RENOVATION STRATEGY

UNIVERSITY OF FLORENCE
building stock

NOTE

The proposed strategy is intended to generate a range of possible future pathways for the long term renovation of the public university building stock in Italy.

Looking towards the fully decarbonized European Union of 2050, the strategy envisions renovation scenarios for the Italian university building stock, by modelling and profiling the existing to better understand, quantify, design and build the most sustainable university buildings of tomorrow.

The strategy is dedicated to higher educational buildings and focused on the building stock of the University of Florence.

The section "*Policy appraisal*" has been elaborated by Università della Campania "L. Vanvitelli" - Med-EcoSuRe associate partner, which also highly contributed to the section "*Roadmap*".

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1. Overview

University can be defined as an institute of higher education and research, where academic degrees are granted in a variety of fields and subjects of knowledge.
The name derives from the Latin universitàtem meaning "the whole of all the things", turning from univèrsus. The name is intended as "understanding of all the things", but also the "place of public study where it is teached the universality of science | universitas studiorum". It has to be noted that the term was referred to, until the Middle Ages, corporations and guilds, alluding to groups of teachers and students.
The concept of modern universities emerged in Europe of the late Middle Ages (since the XII cent.), with the foundation of the oldest universities of Bologna (1088), Paris (1150), Oxford (1167) and Cambridge (1209). University of Bologna can be considered as the most influential model for the development of universities in South Europe.
Yet, more informal traces of higher education systems can be found in ancient times since the semitics, influencing the ancient Greek culture (e.g. Aristotelian School), the Roman, and the Christian, at the basis of mediaeval universitie.g.
Referring to the mediaeval foundation of universities, McCormick explains that "the renaissance of the twelfth century began with the monastic and cathedral schools and ended with the earliest universitie.g. (...) The twelfth century expanded the courses of study in the curriculum of the Seven Liberal Arts which furnished the basis of university studies and led to the development of the professional faculties of law, medicine, and theology" (McCormick et al. 1953, pp. 315)[1].
First universities in continental Europe were lecture halls in available buildings gathering teachers and students. Didactic activities took place in buildings rented by the masters and larger events such as examinations and assemblies took place in churches and convents (Ilgaz, 2014)[2].
According to Coulson et al. (2011)[3], only in the 15th century the University of Paris started to procure property and build a number of lecture halls, colleges, lodgings and churches:
"As the Renaissance progressed, universities old and new acquired befitting academic quarters, comprising lecture theatres, assembly rooms, chapels, libraries and lodgings. These structures, often incredibly lavish, were physical manifestations of the omnipresence of the European university, a visible sign that the university had evolved from a loose association of scholars and masters into an institution" (p. 3).

[1] McCormick, P. J. and Cassidy, F. P. (1953) History of Education, A Survey of the Development of Educational Theory and Practice in Ancient, Medieval, and Modern Times. The Catholic Education Press, Washington D.C.
[2] Ilgaz, B. (2014) University campus design in spatial, social and political considerations, Master thesis, Master of Science in Urban Design in City and Regional Planning Department, Middle East Technical University (Turkey).
[3] Coulson, J.,Roberts, P. and Taylor, I. (2011) University Planning and Architecture, The Search for Perfection. Routledge, New York.

Looking at the religious background of first universities, in a recent essay on the topic of "university as a building typology" Wilkinson (2014) sustains that "the ancient madrasas of Fez and Cairo and the universities of Bologna, Paris and Oxford originated as training facilities for the feudal elites, and since they were administered by prelates, they borrowed forms familiar from buildings of worship. The cloister became the quad, monastic cells became student rooms, and both facilitated the control of unruly youths".

During the Enlightenment, starting from France, new kinds of high educational institutions were established, with the activity of the university increasingly focusing on research and technology (polytechnics).

Until the second half of the 19th century European universities operated in the old buildings remaining from the 15th to 17th centuries. The majority of these buildings were initially designed for other purposes, such as convents, evolved across time and still adapted, not without criticism, to the contemporary high educational needs.

The distribution of universities in city centres is diffused in European historical big and medium size cities, and has been accompanied by a related urban development of services and collateral spaces (commercial, cultural, etc.) contributing to the creation of "European university cities", where the students and university services are distributed across the city (gravitating around the historical university building locations in the city-centre).

A different path has evolved in the non-continental Europe (UK) from the Oxford and Cambridge mediaeval universities, then diffused in the new world and finally coming back to Europe at the post II WW's awakening and following economic boom, when new needs and numbers required the construction of wider high educational spaces, mostly in the periphery of cities.

The term "university campus" commonly refers to a piece of land on which a university and other related institution buildings are situated.

The word derives from the Classical Latin "camp" , originally meant garrison, a military camp based on the war-field. Only in the 18th century the term was used in reference to university grounds (firstly referring to the College of New Jersey, now Princeton University, Ilgaz, 2014). The reference to "campus university" became more popular after the II WW, when the growth of students gave rise to large campuses, whose structure and characteristics developed from the English universities, dating back in the 12th century, of Oxford and Cambridge (model "Oxbridge"). The distinctive character of the Oxbridge model, in comparison with the ones in the continental Europe (Paris, Bologna), was the organisational structure, composed of a central university body and several autonomous colleges, with their own buildings, staff and endowments. The model has been largely adopted by the new world, starting from America, where it developed a specific path originating what can be defined today as an "international university campus" typology.

From an architectural point of view, the enclosed courtyard of the Oxbridge model can be derived both from islamic madrasas and the cloisters of mediaeval convents, implying the will to keep separated the students and the city life, consenting a major control over them, played by building themselves. Nowadays, university campuses have spreaded worldwide with similar functional-spatial areas, but adapted to the local context and socio-climatic conditions.

In the last century, the development of European university campuses has been usually an enlargement of the existing university cities, mainly interesting their outskirts, to cover an even wider and differentiated offer of education and research paths and services for students, which the historical city cannot host anymore.

1.1 Functional and spatial university aspects

Beyond their urban configuration (following the European model of university cities, with buildings distributed in consolidated-historical urban tissue or the American model of spreading isolated campuses), universities require specific functional spaces, with related spatial requirements and performance, for the correct conduction of all the university activities Functional aspects are fundamental in the assessment/evaluation of buildings, since they originate the demand of spaces and performance of the specific building typology (from occupancy and activities to be carried out), influencing the building energy and comfort profiles, but also the architectural and environmental quality.

