signed a framework agreement (term sheet) with Hera S.p.A. for district temperature control services (heating and cooling) for the buildings in the city of Bologna; the agreement has five main aspects:

a. new connections in the heart of the Bologna Campus, based on the connection timeline for the 2023-2025 period (12 total buildings connected);
b. new connections in the Bertalia District in order to develop the area dedicated to the new teaching centre of the Engineering department and a student residence with 380 beds;
c. maintenance activities to improve equipment efficiency and a periodical re-evaluation of the subscribed demand for each connection, in order to limit fixed costs;
d. the setting of a new price to have better control over service costs and guarantee a review of any discounts offered;
e. innovative services to monitor, manage and control consumption through dedicated smart metres and a digital dashboard

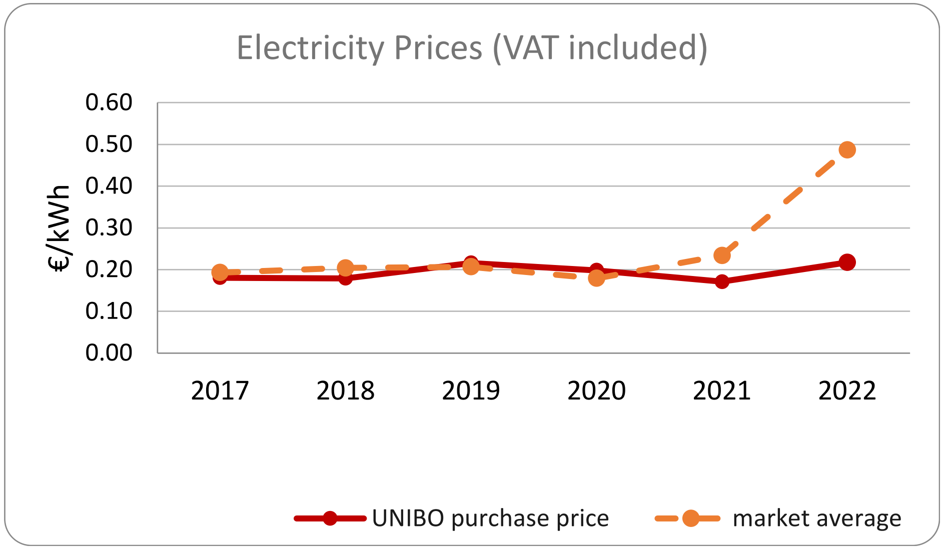
The price of thermal energy from the district heating network is tied to the "non-residential two part tariff" used by Hera, based on a price list that is updated monthly. A discount is applied to the two part tariff to compensate for Hera's use of university land; more specifically, where the San Giacomo thermal power station is located. The new contract foresees the application of a price cap to subscribed demand in order to limit the supply price in the case of spikes in natural gas prices, like those experienced in 2022.

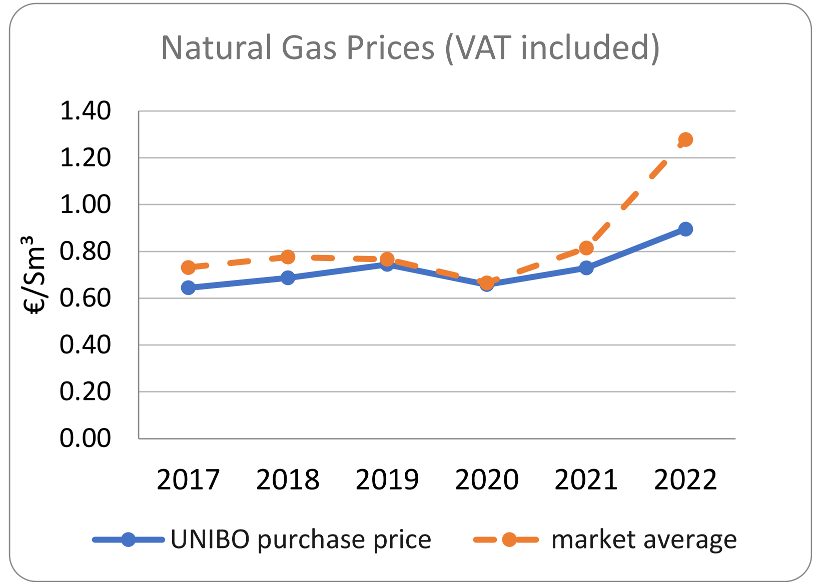
The tariff in Rimini (SGR) was shown to be less dependent on the market cost of natural gas, instead remaining closer to the average market values recorded by the Italian Regulatory Authority for Energy, Networks and Environment (ARERA), as shown in Figure 2.2c.

The University of Bologna has also purchased refrigerated water from Hera since 1993, used in just one building, the Physics Department located at Viale Berti Pichat 6/8. The refrigerated water tariff was reviewed in 2022/2023 and this revision guarantees a 15% discount on previously established tariffs.

2.5 COMPARISONS BETWEEN UNIVERSITY PURCHASE PRICES AND AVERAGE NATIONAL PRICES

From 2017 to today, participation in the Consip and Intercent-ER agreements allowed the university to consistently purchase electricity at a lower price compared to the market average, with 2020 as the only exception (Figure 2.2a). Due to the pandemic, there was a significant fall in the consumption of all energy resources in 2020, which led to a reduction in prices over the year. Since the university participated in the Consip fixed-price agreement from 1 January 2020 to 31 December 2020, the agreed upon purchase price did not decrease like market prices did throughout the year. Nonetheless, the difference in the price paid and the market average in 2020 was of little significance, 1.94¢/kWh. On the other hand, participation in the Consip and Intercent-ER fixed price agreements proved to be beneficial in 2021 and 2022. The electricity market was particularly volatile in this period, with a pronounced tendency towards price increases; the university defended itself well against these price hikes by participating in the fixed-price agreements made available by central purchasing authorities. Savings were significant, going from €0.06 to €0.27/kWh from 2021 to 2022.





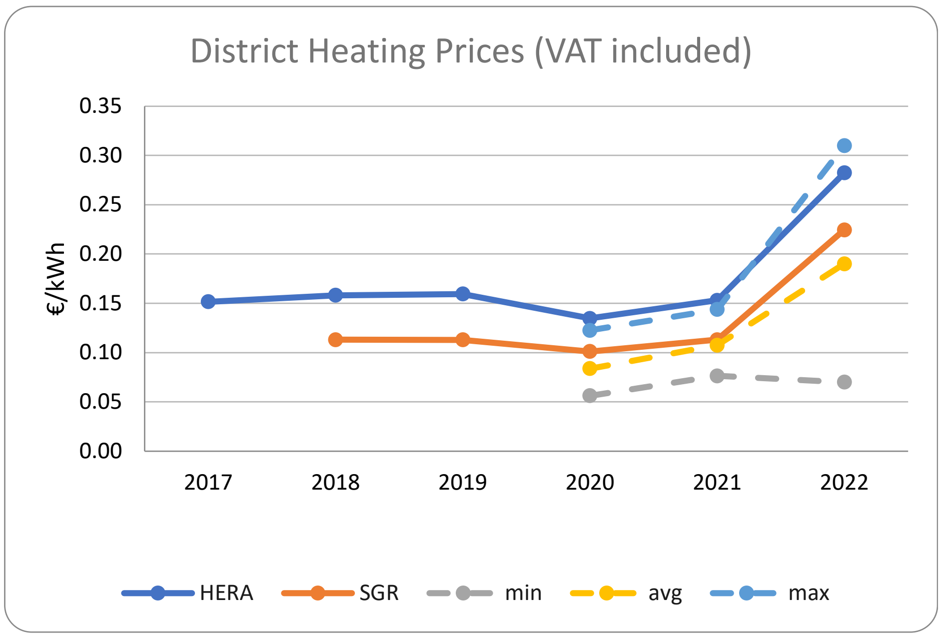


Figure 2.2 – Comparison between average annual purchase price of main energy resources and market averages. (source: ARERA)

Similarly, for the supply of natural gas participation in the fixed-price agreements made available by central purchasing bodies (Consip and Intercent-ER) allowed the university to purchase natural gas at a lower price compared to the average market price for the entire 2017-2022 period (Figure 2.2b). The benefit was significant in 2021, and even more so in 2022. In 2022 in particular, the university was able to limit the increase of natural gas prices that was seen in market prices, purchasing natural gas at a price only 20% higher than the year before the pandemic (2019), compared to the significant hike in average market prices between 2019 and 2022 of 67%.
The supply contract for thermal energy from the district heating network is a local, and thus variable-price, contract; this contract is managed as part of the concessionaire's monopoly. This excludes the possibility of taking advantage of competitive offers from other concessionaires working in the same area. This problem was highlighted by ARERA, which began to monitor concessionaire pricing starting in 2020. The purchase price of thermal energy from the district heating network of Bologna remained stable from 2020 to 2022, close to the maximum values recorded by ARERA (Figure 2.2c).

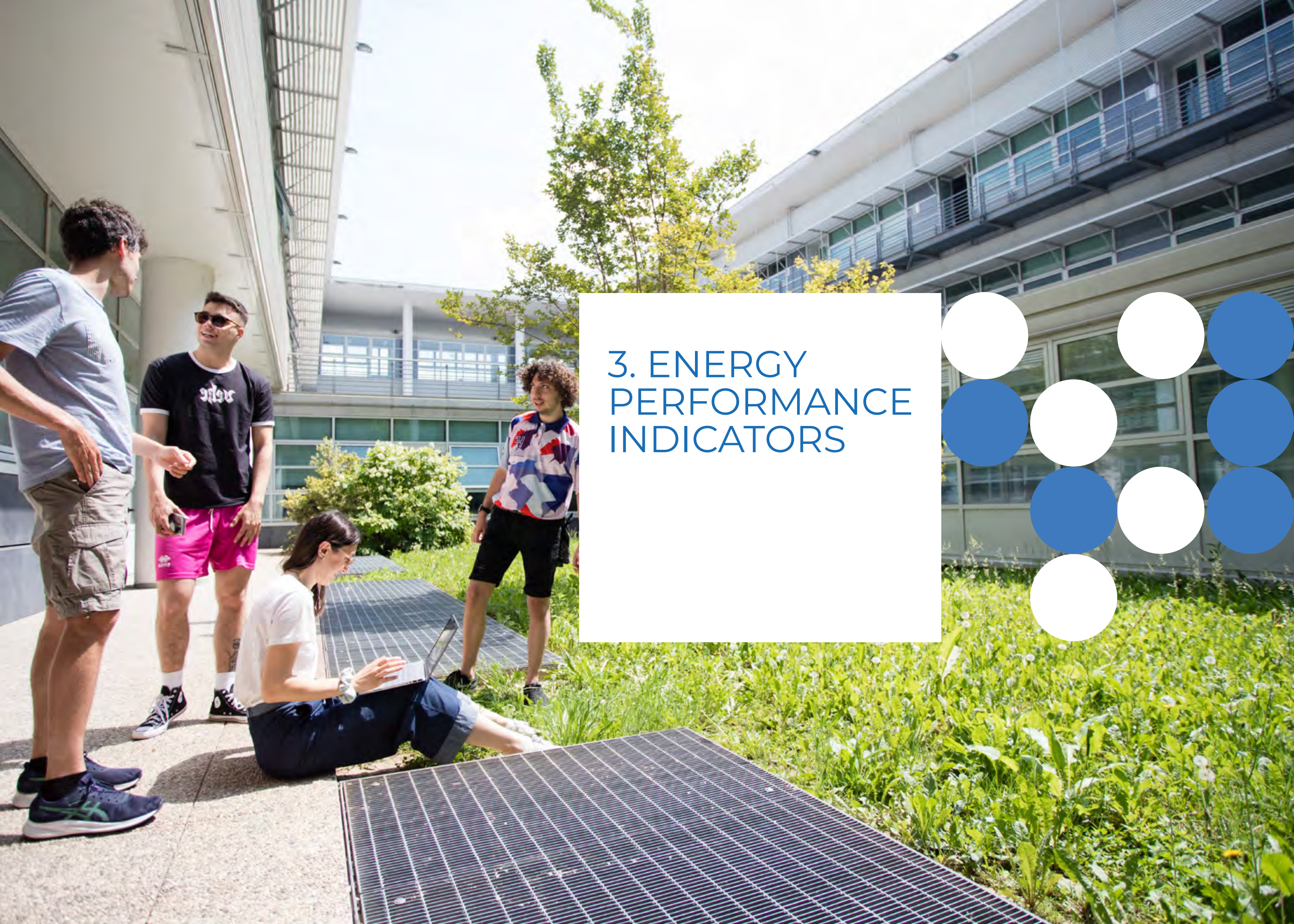
As it was a variable price contract, the university was not able to avoid the surge in natural gas prices seen in the last two years, paying 77% more per kWh in 2022 compared to 2019. On the Rimini Campus, the increase in price from 2019 to 2022 reached 99%, but in absolute terms the price per kWh was closer to the average national value indicated by ARERA.
This particularly negative situation in 2022 led the university to discuss current energy prices with HERA, introducing a price cap to prevent the price of thermal energy from becoming too high due to atypical natural gas prices.
In Rimini, no discussion of the prices established by SGR has taken place because the average kWh cost has remained very close to average market values, according to the data supplied by ARERA (see Figure 2.2c).
Table 2.1 shows the cost of energy bills paid by the university from 2015 to 2022. An increase of 44.4% in annual energy supply costs can be seen from 2021 to 2022, tied to the international crisis resulting from the war in Ukraine.

Table 2.1 – Cost of energy bills and total primary energy consumed (2015-2022).

		2015	2016	2017	2018	2019	2020	2021	2022
Total Primary Energy	toe	13,575	12,058	14,215	14,362	13,727	12,305	14,461	14,062
Total costs	€	15,864,682	17,321,819	14,770,805	15,457,015	16,438,566	13,237,445	15,210,829	21,967,878
Increase in total costs compared to the previous year		-	9.2%	-14.7%	4.6%	6.4%	-19.5%	14.9%	44.4%


evapco

3. ENERGY PERFORMANCE INDICATORS



Energy indicators (or Energy Performance Indicators, EnPI) are numerical indexes that summarise the energy consumption of a system, highlighting the level of efficiency of a specific energy service or of all active energy services. Generally, the purpose of energy indicators is to compare the consumption of different systems with similar characteristics and end uses, expressing absolute consumption in comparison to quantities that are assumed to significantly influence the system (so-called "consumption drivers").

These indicators are established considering the following:

1. the types of activities carried out in university buildings (offices, classrooms, laboratories, etc.);
2. the main drivers that influence energy consumption according to activity type (e.g., net area, volume of the heated space, external climatic conditions, number of people present in a building, illuminated area, etc.);
3. the indicators already used and/or defined by other universities and/or proposed by the Ministry of University and Research (MUR) to comparatively evaluate energy consumption of various universities.

The significance of the indicators is evaluated by analysing the following:

1. the indicator values collected based on past consumption data (from 2018 to today);
2. past relationships between consumption and consumption drivers.

This analysis enabled the identification of a series of indicators that aid in evaluating how the university uses energy to perform institutional activities.

The Energy Performance Indicators (EnPI) selected (Table 3.1) can be subdivided into four categories:

- **specific consumption indicators:** provide information regarding the energy consumption of the university, normalised according to the main drivers of consumption. "Normalised" indicators aid in comparing the consumption of the University of Bologna with those of other, similar institutions. Overall consumption values provide information regarding the average energy use of the university in relation to certain parameters like square metres serviced, volume, number of students, etc.;
- **strategic indicators:** make it possible to measure the university's progress towards energy objectives established in the Strategic Plan;
- **energy expense indicators:** aid in the analysis of costs incurred for energy supply per each energy service and are normalised based on drivers or specific parameters;
- **environmental indicators:** enable an evaluation of the environmental consequences of different types of energy consumption, which also indicate expected levels of emissions, normalising them based on specific parameters.

Table 3.1 – List of main indicators (EnPI) used to describe the university energy system (Net area serviced by active electricity connections: 904,857 m^2; net area heated by natural gas and the district heating network: 529,472 m^2).

Indicator name	Indicator definition	Unit	Purpose	2022
Indicators of specific energy consumption				
CEStot	Specific consumption of primary energy per unit area served (total)	kWh/m²/year	To evaluate primary energy consumption in relation to total area	181
CESel	Specific consumption of electricity per net unit area served	kWh/m²/year	To evaluate electricity consumption in relation to the area served	42
CESth	Specific consumption of thermal energy per net unit area served	kWh/m²/year	To evaluate the specific consumption of thermal energy in relation to the area served	134
Strategic indicators				
"STLR (IS.13)"	Gross interior area connected to the district heating network (indicator used in the University Strategic Plan)	m²	"To evaluate the use of heating methods with a low environmental impact Strategic Plan Objective IS.13"	0
"CESg (IS.11)"	Consumption of heating oil per gross interior unit area (indicator used in the University Strategic Plan)	litres/m²/year	"To evaluate the university's consumption of fossil fuels with a high environmental impact Strategic Plan Objective IS.11 "	5.92
"PFV (IS.14)"	Peak power of solar panel systems during self-consumption mode (indicator used in the University Strategic Plan)	kWp	"To evaluate the consistency of university solar panel systems used to self-generate electricity Strategic Plan Objective IS.14"	1,239.9
%FV (EEA)	Amount of self-generated electricity relative to electricity consumed annually	%	To evaluate the impact of university electricity generation systems on total annual consumption	2.92
%QRel	Percentage of electricity produced from renewable sources relative to annual consumption	%	"To evaluate the role of renewable resources on university electricity consumption (Purchase with Green Option)"	"20.1 (100)"
%QRth	Percentage of thermal energy from renewable resources consumed annually	%	To evaluate the role of renewable resources on university thermal energy consumption	0.60

Indicator name	Indicator definition	Unit	Purpose	2022
Energy expense indicators				
CSTUD	Cost incurred for energy supply per student	€/(student*year)	To evaluate energy costs per student	245,2
CSUP	Total cost incurred per unit area served	€/(m²*year)	Total cost incurred per net unit area served	33,5
%FFO	Percentage of energy expenditure from Ordinary Financing Fund (FFO) (net FFO = FFO - salary expenses)	%	Evaluation of the weight on the University budget of energy charges	4,7% (28,0%)
Environmental indicators				
EMtot	C02 emissions per unit of primary energy consumed	tCO2/toe		2.26

3.1 UNIVERSITY INDICATORS IN 2022

The 2022 values of the main EnPI calculated for the university (Table 3.1) depict the following situation:

- the university had a higher specific energy consumption (in terms of area serviced), as evidence of the low efficiency of existing electrical and mechanical systems and/or the improper operation of equipment and the inadequate performance of building envelopes;
- university specific consumption of electricity (CESel) was double that of a typical family in Italy (which has an annual CESel of 20 kWh/m^2). The CESel value of the university, 42 kWh/m^2/year, is in part justifiable when considering the specific activities of the university, which involve laboratories throughout the territory, teaching activities that require massive amounts of air ventilation and the use of air conditioning in classrooms and offices in the summer months, as well as large internal and external spaces that require illumination, even at night;
- the specific consumption of thermal energy (CESth) of the university is in line with the Energy Performance Certificates (EPC) for schools and offices in the Emilia-Romagna Region, but was double that of the expected value of new constructions, proof of the university's outdated, inefficient and poorly insulated building stock;
- the university had significant levels of consumption of thermal energy from district heating networks (both on the Bologna Campus and the Campuses in Romagna). The amount of buildings connected to district heating networks has grown since use of the district heating network began (1993) to today;
- the use of heating oil and fuel oil for heating buildings is in strong decline, and the elimination of boilers powered with heating oil and fuel oil is one of the goals of this plan;
- the amount of renewable energy used for thermal energy consumption is negligible, which demonstrates the almost exclusive use of fossil fuels for heating university buildings;
- the amount of self-generated electricity from renewable energy equipment (e.g., university-owned solar pv panels) is around 3%, with an installed electric load of more than 1.2 MWp;
- the amount of renewable energy used for electricity consumption, given that 97% of the electric energy consumed was taken from the national grid, is slightly greater than 20%, in line with the amount of renewable electricity available through the grid. In recent years, the university purchased "green" energy (with a guarantee of origin from the distributor) to bring this amount up to 100%;
- the cost incurred by the university for energy supply compared to the number of students (CSTUD) saw a significant increase in 2022, exceeding €240/ (student*year). This increase can be explained by the rise in energy costs that occurred starting during the later months of 2021 and that worsened throughout 2022 due to the Russia-Ukraine crisis;
- the average expense per square metre of area serviced (CSUP) paid by the university in 2022 was over €33.50/ (m2*year);
- in 2022 the university invested around 4.7% of the Ordinary Operation Fund (FFO) received from the MUR to cover energy expenses. If energy expenses are compared to net ministerial funds (defined as the amount of ministerial funds received by the university in 2022 minus the cost of paying staff salaries), 28% of net ministerial funds were spent on energy in 2022, due to the increased price of energy commodities;
- emissions (EMtot) totaled 2.26 tCO2 emitted per toe consumed in 2022; this information confirms the large use of fossil fuels and electricity from the grid to satisfy the energy needs of the university. The university's EMtot value is slightly lower than the emission factor tied to the national thermal mix, which is equal to 2.52 tCO2e/toe, thanks to the electricity produced by the university's solar pv panels

3.2 MUR ENERGY COMMITTEE AND BENCHMARK DATA FROM 2021

From the point of view of energy prices, 2022 represented an "atypical" year that caused budget crises for many public institutions.

With the goal of making Italian universities more resilient to the volatility of energy markets, the MUR established an Energy Committee in 2022, dedicated to developing energy saving strategies designed for higher education institutions (universities and institutes for higher education in the arts, music and dance [AFAM]) and research organisations.

The first concrete action taken by the committee was an analysis of the energy consumption recorded in recent years by higher education institutions and research organisations in Italy, which were invited to communicate their energy records to the ministry. A structured questionnaire was developed in order to gather this data, which includes 18 indicators regarding, by way of example, energy consumption, structured personnel units, number of students (for universities and institutes for higher education in the arts, music and dance [AFAM]), building dimensions and self-generated energy.

The questionnaire was sent to 264 institutions belonging to these categories, requesting that it be completed within 30 days of its reception. 101 institutions (38% of total receiving institutions) completed the questionnaire.

The committee then invited five universities (Bergamo, Bologna, Cassino, Catania and Parma) and one national research institute (CNR – National Research Centre) to send more detailed data from 2021 to the MUR, in order to calculate values for a series of indicators to be used as a benchmark for institutions in this category.

The five universities were chosen so as to have a representative sample in terms of size, building and structure type, geographical location and climate.

The committee then published an Executive Summary which included a portion of the data.

Figure 3.1 compares the 2021 CEStot indicator values from the five universities that participated in the detailed data collection process.

In 2021, the CEStot indicator value for the University of Bologna was 158.4 kWh of primary energy/m2/year; this value was below the average of 197.0 kWh of primary energy/m2/year, calculated using the total specific consumption values communicated by the five universities that participated in this analysis. The University of Bologna had the lowest value out of the 5 universities included in the MUR's study.

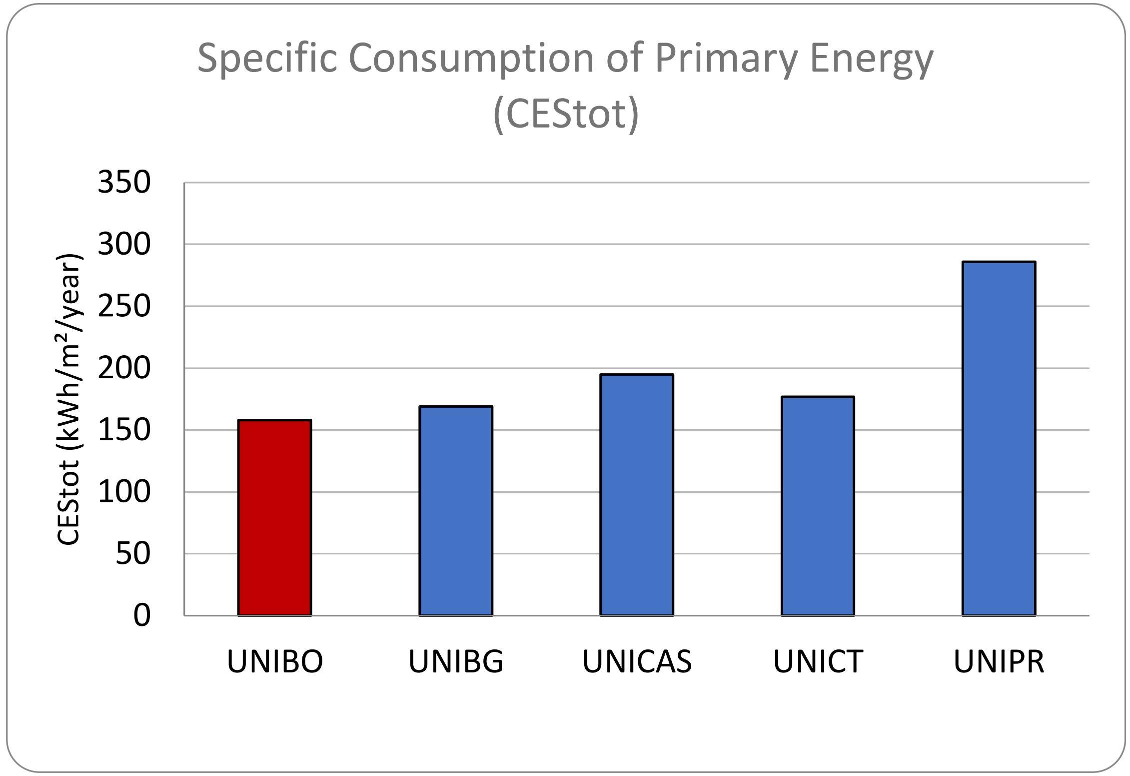


Figure 3.1 – Comparison of the specific consumption of primary energy of the five universities that participated in the data collection campaign of the MUR's Energy Committee (data from 2021). The area referenced in this case was 1,070,661 m^2.


THE CONCISE OXFORD DICTIONARY
OXFORD

4. IMPROVEMENT MEASURES FOR ENERGY EFFICIENCY (IMEE)

This section describes the strategic improvement measures for energy efficiency planned by the university.

4.1 MANAGEMENT INTERVENTIONS

The university has not yet established an internal Energy Management System (EMS), although it has already selected an Energy Manager that has been working within the Technical Office of the University (ATES) for some time.

The definition and implementation of a series of management interventions is a goal of this Energy Master Plan, with the aim of obtaining UNI CEI EN ISO 50001 certification (Energy management systems). Voluntary UNI CEI EN ISO 50001 certification allows organisations to create and maintain an EMS that continually improves the energy performance of the organisation itself, in compliance with energy laws. ISO 50001 certification will allow the university to define the criteria of an internal energy management system, which does not currently exist.

The EMS will define criteria regarding the following activities:

- cataloguing, storage and analysis of documentation related to energy accountancy, defining methods for information exchange between the relevant components of the university (APAT, ATES, ARAG);
- planning of Improvement Measures for Energy Efficiency (IMEE);
- measurement and verification of energy performance levels;
- purchase of equipment and devices to be installed;
- staff training on energy efficiency.

In order to realise an internal EMS, a series of preliminary actions are required, listed below.

AUTOMATIC ACCOUNTING AND MONITORING OF CONSUMPTION

The IT system Archibus, which has been used to manage the university's building stock for years, will also be used to create energy reports thanks to the activation of a dedicated application (Energy module). This application will allow all of the energy consumption data collected and validated in recent years to be recorded and associated with individual buildings. A verification of all of the spaces registered on Archibus will be performed in parallel, introducing an assessment of the area and volume heated and cooled for each building (up until now these values have been estimated). This makes it possible to collect in a single database both the energy consumption and the dimensional information (area and volume served) of each building within the university's building stock.

The reconstruction of the past consumption of each building makes it possible to create an automatic alert system to identify any differences between measured/invoiced consumption and expected consumption. A comparison with past data also facilitates the verification of actual savings achieved after implementing efficiency measures.

BILL AUDIT

An analysis system for energy billing will be implemented. The Bill Audit system is based on a "pre-calculation" phase in which the expected energy charge for a single supply point is estimated, followed by another phase in which issued bills are verified. A comparison of estimated and actual expenses will make it possible to verify monthly energy bills (electricity, natural gas, district heating) sent from suppliers. Suppliers will be contacted in the case any discrepancies are found in issued bills. This Bill Audit will enable the university to verify the proper application of excise duties and levies, and to distinguish billed consumption from measured and adjusted consumption.
In addition, the verification of bills will highlight the application of fines (e.g., elevated values of reactive energy, in the case of electricity supply), making it possible to identify possible countermeasures in a timely manner, so as to avoid them.
The data included on the bills will also make it possible to study consumption trends for each established time period to compare actual consumption with expected consumption for each type of end use in buildings (classrooms, laboratories, offices, etc.).

CONSUMPTION PROFILE ANALYSIS

Using the active electronic metres that enable users to read them remotely and that store consumption data on an hourly basis, collected data will be stored in a dedicated database to be used for detailed analyses of consumption profiles.
Hourly data will make it possible to associate typical consumption profiles for intended use with university buildings. A detailed knowledge of consumption profiles is useful in the planning phase for new equipment and/or for the optimisation of the operation of existing equipment.

DATA WAREHOUSE REPORT

The university's Data Warehouse (DW) will be connected to Archibus, the university's IT system, making it possible to cross-reference energy and building stock data with other university data that can influence consumption, like the number of users, the number of hours classrooms are occupied, etc. Dedicated dashboards will be created, enabling university staff to monitor energy performance of buildings and correlate them to institutional activities.

EQUIPMENT ASSET AUDIT

An audit will be performed on the asset present in all of the university's buildings; each piece of equipment, linked to its position within the building and registered in the university IT system, Archibus, will be assigned a code that contains its history (previous maintenance, next planned maintenance, previous malfunctions, etc.).
This audit will aid in gathering detailed information on the electrical and mechanical equipment in the university's buildings, so as to optimise the stipulation of maintenance contracts and the activation of Energy Performance and Integrated Energy Services contracts.

PLAN FOR EX-POST MEASUREMENT AND VERIFICATION EFFICIENCY MEASURE RESULTS

The monitoring of results following the implementation of various measures defined by the Energy Master Plan will be performed through the application of a Measurement and Verification protocol based on the International Measurement and Performance Verification Protocol (IPMVP®), which gathers the best practices available today to verify the results of energy efficiency, water efficiency and renewable energy projects in any area. The direct measurements, combined with fiscal measurements gathered from metres, will be used to verify the values associated with the main energy indicators, so as to monitor progress towards the main goals defined in the Energy Master Plan. The measurement and monitoring system is based on the IT and building management system of the university that, beyond being used as an instrument to record and update data, allows data to be processed to evaluate results and compare them to expected results, activating any corrective or mitigation measures deemed necessary. The IPMVP protocol will be used as a tool to evaluate the actual benefits in terms of costs and energy consumption, achieved through the verification of savings trends over time. External actors involved in the realisation of the Energy Master Plan will also be required to adopt this protocol. In particular, the protocol will be used as a monitoring and verification instrument within contracts that involve incentive systems based on results (e.g., Energy Performance Contract – EPC). Upon the completion of each efficiency measure, projected consumption and actual consumption will be compared so as to verify the effect of the measure itself. Each comparison will highlight problems tied to commissioning (inspection and management) of building and equipment systems, making it possible to identify any energy waste and/or malfunctions in a timely manner, in particular in the period directly following the completion of efficiency measures.

ENERGY AUDIT PLAN AND ENERGY MODEL DATABASE

An energy audit will be performed on the university buildings with the highest specific consumption (thermal energy and/or electricity). In recent years, an energy audit of selected university buildings was planned as part of the framework agreement for maintenance services on the Bologna Campus, an additional measure to incentivise the university to choose this supplier. This operation produced detailed technical reports on the status of the main energy services and the improvement measures to consider for the buildings that were audited. An energy model of the audited sites was also created.
The Energy Audit Plan establishes a goal of publishing the energy audits and adjusted energy model for the 20 buildings with the highest specific consumption by 2026.

PLANNING OF EQUIPMENT ON/OFF PERIODS

Based on the results of the analysis of the consumption data of each individual building and the data regarding staff use, classroom usage hours, etc., an annual calendar of on/off periods for equipment will be proposed based on typical consumption profiles. Optimisation will involve the periods in which heating and cooling systems are used, the use of an intermittent/continuous operating procedure and/or variations in equipment use based on the time of day.
Possible off periods for equipment will be established, taking into consideration the amount of staff working off-site. The creation of reservable "flexible" workstations for staff makes it possible to concentrate working employees in assigned areas, so as to limit main energy supply to those areas on certain days.

For this purpose, the following measures will be implemented:

1. evaluation of thermal and electric loads that are interruptible, controllable or able to function at a reduced regime during specific times of the year;
2. collection of data regarding the staff presence in individual buildings;
3. precise audit of all structures in which service can be totally interrupted, with the goal of identifying a minimum service regime for these structures;
4. experiments with setpoint regulation of internal temperature based on the type of equipment (radiators, tube heaters, fan coils, all-air, air-water);
5. definition of rules to determine the period in which summer cooling will be guaranteed in buildings;
6. experiments involving reduction of energy services made possible through the rationalisation of spaces due to the rise in telework;
7. publication of a calendar with building open and close dates and equipment on/off schedules.

4.2 COMMUNICATIONS AND COMMUNITY EMPOWERMENT

To increase the possibility of an actual reduction in consumption, it is fundamental that the entire university community is actively involved and responsible; the role of the community in changing energy consumption habits and promoting behaviours aimed at increasing efficiency and savings cannot be ignored. It is estimated that responsible and proactive behaviours can reduce consumption by up to 7% compared to seasonal baselines. Various studies have shown that in addition to technical knowledge, economic evaluations, administrative and procedural aspects, every phase – the production, distribution, conservation and consumption of energy – requires the proactive involvement of what scholars call the "human dimension" of energy. The role of the individual is becoming increasingly important in the green transition, in terms of a resistance to changing certain habits, as well as in terms of motivating others to practise energy-saving behaviours. Both of these aspects are central and can contribute significantly to achieving goals, just as much as increasing efficiency and the use of renewable energy. To promote these behaviours, it is necessary to first understand that each individual's actions have a strong impact on protecting the environment. It is therefore imperative to incentivise changes in behaviour and retrospectively highlight the resulting benefits, taking full advantage of this precious individual contribution in terms of economic, environmental and social sustainability.
The main communication and empowerment measures foreseen are listed here.

ENERGY USE WEB PAGE

The data on consumption recorded on Archibus, the IT system of the university, will be made public through web pages dedicated to the University Energy Plan. This instrument will provide the university community and external users with a constantly updated summary of how the university is using energy to perform various services. Users will be able to find information on meaningful energy saving actions related to equipment use.

COMMUNICATION PLAN

The communication plan is the vehicle with which the university will provide detailed information on the measures, timeline and resources used to implement the Energy Plan. The data and information will be presented and shared with users in an understandable, accessible, updated and accurate form.

REPORTING SYSTEM FOR ENERGY WASTE AND EQUIPMENT MALFUNCTIONS

In 2022 the IT System and Services area of the University of Bologna (CeSIA) developed a system that will allow all members of the university community to report broken equipment and/or malfunction in energy services, like, for example, ambient temperature that is excessively high or low, lights and electronic devices turned on during off periods, leaks, etc.
The system uses a smartphone application with which the user scans the QR code associated with the area where the malfunction was observed, and then anonymously reports the issue directly to the District Manager. This reporting system will facilitate the identification of significant equipment issues. The system will also be shared with cleaning services managers, so as to use a single application for multiple purposes.
In the 2023/2024 thermal season, the system will be tested on all of the buildings in Bologna, with a predicted roll-out to the other campuses in the 2024/2025 thermal season.

THE UNIVERSITY AS AN "OPEN LABORATORY"

The university is dedicated to being an "open laboratory" for experimenting with innovative technologies and energy source usage models, both through specific research and didactic activities. These opportunities arise from collaborations with local public administrations as well as the implementation of energy sustainability measures, like participation in the Climate City Contract launched by the Municipality of Bologna as part of the EU City Mission on climate neutrality. As such, the university has made its buildings and laboratories available for testing new devices and energy management techniques.

In addition, internships with the Construction and Sustainability Technical Area (ATES) and the University Estate Area (APAT) of the University of Bologna will be established to bring students closer to the fields of Building Facility Management (BFM) and Energy Management for Public Administrations. Students will be involved with various topics, such as:

- the management of the building stock of a public institution (Archibus IT system);
- the creation of static and dynamic thermal models for the main buildings of the university;
- mapping of the university's building stock;
- the execution of energy audits on university buildings;
- the use of Building Information Modelling (BIM) techniques for an optimised management of equipment maintenance and use;
- calls for tenders and the use of BIM;
- the drafting of Economic and Financial Plans (PEF) for energy efficiency measures performed on university buildings;
- the development of awareness raising initiatives regarding good energy practices for users.

4.3 INTERVENTIONS ON BUILDING ENVELOPES

The analysis performed on the building and equipment assets of the university demonstrated how in many of Bologna's Districts (Poggi, S. Giacomo, Nord-Ovest, Sud-Est, Risorgimento), the percentage of listed historic buildings is significant, a fact that limits the possible interventions that can be performed on building envelopes; this means that actions on equipment and non-visible parts of the building (e.g., insulation of attics and roofs) should be prioritised to improve the energy performance of these buildings.

The situation of the thermal insulation of university buildings is summarised by the data in Table 4.1., which lists the average thermal transmittance values of vertical walls, roofs and windows for each district. The percentage of outer walls and roofs with thermal insulation and the percentage of double-glazed windows is also included.

In order to facilitate the interpretation of the data in Table 4.1, it should be noted how elevated values of thermal transmittance (U-value) demonstrate the poor thermal insulation of the element considered (walls, roofs, windows). If the average values of thermal transmittance (U-values) of buildings in various districts or campuses are compared with the maximum values required for new buildings by the Decision of the Regional Council 1261/22 in Emilia Romagna, it can be seen that the thermal insulation of university building is quite far from the requirements of new buildings.

Table 4.1 – Average thermal transmittance values (U-values) of the buildings of various campuses and districts and the percentage of insulated area.

	U-value walls	U-value roof	U-value windows	Percentage of insulated external walls [%]	Percentage of insulated roofing [%]	Percentage of double-glazed windows/ doors [%]
BOLOGNA CAMPUS						
Fanin	1.45	0.91	3.22	5.00	11.00	84.00
Navile	0.65	0.61	1.98	88.00	79.00	93.00
Nord Ovest	1.84	1.27	4.63	3.00	24.40	43.50
Risorgimento	1.60	0.72	4.19	0.00	64.00	22.60
Bertalia	1.28	1.06	3.09	0.00	58.00	100.00
S. Giacomo	1.86	0.89	3.80	0.00	55.00	41.00
Sud-Est	1.89	1.51	4.10	1.00	28.00	57.00
Zamboni-Poggi	1.80	0.87	4.80	0.00	45.00	16.00
Ozzano	0.94	1.56	3.15	30.00	8.00	93.00
Filippo Re	1.35	0.73	3.39	9.00	79.00	61.00
CESENA CAMPUS	1.14	1.00	2.10	14.70	24.00	93.00
FORLÌ CAMPUS	1.80	1.28	2.37	3.00	31.00	87.00
RAVENNA CAMPUS	1.40	1.31	3.38	20.00	36.00	59.00
RIMINI CAMPUS	1.60	0.71	2.83	13.00	59.00	78.00

The Navile District clearly has the buildings with the highest level of thermal insulation, due to the fact that the buildings part of the Navile hub were recently constructed. The buildings within Bologna's "cittadella universitaria" (Poggi-Zamboni, S. Giacomo, Filippo Re) are those generally characterised by the lowest values of thermal insulation of outer walls and windows. The buildings on the Romagna campuses had better thermal insulation on average because in some cases (e.g., Cesena Campus) buildings were constructed recently.
The data in Table 4.1 demonstrates how many university buildings have poor levels of thermal insulation, which causes a significant waste of energy in both winter and summer. In addition, a low level of thermal insulation is synonymous with unstable acoustic and thermal comfort in interior spaces, caused by the low levels of radiant temperature within spaces and poor acoustic insulation (e.g., due to single-glazed windows).
The efficiency measures to be performed on building envelopes are summarised below.

REPLACEMENT OF WINDOWS AND DOORS

Many buildings of the University of Bologna feature transparent surfaces characterised by elevated thermal transmittance values (Uf>3.5-4 W/m^{2}K) because they are single-glazed and have frames with high conductivity and no thermal break. Furthermore, over 20% of the total dispersion area is made up of transparent surfaces. The replacement of existing glass windows and doors with double- or triple-glazed low emissivity glass (with a noble gas in the air gap) and frames with thermal break making it possible to significantly lower standing loss in the winter and, as a result, the thermal energy needs for heating, while simultaneously improving thermal (and acoustic) comfort of spaces.
As for listed historic buildings, the relevant local Superintendency will evaluate the designs of the new windows and doors before granting approval for the proposed operation; these designs also serve as a tool that makes it possible to replace windows and doors in stages, but still within a single project. The drawings will depict design solutions that, in a way that is coherent with the original windows and doors, will decrease thermal transition values to below the legal limit (currently Uf<1.4 W/m^{2}K in climate zone E).

THERMAL INSULATION OF VERTICAL WALLS

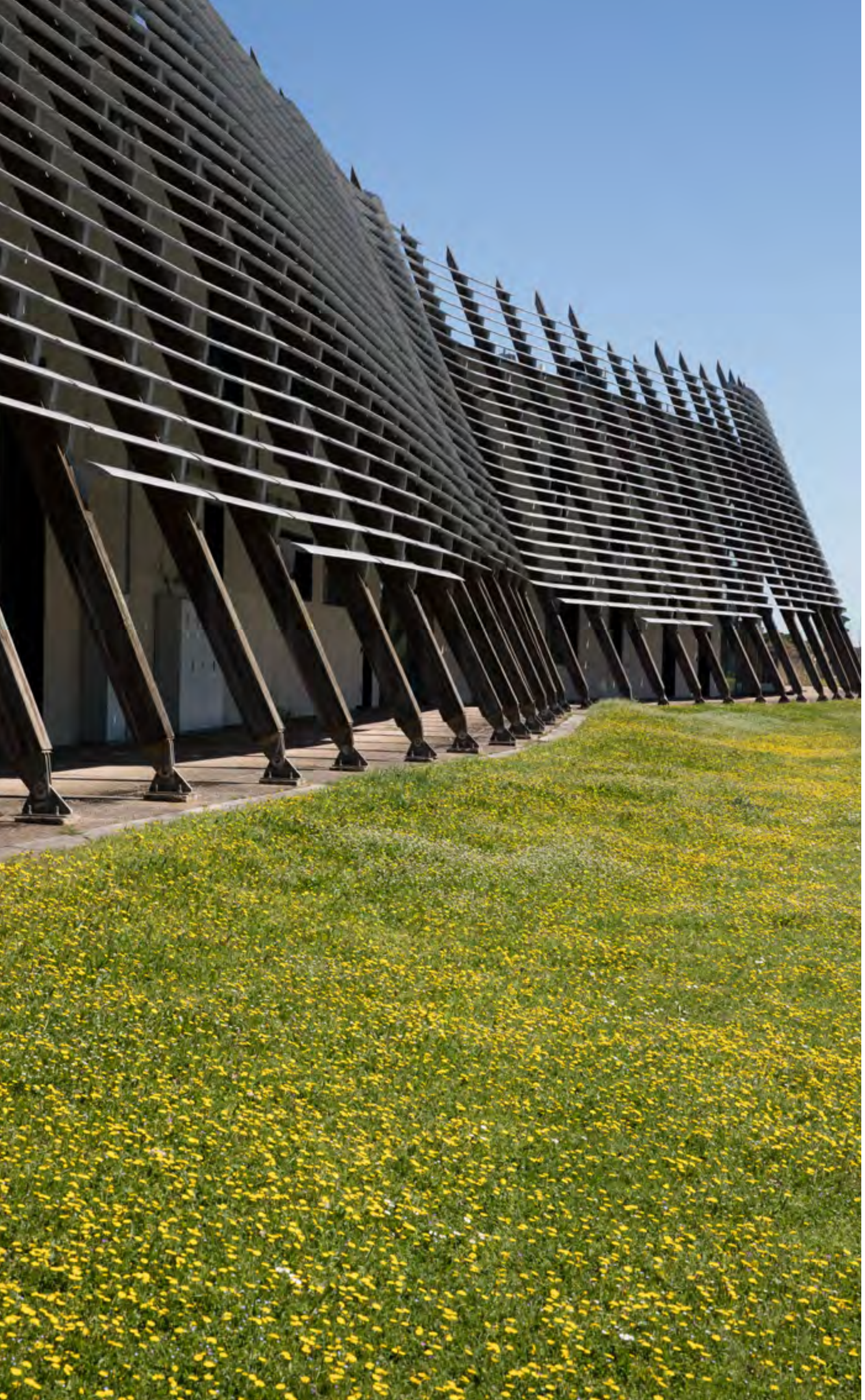
For the renovation of existing buildings with perimeter walls with high levels of thermal transmittance (Uw>1 W/m2K), barring any limitations, the application of a thermal insulation on the outer face of vertical walls (exterior insulation) significantly reduces standing loss in winter and summer. The dimensioning of the layer of insulation to apply is usually performed with the goal of reaching the current maximum transmittance value for renovated buildings (U_W<0.26 W/m2K in climate zone E). Solutions that involve the presence of a ventilated air gap between external finishings and the vertical wall may also be considered. This can significantly reduce the transmission of heat in summer through perimeter walls, taking advantage of the stack effect that occurs in the air gap, but requires a detailed analysis of the fire precaution measures to adopt to avoid that the air gap can facilitate the passage of fire from one floor to another in a building.
Where external insulation actions are not possible (due to technical or architectural limitations), the creation of an internal insulation finishing system can reduce dispersion even if, in this case, it is not possible to correct all of the existing thermal bridges present.

THERMAL INSULATION OF ROOFS AND ATTICS

The thermal insulation of roofs (with the possible addition of a ventilated air gap beneath the shingles) can reduce standing loss in winter and, above all, the passage of heat through the roof in summer. The insulation operation can also be carried out by applying insulating materials on the ceiling of the attic without taking direct action on the roof. Insulation of roofs and attics makes it possible to reach transmittance values below 0.22 W/m^{2}K, drastically reducing standing loss without any significant impact on the external appearance of the building.

SUN SHADES

Limiting energy consumption for summer cooling of buildings can also be achieved by the placement of sun shades, either fixed or mobile, near transparent windows and doors. Shades reduce the amount of solar energy that enters through windows in cooled spaces and therefore reduces the summer thermal load that must be neutralised using equipment. It is also possible to reduce the transmittance of glass using adhesive films that change the solar factor of the glass. The use of shades and/or protective films is particularly useful in buildings with large transparent openings through which significant amounts of solar energy enter in the summer.



4.4 ACTIONS ON BUILDING EQUIPMENT

The state of maintenance and the efficiency of the university's electrical and mechanical equipment varies greatly among buildings.

The Energy Master Plan includes actions that eliminate the situations that lead to low equipment efficiency and/or conditions that hinder the fulfilment of requirements for certifications that are necessary for the safe performance of university activities (e.g., fire prevention certificate (CPI)).

The highest priority actions to be performed on existing equipment are listed below.

ELIMINATION OF THERMAL POWER UNITS POWERED WITH HEATING OIL OR FUEL OIL

The university's Strategic Plan 2022-2027 also included the intention of eliminating existing thermal power units fueled with heating oil or fuel oil (Goal 48). In 2023, the thermal power units using heating oil or fuel were the following, all located in Bologna:

1. Via Foscolo 7 (fuel oil);
2. Via S. Vitale 59 (heating oil);
3. Via S. Giacomo 9 (heating oil);
4. Via S. Giacomo 11 (heating oil);
5. Via Belmeloro 8/2 (heating oil).

Existing boilers that use heating oil and fuel oil will be replaced with substations connected to the district heating network or gas condensing boilers (Via Foscolo 7 and Via San Vitale 59).