If the historical function of universities is to host didactic and research activities, the development of university campuses added many other student services, starting from the provision of accommodation. It has to be noted that in the historical European university model, the progressive introduction and enlargement of student services (starting from student housing) developed across the historical city but also outside, with the new functions settled in existing or new buildings (usually at a neighbourhood scale/proximity with the pre-existing historical university buildings) and/or in more peripheral available areas (e.g. sport centres), even connected by urban mobility systems.

In more recent European campuses, all the university functional spaces are gathered together in a defined area (the campus), usually with an internal pedestrian mobility and a good connection with the rest of the city.

The functional spaces characterising universities/university campuses can be grouped in the following categories:

1. Education and research
2. Related services (administration, management, student services)

3. Accommodation
4. Other services (sports, culture and leisure activities)

Each functional-spatial category (or functional area) is characterised by the presence of spaces characterised by very different spatial requirements (and deriving energy and environmental quality performance):

1. Educational and research spaces

The most representative educational university space is the "aula magna", the biggest classroom where academic lectures for many students are performed in an appropriate space (in terms of dimensions and configuration, but also of acoustic, visual, air quality for a large numbers). For the specific needs of the different didactic and research activities in the wide range of knowledge fields, and to the number of enrolled students, universities offer for a high-medium- and small classrooms. For lectures, school classrooms can be considered as a reference. According to the type of studies, the university can be equipped for example with laboratories for engineers and applied sciences, workshop and atelier for art and design schools, demanding for very specific spatial requirements (e.g. visual quality, ventilation, controlled thermal conditions); medical studies are usually hosted in operating hospitals for practical education.
In all cases, the organisation of didactic and research activities requires the presence of a proportional number of offices, where the academic boards can carry out their activities on a daily basis.
Another common, indispensable and symbolic university functional-space is the library, which can be dedicated to a specific discipline or gathering different ones; it can be considered as an ad-hoc architectural typology. To stimulate personal and group study sessions, universities also offer dedicated and open study rooms, equipped with free wifi and charging stations.
Less specialists but indispensable for education and research purposes are the common indoor and outdoor spaces where the academic community can spontaneously interact, meet and socialise beyond teaching, studying and working formal activities. Such spaces are usually placed upon the indoor distribution and outdoor circulation systems of linear connecting spaces, and in particular in their knot points, such as halls and square.g.

2. Spaces for services

This category of university spaces refers to workspaces where the university administration and management body works, comprising front-offices for students, but also spaces where university services of various typologies are provided for students (e.g. refectories,) . The functional typology of these spaces can be assimilated to offices, representing another well represented building typology.

It has to be noted that in historical universities these functions may be located in representative heritage buildings (e.g. rectorate), or they can be distributed in buildings where research and education activities are concentrated, while in campuses such functions are usually centralised.

3. Spaces for accommodation

The provision of dedicated housing solutions for enrolled university students is the salient characteristic of campus models, with dormitories, apartments, lodgings and/or housing and linked services (e.g. communal spaces, but also groceries, pharmacies) as an extension of the university spaces. The accommodation solutions vary in a range of specific typologies (e.g. students housing, guest rooms), following defined functional-spatial requirements for the settlement of the young and temporary population of students, but also to host the international academic mobility.

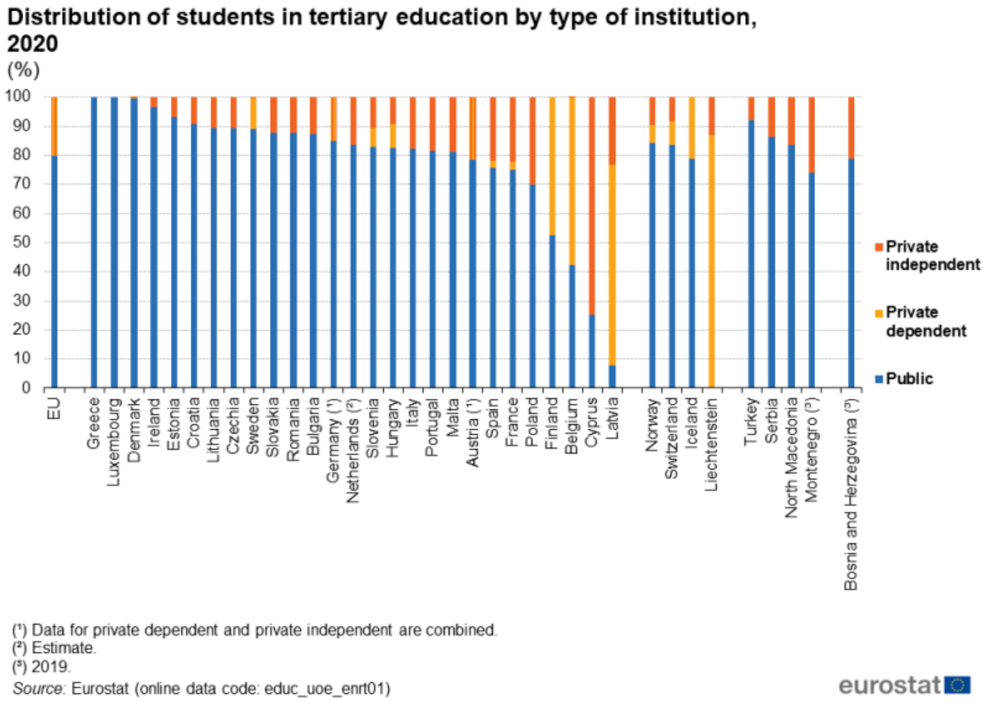
4. Spaces for other services

Many universities also have venues for sports, culture and leisure activities. The typology, number and location of these activities vary greatly according to the dimension and the implemented policies of the universities encouraging, for example, sports and active life-styles (e.g. sporting centres), or cultural attainments (e.g theatres, music hall),

The presence of large numbers of students for university education originates, both inside campuses and in the surroundings/neighbourhood of university urban locations, the development of commercial activities selling goods and providing services (e.g. bars, cafes, stationary groceries, banks).

1.2 European and Italian University

According to EUROSTAT (link), in all Member States (excluding Latvia and Liechtenstein) public universities are the most representative type of higher level / tertiary education.