UNIVERSITY BUILDING MANAGEMENT SYSTEM (BMS)

With the G.E.CO. Project, which was rolled-out in 2009, the university began implementing instruments used for monitoring, and remote control of the heating and cooling systems of its buildings.
The project aims to obtain maximum energy savings in buildings through the control of energy flows and environmental parameters, so as to limit consumption related to technological equipment and ambient temperature systems. Various control and data acquisition networks will be created as part of the project, and the already operational single web-based platform for the management, collection and processing of data will be developed further, enabling it to use various operational parameters and schedules.
The project structure has two levels: Energy Management and Remote Control.

The university chose to make use of an open-source BMS platform to manage Building Automation. The BMS platform chosen was the iOTTO platform, a web-based software that is integrated with the Internet of Things, i.e., it is able to manage a series of "smart objects" (sensors and activators) installed in the thermal power units and the electrical cabinets of various buildings via network. This system is able to collect and store the data recorded by on-site metres, making them available for analysis, and remotely control all active "smart" devices.
Moreover, the system can be integrated with control units that are managed using third-party softwares, making it possible to monitor and control equipment using different regulation systems within a single operational environment. All of the iOTTO controllers are freely programmable and can be managed/programmed through free tools that do not require a specific licence.
Figure 4.1 is a diagram of the thermal energy distribution circuit of the building at Via Belmeloro 4.

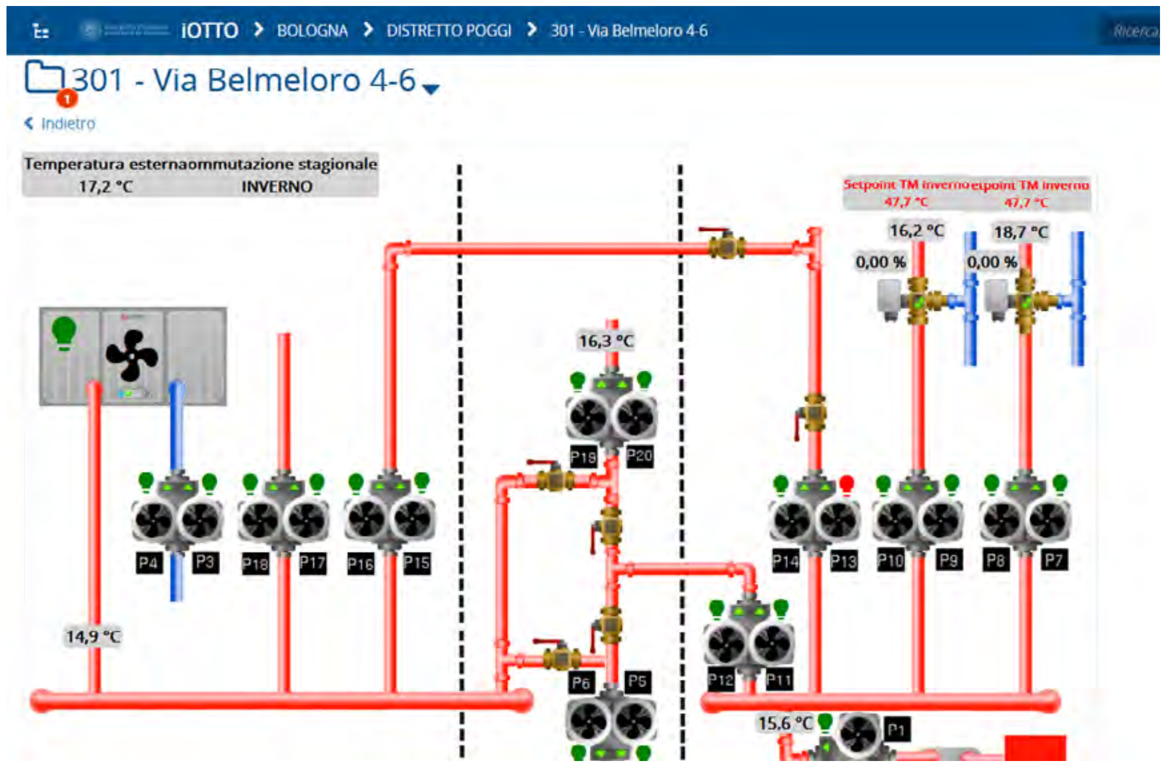


Figure 4.1 - Example diagram of the thermal energy distribution circuit in the building at Via Belmeloro (FABIT) created with iOTTO.

Extending the iOTTO system to the entire building stock of the university will make the following actions possible:

- compare projected energy consumption with actual and invoiced consumption;
- remotely verify equipment set-point parameters (e.g., ambient temperature in summer and winter);
- remotely correct equipment activation and deactivation times;
- send the maintenance team alert signals in real time in the case of malfunctions;
- create a database that makes it possible to associate each building to a specific list of equipment malfunctions;
- allot consumption quantities for specific zones of a building (e.g., spaces rented to external parties) using dedicated metres.

64 buildings are currently controlled and monitored using the university network, with the following distribution: Bologna – 50, Ravenna – 7, Rimini – 3, Cesena – 3 and Cesenatico – 1. However, the placement of sensors and activators in various units is unfortunately quite irregular, and in many cases it is not possible to monitor/control all of the parameters of interest.
The Bertalia District was selected for a pilot project during which a series of tests will be performed on the network of sensors, metres and activators to be installed in the various units, with the end goal of determining the minimum number of sensors to be installed on thermal power units and expanding the university's monitoring and control network. The minimum number of sensors determined during the tests performed in the Bertalia District will be applied to all thermal power units in the coming years, starting with the completion of sensing systems in the buildings already connected to the network and subsequently equipping other buildings ex novo, starting with those with the highest levels of consumption.

One of the university's primary objectives is to complete the university BMS by connecting all occupied buildings by 2030.

BOILER REPLACEMENT PLAN

Thanks to a survey of the state of repair, function and compliance of the 105 thermal power units in Bologna, 11 thermal power units were marked as requiring priority intervention to increase their energy efficiency, replacing heat generators with condensation boilers, electric heat pumps and/or hybrid systems (boiler + heat pump).

The same analysis will be performed on the Romagna campuses in 2024.
In buildings where existing gas boilers cannot be replaced with heat pump systems due to technical limitations, gas condensing boilers able to work with gas blends containing hydrogen (up to a maximum of 20%) will be installed, especially for thermal power units in urban buildings.

Hera is developing a project in Bologna that foresees the use of biomethane in the city gas network. Hera's SynBioS project (Syngas Biological Storage) will make it possible to create a "power to gas" system using the purifier in Corticella, so it can convert renewable electricity and waste waters into "green" hydrogen and then biomethane to be used in the city gas network. Green hydrogen is produced through electrolysis powered by renewably generated electricity and water reclaimed from the purifying process, while biogas is derived from the anaerobic digestive process of sludge itself.

The use of biomethane created from green hydrogen in thermal power units in the city centre can be beneficial to the energy balance of the university in terms of emissions of climate-altering substances in the atmosphere and consumption of primary energy.

The replacement of generators is integrated into the planned Energy Audit. This operation can be partially funded through incentives of the Conto Termico 2.0 provided by the Energy Service Manager (ESM) or Energy Performance contracts (EPC) with external partners (e.g., Consip agreement Sistema Integrato Energia SIE4).

THERMOSTATIC VALVES

The university still has many radiator heating systems that do not have a ways of controlling ambient temperature. As such, thermostatic valves will be gradually installed on the radiator systems that do not yet have them, with the simultaneous replacement of circulation pumps equipped with inverters. In many cases this operation will be accompanied by the replacement of gas-powered heat generators with condensation boilers (see the boiler replacement plan), because the use of thermostatic valves leads to lower return temperatures of water at part loads, with a significant increase of the condensation index and therefore average seasonal heat generation efficiency. This operation will be partially funded by the incentives foreseen by the Conto Termico 2.0 provided by the Energy Service Manager (GSE) or through Energy Performance Contracts.

NEW CONNECTIONS TO THE DISTRICT HEATING NETWORK

In the new contract regarding the thermal energy supply from the district heating network of the city of Bologna, multiple new connections to the network are scheduled, for a total of 1.65 MW by 2026 (Table 4.2); the new connections will make it possible to eliminate thermal power units with obsolete technology, obtaining noticeable primary energy savings and a reduction of green-house gas emissions.
Towards the end of 2025 the S. Giacomo ring, which services the "cittadella universitaria", will be connected to the Frullo waste to energy plant (CAAB Pilastro). Beyond increasing the flexibility of the district heating network by reducing the risk of interruptions in service, this will make it possible for the university to access the tax deductions available for district heating networks powered by waste treatment plants.
Figure 4.2 shows the system of pipes planned to connect the current district heating systems of CAAB-Pilastro, Navile, Fiera and Berti-S. Giacomo ("cittadella universitaria").
Thanks to this new piping, local networks will be interconnected by creating a single city network in which the thermal energy generated will be shared. This interconnection will make the network more resilient to energy crises and the impact of climate change, making the whole system more reliable.

Figure 4.2 – Planned extension of the district heating network of Bologna.

In order to reduce the cost per thermal kWh purchased from Hera, the subscribed thermal demand associated with each substation will be evaluated; this process began in 2022, thanks to the monitoring of instantaneous power needs of individual buildings in the winter using remote reading equipment provided by Hera as part of the new agreement.

Table 4.2 – List of new hook-ups to the district heating network of Bologna scheduled in the new agreement with Hera, to be completed by 2026.

ID No.	building code	location	area served (m²)	TLR Thermal Nominal Power Subscribed (kW)	Estimated activation date		
					2023	2024	2025
1	729	Via San Giacomo 11	891	73		15/10/2024	
2	701	Via Belmeloro 8/2	1,167	114		15/10/2024	
3	718	Via Belmeloro 8/3	450	29		15/10/2024	
4	733	Via San Giacomo 9/2	891	70		15/10/2024	
5	221	Viale Carlo Berti Pichat 8	986	120	15/10/2023		
6	105	Via San Giacomo 3	1,296	85			15/10/2025
7	175	Piazza Verdi 3	2,343	145			15/10/2025
8	23	Mura Anteo Zamboni 7	1,161	120	15/10/2023		
9	6	Via Vinazetti 2 Via Francesco Acri 3	722	58			15/10/2025
10	188	Via Ranzani 14	5,723	303			15/10/2025
11	13	Largo Trombetti 3 Via F. Acri 8-10-12	1,838	145			15/10/2025
12	191	Piazza Antonino Scaravilli 2	4,000	388	15/10/2023		

RELAMPING

In recent years the University of Bologna has replaced incandescent and fluorescent lighting fixtures with high-efficiency and LED bulbs in a series of buildings, for a total serviced area of 427,000m². Lighting fixtures were replaced as part of the energy requalification projects of specific buildings and in part thanks to incentives in maintenance contracts (improvements from the public tender process).
As part of the maintenance services management framework agreement for the Bologna Campus, 10,000 lighting fixtures were slated to be replaced with high-efficient LED technology; the equivalent of 7,600 lighting fixtures were installed in the Food and Agricultural Sciences and Technology department, and the other 2,400 were installed in the warehouses in the Bertalia district.
In 2022 and 2023, within the maintenance services management framework agreement for the Romagna Campuses, the replacement of a further 1,700 lighting fixtures was planned.
Previous experience highlighted how replacing lighting fixtures for efficiency reasons must also include a lighting engineering study, because changes in the colour and spatial distribution of light can cause glare and localised visual discomfort.
The goal is to eliminate all incandescent and fluorescent lighting fixtures in every university classroom and office, replacing them with LED light sources by 2027. Where possible, the relamping will be combined with the creation of "smart lighting" systems with which LED lights integrated with the IoT will be managed online, enabling remote control and management.
A list of the lighting systems that need to be the object of relamping throughout the university system already exists. Relamping operations will begin in buildings with elevated levels of specific consumption of electricity.

SOLAR ENERGY PLAN

The university has a high level of electricity consumption that, in 2022, was equal to 56% of total primary energy consumption. At the same time, the university has several buildings whose roofs are ideal for the installation of solar pv panels for the generation of electricity; an increase in self-generated electricity from the installation of new solar panels on the roofs of selected university buildings would limit the university's exposure to the volatility of electricity prices (which are predicted to increase due to increased electricity consumption for heating and transportation), as well as CO2 emissions, in terms of the amount of energy supplied.

For these reasons, the Energy Master Plan identifies the installation of new solar pv panels on the roofs of university buildings as a priority action to achieve greater energy security, a decrease in expenses related to energy supply and a diminished environmental impact of university activities.

Legislative Decree 199/21 on Renewable Energy Communities (CER) makes it possible to view the university as an aggregator of local CERs regulated by Decisions 318/2020/R/eel and 727/2022/R/eel of ARERA; these decisions provide for the open and voluntary participation of parties (commonly called stakeholders or members) located near production systems that, in the interest of sharing energy, are available to and under the control of the energy community.

Within this community, the university can:

- increase the size of electricity production systems that use renewable energy, aggregating the consumption of multiple buildings connected to the same electrical substation;
- stimulate the creation of new CERs involving other external members located near university systems.

Using the first model, the university will pool the electricity consumption of sites that are geographically close (laboratories, classrooms, offices) to increase the self-consumption capacity of energy generated with its solar panels. This is the model with which the university intends to primarily participate in CERs in the short to medium term.

As for the second model, the university is a local catalyst for participants (private citizens, businesses, local public entities or small and medium-sized enterprises) interested in sharing the consumption of energy produced by one or more renewable energy systems (e.g., solar pv panels installed on the roofs of university buildings) and in collaborating towards the goal of producing and consuming energy within a certain geographic area. The university can reasonably predict to participate in this second CER model, as a magnet for outside participants, when the amount of electricity produced and self-consumed by the university (%FV) will have surpassed 50%.
In both models the creation of CERs has the goal of the self-consumption of all renewable energy produced locally, with resulting economic, social and above all environmental benefits for the area in which the university operates.

In addition, self-consumed energy within CERs is financially compensated, considering the reduced operating costs of the electricity grid due to the simultaneous connection between production and consumption of electricity in a certain district, with the specification, however, that the electrical system connection points must be located in the established area of the same primary substation.
Figure 4.3 depicts the established areas of the primary electrical substations according to e-distribution, divided into 11 zones, one for each sub-station, which serve the

building stock of the of the university in Bologna.
This means that solar pvpanels on the roofs of university buildings can power all of the university buildings in the same area served by the same sub-station with self-consumption, following the first CER model described above.

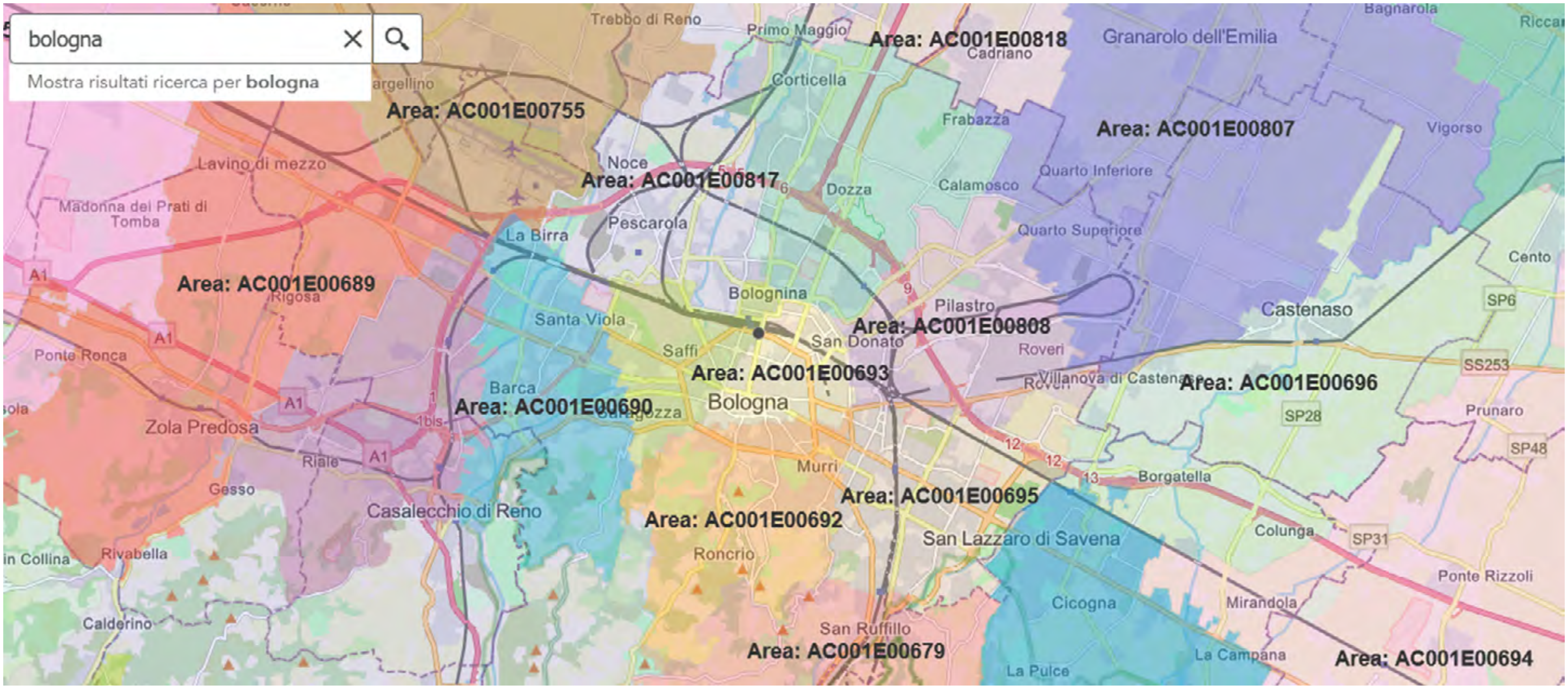


Figure 4.3 – Areas of the sub-stations in relation to the city of Bologna (source: E-distribution).

Decree 199/21 on Renewable Energy Communities (CER) dictates that only production systems powered by renewable energy with a maximum capacity of 1 MW can be included in CERs. Production systems powered by renewable energy must have been implemented following the effective date of the decree (8 November 2021), although systems implemented before this date can be included if their total nominal capacity is not over 30% of the overall capacity of the CER.

This rapidly evolving legal situation is conducive to the development of a University Solar Energy Plan in the short to medium term.
In order to analyse the potential of the roofs of university buildings in terms of the installation of new solar panels, a detailed study on the university building stock was carried out.

The study identified the buildings that are best suited to the installation of solar pv panels, which in essence are roofs on which solar pv panels can be installed with a relatively low installation cost. The analysis demonstrated that it is possible to project the installation of around 6 MWp with installation costs under €1500/kWp, in addition to another fee of €800 (per accumulated kWh) if the installation includes batteries to accumulate electric energy in order to maximise self-consumption of solar energy.

Primarily monocrystalline silicon solar pv panels will be installed, but other options involving the installation of innovative prototypes of solar pv panels proposed by manufacturers will be considered, to aid in testing their performance.

4.5 IMPROVEMENT MEASURES FOR ENERGY EFFICIENCY (IMEE): PRIORITY ACTIONS

To determine the list of priority actions in terms of energy efficiency, an analysis of energy consumption (electricity and thermal energy) in absolute terms (kWh of energy consumed per year) and specific terms (kWh of energy consumer per unit of surface served per year) was performed on every building. Overall consumption refers to the economic impact of each building on the total energy charge of the university, while specific consumption indicates the energy efficiency of the building itself. Figures 4.4a and 4.4b show the distribution of various university buildings regarding absolute energy consumption (x-axis) and specific energy consumption (y-axis).The red lines indicate the average annual absolute and specific consumption of the university (data from EE_{2022}, ET_{2022}, $CESth_{2022}$ and $CESel_{2022}$). The point of intersection represents the average consumption of electricity or thermal energy of university buildings. The red lines separate the graph into four quadrants that will be used to assign priority levels to each university building. Each year, with new improvements to energy efficiency, the intersection of the red lines will drift towards the origin, and the boundaries of the four priority quadrants will change as a result.

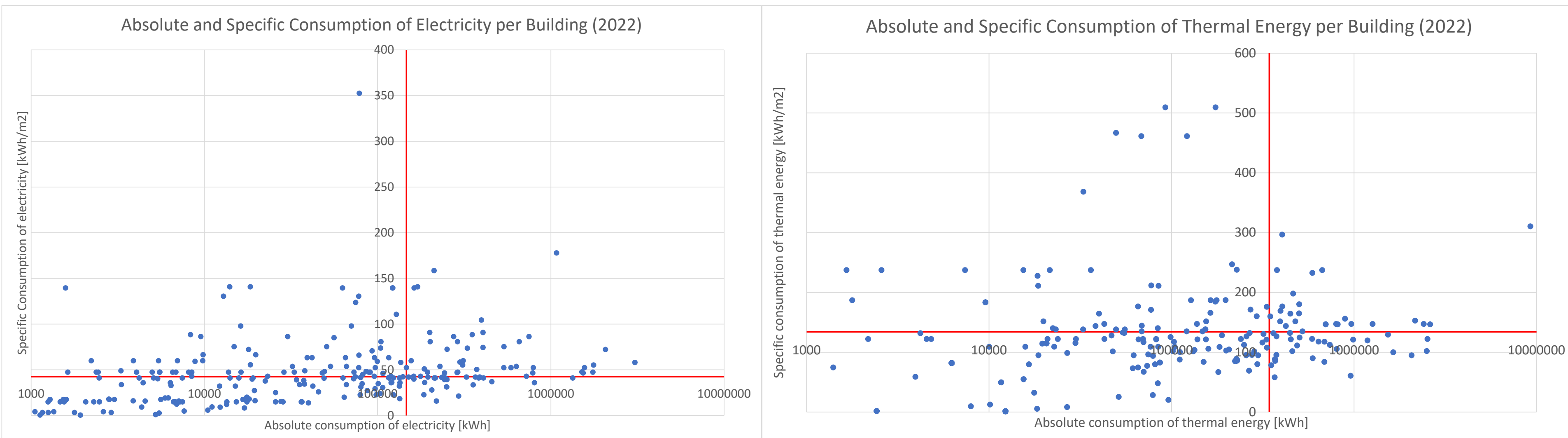


Figure 4.4 – Priority action maps. Distribution of university buildings according to: a) electricity consumption (absolute and specific); b) thermal energy consumption (absolute and specific) (2022 data).

Figure 4.5 combines specific energy consumption (thermal energy on the x-axis, electricity on the y-axis) to identify the most inefficient buildings, in terms of consumption of both electricity and thermal energy.
As with the other graphs, the red lines indicate the average specific consumption of electricity and thermal energy of university buildings ($CESel_{2022}$ = 42 kWh/m2/year and $CESth_{2022}$ = 134 kWh/m2/year, respectively) and divide the plane in four quadrants that can be used to assign different priority levels.