Among the 18.0 million tertiary education students in the EU:

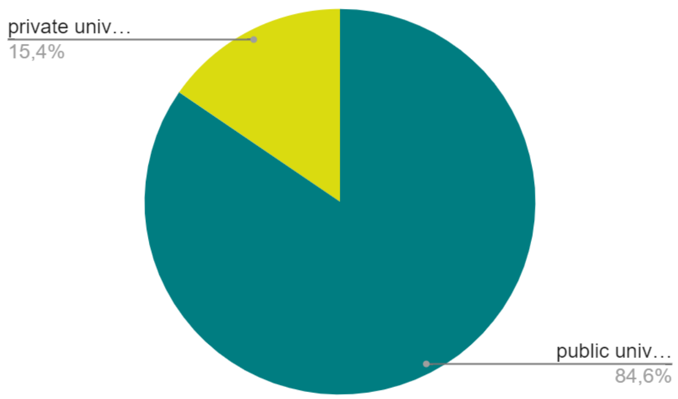
- ➔ 7.3 % were following short-cycle tertiary courses;
- ➔ 59.7 % were studying for bachelor's degrees;
- ➔ 29.4 % were studying for master's degrees; and
- ➔ 3.6 % were studying for doctoral degrees

Number of tertiary education students by sex and level of education, 2020
(1 000)

	Tertiary total			Short-cycle tertiary			Bachelor's or equivalent			Master's or equivalent			Doctoral or equivalent		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
EU	18 010.3	8 282.7	9 727.6	1 322.3	680.3	642.0	10 749.9	5 007.2	5 742.7	5 287.4	2 261.3	3 026.1	650.8	333.9	316.9
Belgium (¹)	521.2	229.1	292.1	21.4	9.0	12.4	371.7	161.9	209.8	110.2	48.6	61.6	18.0	9.6	8.4
Bulgaria	226.6	104.2	122.4	–	–	–	147.9	71.3	76.7	72.2	29.9	42.3	6.4	3.1	3.4
Czechia	318.7	137.2	181.5	1.0	0.4	0.6	190.7	82.8	107.9	105.8	42.2	63.6	21.2	11.7	9.4
Denmark	307.6	132.6	175.0	35.3	19.1	16.2	194.5	79.2	115.3	68.8	29.9	38.9	9.1	4.4	4.7
Germany	3 280.0	1 667.2	1 612.9	10.0	5.4	4.6	2 002.6	1 067.4	935.2	1 084.7	496.4	588.2	182.8	97.9	84.9
Estonia	44.9	18.5	26.4	–	–	–	27.5	11.9	15.6	15.1	5.7	9.4	2.3	1.0	1.3
Ireland	236.7	110.6	126.1	23.2	10.8	12.4	167.8	79.6	88.2	36.8	16.1	20.7	8.9	4.1	4.8
Greece	802.4	404.8	397.5	–	–	–	687.1	354.9	332.2	84.1	33.7	50.4	31.2	16.2	14.9
Spain	2 145.3	985.4	1 159.9	462.9	238.5	224.4	1 224.2	552.1	672.1	365.6	148.5	217.0	92.7	46.3	46.3
France	2 748.3	1 239.4	1 508.9	546.9	285.0	261.9	1 116.6	446.3	670.3	1 018.7	473.2	545.6	66.1	34.9	31.2
Croatia	161.6	69.1	92.5	0.0	0.0	0.0	93.2	43.2	50.1	64.5	24.2	40.3	3.9	1.7	2.1
Italy	2 030.8	897.8	1 133.0	19.9	14.7	5.3	1 227.2	559.9	667.3	752.1	307.0	445.0	31.5	16.2	15.4
Cyprus	53.2	24.4	28.8	5.5	3.8	1.7	24.0	13.0	11.0	22.1	6.9	15.2	1.6	0.7	0.9
Latvia	79.4	35.1	44.3	13.9	5.2	8.7	44.9	21.6	23.3	18.6	7.5	11.2	2.1	0.9	1.1
Lithuania	106.5	45.5	61.0	–	–	–	77.1	34.8	42.3	26.6	9.4	17.1	2.7	1.2	1.5
Luxembourg	7.4	3.5	3.9	0.8	0.4	0.5	3.1	1.4	1.7	2.7	1.2	1.4	0.9	0.5	0.4
Hungary	285.1	131.2	153.9	11.2	4.7	6.5	184.9	87.1	97.7	79.6	34.6	45.1	9.4	4.9	4.6
Malta	17.1	7.3	9.7	2.2	0.8	1.4	8.9	3.9	5.0	5.7	2.5	3.2	0.2	0.1	0.1
Netherlands	*937.4*	*444.4*	*493.0*	30.2	13.5	16.7	695.4	333.6	361.9	195.4	88.9	106.5	*16.4*	*8.5*	*8.0*
Austria	422.0	195.4	226.6	72.3	33.6	38.7	196.3	90.2	106.1	134.4	61.3	73.2	19.0	10.4	8.6
Poland	*1 390.0*	*570.2*	*819.8*	*0.2*	*0.0*	*0.2*	917.0	404.2	512.8	439.2	150.7	288.5	33.7	15.3	18.4
Portugal	380.2	175.7	204.5	17.4	10.6	6.8	216.1	97.9	118.3	125.1	56.9	68.2	21.6	10.3	11.3
Romania	543.3	246.7	296.6	–	–	–	349.4	167.7	181.7	171.9	68.2	103.7	22.0	10.8	11.2
Slovenia	76.7	32.8	44.0	10.7	6.6	4.1	41.9	17.2	24.8	20.8	7.5	13.3	3.3	1.5	1.8
Slovakia	138.4	57.4	81.0	2.4	0.8	1.5	78.5	33.6	45.0	50.9	19.6	31.4	6.6	3.4	3.2
Finland	295.9	136.5	159.4	–	–	–	204.7	98.0	106.6	72.8	29.8	43.0	18.5	8.6	9.8
Sweden	453.4	180.6	272.9	34.8	17.4	17.4	256.7	92.5	164.1	143.2	61.0	82.1	18.8	9.6	9.3
Iceland	19.2	6.7	12.5	0.8	0.3	0.5	13.0	4.7	8.3	4.8	1.4	3.4	0.6	0.2	0.3
Liechtenstein	0.9	0.6	0.3	–	–	–	0.4	0.2	0.2	0.3	0.2	0.1	0.2	0.1	0.0
Norway	294.0	122.6	171.5	9.3	7.7	1.7	192.8	76.6	116.3	82.6	34.1	48.6	9.2	4.3	5.0
Switzerland	319.5	158.1	161.4	3.8	1.4	2.4	214.4	107.0	107.4	75.4	36.1	39.3	26.0	13.6	12.4
Montenegro (²)	22.7	10.2	12.5	–	–	–	21.3	9.6	11.7	1.3	0.5	0.8	0.1	0.0	0.0
North Macedonia	56.1	24.1	32.0	–	–	–	51.7	22.2	29.5	3.9	1.7	2.3	0.5	0.2	0.2
Serbia	242.0	104.1	137.9	–	–	–	182.8	80.9	101.8	48.1	18.4	29.6	11.2	4.7	6.4
Turkey	7 976.1	4 125.4	3 850.7	3 003.0	1 476.8	1 526.1	4 383.5	2 343.8	2 039.7	452.4	233.6	218.8	137.2	71.1	66.1
Bosnia and Herzegovina (²)	89.0	37.0	52.0	–	–	–	67.0	29.2	37.8	21.0	7.3	13.7	1.0	0.5	0.5

(¹) Short-cycle tertiary education: excluding the French Community for vocational education. Bachelor's or equivalent: including marginal enrolments of vocational short-cycle tertiary education for the French Community.
(²) 2019.
(–) not applicable
Source: Eurostat (online data code: educ_uoe_enrt01)

Looking at official national data (USTAT), Italian students enrolled in university in the academic year 2021/2022 have been 1.822.141, mainly distributed in public universities (1.541.753 students), with a low percentage attending private ones (280.388 students).



Italian universities are almost all public (accounting for the 84,6% of enrolled students in 2021-2022), with historical education institutions resulting from amillennial evolution dating back in the Middle Ages (the University of Bologna, still maintaining the motto Alma Mater Studiorum, is considered the most ancient university, founded in 1088).
Considering the number of enrolled students, Italian public university are classified in five main dimensional classes:

- Mega (more than 40.000 students)
- Big (20.000-40.000 students)
- Medium (10.000-20.000 students)
- Small (to 10.000 students)
- Politecnici (autonomous under an administrative and didactic point of view)

More nuanced data on Italian educational institutions are officially provided only for schools of all levels (link), not comprising universities.
At EU and national level, no data are available in official websites/databases on the composition of the university building stock.
Since the majority of EU and Italian students are enrolled in public universities, the strategy on university buildings refers to statistics and standards on public buildings, retrievable both at EU and national level. This choice is also enforced by the opportunity to to take into account the historical and heritage dimension of European university cities.

According to national statistics (USTAT), the University of Florence (UNIFI) is a "mega university" (7/10) accounting for more than 40.000 students.

Institution (mega: > 40.000 st.)	Number of enrolled students
University of Rome - La Sapienza	107.342
University of Bologna	84.242
University of Torino	77.820
University of Naples - Federico II	73.553
University of Padova	66.442
University of Milan	60.988

Institution (mega: > 40.000 st.)	Number of enrolled students
University of Florence	**53.056**
University of Pisa	43.584
University of Palermo	41.610
University of Bari	40.530

The University of Florence is an historical public university dating back to the Middle Ages, UNIFI dynamically evolved over time (university in 1924) to become today one of the biggest research and didactic institutions in Italy.

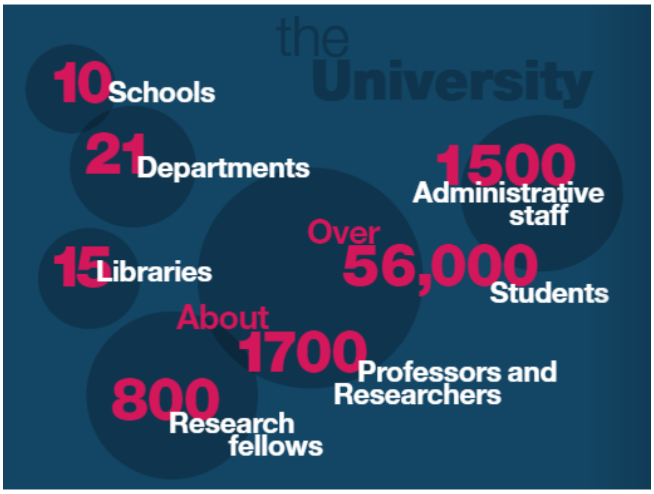
1.3 University of Florence

The University of Florence is a very old public institution, whose persistence in the historical and protected heritage urban context (the UNESCO city centre) determines important challenges for the sustainability of the university building stock.
The origins of the university date back to the Studium Generale set up by the Florentine Republic in 1321. The subjects taught were Civil and Canon Law, Literature, Medicine. There have been illustrious scholars such as Giovanni Boccaccio, who lectured on the Divina Commedia.
The importance of the Studium was ratified with a bull by Pope Clement VI whereby all titles awarded were officially recognised. The course of Theology was subsequently added. The Studium had also the *privilegia maxima* extended to it, as it was the case with the universities of Bologna and Paris.
In 1364 the Studium became an imperial university. When the Medici came to power in Tuscany in 1472 it was exiled to Pisa. From that time onward there were frequent transfers between Florence and Pisa according to the different changes in the government. Charles VIII brought back the Studium to Florence between 1497 and 1515. Then, a comeback of the Medici moved it again to Pisa. Throughout this period many teachings and research remained active in Florence supported by the numerous academies that came to flourish in the meantime, such as Accademia della Crusca and Accademia del Cimento.

In 1859 with the expulsion of the Grand Duke from Tuscany a unified structure re-emerged in the shape of the Istituto Superiore di Studi Pratici e di Perfezionamento (Higher Institute of Vocational and Advanced Studies). In 1924 the Istituto was officially granted the title of university.

Between 1924 and 1938 the university organised itself into the Faculties of Agriculture, Architecture, Economics, Pharmacy, Law, Humanities, Education, Medicine, Mathematical, Physical and Natural Sciences and Political Sciences. Engineering was added in 1970 and Psychology in 2002.

Today, the university offers a wide range of study programmes at various levels and in all areas of knowledge, with over 140 Degree courses (link).



There are over 9,000 degrees awarded each year in Florence.The University of Florence has a natural international vocation and the development of internationalisation is one of its strategic priorities.