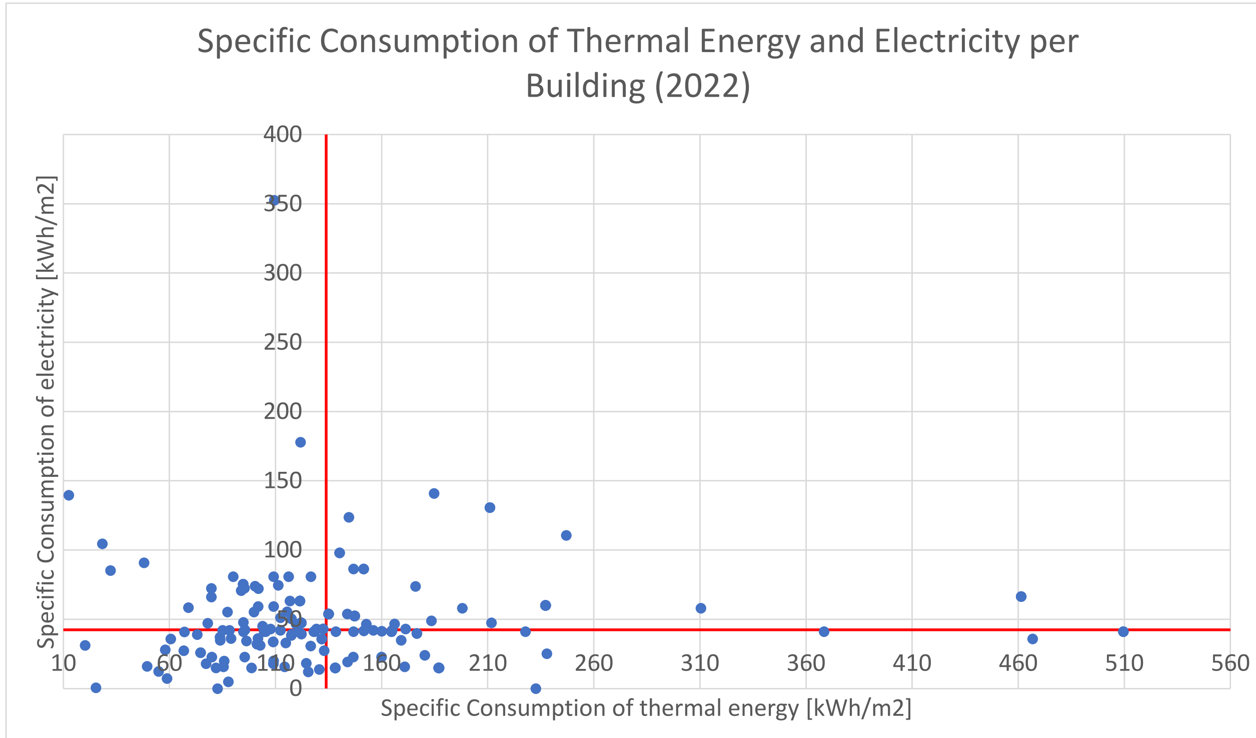


Figure 4.5 – Priority action map. Distribution of university buildings according to specific consumption of thermal energy and electricity (2022 data).

Figures 4.4 and 4.5 highlight which buildings should be prioritised from an energy point of view because of high levels of consumption and inefficiency, using the following priority criteria:

- HIGH priority: the upper right quadrant of Figures 4.4 and 4.5 includes the buildings characterised by significant levels of energy consumption, both total and specific; these buildings are high consuming (e.g., because the existing building system is inefficient and/or they are very big and/or they house energy-intensive equipment) and inefficient (high levels of consumption per unit of area serviced).
- MEDIUM priority: buildings with low overall consumption but high specific consumption (upper left quadrant of Figures 4.4 and 4.5); these buildings are energy inefficient, but the actions required are not high priority because the overall consumption of these buildings is of little significance for the university balance sheet.
- MEDIUM-LOW priority: buildings with high absolute consumption and low specific consumption (lower right quadrant of Figures 4.4 and 4.5); these are buildings with high levels of consumption but the building and its systems are in good condition (e.g., good thermal insulation or efficient lighting system). It is ideal to eventually re-evaluate these buildings; priority level rises with absolute consumption, but nonetheless these buildings are not high priority.
- no necessary actions: buildings with low overall consumption and low specific consumption (lower left quadrant of Figures 4.4 and 4.5); these are efficient buildings with low consumption.

Table 4.3 presents the list of 15 university buildings characterised by the highest levels of specific consumption (thermal energy and electricity); the 15 buildings in Table 4.3 represent a cluster of buildings with inadequate performance in terms of specific consumption of both electricity and thermal energy.

These buildings usually have inefficient and/or poorly run systems and/or equipments that consumes a lot of energy (e.g., large laboratories) and/or energy-intensive processes and/or envelopes that are poorly insulated.

Table 4.3 – List of the 15 university buildings with the highest combined values of specific consumption of electricity and thermal energy.

	Building code	CESth [kWh/m²/year]	CESel [kWh/m²/year]	CSUP/CSUPm
Viale Fanin, BO	475	310.4(*)	58	293%
Anteo Zamboni 7, BO	23	247	110.6	219%
Tecnopolo ex Macello, RN	6281	184.7	140.8	249%
Via Filopanti 1-7, BO	67	121.7	177.9	224%
Villa Almerici, Cesena	65	237.2	59.9	125%
Serre Fanin, BO	6140	198	58	202%
P.zza PP Pasolini, BO	75	175.9	73.7	113%
Chimica Industriale "Toso Montanari", BO	401	146.7	86.3	112%
Pallareti, FO	6205	171.3	42.9	170%
Dip. Statistica, BO	193	164.9	42	164%
P.zza S. Donato 2, BO	927	165	41	156%
P.zza Scaravilli 1-2, BO	191	116	81	147%
Via Filopanti 9, BO	725	135	54	148%
Berti Pichat 6, BO	219	147	41	149%
P.zza A. Moro, Cesena	937	111	74	143%
Average university value (2022)		**134**	**42**	**100**
(*) thermal energy also used for summer cooling				

The cost per unit area incurred yearly by the university to power the 15 buildings listed in Table 4.3 in 2022 was equal to €91/m2/year (for Viale Fanin) and €35/m2/year (for the "Toso Montanari" building), where the average university value was €33.50/m2/year (CSUPm).

The buildings included in Table 4.3 indicate an annual specific consumption (CSUP) 2.9 to 1.1 times greater than the average university level (CSUPm), and therefore must receive an in-depth energy audit (Energy Audit Plan).

4.6 SELECTION AND IMPLEMENTATION OF IMPROVEMENT MEASURES FOR ENERGY EFFICIENCY (IMEE): NEW COORDINATION STRUCTURE OF THE ENERGY PLAN

The university has had an Energy Master Manager (EM) for several years. Until now the Energy Manager played a strictly operational role, primarily dealing with energy supply and the filing and analysis of invoices from suppliers.

The EM has the task of implementing the University Energy Master Plan. The EM is a third-party figure who has specific skills in the areas of Energy and Energy Management.

In order to coordinate the operational and decision-making aspects of the Energy Master Plan, the figure of the Energy Manager and its support structure will be reassessed, accompanied by the establishment of a University Energy Committee (TEA) composed of members with complimentary specialised knowledge and figures from the university leadership with whom the EM can discuss the implementation of the Energy Master Plan.

Energy Manager

According to Law 10/91, an Energy Manager (EM) is a required figure for public entities with energy consumption of over 1,000 tonnes of oil equivalent per year (toe/year). The EM monitors the energy accounting of the entire university and implements the action plans within the Energy and Strategic Plans of the university. The EM monitors the development of tenders for energy efficiency projects and energy purchasing, verifies the maintenance of equipment and the consumption of single sites; they manage active Energy Service Contracts (CSE) and the Energy Performance Contracts (EPC) and monitor energy bills. The EM evaluates trends of the main energy indicators and achievement of energy goals indicated in the Energy and Strategic Plans, helping define and diffuse good practices within the university community..

The Energy Master Plan Implementation Committee (TEA) will have the task of verifying that the Improvement Measures for Energy Efficiency (IMEE) listed in the Energy Plan are implemented.

University Energy Committee (TEA)

The committee is made up of 7 members:

1. the Rector's Delegate for Sustainability, who coordinates the committee and ensures the actions indicated in the Energy Plan are in line with university sustainability policies;
2. the Rector's Delegate for buildings, who guarantees the coordination of the university's building development and the actions indicated in the Energy Plan;
3. representative from the CdA, the body responsible for the approval of the University Energy Plan;
4. university Energy Manager;
5. APAT Delegate, who provides information regarding the university's building stock and its use;
6. CESIA Delegate, who provides the computer science knowledge necessary to implement equipment monitoring and control systems and use management software, with the goal of improving the overall knowledge, management and automation of the energy system;
7. student representative, who presents issues raised by the student community

The committee will have the task of preparing the needed documentation to request approval of the actions described in the Energy Plan by the decision-making bodies of the university, as well as implementing the approved actions and monitoring their completion. The committee will perform an annual analysis of the results obtained upon implementing the plan, and will inform decision-making bodies regarding progress towards milestones. The committee will annually approve the Energy Accounting Report (RCE) prepared by the EM, which will highlight expenses for the purchase of various energy sources, energy consumption per district, area and department, and completed and unfinished efficiency measures.

The university will share the data and methodologies it uses for energy accounting with other Italian universities by participating in the Technical Committees established by the MUR starting in 2022.
Since 2022 the EM of the University of Bologna has participated in the Energy Work Group organised by the Italian University Network for Sustainable Development (RUS) and the committee dedicated to university Energy Managers.

The Energy Work Group recently published a document (Green Paper Sustainable Energy Management) that is a consultative tool accessible to all universities to facilitate a deeper reflection on the wide realm of Energy Management in relation to the commitment of rectors to create a structure dedicated to sustainability (Rector Commitment of May 2019).
The university has long had a dedicated sustainability portal (https://site.unibo.it/multicampus-sostenibile/it) through which information on actions carried out in the areas Energy, Environment and Mobility are published. The portal will be updated and will include information on the status of the implementation of the Energy Master Plan and the implications of the plan on the themes of transport and the environment.

Guided by the advice of the RUS, in the coming months the Energy Plan will be supplemented with a document communicating information on water consumption, waste treatment and mobility policies in order to connect all of the areas that fall under the issue of environmental sustainability within the university.

5. UNIVERSITY ENERGY STRATEGIES 2023-2030

In order to project the evolution of energy consumption in the medium and long term, the effects of a series of actions to be carried out from 2023 to 2030 have been considered.

5.1 OVERVIEW OF REGIONAL, NATIONAL AND EUROPEAN REGULATIONS 2023-2030

In the last five years the European Union has significantly modified the minimum targets to meet by 2030 in terms of the amount of energy consumed from renewable energy, energy efficiency in end use and emissions of greenhouse gases. With the approval of the Clean Energy Package in 2018, the EU set a goal of 32% of consumed energy from renewable resources by 2030 and a 32.5% improvement of end use efficiency, also by 2030. In June 2021, Regulation (EU) 2021/1119 amending the European Climate Law of 2018 introduced the new goal of reducing greenhouse gas emissions by at least 55% compared to 1990 levels by 2030. On 14 July 2021, the new package "Fit for 55%" was presented, with a series of legislative proposals and new goals in various strategic and economic sectors. "Fit for 55%" amends the Directive on renewable energy with the goal of producing 40% of European energy from renewable resources by 2030. In terms of energy efficiency, it set the goal of reaching a 9% reduction in energy consumption compared to projections of the 2020 baseline scenario. In addition, it required the public sector to renovate 3% of its buildings each year, integrate energy efficiency requirements into public purchasing, promote the use of energy performance contracts and reduce annual consumption by 1.7%.

On 8 March 2022, following the Russia-Ukraine conflict, the European Commission proposed the draft plan ("REPowerEU") to free Europe from Russian fossil fuels by 2030 through: (i) energy savings; (ii) the diversification of energy supply; (iii) faster diffusion of renewable energy as a substitute for fossil fuels in homes, industry and the generation of electricity. REPowerEU increased the main goal for renewable energy from 40%, as indicated in "Fit for 55%", to 45% for 2030.

In light of these most recent changes, the new 2030 goals of "Fit for 55%" are as follows:

- Reach a 55% reduction in total emissions compared to 1990 numbers.
- Reduce emissions by 40% compared to 2005 in the areas of agriculture, construction, transport and waste management, small and medium industries; Italy's specific goal is a 43.7% reduction in emissions.
- Bring the percentage of energy from renewable sources to 42.5% (+2.5%) starting from the current 22%.
- For buildings, the amount of renewable energy should reach 49%; for heating and cooling, renewable energy should increase by at least 0.8% per year until 2026, and then 1.1% per year until 2030.
- Reduce end energy consumption by 38% compared to European numbers from 2007 (the current average reduction level in Europe is 29%); by 2030 primary energy consumption should decrease by 40.6% compared to 2007.
- From 2024 to 2030, obtain an annual average reduction of 1.49% of end energy consumption; this reduction must be 1.9% for the public sector.
- Restructure at least 3% of flooring of public buildings.

With its Regional Energy Plan (PER), approved by D.A.L. no. 111 of 01/03/2017, the Emilia-Romagna region defined its strategy and goals for climate and energy for 2030. By signing the Work and Climate Agreement in December 2020, the region confirmed its commitment to lead Emilia-Romagna through the Green Transition, reaching total decarbonisation before 2050 and passing to 100% renewable energy by 2035, a very ambitious goal.

Bologna and Parma are among the 9 Italian cities in a total of 100 European cities that will participate in the EU mission for 100 smart, climate-neutral cities by 2030. Climate-neutral cities have the goal of maintaining CO2 at zero (decarbonisation) and extending the concept of anthropogenic greenhouse gases (GHG). Bologna nominated itself as a pioneer city aiming for climate neutrality, acting as an ecosystem of experimentation and innovation for other cities as well, helping them achieve climate neutrality by 2050. The actions that will be performed in Bologna are in the areas of mobility, energy efficiency and green city planning, with the possibility of establishing joint initiatives with other EU programs. The University of Bologna intends to actively participate in this mission, implementing measures aimed at reducing the impact of institutional activities on the climate.

In agreement with these action directives, the University Energy Master Plan includes contributions to the improvement of energy efficiency in end use, an increase in consumption of energy from renewable sources, and the rationalisation and reduction of specific consumption by implementing the following actions by 2030:

- creation of an internal Energy Management system, which requires obtaining UNI CEI EN ISO 50001 certification by 2027;
- increasing efficiency of thermal power units through the replacement of old gas boilers with the latest generation of condensation boilers and/or aerothermal, hydrothermal or geothermal electric heat pumps;
- increasing the connection to the urban district heating network;
- replacement of traditional lighting fixtures with new high-efficiency light sources (relamping);
- enhancement of the University Building Management System (BMS);
- thermal insulation of buildings (external insulation, roof insulation, window insulation)
- installation of pv panels for the on site production of electricity for self-consumption.

These actions are in line with the current European (“Fit for 55%”), national and regional regulatory landscapes.

5.2 SCENARIO 1 (BASELINE): THE EFFECT OF NEW BUILDINGS AND EFFICIENCY IMPROVEMENT MEASURES WITHIN THE THREE YEAR PUBLIC WORKS PROGRAMME OF THE UNIVERSITY

In the coming years the university will finalise an ambitious building development plan that includes several new constructions that will be operational by 2030, among them the Navile complex, the creation of a new Engineering complex in the Bertalia District (Lazzaretto) and the creation of the Biomedical Tower in the S. Orsola area.
The complete list of works contained in the three year university program is available at the following link:
https://www.unibo.it/it/ateneo/chi-siamo/programma-triennale-2023-2025-dei-lavori-pubblici

5.2.1 Development schedule for new buildings

The implementation of the three year building development program will lead to an increase of roughly 106,000 m^2 in covered area by 2027, which, despite the adoption of design and technological strategies for limiting consumption, will be accompanied by an estimated increase in primary energy consumption of roughly 1,826 toe/year (equivalent to a 13% increase in primary energy consumption compared to 2022, without considering any spaces not managed by the university because of rental agreements, loans or sales).

Figure 5.1 depicts the evolution of primary energy consumption projected for 2023-2030 following the construction of new buildings that have already been approved.

The proportion of energy consumed and area easily observable in the graph.

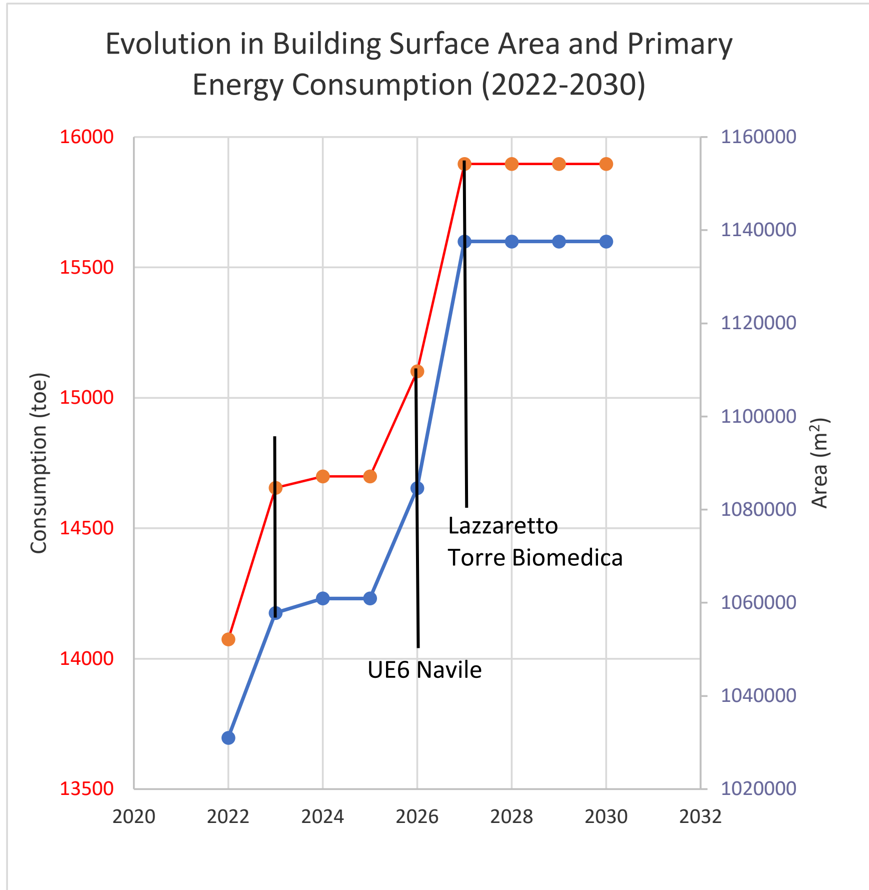


Figure 5.1 – Trends of primary energy consumption and newly constructed area.

5.2.2 Energy renovation programme for existing buildings

Alongside these new constructions, the three year programme includes a series of energy renovation actions for existing buildings. The main energy renovation measures of the projects within the three-year program are summarised below, organised by type; for these operations, ministerial funding can be advantageously paired with tax deductions and other incentives like those part of the Conto Termico (Ministerial Decree 16/2/16), as an example.

Many of the renovation actions within the three-year program include enhancements to building envelopes to reduce the heat loss of the refurbished building. In particular, these actions include:

- The replacement of 3,050 m^2 of windows for a total cost of €2.4 million;
- the thermal insulation and retrofit of 13,726 m^2 of roofing for a total cost of €3.6 million;
- the application of insulation techniques on 3,272m^2 of vertical walls in listed buildings for a total cost of €175k.

It is estimated that the planned retrofit interventions for building envelopes will lead to annual savings in energy consumption of 177 toe/year, corresponding to roughly 1.2% of total annual primary energy consumption. The total expenditure is €6.1 million, which, more specifically, is equal to pay of €2.8 per thermal kWh saved.

In addition to the building envelope retrofit, the three-year programme involves a campaign to replace heat generators aimed at:

- eliminating old generators, thus increasing the average seasonal performance of heating systems;
- eliminate all of the thermal power units with generators powered by heating oil or fuel oil.

A survey of all of the thermal power units was performed to identify the most critical situations, in terms of both the state of repair of generators as well as the efficiency of existing systems. This survey made it possible to draw up a list of generators that need to be replaced, in order of priority based on: i) nominal thermal capacity of the generator (higher the capacity, higher the priority); ii) age of the generator; iii) state of repair of the generator; iv) presence or lack of maintenance history of the power unit (or system); v) registration of systems in CRITER (Regional Register of Thermal Systems of Emilia-Romagna).
Where possible (e.g., upon confirming the availability of substation capacity, type of terminals, etc.), boilers will be replaced with electric heat pumps.
The replacement of generators will be paired with the installation of regulating elements that make it possible to control the ambient air temperature of each space (e.g., thermostatic valves on radiators) that will be able to interact with the building automation system (if present).
The total cost for the planned replacement of heat generators in university buildings in the coming years is €1.3 million. This action will lead to expect thermal energy savings of 1.2 GWh/year, equal to 98 toe/year (0.7% of total annual primary energy consumption), with expected cost of €1.06/thermal kWh saved.

In the three year construction plan, the retrofitting of mechanical equipment is generally associated with the installation of building automation systems.
The total cost of the projected installation of building automation systems in university buildings in the coming years is equal to €340k. This action will lead to an expected savings of 283 MWh/year in terms of thermal energy and of 135 MWh/year in terms of electricity. The overall savings in terms of primary energy is equal to 48 toe/year with projected cost of €0.60/kWh of primary energy saved.
Another measure included in the three-year programme is replacing existing lighting fixtures with LED systems. The total cost of the planned relamping campaign is €1 million. This action will create a savings of 483 MWh/year in terms of electricity. The overall savings in terms of primary energy is equal to 90 toe/year with projected unitary costs of €0.97/kWh of primary energy saved.

Table 5.1 contains a summary of the projected results following the implementation of the various energy efficiency measures that are part of the three-year programme. Note that in the next 3 years, the total amount invested by the university for energy restoration will total €8.7 million; this investment will lead to thermal energy savings of over 3.7 GWh/year and electricity savings equal to 0.6 GWh/year. Total primary energy savings are 414 toe/year, which corresponds to 1,001 tCO2e/year of avoided emissions. The data in Table 5.1 highlights how building envelope insulation actions are characterised by high specific costs (defined as the relationship between euros invested per kWh of primary energy saved), over €2.5/kWh in some cases. These costs correspond to very long payback periods that complicate the economic sustainability of these actions without partial funding and/or specific incentives.
Operations on mechanical and lighting systems have lower specific costs (< €1.6/kWh) and therefore present shorter payback periods (usually < 12 years) without incentives.

Intervention	Investment (€)	Specific cost (€/kWh)	Savings (toe/year)	Savings (tCO2/year)
Building automation	343,700	0.60	48	115
Replacement of generators	1,275,000	1.06	98	241
Replacement of windows	2,370,993	2.90	66	163
Insulation of vertical interior walls	174,800	0.45	32	78
Insulation of roofs/attics	3,554,623	3.67	79	193
Relamping	1,017,301	0.97	90	209
Total	**8,736,417**		**414**	**1,001**

Figure 5.2 shows the buildings that are slated to receive energy efficiency measures (yellow symbols); all of the buildings subject to these operations are in quadrants with high or medium priority levels, based on the methodology defined in Chapter 4.

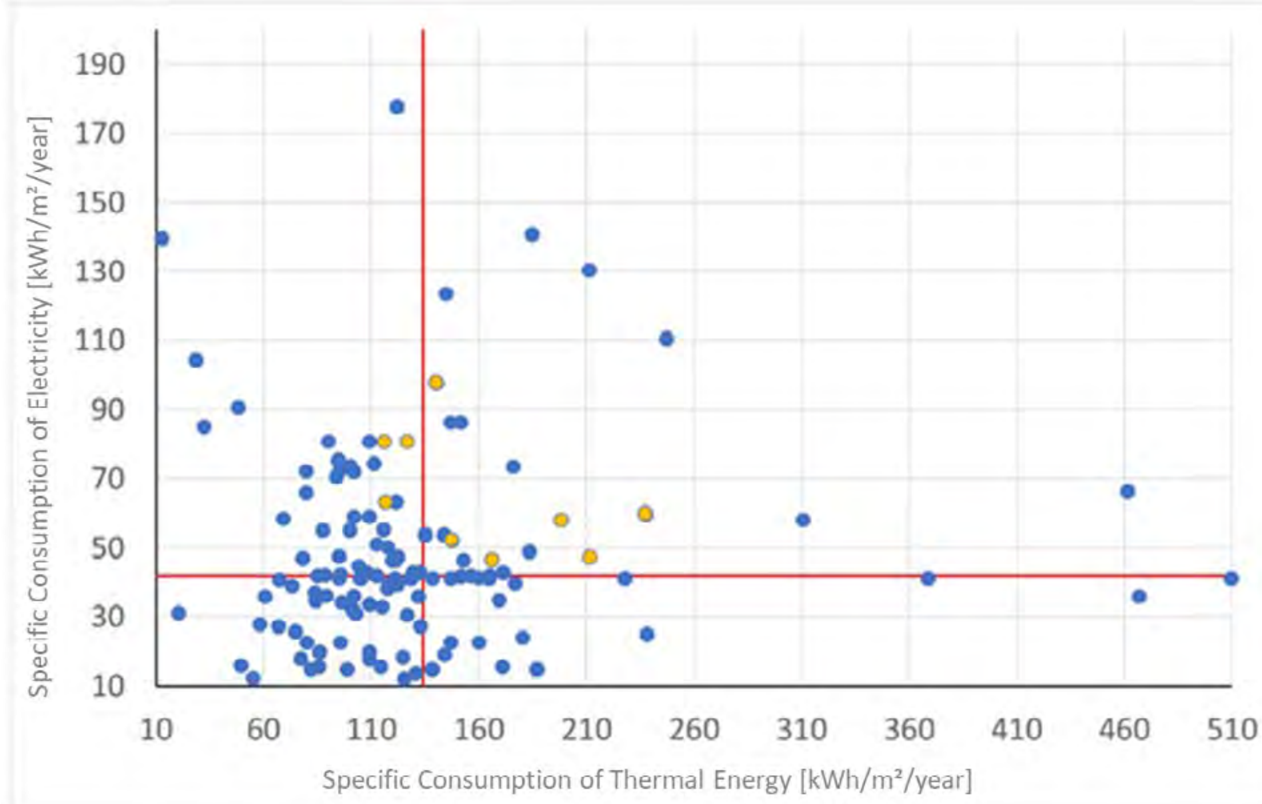


Figure 5.2 - Buildings that are slated to receive energy efficiency measures (yellow symbols).