The university is organised in:

- 21 department (7 excellence)
- 10 schools
- 21 service centres
- 20 research centres
- 52 inter university centres (17 located in UNIFI)
- 1 library system (19 libraries)
- 1 museum system (7 museums, 6 of them historical)

The educational offer accounts for:

- 9 single-cycle degrees

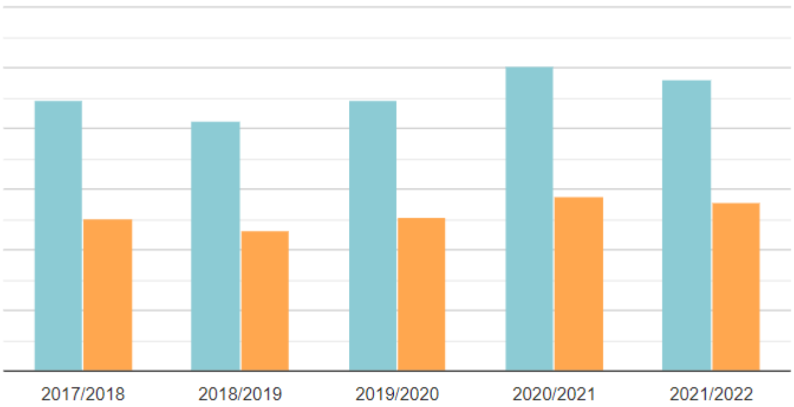
- 60 bachelor degrees
- 73 master degrees
- 58 specialistic schools
- 45 specialisation courses
- 26 research doctorates (+ 11 convent/cons)
- 12 professional training courses

Because of the presence of UNIFI and other private universities (high presence of international universities), Florence can be defined as a university city, hosting a dynamic, young and ever changing temporary population of tens of thousands students and researchers.
UNIFI's "permanent" community is composed of a board of about 11.200 workers, comprising 8.000 professors, 1.600 technicians/officers, and 1.600 doctoral students/ researchers assistants.
The "temporary" population of students enrolled in UNIFI accounts for 53.056 enrolled in the academic year 2021-2022, one-fourth of which come from outside of Tuscany, with a wide presence of women (~63%) and a good presence of enrolled international students (~7%), not considering the temporary presence of students and researchers determined by the high number of internationalisation projects.

Students	**Total**	**Women**	**Foreigners**
New students	9.595	5.569	646
Enrolled	53.056	31.011	3.853
Graduate	9.929	5.895	516

The total number of enrolled comprises the new students; total new students refers to students of degree courses of 3-years and single-cycle; the number of graduate refers to the single year 2021

The "temporary" population of students accounts for 53.056 enrolled in the academic year 2021-2022, with a wide presence of women (~63%) and a good presence of enrolled international students (~7%).



Historical series of enrolled students in degree courses of 3-years and single-cycle (sky blue) and relative number of women (orange).

1.4 UNIFI sustainability approaches

➔ **ATENEO SOSTENIBILE - GREEN OFFICE**

The recent establishment of the University Green Office concretised the UNIFI political choice **to address environmental sustainability as a priority**, central in the strategic plan and in the overall organisation of university activities.

The Green Office works in network with national and international research institutions (Rete Universitaria per lo Sviluppo Sostenibile, EUniWell, New European Bauhaus, and others), and collaborates with Technological National Clusters (enterprises, universities, public institutions, start up, etc) and internationally.

The office is **in charge of assess, improve and valorise a range of sustainability aspects in university life and its management**, related to: accessibility, water, climate change, food, knowledge, building, energy, mobility, waste and green.

Referring to building, **the office sustains the adoption of sustainability principles for building design, aimed at reducing the building's energy consumption** (link). Following the most representative criteria:

Control of heat dissipation: the structure must contain heat losses within predetermined levels through conduction, convection, and radiation

Thermal insulation: the structure must ensure appropriate resistance to the passage of heat depending on climatic conditions

Recoverability: the structure must allow for the reuse of materials or technical elements after demolition and removal

Energy and environmental sustainability: the structure must tend towards the use of sustainable energies, aiming to abandon fossil sources, preferring the use of renewable energy sources, and improving resource management with the use of bio-architecture and green technology (following CAM "Criteri Ambientali Minimi per l'affidamento di servizi di progettazione e lavori per la nuova costruzione, ristrutturazione e manutenzione di edifici pubblici" D.M. 11 October 2017)

Economic sustainability: the project must take into account economic convenience, namely the ability to create value, generate a level of profitability for the invested capital, and meet the expectations of the University in the investment

Financial sustainability: the project must be able to generate a sufficient economy of monetary flows to guarantee the repayment of activated financing and an adequate remuneration of its own means invested in the realisation and management of the initiative. In addition, it has outlined the four main areas (materials, energy, water, health) to project design development towards sustainable construction

Materials: materials must be natural, obtained through the use of renewable sources, managed and collected sustainably or sourced locally to reduce transport costs; recycled from recovery materials at nearby sites and must meet specific Life Cycle Analysis (LCA) procedures in terms of embedded energy, duration, waste minimization, and ability to be reused or recycled

Energy: orientation towards passive solar design in order to drastically reduce heating and cooling costs and towards high levels of building envelope insulation

Water: reduction of water consumption by using rainwater collection systems for recycling in irrigation or toilet flushing

Health: use of non-toxic products and materials, or zero or low emissions of organic compounds (VOCs).

➔ **UNIWELL**

UNIFI is part of the EUniWell alliance.

EUniWell – the European University for Well-Being – is one of 44 European University Alliances, selected for funding by the European Commission under the ERASMUS+ programme in 2020 (link). It is composed of a core of **ten universities across Europe**, supported by more than 100 associated partners from all sectors of society.

Core mission of the alliance is **"to understand, improve, measure, and rebalance the well-being of individuals, our own community, our environment and society as a whole on a regional,**

European, and global level". The alliance focuses on four interdisciplinary research key areas, the so-called Research Arenas, one of which is "The environment and climate".
Background of the alliance is the EU's flagship initiative "European Universities Initiative" (link), aimed at removing barriers to learning and improving access to quality education for all.

➔ UNIFI STRATEGIC PLAN 2022-2024

The UNIFI Strategic Plan 2022-2024 (link) draws medium and long term scenarios on the impact of university on society through its academic missions of didactics, research, knowledge transfer and innovation.
The strategic plan clearly expresses the commitment towards environmental sustainability.
In the phase of context analysis, the plan recognises as a weakness the dimension of building heritage and the need for its adaptation and as threats the difficulties in collaboration with other territorial institutions as well as the complex management.
Among the various goals, a focus has been posed on:

- **Health and Wellbeing**: with the objective to promote health and fiosio-psychological wellbeing in work and study spaces
- **Energy Efficiency**: with the objective to identify most energivores buildings, analysing their energy profiles to develop energy efficiency plans;
- **Reduction of the environmental impact**: with the objective to plan actions for the reduction of consumption/emissions and a relative measurement/monitoring system;
- **Informative systems**: systematic collection and analysis of data on the environmental sustainability of the university (in terms of research, didactic and communication), enriching the "Ateneo Sostenibile" online portal (link).

➔ UNIFI INTEGRATED PLAN FOR ACTIVITIES AND ORGANISATION 2023-2025

The Integrated Plan for Activities and Organization (PIAO) contains the overall planning of the university, according to the various areas of activities (link).
Looking at future education, the plan foresees the **improvement of both physical and virtual spaces for teaching**. A project has been approved by the Ministry of Education, University and Research (MUR) within the 2021-23 three-year plan: acquiring new spaces for teaching, **converting and redeveloping existing spaces** for educational and study activities. Moreover, it forecasts to evaluate and activate spaces dedicated to coworking areas equipped with Wi-Fi coverage and electricity supply for personal device.g.
These actions are aimed at increasing the space dedicated to teaching while **improving the comfort, usability and safety of available spaces**, also **protecting and promoting the cultural**

and historical-architectural heritage of existing buildings. The indicator used to measure the success of these actions will be the **square metres available for educational activities** compared to the number of students enrolled within a year beyond the normal duration. The initial value is 1,383, while the target for 2025 is 1,56.

Environmental sustainability is a strategic objective. The plan recognises that the university is a large community and, in carrying out its activities, it can generate significant environmental impact. Therefore, the academic community can have a significant impact on reducing environmental impact, educating responsible citizens, and supporting research and technological transfer to **promote the ecological transition**.

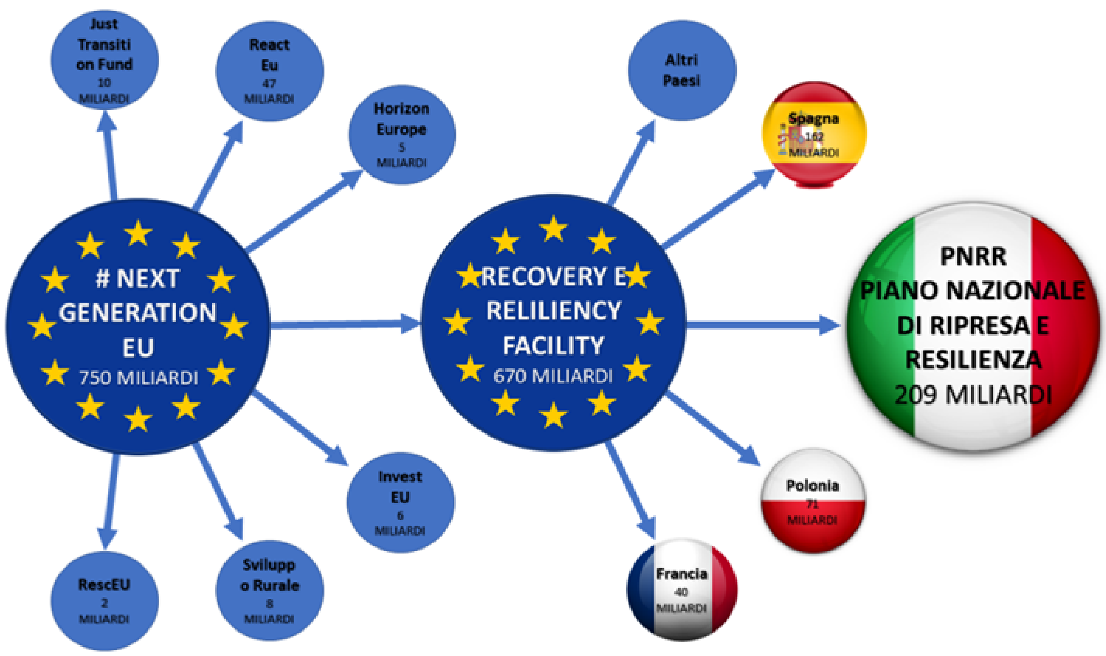
In this perspective, the **management of the university infrastructure**, energy efficiency, and alternative energy production are heavily focused on reducing both environmental and economic impacts. This effort is particularly necessary in the current economic situation, where the increasing costs of energy services have required a significant financial commitment in the budget forecast for 2023. The plan prioritises **energy efficiency interventions**, including building insulation, photovoltaic energy production, lighting, heating and air conditioning systems. Moreover, the plan aims at reducing the degree days/hours of heating and scheduling closures of facilities when not in use.

The larger infrastructure projects planned, such as the **Agriculture Campus in Sesto Fiorentino**, will use **renewable energy sources for no less than 50%** of the total energy needed. For example, a new **photovoltaic carport** for an area of over 500 square metres is planned The University is also planning to further research and develop energy-efficient internal lighting systems using **LED technology**, with economic resources already programmed.

2. Policy Appraisal*

The current European and Italian policy framework concerning building renovation and in particular the energy requalification of buildings was analysed in detail. Energy-efficiency and building retrofit objectives, action plans and tools put in place to achieve these objectives, as well as the effectiveness of current policies and the need for any additional policies to stimulate the building renovation market were assessed. In particular, as POLICY TOOLS for Energy-Efficiency retrofit in Higher Education Buildings were analysed:

- The 2030 Agenda and the SDGs
- The European Green Deal
- The Renovation Wave and the NGEU financing plan
- National Research Programme (NRP)
- NATIONAL RECOVERY AND RESILIENCE PLAN (PNRR)
- National Action Plan on Green Public Procurement (PANGPP) _MINIMUM ENVIRONMENTAL CRITERIA (CAM)
- GREEN BUILDINGS DIRECTIVE



2.1 The 2030 Agenda and the SDGs

On 25 September 2015, 193 countries of the United Nations adopted an action plan to ensure sustainable development: The 2030 Agenda. The latter aims to provide guidelines and actions to reorient humanity towards sustainable development, in particular, through 17 Sustainable Development Goals (SDGs) divided into 169 targets or goals. "The official launch of the goals took place at the beginning of 2016, guiding the countries of the world on the path to be taken over the next 15 years: countries have committed to achieving them by 2030.