5.2.3 Solar pv panel installation plan

At the end of 2022, the power of solar pv panels installed on university structures totalled 1,294 kWp with an annual production of 1.4 GWh/year; this production contributed to covering roughly 16% of the electricity needs of the ten sites where these systems are installed (Table 5.2.).

Table 5.2 - List of solar panel systems owned by the University of Bologna operational before 2023.

System name	Address	Campus	Building code	Operational as of	"Installed load [kWp]"	"Energy produced [kWh/year]"
Agronomy - Cadriano 1	Via Gandolfi 19	Bologna	513+6212+501+ 6180+517+506	29/06/2012	**239.5**	234,252
Cesena - Technopole	Via Quinto Bucci 336	Cesena	6278	20/04/2018	**50.5**	54,338
Fano - Marine Center 1	Viale Adriatico 1N	Fano	245	21/06/2018	**3.7**	3,960
Physics 1	Viale Carlo Berti Pichat 2-8	Bologna	219+221	30/06/2012	**67.7**	69,497
Forlì - Teaching Hub 1	Via Corridoni 40	Forlì	6235	19/06/2018	**19.8**	21,305
Forlì - Technopole	"Via Fontanelle 67 Via Baldassarre Carnaccini "	Forlì	6277	23/11/2017	**12.0**	12,912
Engineering - Lazzaretto 1	Via Terracini 24-34	Bologna	341+342+346	28/06/2012	**440.4**	518,766
Rimini - Alberti 1	Via Carlo Catta-neo SNC	Rimini	997	01/06/2018	**20.0**	21,520
Veterinary Sciences - Ozzano 1	Via Tolara di So-pra 50 Ozzano	Ozzano	642	26/06/2012	**438.3**	493,654
Veterinary Sciences - Ozzano Tolara 1	Via Tolara di So-pra 73 Ozzano	Ozzano	629+630	21/09/2010	**2.1**	2,260
TOTAL					**1,293.9**	**1,432,463**

In the university's three-year programme, eight new systems were included – four of which became operational during 2023 – with an additional installed capacity of 979 kW and an expected production of over 1.0 GWh/year (Table 5.3).
The university has invested a total of €662k in new solar pv panels. Some systems were proposed by the companies that won the public tender as design improvements, and as such they did not have an effect on the university's budget.
In total, by 2027 the University of Bologna's solar energy production should approach 2,600,000 kWh/year which will cover over 5% of the total electricity need of the university; considering the new connections due to expansions and new buildings, total electricity need will be just under 49 GWh/year in 2027, which is described in more detail below.

Table 5.3 - List of solar panel systems installed as part of the university's three-year programme.

System name	Address	Campus	Building code	Operational as of	"Installed load [kWp]"	"Energy produced [kWh/year]"
"Cesena (Campus Head Office)"	Via dell'Università 50	Cesena	6137	2023	**150.0**	**161,400**
"Cesena (Student residence)"	Via Salvatore Quasimodo SNC	Cesena	6441	2023	**25.0**	**26,900**
Cesenatico - DIMEVET 1	Viale Magrini 31	Cesenatico	6187	2023	**24.0**	**25,824**
"Engineering - Lazzaretto 3 (Bertalia DICAM + Student residence)"	Via Terracini	Bologna	nn	2027	**440.0**	**473,440**
"Engineering - Risorgimento R2 Stables"	Viale del Risorgimento 2	Bologna	325	2023	**28.9**	**31,096**
Navile Battiferro	Via della Beverara 123	Bologna	6218	2026	**129.6**	**139,450**
Palacus 1	Via del Carpentiere, 44	Bologna	29	2024	**49.0**	**52,724**
Psychology Cesena	Piazza Aldo Moro, 90	Cesena	6442	2026	**132.0**	**142,032**
TOTAL					**978.5**	**1,052,866**

5.2.4 Evolution of the university's energy consumption in the baseline scenario (Scenario 1)

Figure 5.3 shows the breakdown of consumption of each energy source after the complete implementation of the university's three-year programme (new locations and efficiency measures), in which it is projected that from 2024 to 2027 roughly 70,000 m2 will be subject to constructionsites and/or no longer be used by the university in favour of the new spaces.

This will become an energy baseline reference to evaluate the effects of further efficiency measures on the university's energy balance.

Based on Figure 5.3, it can be concluded that a 10-15% increase in absolute consumption of electricity and thermal energy in the 2023-2030 period is expected, due to the realisation of all of the operations included in the three-year programme; more specifically, due to the increase in area following the construction of new buildings. Considering this increase in energy consumption tied to university building development, total annual consumption of primary energy will grow to 16,000 toe/year in 2030.

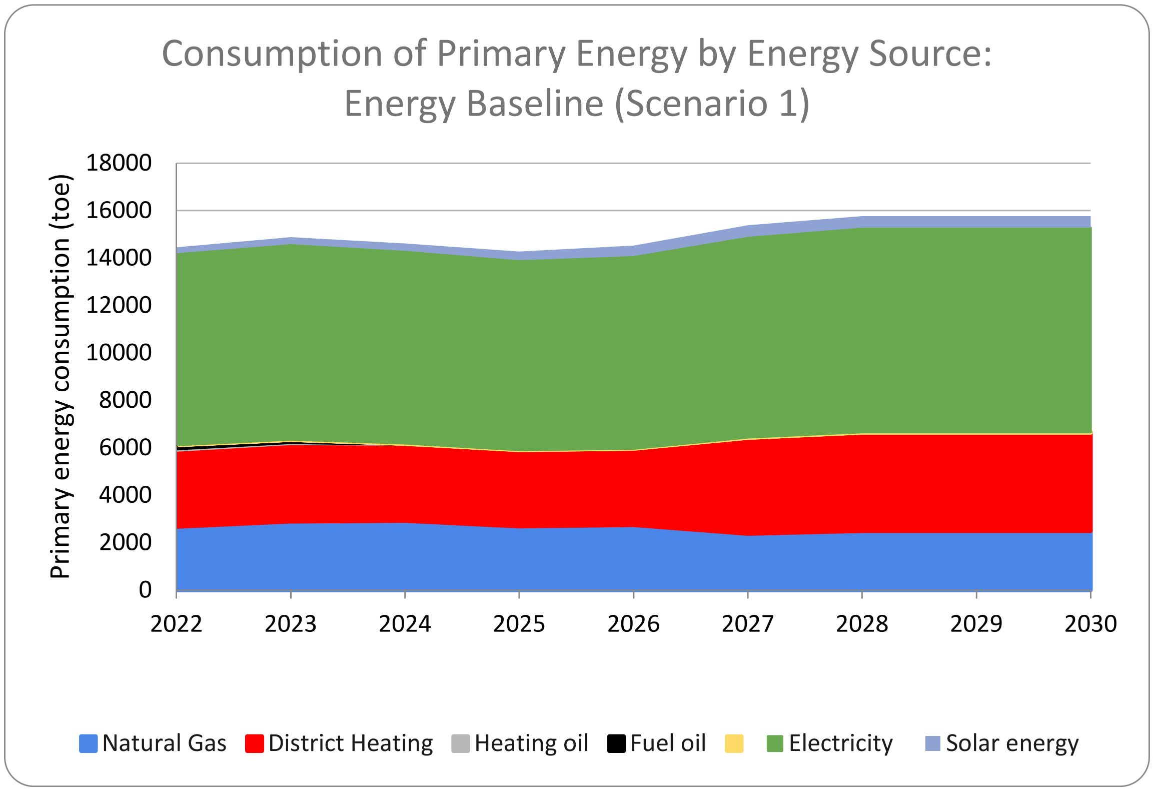


Figure 5.3 - Evolution of the university's primary energy consumption per energy source, due to use of new locations and implementation of efficiency measures included in the three-year programme (2022-2030).

The Baseline Scenario depicted in Figure 5.3 shows how natural gas, which will cover 18.8% of consumption in 2023, will reach 19.8% of total consumption in 2026, to then decrease to 16.5% in 2030 due to the increase of connections to the district heating network that will replace natural gas throughout the Bertalia District starting in 2027. The increase in the use of natural gas in the short term is due to the planned phase-out of heating oil and fuel oil by 2025.

The increase of district heating stations, which covered 22.9% of total university consumption in 2022, will increase to 23.2% in 2026 due to the new connections planned for the "cittadella universitaria" in Bologna, and in 2030 they will cover 27.3% of total primary energy consumption.
Electricity consumption will continue to cover 57% of primary energy consumption for the entire 2022-2030 period.
Table 5.4 presents the expected evolution of the values of selected energy indicators in the 2022-2030 period.

More specifically, with the full implementation of the measures included in the university's three-year programme, it will be possible to meet the following goals in the 2023-2030 period:

- limit the increase of absolute consumption of electricity (EE) and thermal energy (ET) caused by the use of new locations;
- increase of over 5% in the amount of self-generated electricity (%FV) through the installation of new university's solar pv panels;
- stabilise the specific consumption of both electricity (CESel) and thermal energy (CESth) per unit area served by 2030, after seeing a reduction in the short term (2026);
- increase the amount of thermal energy produced by renewable sources (%QRth) thanks to the installation of thermal systems based on heat pump technology;
- limit the increase of annual greenhouse gas emissions caused by increased consumption.

Table 5.4 - Evolution of energy indexes of the university following implementation of the three-year construction programme (baseline scenario).

Scenario 1 **Energy Baseline 2023-2030**	**2023**	**2026**	**2030**
EE Electricity consumed (GWh/year)	45.6	45.8	48.7
%FV	3.4	5.3	5.4
CESel "Specific consumption of electricity ($kWh/m^2/year$)"	42	41	42
ET Thermal energy consumed (GWh/anno)	67.8	66.4	73.6
CESth "Specific consumption of thermal en-ergy ($kWh/m^2/year$) "	134	126	133
%QRel Percentage of renewable energy - Electricity	20.1	20.6	20.5
%QRth Percentage of renewable energy - Thermal energy	0.6	1.9	1.8
Primary energy consumption (toe/year)	14,727	13,653	13,841
Annual emissions (tCO2/year)	33,274	28,430	26,608

Comparing the results of this analysis with the objectives laid out by "Fit for 55%", it can be noted that:

- total primary energy consumption will grow by 7.3% by 2030 due to new constructions;
- the reduction of specific consumption of primary energy foreseen for the 2023-2030 period is equal to 0.4% annually (compared to the 1.7% decrease indicated in "Fit for 55%");
- the amount of renewable energy consumption will reach 12.6% of total primary energy consumption (compared to 45% as indicated in "Fit for 55%").

Based on these indicators, it can be concluded that the efficiency measures projected by the three-year programme are insufficient to reach the minimum objectives indicated in current Directives.
The effects of a series of further energy efficiency measures on the university's energy balance sheet will be analysed below.

5.3 ANALYSIS OF THE IMPACT OF FURTHER ENERGY EFFICIENCY MEASURES ON THE UNIVERSITY'S ENERGY BALANCE SHEET

To push the university closer to reaching the objectives defined in "Fit for 55%" and the "Green Deal", it is necessary to plan additional actions to be implemented in the 2023-2030 period.
The next section describes a series of scenarios in which the implementation of combinations of the aforementioned measures are analysed to determine their effect on the university's energy balance sheet. This will facilitate in determining the importance, in terms of savings, of the various measures and to therefore identify which measures should be implemented to increase energy efficiency and decrease consumption of university buildings and structures.

5.3.1 Scenario 2: Management actions

In Scenario 2, the measures foreseen by the three-year programme will be accompanied by an internal Energy Management System that includes receiving UNI CEI EN ISO 50001 certification for the university by 2027. The estimated cost for the creation of an internal Energy Management System is €405,000.

The management interventions necessary to reach the minimum standards required for UNI CEI EN ISO 50001 certification are grouped into four macro-categories (Table 5.5).

- bill audit (monitoring bills and consumption, recording of consumption data, automatic alarm systems, benchmark indicators, construction of a consumption tree);
- energy audit and asset survey (audit plan, survey of equipment assets);
- implementation of a monitoring and verification protocol (implementation IPMVP, definition of typical consumption profiles, equipment activation and deactivation controls);
- activities regarding communications and waste reporting.

The potential average annual energy savings during the 2023-2030 period were estimated for each macro-category (Table 5.5). The savings from these interventions will be at their highest in the first years following their implementation and will decrease over time once the university's energy management methodology is firmly established. The savings indicated in Table 5.5 should be considered variable in terms of the systematicity with which these management interventions are implemented, and they will be subject to adjustments during implementation.

Table 5.5 - Management interventions: investment, expected savings and emissions avoided.

Intervention	Cost (€)	Expected savings (toe/year)	Expected savings (tCO2/year)
Bill Audit	75,000	60	136
Equipment audit and survey	100,000	30	62
Implementation of measurement and verification protocol	200,000	100	225
Waste reporting	30,000	30	66
Total	**405,000**	**220**	**490**

5.3.2 Scenario 3: The University Solar Energy Plan

Scenario 3 considers the installation of new solar pv panels by 2030, in addition to the measures already included in the three-year programme and the management interventions. Over twenty sites that are suitable for an easy installation of solar pv panels and with good sun exposure were identified (Table 5.6).

Sites were determined to be suitable by evaluating not only the available surface area of roofs (both flat and pitched roofs), but also the electricity needs of the building itself (and/or buildings connected to the same primary substation with the aim of creating local CERs), with the objective of ensuring that the all energy produced from solar pv panels can be self-consumed both in terms of energy as well as peak shaving.

Altogether, it is possible to install new solar pv panels with an installable available peak capacity of roughly 5.4 MWp, with a production capacity of roughly 5.9 GWh of electricity annually. The possibility of connecting solar panel systems to energy storage systems will also be considered, in order to maximise the harnessing of the electricity produced daily.

Table 5.6 - List of sites and possible solar panel installations.

System name	Address	Campus	Installed load [kWp]	Estimated energy	Production of site energy need	Ratio between capacity and need
Engineering - Risorgimento R2	Viale del Risorgimento 2	Bologna	763	843,545	45%	0.78
Forlì - Teaching Hub 1	Via Corridoni, 40	Forlì	740	755,434	53%	1.00
Navile	Via Piero Gobetti, 93/2	Bologna	671	687,523	17%	0.32
Veterinary Sciences - Ozzano 2	Via Tolara di Sopra, 50 - Ozzano	Ozzano	480	566,502	41%	0.67
Agronomy Fanin	Via Fanin 40	Bologna	415	458,126	14%	0.25
Engineering - Lazzaretto 2	Via Terracini 24-34	Bologna	364	398,594	37%	0.62
Pilastro - CUS	Via del Pilastro, 8	Bologna	300	336,355	55%	0.94
Engineering - Risorgimento R4	Viale del Risorgimento 4	Bologna	241	281,462	25%	0.41
Physics 2	Viale Carlo Berti Pichat 2/8	Bologna	234	239,966	23%	0.43
Agronomy - Cadriano 2	Via Gandolfi 19	Bologna	214	222,757	(1)	(1)

System name	Address	Campus	Installed load [kWp]	Estimated energy	Production of site energy need	Ratio between capacity and need
Rimini - Alberti 2	Via Carlo Cattaneo SNC	Rimini	155	186,295	58%	0.94
Cesena - Villa Almerici	Piazza Gabriele Goidanich, 60	Cesena	150	175,552	55%	0.89
Veterinary Sciences - Ozzano Florio	Via del Florio 2	Ozzano	125	145,751	64%	1.06
Ravenna CIRSA	Via Sant'Alberto 163	Ravenna	111	129,004	21%	0.36
Forlì Hangar	Via Cicognani	Forlì	83	97,102	(2)	(2)
Forlì ex-ENAV	Via Montaspro	Forlì	73	84,537	23%	0.38
Fano - Marine Center 2	Viale Adriatico, 1	Fano	59	56,432	49%	1
Veterinary Sciences - Ozzano Tolara 2	Via Tolara di Sopra 73, Ozzano	Ozzano	59	69,758	61%	1
Forlì Airport	Via Fontanelle, 40	Forlì	40	43,310	52%	0.92
Rimini - Navigare Necesse	Via dei Mille, 39	Rimini	39	46,849	45%	0.72
Engineering - Montecuccolino	Via dei Colli	Bologna	25	23,168	47%	0.98
Forlì Predappio	Via Zoli, 63 - Predappio	Forlì	17	19,877	6%	0.09
Cesenatico - DIMEVET 2	Viale Magrini, 31	Cesenatico	12	14,108	54%	0.94
Palacus 2	Via del Carpentiere, 44	Bologna	8	9,712	55%	1
TOTAL			**5,378**	**5,891,719**		
(1) projected expansion with increased consumption			(2) new consumption not yet accounted for			

5.3.3 Scenario 4: Increasing efficiency of thermal power units

The university produces 42% of the hot water used for heating and bathrooms by means of natural gas-fueled boilers. Many of these boilers are outdated and characterised by low average seasonal performance (< 80%). In recent years the university has begun a campaign that provides for the gradual replacement of existing inefficient natural gas boilers with condensing boilers that, while powered with natural gas, consume it more efficiently.
However, current developments in European legislation in this area seem to suggest a time limit in terms of the use of gas condensing boilers with the goal of accelerating reduction of fossil fuel use.
Regulation 813/2013/EU, still currently in a drafting phase, introduces a minimum for average seasonal efficiency for heat generators used in heating systems, to be met by September 2029. One of the proposals is to remove all heat generators unable to guarantee a minimum efficiency threshold of 115% (for boilers) from the market; this threshold is unreachable with condensation boilers.
A further complication to the current situation also regards the market for electric heat pumps; major changes tied to limitations on refrigerants to be used in new devices are underway. Regulations regarding F-gases are currently evolving, and as such it should be taken into consideration that the main gases used as refrigerants in available heat pumps could be removed from the market.
New heat pumps will be required to make use of refrigerants with a low environmental impact, or with a Global Warming Potential (GWP) of less than 150, and instead use natural gases like hydrocarbons (e.g., propane). If the future scenario should require the accelerated substitution of old generators, it is legitimate to expect extraordinary plans or incentives aimed at funding the restructuring of old thermal power units.
For this reason, and using the energy audit plan described in Chapter 4, the university will identify the thermal power units that need to be redesigned and replaced with heat pump systems.

The priority levels of these interventions will be established after considering the following related aspects:

- available electric capacity for the installation of electric heat pumps;
- type of terminals used in the heating system;
- impact of new heat pumps on the Fire Prevention Certificate of the building and any required modifications.

In Scenario 4, all the interventions indicated in Scenario 3 (implementation of three-year construction plan, management interventions and 5.4 MWp solar energy plan) accompany the replacement of gas boilers with electric heat pumps at the rate of 2 MW of boilers/year until 2030. The associated cost for this replacement campaign is estimated at €10 million.
Figure 5.4 depicts the evolution of energy supply coverage to produce thermal energy in the case of Scenario 4. Note how in 2029 it is predicted that the contribution of natural gas-powered boilers will fall below the contribution of newly installed electric heat pumps that will cover, in 2030, 20% of thermal energy consumption, compared to the 15% covered by natural gas (currently 42%).

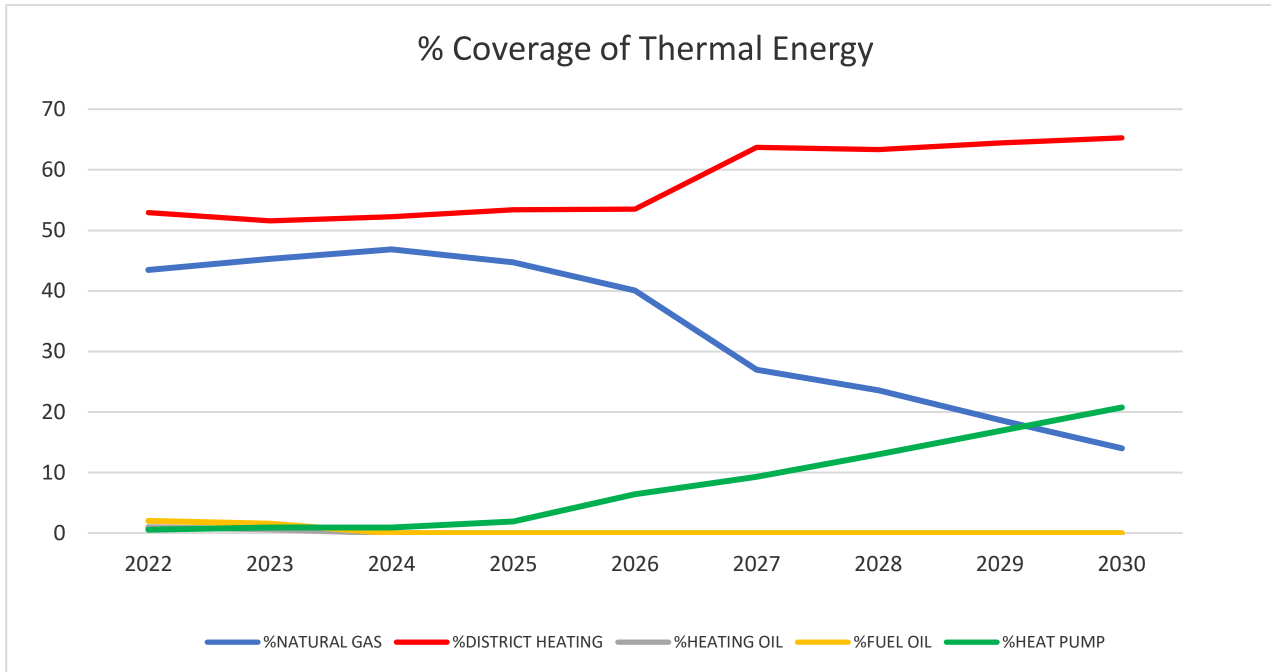


Figure 5.4 - Trends in coverage of thermal energy by source (2022-2030).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5.3.4 Scenario 5: Relamping Plan and upgrading of university BMS

Electricity consumption for lighting was estimated to be 30% of total annual electricity consumption; in 2022 electricity consumption for lighting was equal to 13.3 GWh/year.

In 2023 roughly 40% of incandescent and fluorescent lighting sources were replaced. Relamping is another of the planned interventions in the energy renovation projects within the university's three-year programme. The implementation of these measures will lead to 44% of total light sources being replaced.

Figure 5.5a shows the subdivision of university electricity consumption into three intervals (F1, F2, F3).
Roughly 45% of electricity consumption occurs in F1 (peak hours), between 8 AM and 7 PM, Monday-Friday. 20% of electric consumption occurs in F2 (intermediate periods), between 7 and 8 AM and 7 and 11 PM, Monday-Friday, and from 7 AM to 11 PM on Saturdays.
35% of university consumption occurs in F3 (off-peak hours), from 11 PM to 7 AM, Monday-Saturday, and all hours of Sundays and holidays.
The graph shows that the percentage of electricity consumption per interval has remained more or less constant from 2018 to 2022.
It should be noted that the number of weekly hours associated with each of the three intervals is not equal (F1: 55 hours, F2: 41 hours, F3: 72 hours). If consumption is normalised based on the number of hours in each interval, it can be observed (Figure 5.5b) that consumption in F3 and F2 are similar, while the highest level of consumption is in F1.
The information regarding electric consumption in F3 underlines the impact of consumption for the illumination of exterior areas, which represents a third of all electricity consumption of the university. The majority of exterior lighting fixtures are obsolete and have low levels of energy efficiency.