2.2 The European Green Deal

In December 2019, the 'European Green Deal' or also called the Green Pact was introduced, which is an integral part of the European Commission's strategy to implement the 2030 Agenda and the UN Sustainable Development Goals. The latter is an action plan that defines the strategic legislative and non-legislative actions that the EU aims to achieve in the coming decades in view of the green transition. "It is a new growth strategy aimed at transforming the EU into a just and prosperous society with a modern, resource-efficient and competitive economy that will generate no net greenhouse gas emissions in 2050 and where economic growth will be decoupled from resource use."

The target to be reached by the same date becomes Net Zero, i.e. a balanced budget of emissions: the European economy will no longer have to add a single tonne of greenhouse gases to the atmosphere, and will therefore have to offset every quantity emitted with a similar quantity absorbed from biomass or other systems.

2.3 The Renovation Wave and the NGEU financing plan

In 2020, the European Commission approved the strategy 'A Renovation Wave for Europe: Greening Buildings, Creating Jobs and Improving Lives'24 - also commonly known as 'The Renovation Wave' - and its Action Plan. This strategy consists of the renovation of residential and non-residential buildings, aimed at reducing greenhouse gas (GHG) emissions, in particular CO_2, as well as improving the quality of life of the people living in the buildings and creating jobs.

The EU funded a recovery package: the 'Next Generation EU' (NGEU), a temporary instrument of around EUR 800 billion; accompanied by the Multiannual Financial Framework 2021-2027. It is called recovery, as it was allocated following the COVID-19 emergency and aims to rebuild a post-pandemic, greener, more digital and more resilient Europe.

2.4 National Research Programme (NRP)

In Italy, the PNR, which is the document guiding research policies in Italy, has been put in place. The state administrations, coordinated by the Ministry of Universities and Research, contribute to its implementation.

On 15 December 2020, the CIPE approved the National Research Programme 2021-2027, which is the result of a wide-ranging and in-depth discussion initiated by the Ministry of Universities and Research with the scientific community, state administrations and regional authorities, and extended, for the first time through a public consultation, to public and private stakeholders and civil society.

The result is a participatory and dynamic multiannual framework programming instrument designed to contribute to the achievement of the UN Sustainable Development Goals (SDGs), the priorities of the European Commission, the 2021-2027 Cohesion Policy Goals as well as the Next Generation EU initiative.

2.5 National Recovery and Resilience Plan (NRRP)

Another important step in Italy is the strategic plan National Recovery and Resilience Plan (PNRR), which is part of the Next Generation EU recovery project. It is a EUR 750 billion programme to boost growth, investment and reforms, of which more than half, EUR 390 billion, are grants.

The NRP is divided into 6 missions, and mission 2, called Green Revolution and Ecological Transition, deals with major issues including energy efficiency of buildings, water resources and pollution, in order to improve the sustainability of the economic system and ensure an equitable and inclusive transition to a carbon-neutral society.

The point of contact with the MedEcoSure project concerns the association between the ecological impact studies and the actions proposed in the various intervention areas of the NRP, to ensure coherence between the NRP 2021-27 itself and the objectives of the European Green Deal. The 2021-27 NRP also promotes 'the creation of innovation ecosystems, places of contamination where the proactive and dynamic function of research in connection with the needs of society is evident and explicit'. The living lab also seems to respond perfectly to the concept of 'open science' repeatedly stressed in the Plan, through the active participation of people. With respect to this, however, the Plan adds that: "Open science alone does not automatically guarantee that research results and knowledge will be commercialised or transformed into socio-economic value. For this to happen, open innovation must help connect and exploit the results of open science and facilitate the timely translation of discoveries into social use and economic value."

Since traditional methods seem to fail to meet current needs, anticipating future requirements, 'innovation ecosystems' contribute to this objective as physical or virtual places, also networked, where open innovation is realised through innovative education (e.g. academies), multidisciplinary laboratories in collaboration with the public and private sector, mixed innovative spaces to host innovative enterprises and start-ups, places for contamination with the territory, including third sector operators. Innovation ecosystems are, in fact, functional to the interaction between different stakeholders (companies, research institutions, universities, third sector and PA) in an exchange that crosses the boundaries between organisations, sectors, disciplines and communities and that strengthens and integrates different competences. Access to the laboratories and infrastructures of universities and research institutions, equipped with state-of-the-art instruments, by users from outside the academy enables direct collaboration that facilitates innovation activities. Universities and research institutions act as sources of knowledge and potential development partners. In addition, in the context of innovation ecosystems, the elimination of barriers and delays in the way knowledge is transferred and appropriated helps to realise the competitive advantage of the production system of the territories in which they are located. To the dimension of market-oriented technological and industrial innovation must be added the social and cultural dimension that, in the national system, is pursued through third mission initiatives aimed at consolidating the synergy between science, technology, culture, art and territories. Innovation, in fact, is not only an imperative for the market, but also represents an added value for progress through the creation of new knowledge, community awareness and mobilisation, training and the development of qualified skills. Therefore, open innovation also considers the impact on society and places the assessment of technological maturity levels (TRL-Technology Readiness Levels) alongside that of societal maturity levels (SRL-Societal Readiness Levels)." This explanation is not far removed from the living lab proposed in the MedEcoSure project, but rather seems to be configured precisely to meet such a need.

2.6 National Action Plan on Green Public Procurement (PANGPP) _Minimum Environmental Criteria (CAM)

Minimum environmental criteria (building CAM) are requirements aimed at identifying the best design solution, product or service from an environmental perspective.

The application of minimum environmental criteria enables contracting authorities to enhance the environmental and social quality of their tendered activities, rationalise their consumption and reduce related expenditure.

The adoption of minimum environmental criteria serves to ensure compliance with the objectives set by the NAP GPP (Plan for the Environmental Sustainability of Public Administration Consumption) and to promote more sustainable production and consumption models in order to reduce:

environmental impacts;

spreading green employment;

develop Green Public Procurement (GPP).