In addition to the measures indicated in Scenario 3 (implementation of three-year programme, management interventions and 5.4 MWp Solar Energy Plan), Scenario 5 includes the replacement of all remaining obsolete fixtures installed within university buildings by 2027, but also foresees the relamping of all exterior lighting fixtures by 2027. Based on the data on electricity consumption tied to F3, the relamping of exterior lighting fixtures will be prioritised in the first phase of implementation (2024-2025).

The relamping initiative will be paired with the upgrading of the university's Building Management System (BMS), with a total investment of roughly €10 million.

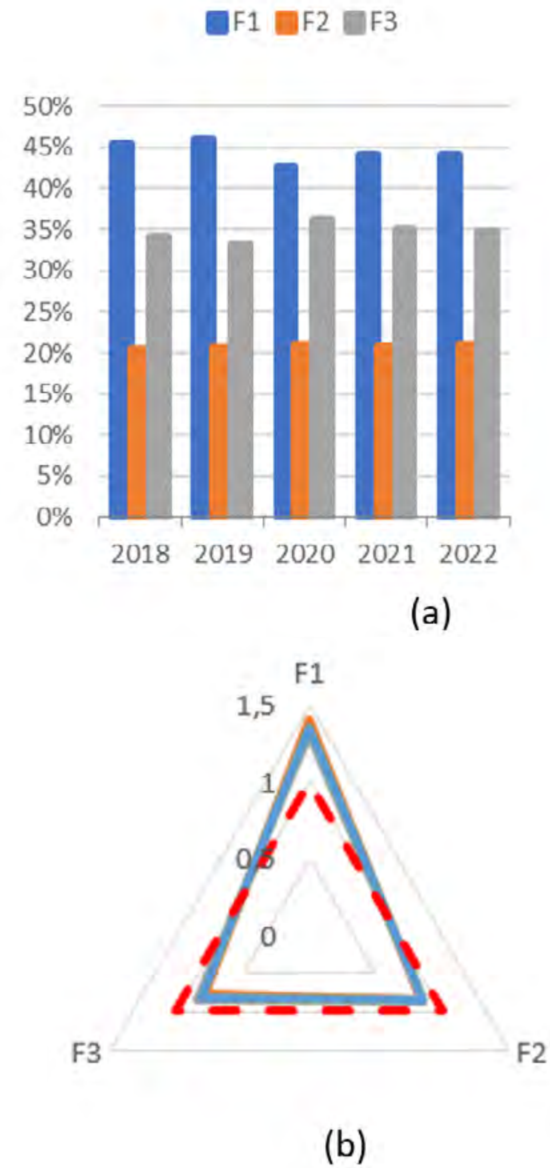


Figure 5.5 - Percentage of electricity consumption per interval.

The relamping campaign includes not only the replacement of traditional light sources with LED lights but, where possible, the creation of a "smart lighting" system that integrates all LED light sources connected to devices that can access the IoT, making remote control and supervision of lighting possible. In addition, this campaign provides the possibility of receiving incentives for energy efficiency, through Energy Efficiency Certificate (or white certificate) programs, as well as the Conto Termico 2.0. Thanks to these new incentives, payback periods are short (< 5 years). This aspect makes relamping attractive to private companies, like Energy Saving Companies (ESCos) in particular, which can propose interesting forms of third party financing for relamping initiatives of public administrations, and through the creation of public-private partnerships (PPP).

To explore this possibility, the university is currently in dialogue with local ESCos to define a "sample" relamping initiative to be implemented using the "guaranteed savings" formula.
The pairing of the Solar Energy Plan with energy savings from more efficient lighting systems can offer remarkable benefits in terms of absolute and specific electricity consumption.

5.3.6 Scenario 6: New efficiency measures performed on buildings

Scenario 6 considers the impact of a series of new retrofit measures to be performed on university buildings with the highest levels of thermal energy consumption per surface unit (CESth2022 > 134 kWh/m2/year) on the university energy balance. It is assumed that these actions can be financed through participating in ministerial tenders regarding the energy efficiency of public buildings.

The design and realisation of a series of measures aimed at the following areas is projected to begin in 2027: i) replacement of single-glazed windows and frames without thermal break (e.g., the Engineering School site, Mathematics Department, Psychology Department, ex-seminary in Ravenna, etc.); ii) the placement of insulation on vertical walls of the buildings with the highest amounts of loss; iii) insulation of roofs (or attics) of buildings with the highest amounts of thermal loss (e.g., Palazzo Angherà in Rimini); iv) installation of sun shades on the windows of buildings with the high consumption for summer cooling (e.g., Agraria Fanin).
These measures can be planned only for 2027 and on because the number of active work sites up to this date places a significant limit on the ability to manage other simultaneous initiatives.

All of the interventions indicated in Scenario 3 (implementation of three-year construction plan, management interventions and 5.4 MWp Solar pv Energy Plan with energy storage) accompany a plan for new building interventions for an investment of €20 million at 2023 prices.

5.3.7 Scenario 7: the combination of all interventions

Lastly, Scenario 7 (Best Case) will be considered, in which all of the interventions included in Scenario 2 (implementation three-year programme and management interventions) are carried out in addition to:

- a €10 million plan for the installation of 5.4 MWp of new solar pv panels on the roofs of selected buildings by 2030;
- a €10 million plan for the replacement of the oldest and least efficient natural gas boilers with electric heat pumps by 2030;
- a €10 million plan for relamping and upgrading the BMS network of the university to be completed by 2026, and the elimination of all incandescent and fluorescent lighting fixtures and a twofold increase in remotely controlled thermal power units;
- a €20 million plan for new building interventions, to be implemented starting in 2027, on the envelopes with the highest levels of standing loss of the buildings with annual levels of specific consumption of thermal energy (CESth) over 134 kWh/m2 (CESth2022).

5.3.8 Comparison of scenarios

Table 5.7 summarises each of the scenarios analysed and the total investment necessary to implement each one.

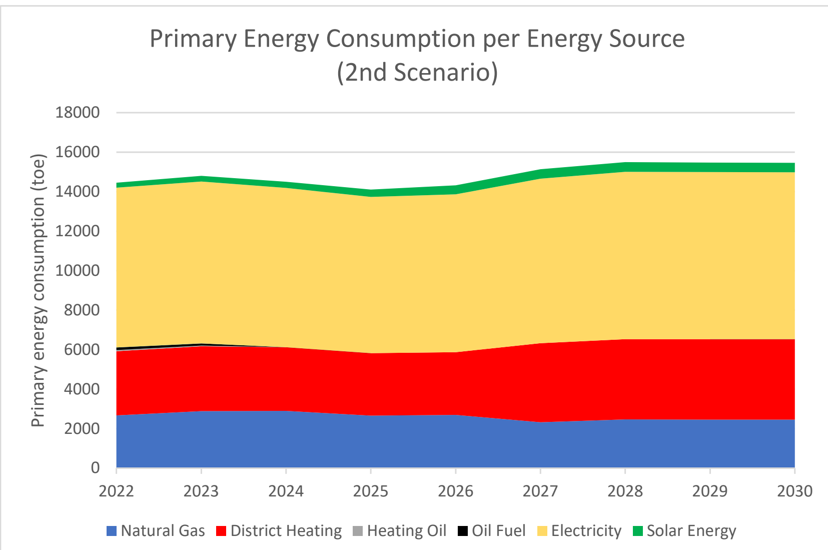
Table 5.7 – List of scenarios analysed as part of the Energy Plan and the corresponding investment required..

Intervention	Investment (M€)
Scenario 1 - Baseline: Implementation of three-year programme	9.4
Scenario 2: Scenario 1 + Management interventions	9.8
Scenario 3: Scenario 2 + Solar Energy Plan (5.377 MWp)	19.8
Scenario 4: Scenario 3 + Replacement of boilers	29.8
Scenario 5: Scenario 3 + Relamping and BMS upgrade	29.8
Scenario 6: Scenario 3 + New interventions on building envelopes	39.8
Scenario 7: Scenario 3 + Replacement of boilers + Relamping and BMS upgrade + New interventions on building envelopes	59.8

Figure 5.6 shows the trends of total primary energy consumption per energy source in the 2023-2030 period for each of the 6 scenarios analysed.
The implementation of the efficiency measures included in the three-year programme will lead to a reduction in consumption in the short term; a relative minimum in terms of consumption is expected to be reached in 2026. In 2027, new buildings will become operational, which will lead to a new increase in consumption that can only be kept under control with the realisation of new efficiency measures between 2027 and 2030.

The 2024-2027 Solar pv Energy Plan, in addition to the three-year programme and the management interventions (Scenario 3), would significantly increase the amount self-generated electricity, bringing it to 17.5% in 2027, and reduce greenhouse gas emissions by 2,000 tCO2/year by 2030, compared to 2023 numbers.
Increasing the efficiency of thermal power boilers alongside the three-year programme, the management interventions and the Solar Energy Plan (Scenario 4) would significantly increase electricity consumption compared to Scenario 3 (+6 GWh/year in 2030 due to the installation of electric heat pumps in thermal power units) and therefore lead to a decrease in the percentage of self-generated energy from solar panels (from 17.5% to 15.7% in 2030).
Electricity consumption, which covered 56% of primary energy consumption in 2022, would remain almost constant in 2026 in terms of percentage (58%), to then rise to 63% in 2030 due to the installation of electric heat pumps. Natural gas, which will cover 18.8% of total primary energy consumption of the university in 2023, would reach 18% in 2026 and fall to 6.8% in 2030, after the gradual replacement of natural gas heat generators.
New substations of the district heating network would cover 30.3% of total primary energy consumption in 2030.

The replacement of all traditional light sources with the latest LED bulbs and the upgrading of the university BMS, together with the three-year programme, management interventions and the Solar pv Energy Plan (Scenario 5), would lead to a significant decrease in absolute electricity consumption in the next three years and, as a result, an increase in the amount of self-generated energy from solar panels (from 17.5% to 19.2% in 2030). In 2022 electricity consumption represented 56% of primary energy consumption, and in 2026 it would decrease to 53.4%, to decrease even further in 2030 to 50.7%.



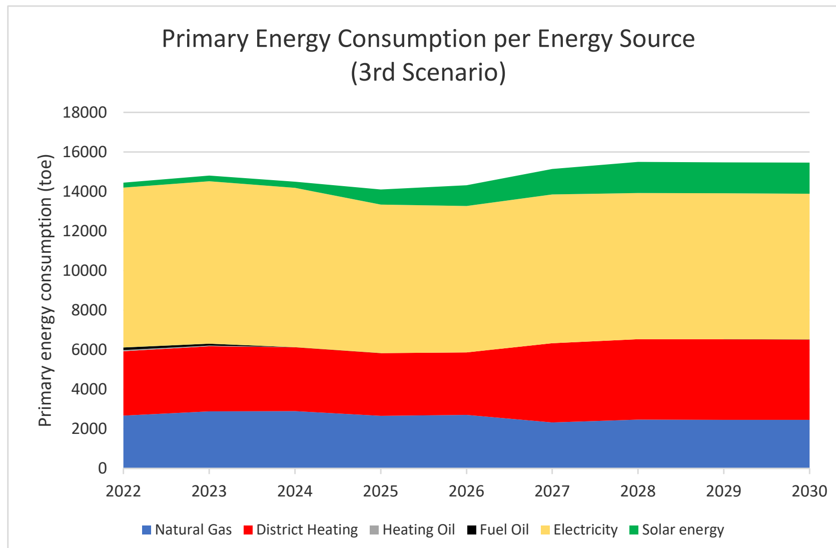
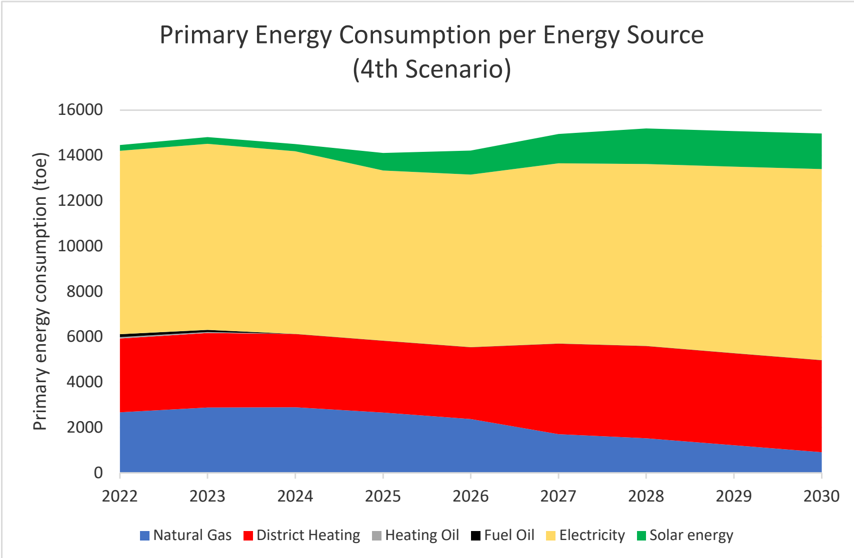
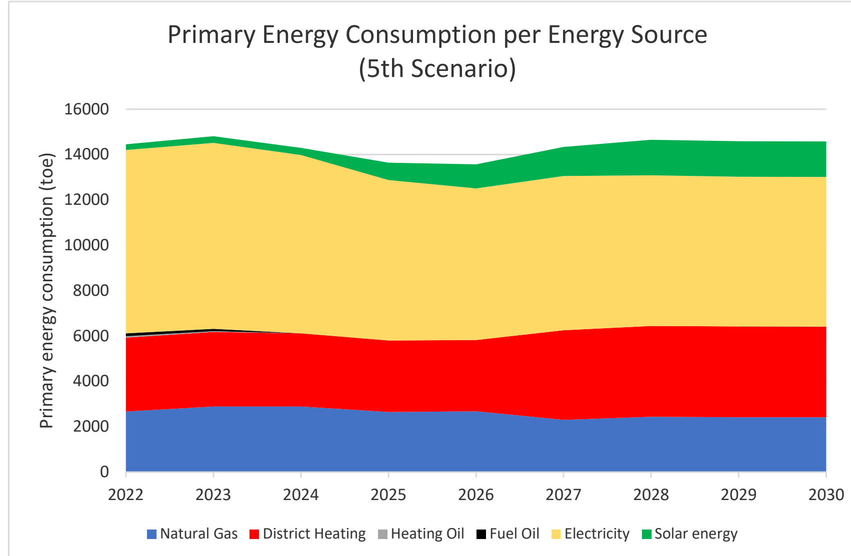
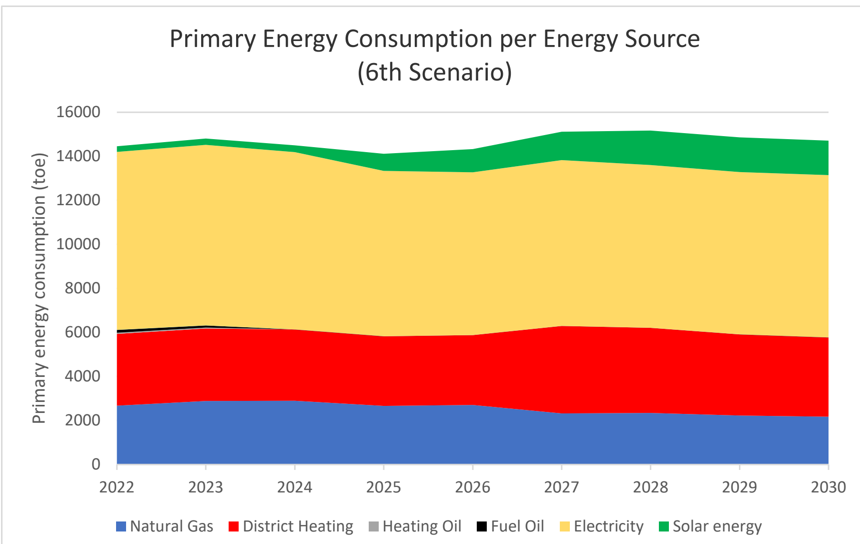
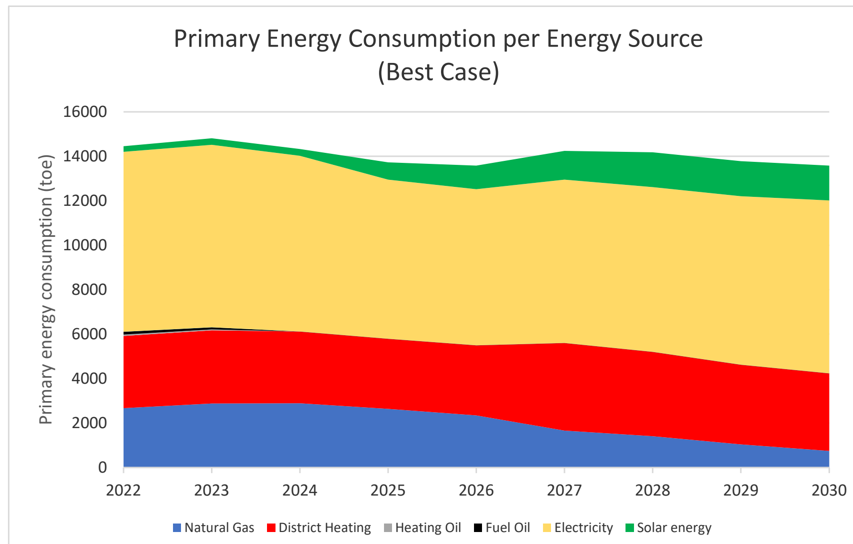


Figure 5.6 – Trends in total primary energy consumption for the 6 scenarios analysed (2023-2030).


Primary Energy Consumption per Energy Source
(4th Scenario)
Primary energy consumption (toe)
16000
14000
12000
10000
8000
6000
4000
2000
0
2022
2023
2024
2025
2026
2027
2028
2029
2030
Natural Gas
District Heating
Heating Oil
Fuel Oil
Electricity
Solar energy


Primary Energy Consumption per Energy Source
(5th Scenario)
Primary energy consumption (toe)
16000
14000
12000
10000
8000
6000
4000
2000
0
2022
2023
2024
2025
2026
2027
2028
2029
2030
Natural Gas
District Heating
Heating Oil
Fuel Oil
Electricity
Solar energy


Primary Energy Consumption per Energy Source
(6th Scenario)
Primary energy consumption (toe)
16000
14000
12000
10000
8000
6000
4000
2000
0
2022
2023
2024
2025
2026
2027
2028
2029
2030
Natural Gas
District Heating
Heating Oil
Fuel Oil
Electricity
Solar energy


Primary Energy Consumption per Energy Source
(Best Case)
Primary energy consumption (toe)
16000
14000
12000
10000
8000
6000
4000
2000
0
2022
2023
2024
2025
2026
2027
2028
2029
2030
Natural Gas
District Heating
Heating Oil
Fuel Oil
Electricity
Solar energy

The new requalification actions of the envelopes of buildings with the highest levels of standing loss (Scenario 6) would led to a significant decrease in absolute consumption in 2030: the absolute consumption of thermal energy would go from around 68 GWh/year (2023 numbers) to roughly 63 GWh/year in 2030, with a decisive increase in efficiency with which the university uses thermal energy. The annual specific consumption of thermal energy, following improved insulation of university buildings, would decrease from 132 to 113 kWh/ m2 from 2023 to 2030. In addition, improved thermal insulation of the buildings with the highest levels of heating loss would lead to a reduction of roughly 3,500 tCO2/year of greenhouse gas emissions.
Scenario 7 (Best Case), which includes all of the aforementioned actions, is characterised by a primary energy consumption of natural gas that would stabilise at 18.8% from 2023 to 2026, but after 2026 it would decrease dramatically, to 6.2% in 2030, thanks to the gradual "electrification" of thermal power units and an increase in the number of substations connected to the district heating network.
Electricity, which would be responsible for 56% of total primary energy consumption in 2026, would increase to cover 64.7% of total primary energy consumption in 2030.
The number of new substations of the district heating network would continue to increase, thus passing from 23% of primary energy consumption in 2023 to 25% in 2026, with a further increase to 29% by 2030.
The percentage of self-generated electricity from solar panels would cover 8.4% of total primary energy consumption in 2026 and 13% in 2030.
The Best Case Scenario would limit the increase in absolute electricity consumption related to the "electrification" of heating systems to under 50 GWh/year in 2030.
New solar panel systems would be able to cover 16.8% of total electricity consumption by 2030.
Specific electricity consumption (CESel) would remain generally stable around 43 kWh/m2/year, including the part of electricity consumption responsible for thermal energy production.
Consumption of thermal energy would pass from 67 to 43 GWh/year thanks to the installation of electric heat pumps to replace gas boilers.
This would lead to a substantial reduction in specific consumption of thermal energy per heated unit area (CESth), which would pass from 134 to 90 kWh/m2/year.
The consumption of electricity and thermal energy generated from renewable energy sources would tend to increase from 2023 to 2030. In particular, 2030 would see 23% of electricity consumption covered by renewable energy and 26.4% of thermal energy consumption covered by renewable sources thanks to the installation of heat pumps.
From the point of view of total consumption of primary energy, in 2023 there would be a reduction in annual consumption of primary energy, even in the face of increased serviced surface area due to new buildings.
The optimisation of the thermal energy (heat pumps) and electricity (new solar pv panels) production systems, together with a reduction in consumption due to management interventions, the relamping campaign and new energy requalification actions of buildings, would lead to a decrease in greenhouse gas emissions of roughly 7,000 tCO2/year in 2030, compared to 2023.
Table 5.8 presents the projected evolution of selected energy indicators in the 2022-2030 period for Scenario 7 (Best Case).

Table 5.8 – Evolution of university energy indicators (Scenario 7).

Scenario 7 (Best case)	**2023**	**2026**	**2030**
EE Electricity consumption (GWh/year)	45.4	43.2	50
%FV	3.4	13.1	16.8
CESel Specific consumption of electricity (kWh/m²/year)	42	39	43
ET Thermal energy consumed (GWh/year)	67.8	60.8	43,0
CESth Specific consumption of thermal energy (kWh/m²/year)	134	118	90
%QRel Percentage of renewable electricity	20.1	22.3	23.1
%QRth Percentage of renewable thermal energy	0.6	6,1	26,4
Primary energy consumption (toe/year)	14,727	13,653	13,841
Annual emissions (tCO2/year)	33,274	28,430	26,608

It can be observed that the sum of the projected interventions involved in the Energy Master Plan is able to bring about:

- a significant decrease in absolute consumption of thermal energy (ET);
- limited growth of absolute consumption of electricity (EE);
- a distinct decrease in specific consumption of thermal energy (CESth);
- a stabilisation of specific consumption of electricity (CESel), even with an increase in m2 served and heating systems using electric heat pumps, proof of a more efficient use of electricity for various energy services;
- a significant decrease in greenhouse gas emissions, a result of the decrease in annual primary energy consumption, even in the face of university expansion (in terms of heated area) due to the new buildings that will become operational by 2030;
- a marked increase in the amount of energy produced from renewable resources.

In this scenario, the university predicts it will reach the following goals by 2030:

- 24% of total consumption covered by renewable resources; considering that this value was 12% in 2022, this plan makes it possible to double the current amount by 2030 thanks to the overall effect of the efficiency measures implemented;
- a 5.8% reduction of primary energy consumption in 2030 compared to 2023, even in the face of a 10% increase in surface area served compared to 2022;
- annual energy savings of about 2%, in line with the objectives declared in “Fit for 55%”;
- a significant reduction in greenhouse gas emissions in 2030, of 20% compared to 2022 numbers.

The results that can be achieved with the realisation of Scenario 7 (Best Case) are quite positive, even if they are still far from meeting the objectives established by “Fit for 55%” and the European Green Deal.

5.4 "EXTERNAL" OPPORTUNITIES FOR IMPROVING THE UNIVERSITY'S ENERGY BALANCE SHEET

Some "external" factors can impact the energy and environmental balance sheet of the university.
Mention has already been made to the fact that in Consip agreements, it is possible to obtain a guarantee of origin for electricity purchased. In the agreements between EE13 (2016) and EE20 (2022), the average surcharge for "100% renewable" electricity varied between €0.29 and €2.80/MWh, following the trends of the guarantee of origin market, but it is predicted that this cost will increase significantly in coming years, in light of growing demand.
In recent years the university has purchased "100% renewable" certified electricity to obtain, beyond the environmental benefit (indirect, as it stimulates the production of renewable electricity), important positive effects in terms of placement in international rankings on sustainability in the academic world. (To be more conservative, this aspect was not considered in the calculations performed in this plan).
Another aspect to consider is tied to the projects that Hera is developing in the city of Bologna regarding the district heating network and gas distribution.
As mentioned in Chapter 4, Hera will connect all of the loops of Bologna district heating network in the city by 2026 using new pipes that will connect Navile, Fiera, CAAB-Pilastro and S. Giacomo. This modification to the district heating network has an impact on the university's energy balance sheet because the substations currently served by the hydraulic loop connected to the S. Giacomo thermal plant will also be heated with the thermal energy produced by the Frullo waste to energy plant.
While the thermal energy produced by the S. Giacomo thermal plant cannot be considered renewable (the S. Giacomo plant only has gas boilers), the energy produced by the Frullo waste to energy plant is considered a partially renewable resource.

The connection of these currently separate distribution loops has the following effects for the university:

- a part of the thermal energy consumed by the substations in the "cittadella universitaria" can be considered renewable;
- the university can access tax exemptions from using the district heating network powered by the Frullo waste to energy plant; for the university, this means expanding the rebate for the Agraria Fanin substations to all of the substations of the "cittadella universitaria";
- increased reliability of the thermal energy distribution network because each substation can be reached by different internal paths within the network; this plurality of paths drastically reduces the probability that a broken pipe will cause an interruption to thermal energy supply.

Unfortunately, the effect from the connection to the waste to energy plant is not applicable for the new substations placed in the Bertalia District because there is no plan to connect the network that serves this area to the Frullo waste to energy plant.

To facilitate the understanding of this effect, in terms of emissions of CO2-eq, if the university ensures all of the electricity it purchases is 100% renewable and the connection of the district heating network to the Frullo waste to energy plant is completed by 2026 as predicted, it will lead to the decrease in CO2 emissions from 2022 to 2030 depicted in Figure 5.7.
It can therefore be concluded that the realisation of these energy retrofit measures for buildings and equipment, the management interventions, the new solar panel installations (Scenario 7 Best Case), together with the purchasing of renewable electricity and the connection of the "cittadella universitaria" substations to the Frullo waste to energy plant, can drastically improve all of the main energy indicators.

In particular:

- the percentage of thermal energy consumed by the University and produced from renewable sources will near 40%;
- self-generated electricity from solar pv panels will account for 17% of electricity consumption;
- greenhouse gas emissions can be reduced by 75% compared to 2022 numbers;
- the amount of renewable electricity can be maximised (100% green option).

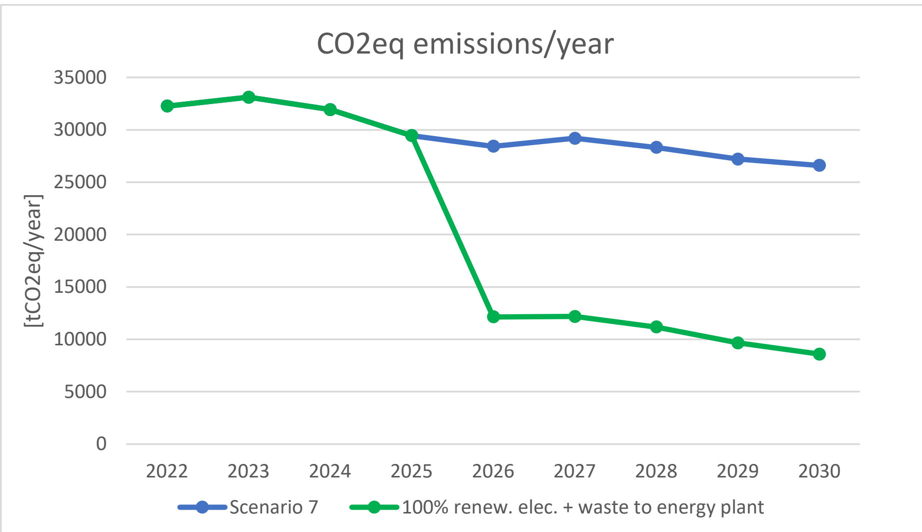
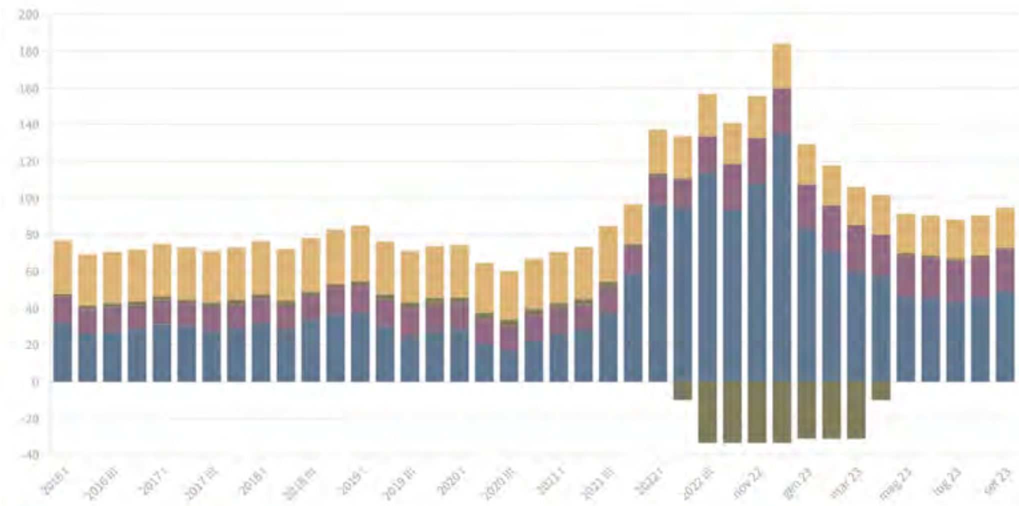
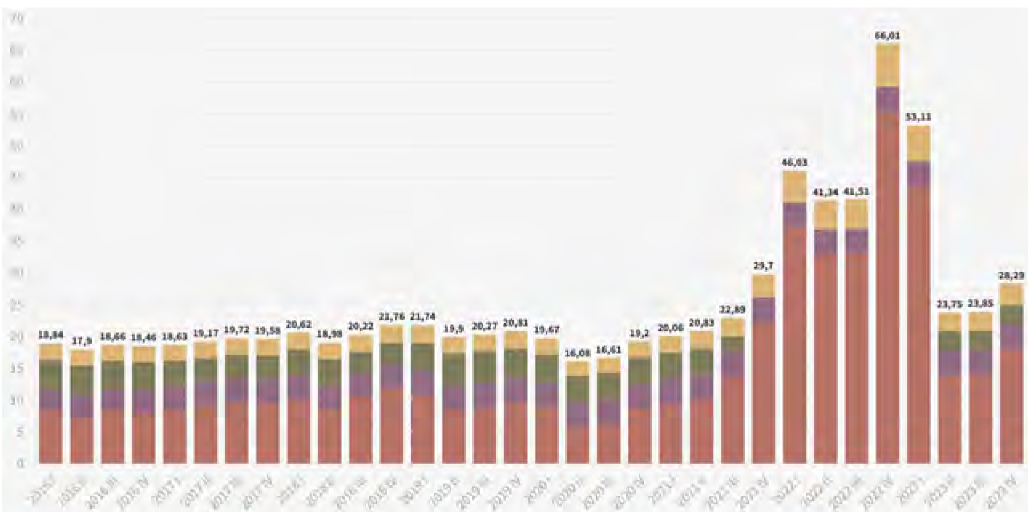


Figure 5.7 – Evolution of annual CO2-eq emissions of the university for Scenario 7 (blue curve), following the purchase of electricity with a guarantee of origin and the connection of the district heating network to the waste to energy plant starting in 2026.





5.5 PAYBACK PERIOD ANALYSIS FOR THE PLANNED INVESTMENTS

In order to decide which energy retrofitting measures to implement, it is necessary to perform an economic evaluation of each scenario, establishing the necessary investment for each intervention, any available funding and the payback period (PBT).

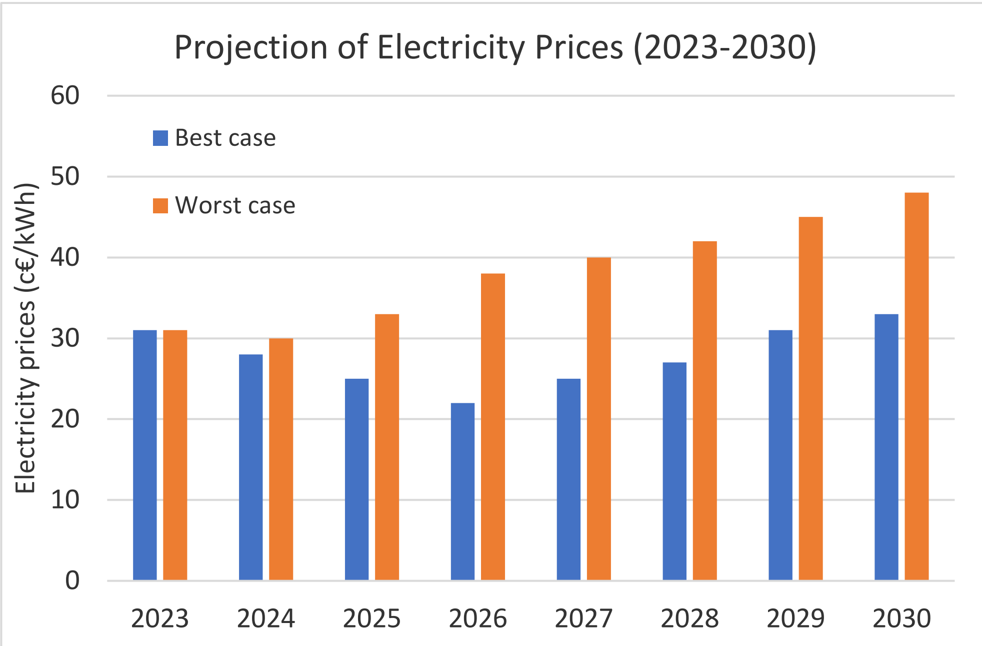
To calculate the payback period for the investment required to implement the various scenarios it is necessary to project expected energy prices for the period 2023-2030.

Figure 5.8 – Trends in natural gas prices (expressed in ¢/Sm3). (Source: ARERA)

Figure 5.8 shows the trends of average natural gas prices (expressed in ¢/Sm3) and electricity (expressed in ¢/kWh) in Italy in recent years; the data used was calculated by ARERA based on typical domestic use. The price of thermal energy for heating is tied to the price of natural gas and therefore experienced a similar trend.
It can be seen in Figure 5.8a that for domestic utilities the average price of natural gas in Italy was between €0.60 and €0.80/Sm3 from 2016 to 2021, while, in the same period, electricity prices oscillated between €0.20 and €0.22/kWh.
The university is in line with these numbers, having paid between €0.65 and €0.75/Sm3 for natural gas and between €0.18 and €0.22/kWh for electricity from 2016 to 2021.
The last trimester of 2021 and all of 2022 saw a rise in natural gas and electricity prices to a maximum of €1.80/Sm3 (natural gas – December 2022) and €0.66/kWh (electricity – IV trimester 2022).
Prices gradually lowered in the first half of 2023, even though prices remained higher compared to those seen before the energy crisis.
In the short term, despite the continuing international tensions in Europe and the Middle East, analysts predict stabilised energy prices slightly above pre-crisis prices (net of current inflation).
In the medium term, the policy established by the European Union with the REPowerEU programme aims at the gradual elimination of fossil fuels for energy production, pushing for the "electrification" of energy services. This trend is evident in transportation, where internal combustion motors are giving way to hybrid and electric motors. Similarly, in buildings there is a push to adopt electric thermal energy production systems (heat pumps) instead of traditional boilers.

In the long term, a gradual decrease of natural gas demand should be witnessed in Europe, with a resulting increase in demand for electricity.
It is therefore legitimate to expect a gradual increase in the price of electricity, following the increase in demand and elevated costs of "green" equipment that will produce it in the future, and a gradual reduction in natural gas prices following the decrease in demand and the introduction of renewable and power-to-gas production systems to distribution networks.
As the main service providers project, in the short term energy costs will remain stable near pre-crisis prices, although slightly higher, and it is not expected to return to pre-2020 prices in the medium term.
When performing these economic evaluations, two possible trends in natural gas and electricity prices were considered for the 2023-2030 period, which are visible in Figure 5.9.
These trends are: a) Best Case: a reduction in electricity prices in the short term (2023-2026) and a gradual increase in the average price in the long term (2026-2030), and for natural gas, prices decrease from 2025 forward; b) Worst Case: an increase in electricity prices from 2024 forward, and for natural gas, prices begin to decline only after 2027.

In the Worst Case Scenario, electricity and natural gas prices will remain higher than pre-crisis prices in the 2023-2030 period.Using this hypothesis, it is possible to estimate the economic savings generated by the efficiency measures proposed in the various scenarios of this Energy Master Plan, and therefore the payback period.



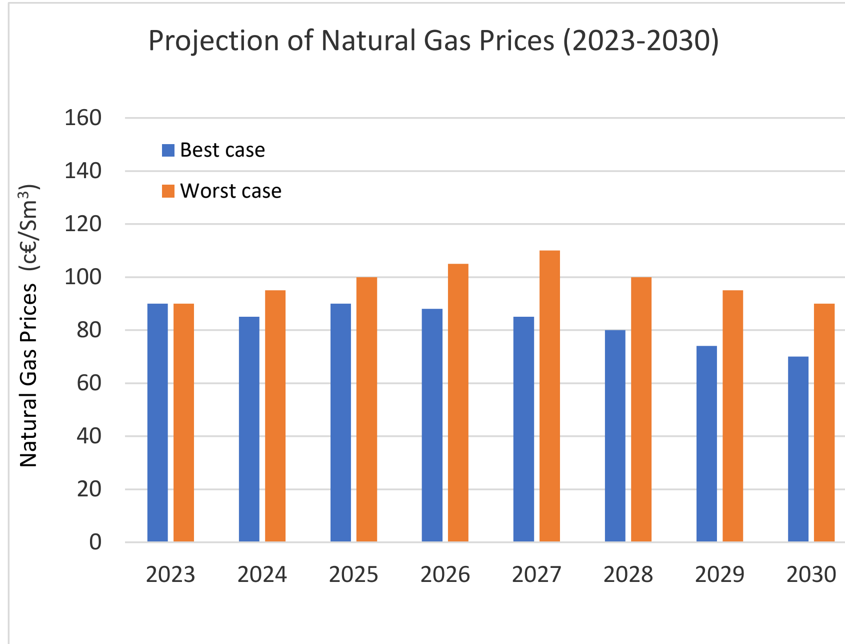


Figure 5.9 – Prediction in trends in market prices of electricity and natural gas (2023-2030).

An analysis of the payback period (PBT expressed in years) was calculated for each of the scenarios analysed in this chapter, taking into account the energy price trends described above, and as such two PBT values were calculated for each scenario; the two values indicate the interval of time in which it is predicted that actual payback period will land for a given scenario.

Figure 5.10 shows the payback period (PBT) for the scenarios analysed.

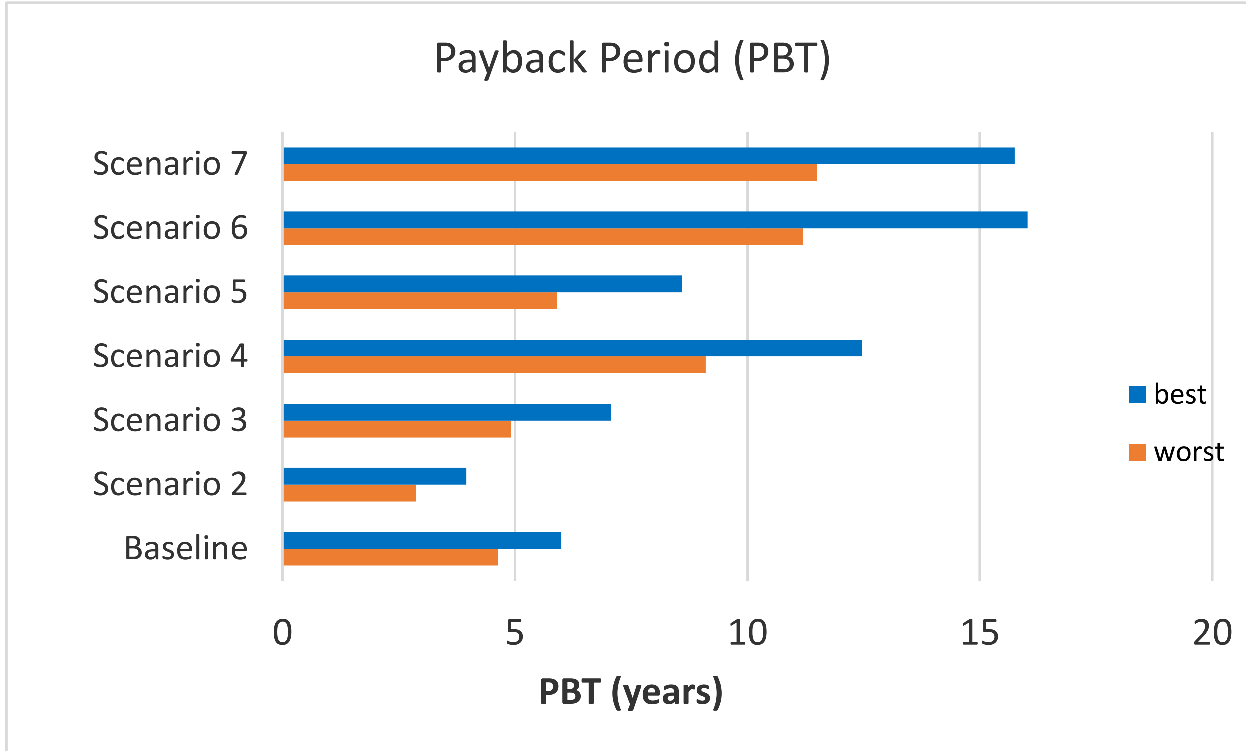


Figure 5.10 – Payback period (PBT) for the scenarios analysed, considering energy price fluctuations (2023-2030).

The expected investment value, amount of funding, €/kWh of annual primary energy savings and the interval in which PBT is likely to occur are indicated for each scenario in Table 5.9.

As shown, Table 5.9 shows the funding already obtained by the university to implement the interventions in the three-year programme thanks to the MUR call for contributions 2 (Ministerial Decree 1274 of 10/12/2021). The amount indicated corresponds to 60% of the expenditures for the implementation of the actions indicated in the projects presented to the MUR, equal to €5,639,050. Thanks to this funding from MUR, the university is expected to see a payback period for the investment in the actions indicated in the Baseline of 4.6 to 6 years. Without this funding from the MUR, the efficiency measures in the Baseline would have had a payback period of 11-15 years.

The values indicated are not gross of the tax deductions that can be obtained from several interventions (e.g., installing solar pv panels). This result underlines how, to shorten the payback periods of the efficiency measures for building envelopes (like those indicated in the three-year program), funding and incentives are fundamental.

This is shown in Scenarios 6 and 7, which require an additional investment of €20 million on buildings that cannot currently come from funding/ incentives, and as such these scenarios are characterised by a payback period of 11-16 years.

Table 5.9 – List of the scenarios analysed in the Energy Plan, including the necessary investment, any funding obtained so far, average annual savings per unit of energy saved and payback period (PBT)

Intervention	Investment (€)	"Average unit cost of energy savings (€/kWh/year)"	PBT (years)
Scenario 1 - Baseline: Implementation of three-year programme	9,398,417	1.69	4.6 – 6.0
Scenario 2: Scenario 1 + Management interventions	9,800,000	1.22	2.9 – 4.0
Scenario 3: Scenario 2 + Solar Energy Plan (5.377 MWp)	19,800,000	3.09	4.9 – 7.1
Scenario 4: Scenario 3 + Replacement of boilers	29,800,000	4.35	9.1 – 12.5
Scenario 5: Scenario 3 + Relamping and BMS upgrade	29,800,000	2.4	5.9 – 8.6
Scenario 6: Scenario 3 + New interventions on building envelopes	39,800,000	4.58	11.2 – 16.0
Scenario 7: Scenario 3 + Replacement of boilers + Relamping and BMS upgrade + New interventions on building envelopes	59,800,000	3.92	11.5 – 15.7

Looking at the data in Table 5.9, it can be observed that:

- the efficiency measures that will be implemented as part of the three-year programme (Baseline) allow the university to recuperate its investment in less than 6 years, thanks to the funding received from the MUR;
- if the management interventions described in the Energy Master Plan are implemented immediately, making consumption control and evaluation processes more systematic, the investment for the interventions in the three-year programme will have an even shorter payback period, less than 4 years (Scenario 2);
- pairing the three-year programme with the Solar pv Energy Plan (5.4 MWP) (Scenario 3), with an additional investment of €10 million, is an advantageous investment even without specific funding as the payback period is less than 7 years;
- the implementation of a relamping campaign paired with the upgrading of the university BMS, along with the implementation of the Solar pv Energy Plan (Scenario 5), has a payback period of less than 6-9 years and is therefore sustainable for the university's budget. In this case, it is important to make use of the Conto Termico 2.0, or involve ESCos to reduce the university's investment, significant reducing the payback period;
- the scenarios include the replacement of heat generators (Scenario 4) and actions to further insulate the buildings with the highest levels of thermal losses (Scenario 6) have payback periods of 9-13 and 11-16 years respectively, and as such are interventions that, from an economic perspective, are not attractive for the university without specific ministerial funding and/or incentives;
- Scenario 7, which is a combination of all of the actions analysed, is also affected by the fact that some actions (replacement of heat generators and building insulation) have longer payback periods, and as such, the entire package of interventions included in the Energy Plan is achievable only with the help of specific funding programmes. Receiving funding for 50-60% of all of the actions planned in Scenario 7 would make it possible to halve payback periods and make the plan achievable and economically sustainable for the university.

It can be concluded that:

1. it is advantageous to immediately implement the management interventions described in the Energy Master Plan as the cost of these interventions is recovered in about a year;
2. the realisation of the Solar pv Energy Plan (5.4 MWp) is an intervention with an interesting payback period, it can be completed quickly and allows for up to 17% of university electricity consumption to be self-generated. In light of the predicted general increase in electricity prices in the medium to long term, the realisation of the Solar pv Energy Plan is able to protect the university from volatility of electricity prices. The results of the analysis show that payback periods tend to grow shorter as installed capacity increases, for which it is advantageous to install the maximum capacity possible from a technical point of view, and not limit actions to partially completed interventions;
3. relamping and upgrading the university BMS are simple to implement and have payback periods of less than 5 years and should certainly be given high priority in the Energy Master Plan. They are scalable actions that lend themselves to being completed in a series of steps based on available financial resources. Relamping and an upgraded BMS make the university eligible for funding thanks to the Conto Termico 2.0;
4. it is necessary to begin planning the modernisation of thermal power units to be prepared in case it is required that natural gas generators be replaced. This type of action is only possible in the presence of funding: therefore, to prepare executive designs of the desired intervention will facilitate the university's participation in the next relevant calls for funding proposals;
5. the same reasoning holds for the energy retrofit actions on building envelopes; they have long payback periods and as such are only sustainable with funding/incentives. It is necessary to begin planning the next actions in order to have the required documentation available to participate in future calls for funding proposals.

The results suggest aiming for the implementation of Scenario 5 in the short term (2023-2026), and, with the help of funding and incentives, striving to implement Scenario 7 (2030).

Figure 5.11 shows the plan for the investments necessary to implement Scenario 7 in the 2023-2030 period.

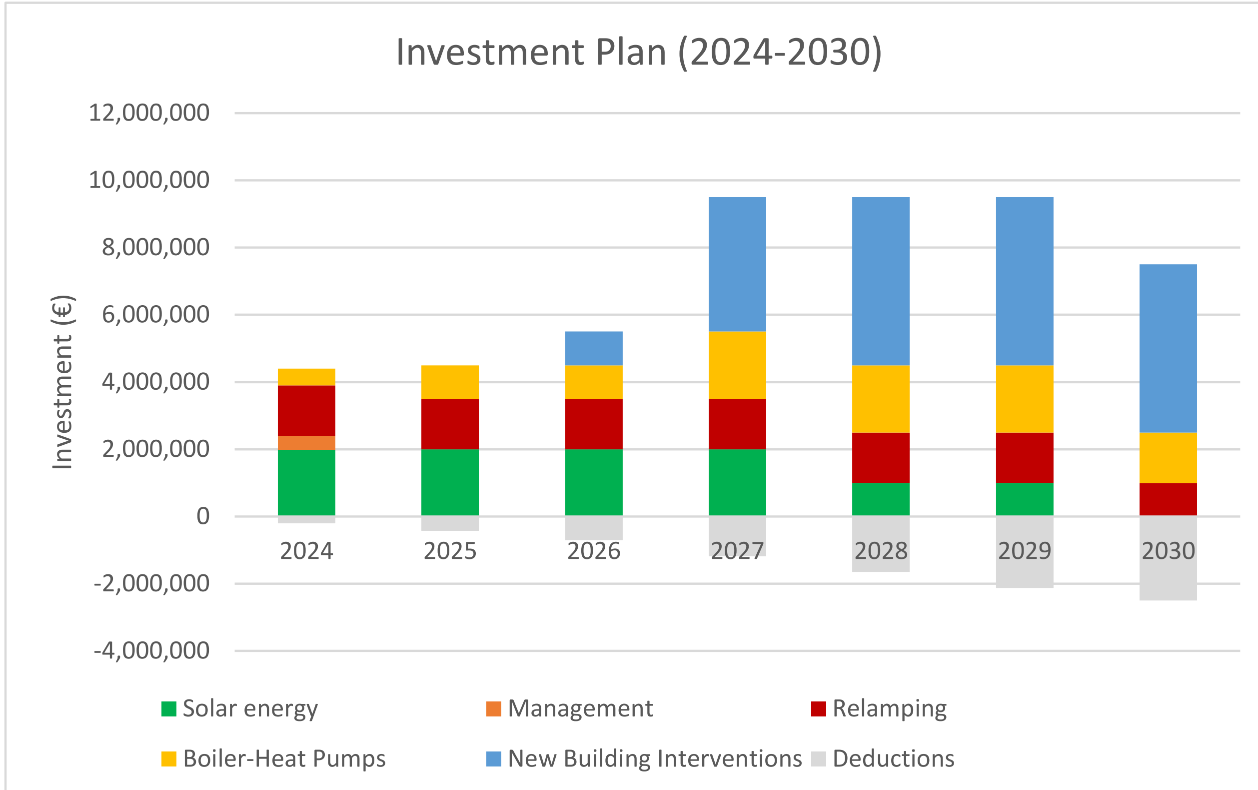


Figure 5.11 – 2023-2030 investment plan to implement Scenario 7 (Best Case).

Figure 5.11 also shows the potential value of deductions related to the actions described in the Energy Plan. The university can use detractions accrued from the implementation of these actions to compensate for corporate income tax (IRES).

From the tax point of view, a detailed analysis of the applicable deductions thanks to the actions carried out will be performed, with the goal of covering as much of the university's corporate income tax (IRES) as possible.
Since 2018, the university's corporate income tax payment has been around €500k/year. The data in Figure 5.11 shows that tax deductions increase over time with the number of actions performed, totaling over €2 million in 2030, an amount over the average corporate income tax paid by the university. This analysis highlights how not all potential deductions will be accessible to the university.

In addition, it is important to remember how the implementation of some interventions can also cause an increase in the taxes paid by the university. As for the installation of solar pv panels, when the system is considered a real estate property with an independent cadastral income, it is necessary to pay property taxes (IMU) on the system. A specific consultation will be requested to understand the tax effects of new solar pv panel equipment in greater detail.

It is important to emphasise once again that in the calculation of the payback periods for the various interventions tax deductions were deliberately left out to make the prediction more conservative.

5.6 MILESTONES OF THE 2024-2030 ENERGY MASTER PLAN

In 2024, the Energy Master Plan foresees an investment of €4.4 million, which will cover the following interventions:

- increase in solar pv panel capacity (around 1.0 MWp);
- exterior and interior relamping;
- upgrading university BMS;
- management interventions and external consultations to obtain UNI ISO EN 50001 certification;
- energy audits to be used when participating in future calls for funding for energy efficiency.

Within the first half of 2024 the calls for funding for the installation of the first lot of solar pv panels and exterior relamping will be published.
In 2025 a further €4.5 million will make it possible to continue solar panel installation, exterior and interior relamping and the upgrading of the university BMS.

By 2025 the phase-out of heating oil and fuel oil power units (Milestone M1) and total relamping of exterior areas will be completed (Milestone M2); in 2026, relamping of interior areas will come to a conclusion (Milestone M3), and in 2027 5.4 MWp of new solar pv panels will be installed (Milestone M4), UNI EN ISO 50001 certification will be granted (Milestone M5), all gas boilers will be replaced and the university's thermal energy systems will be recorded in the CRITER register. In addition, sub-metres will be added to medium voltage electrical cabinets to measure the electricity used by individual buildings with the same metre (POD).

In 2026 the design of new building retrofit interventions will begin for buildings with poorly thermal insulated envelopes and/or problematic summer performance. This planning could be moved up to 2024-2025 if specific calls for funding regarding energy efficiency of public buildings (or university buildings) are published in the coming months.
These requalification actions will be completed by 2030 (Milestone M7). By 2029 the solar panel control systems will be upgraded and the oldest solar panels will be replaced in order to guarantee greater performance of all of the university's solar panel systems (Milestone M8). By 2030 all of the university's thermal power units will be connected to the university's BMS (Milestone M9).

Towards the end of the period in question, 2027-2030, in addition to the implementation of additional building retrofit actions planned at the beginning of the period, the gradual electrification of thermal power units by replacing gas boilers with heat pumps will begin based on the timelines dictated by any European Directives (Milestone M10). Where it is impossible to replace these boilers, the building will be connected to the district heating network, if present.

Milestone		31/12/2023	31/12/2024	31/12/2025	31/12/2026	31/12/2027	31/12/2028	31/12/2029	31/12/2030
M1	Phase-out of heating oil and fuel oil			M1					
M2	Total exterior relamping			M2					
M3	Total interior relamping				M3				
M4	New solar panel systems (5.377 MWp)					M4			
M5	UNI EN ISO 50001 certification					M5			
M6	Registration of all power units in CRITER					M6			
M7	New efficiency interventions performed on buildings								M7
M8	Efficiency interventions for solar panel systems							M8	
M9	Completion of university BMS								M9
M10	Replacement of boilers with electric heat pumps								M10

Table 5.10 –The 10 Milestones of the University Energy Plan.

5.7 FLEXIBILITY IN PLANNING IN THE CASE OF FUNDING FROM THE NATIONAL RECOVERY AND RESILIENCE PLAN OR REPOWEREU

The investment plan may require adjustments in the coming months due to the possible publication of calls for funding dedicated to energy efficiency of public or university buildings. This funding could be tied, in whole or in part, to the National Recovery and Resilience Plan or REPowerEU.
With its approval of the REPowerEU plan, the European Union allocated non-repayable resources for Italy equal to €2.76 billion for energy efficiency actions. In addition, the Italian government declared its plan to use 7.5% of money received from the cohesion fund for 2021 to 2027 for energy efficiency interventions, funds that were already destined to be used for goals in line with those of REPowerEU. This means Italy has an available fund that can be dedicated to energy efficiency and completely cover costs with the only limitation being to report all actions by 2026. If this situation occurs, it will be important to move up some of the interventions in the University Energy Plan using all of the funding opportunities that become available and focusing on the actions that are fastest to implement.

Among the actions in the Energy Master Plan, the following can be considered possible to complete by June 2026:

- installation of around 5.4 MWp of new solar pv panels with the addition of a dedicated storage system (M4);
- completion of the university BMS (M9)
- completion of exterior and internal relamping (M2 and M3);
- requalification of a portion of gas thermal power units and cooling systems.

These actions require a greater investment for the purchase of equipment and reduced amount of work. The purchase of equipment, especially if it involves large quantities, can allow for economies of scale. By 2030 all of the university's thermal power units will be connected to the university's BMS (Milestone M9).
If these conditions are met, the investment plan for the implementation of the Energy Plan will be adjusted as shown in Figure 5.12.

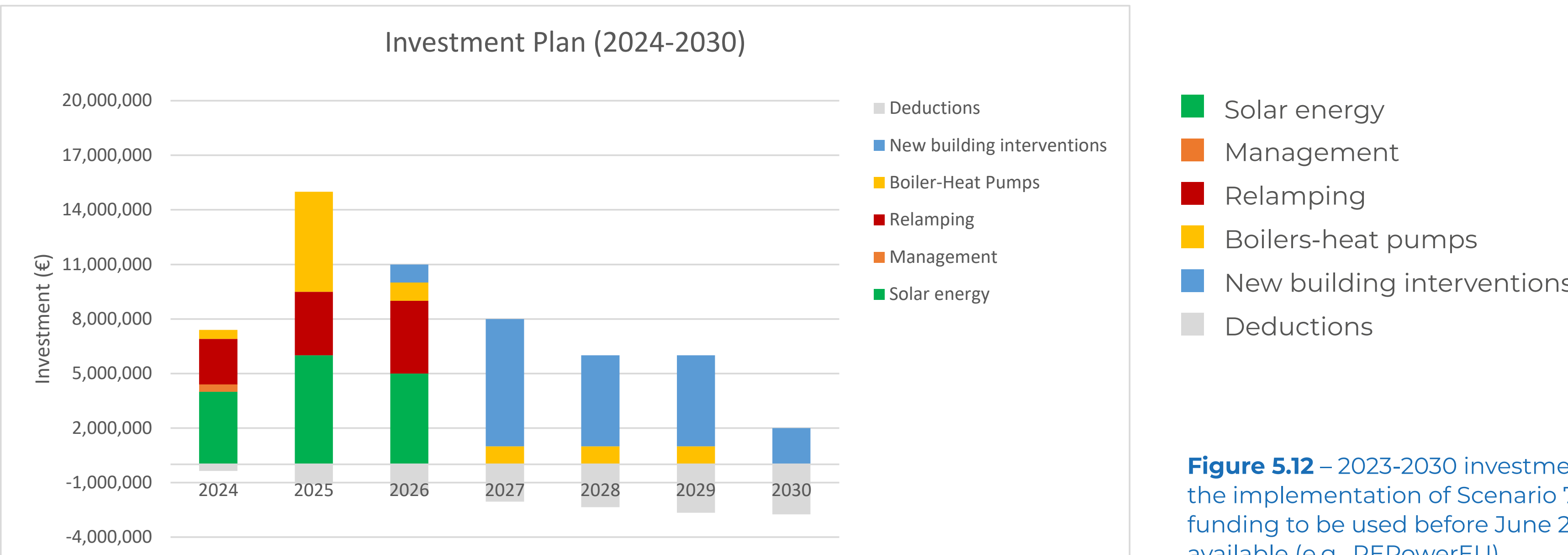


Figure 5.12 – 2023-2030 investment plan for the implementation of Scenario 7 (Best Case) if funding to be used before June 2026 becomes available (e.g., REPowerEU).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Comparing Figure 5.11 with Figure 5.12, it can be seen how the increase in pv solar energy capacity with the addition of storage batteries for another €5 million, relamping and the completion of the BMS network could be entirely funded in the first years of the project (2024-2026) in order to report €33.4 million of the total €55.4 million included in the plan (in addition to the other €9.4 million already funded as part of the three-year public works programme).

In this case, investment in 2024, beyond the €4.4 million required to start management interventions and begin planning, also relies on the publication of the first calls for funding proposals for the installation of new solar panels and the relamping of a first group of exterior and interior lighting fixtures for an additional total of €3 million.
The limited timeline represents a major obstacle for concentrating Milestones M1, M2, M3, M4 and M9 in the short term, which have a deadline of 2026. To attempt to comply with projected implementation times, it is necessary to focus on:

- the use of Consip tools to assign jobs;
- externalisation of design phase;
- involvement of external partners.

Consip's Dynamic Purchase System of the Public Administration (SDAPA) covers the supply and installation of the following for public administrations: (i) solar panels; (ii) solar thermal systems; (iii) heat pump systems for heating and cooling; (iv) condensation boilers; (v) new lighting systems (interior relamping); (vi) transparent windows and doors; (vii) thermal insulating panels.

Therefore, only exterior relamping (M2) and the upgrading of the university BMS are excluded from the energy efficiency areas covered by SDAPA.
For these two areas, the university can make use of external technicians who will plan interventions, including by drawing from the list of suppliers of services relating to architecture and engineering (for totals under €100k), which can speed up the external allocation of planning.
The involvement of external private partners to reach certain Milestones can be another factor able to accelerate the realisation of certain actions, particularly those characterised by short payback periods and that generate Energy Efficiency Certificates (TEE) that are attractive to private ESCos.

5.8 REINVESTMENT STRATEGIES FOR SAVINGS RESULTING FROM THE IMPLEMENTATION OF THE ENERGY MASTER PLAN

The total investment for the implementation of Scenario 7 (Best Case) is €60 million. To start the various initiatives (design, tenders, execution) and reach the first 6 Milestones, it is necessary to invest an average of €6 million annually for the next 4 years.

In the first 4 years, average expected savings are €1.5 million/year for electricity and €0.7 million/year for thermal energy (natural gas and district heating network) based on the predicted price trends in Figure 5.9. This means that in the next 4 years there is a potential savings of €8.8 million compared to a total investment of €34 million (including the roughly €10 million for the works currently underway).
These savings could also be invested in order to fund the remaining interventions included in the Energy Plan (Figure 5.13).

Following this model, the university will allocate what is needed to implement the first package of interventions (red area of Figure 5.13a). These expenditure can be entirely covered by the university's budget or funded through specific national calls for funding proposals at the national (MUR, Conto Termico 2.0) or European (REPowerEU) levels, or by working with external ESCos or sponsors, or beginning a public-private partnership (PPP). In addition, Energy Service Contracts announced by central purchasing bodies allow the university to entrust the realisation of efficiency measures to third parties, which makes it possible to immediately see savings in energy bills.

The savings generated by these interventions (green area of Figure 5.13a) will be entirely used to fund the second package of interventions the following year. This is equivalent to maintaining a fixed amount in the balance sheet to cover energy expenses for N years, after which it is simply energy savings that cover the costs of new efficiency measures.

If the savings generated by these measures were only partially reinvested in new interventions (Figure 5.13b), so as to reduce the expenses related to paying energy bills in the university balance sheet during the implementation of the Energy Master Plan, the timeline for achieving the established goals would be prolonged.

In the case of involvement of external partners (ESCo, PPP), the pre-intervention costs paid by the universities to cover bills becomes a fee that is paid to the private company that assumes the burden of the investment for the realisation of the intervention, and the savings generated are necessary for the private company to see a return on investment (third party financing).

Third party financing can also adopt a "first out" (Figure 5.13a) or a "shared savings" (Figure 5.13b) logic. A "first out" logic involves the private company using all of the savings to see a return on investment, while "shared savings" involves the private company leaving part of the savings to the university.

Comparing Figure 5.11 with Figure 5.12, it can be seen how the increase in solar pv energy capacity with the addition of storage batteries for another €5 million, relamping and the completion of the BMS network could be entirely funded in the first years of the project (2024-2026) in order to report €33.4 million of the total €55.4 million included in the plan (in addition to the other €9.4 million already funded as part of the three-year public works programme).

In this case, investment in 2024, beyond the €4.4 million required to start management interventions and begin planning, also relies on the publication of the first calls for funding proposals for the installation of new solar panels and the relamping of a first group of exterior and interior lighting fixtures for an additional total of €3 million.

The limited timeline represents a major obstacle for concentrating Milestones M1, M2, M3, M4 and M9 in the short term, which have a deadline of 2026. To attempt to comply with projected implementation times, it is necessary to focus on

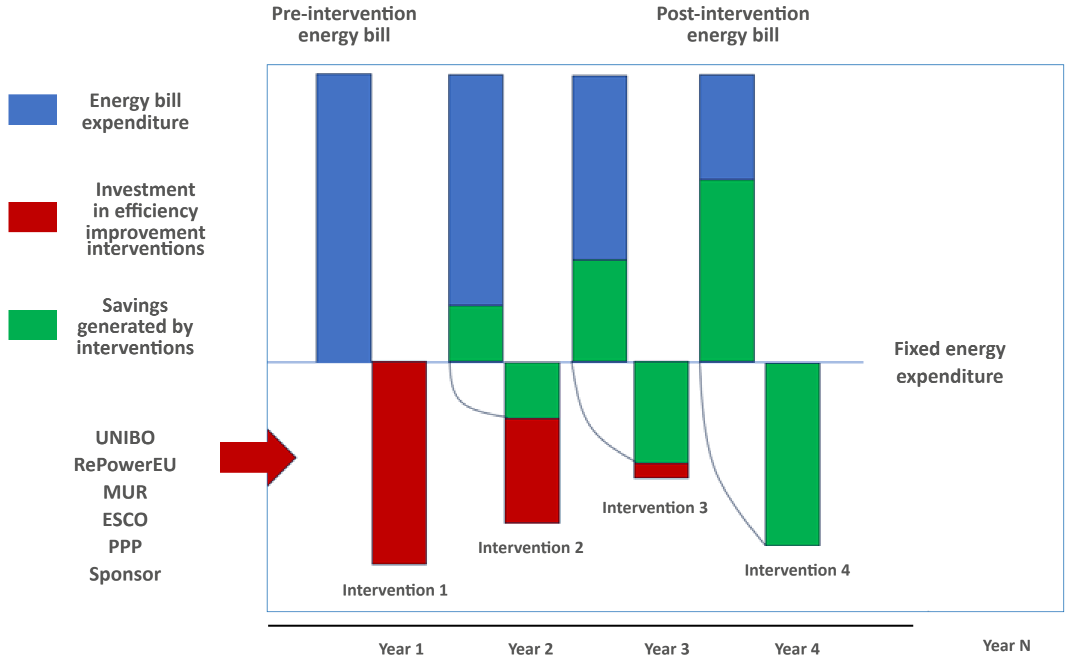

Figure 5.13a – Use of savings generated from efficiency measures to fund new interventions or recuperate investment: "first out" model

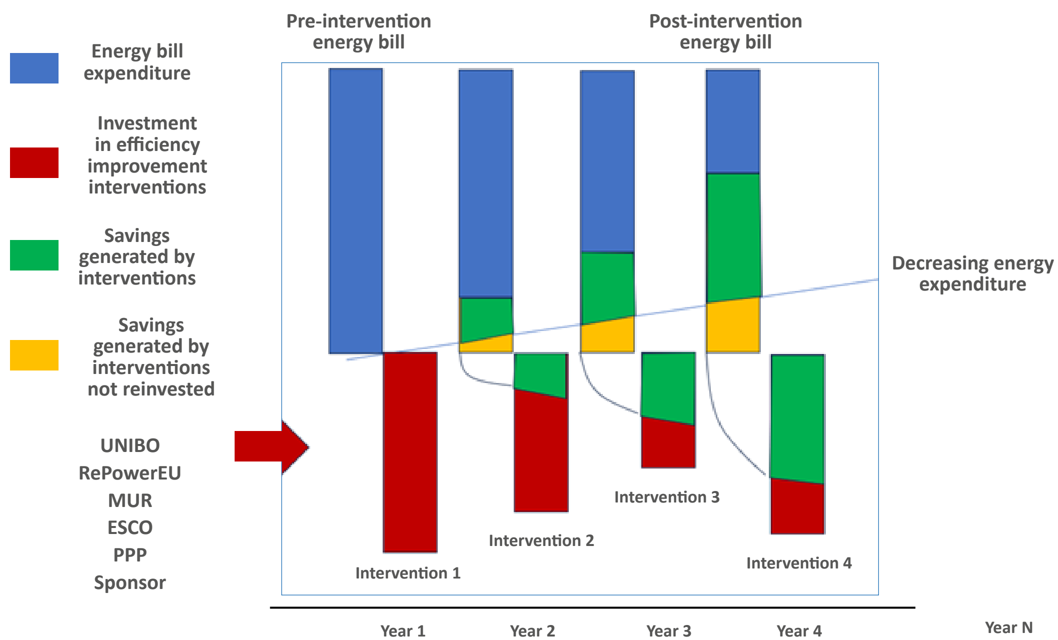

Figura 5.13b – Use of savings generated from efficiency measures to fund new interventions or recuperate investment: "shared savings" model.

6. CONCLUSIONS

The University Energy Master Plan outlines a series of actions able to increase the efficiency of the university's end energy use and make the energy impact of the university's activities more environmentally sustainable.

By 2030, the full implementation of the plan will be able to:

- stabilise electricity consumption below average consumption of recent years (< 50 GWh/year) including after new buildings become operational and the electrification of heating systems;
- stabilise average annual electricity consumption per surface unit (< 43 kWh/m2/year) even with increased use of electricity for heating systems through the introduction of heat pump power units;
- reduce consumption of natural gas to below 10% of annual primary energy consumption;
- increase the amount of energy from renewable resources that covers total consumption;
- achieve amounts of self-generated electricity from solar pv panels that account for 17% of electricity consumption in 2029;
- halve annual consumption of primary energy from non-renewable resources from 2022 to 2030;
- reduce greenhouse gas emission by over 50% by 2030.

There are 10 milestones within the plan to help reach these goals:

1. the elimination of all power units that run on heating oil and fuel oil by 2025 (Milestone M1);
2. total exterior relamping by 2025 (Milestone M2);
3. total interior relamping by 2026 (Milestone M3);
4. the installation of 5.4 MWp of new solar pv panels by 2027 (Milestone M4);
5. UNI EN ISO 50001 certification by 2027 (Milestone M5);
6. replacement of all non-compliant gas boilers and the registration of the university's thermal energy power units in the regional CRITER register by 2027 (Milestone M6);
7. the planning of new energy retrofit interventions on buildings by 2030 (Milestone M7);
8. increasing efficiency of solar panel control systems and the replacement of the most outdated solar panels by 2029 (Milestone M8);
9. the completion of the university BMS by 2030 (Milestone M9);
10. electrification of thermal power units through the replacement of gas boilers with heat pumps by 2030 (Milestone M10).

The Energy Master Plan aims to establish the direction in which the university must move in the short and medium term to reduce energy consumption to make all of the services it offers its students more sustainable.

Centering the objectives in this master plan is only possible with the involvement of the entire university community that, with informed and responsible behaviours, will aid in the completion of the technical actions described in this document.

7. GLOSSARY

%FFO
percentage of energy costs relative to Ordinary Financing Fund

%FV
percentage of self-generated electricity relative to electricity consumed annually

%QRel
percentage of electricity produced from renewable sources relative to annual consumption

%QRth
percentage of thermal energy produced from renewable sources relative to annual consumption

CESg
consumption of heating oil per surface floor unit served [l/m2/year]

CESel
specific consumption of electricity per net surface floor unit served [kWh/m2/year]

CESth
specific consumption of thermal energy per net surface floor unit served [kWh/m2/year]

CEStot
total specific consumption of primary energy per net unit surface floor served [kWhep/m2/year]

CSTUD
cost incurred for energy supply per student [€/student]

CSUP
total cost incurred per unit surface floor served [€/m2]

CSUPm
total average cost incurred per surface floor unit served [€/m2]

d
day

EMtot
equivalent emissions of carbon dioxide per unit of primary energy consumed [tCO2/toe]

FFO
Ordinary Financing Fund [€]

GWP
Global Warming Potential

PBT
payback period

PFV
peak power of solar pv panel systems in self-consumption mode

pv
photo voltaic

STLR
area connected to district heating network

toe
tonne of oil equivalent

TLF
district cooling network

TLR
district heating network

tCO_2
tonnes of carbon dioxide

U
thermal transmittance [W/m2/K]

Uf
thermal transmittance of transparent surfaces [W/m2/K]

Ut
thermal transmittance of roofs [W/m2/K]

Uw
thermal transmittance of external walls [W/m2/K]


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