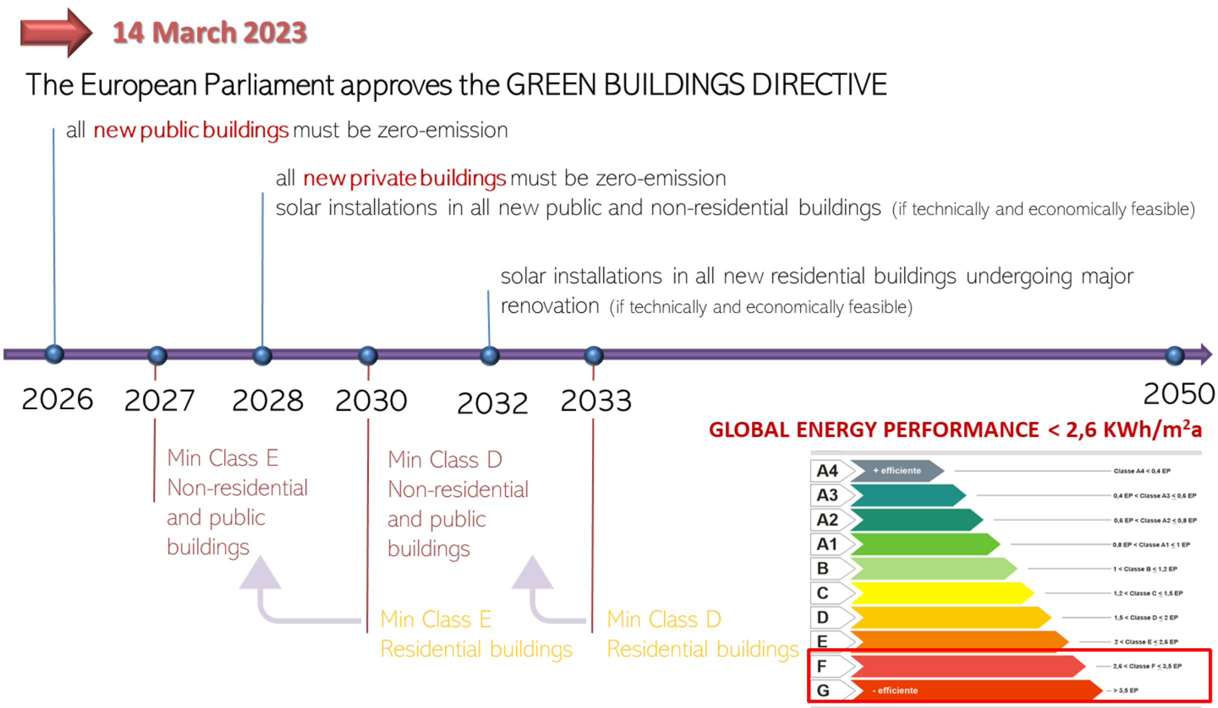
On 6 August 2022, the new CAM Building Decree was published. One interesting aspect is the percentage of recycled materials to be included in building materials. The quantities of recovered, recycled or by-product materials that must be contained within the most common insulation materials are also indicated.

It is precisely from this requirement, as well as the need to reduce the carbon footprint due to thermal insulation, that a reflection on the type of thermal insulation to be used in the energy requalification of university buildings, which as public buildings are in any case required to comply with CAM, has arisen. Therefore, research was started on the added value of thermal insulation made from textile waste, terminated with a publication (Violano, A.; Cannaviello, M. The Carbon Footprint of Thermal Insulation: The Added Value of Circular Models Using Recycled Textile Waste. Energies 2023, 16, 6768. https://doi.org/10.3390/en16196768)

2.7 Green Buildings Directive

The new EPBD was recently approved. The new regulations aim to build only ZEBs (zero emission buildings) by 2030. For existing buildings, however, the target of zero emissions is postponed to 2050. This proposal has already been included in the EU's Fit for 55 package. For new public buildings, it is stipulated that they must be zero-emission as early as 2027. It is required for all existing residential buildings to achieve energy class D by 2033, as well as a ban on the use of fossil fuel heating systems from 2035

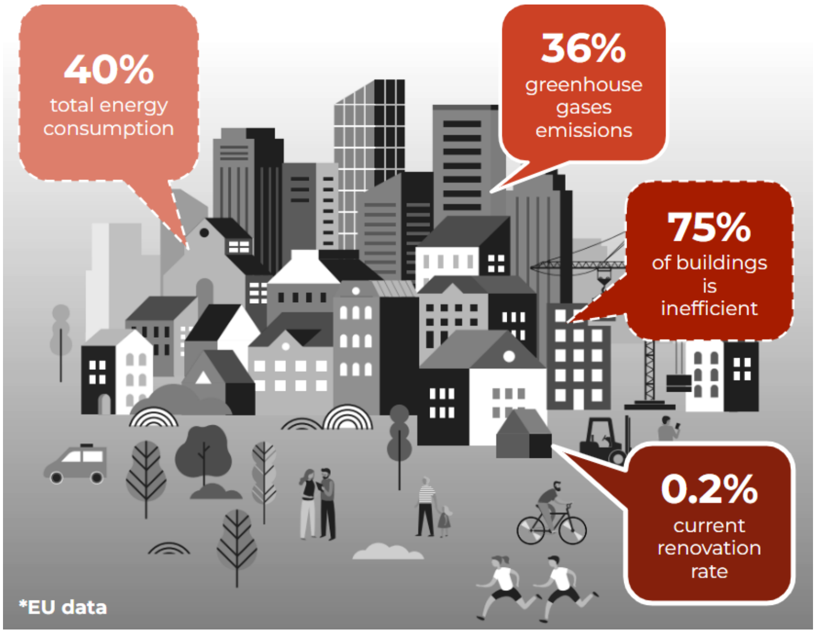
For renovations, new minimum performance thresholds are proposed, according to which 15 % of the least efficient building stock in each Member State will have to be upgraded. In practice, buildings with a Class G energy performance certificate will have to fall at least to Class E, in two stages: by 2027 for non-residential buildings and by 2030 for residential buildings. Member States are also expected to introduce minimum performance thresholds, based on the amount of Ep,MAX (maximum primary energy) per sqm/year that buildings will be allowed to use.



*This chapter and relative contents has been elaborated by University of Campania L. Vanvitelli

3. The Roadmap

As at global level, in the European Union buildings are responsible for roughly 40% of energy use and 36% of energy-related greenhouse gas emissions, making them the largest energy consumers.



Despite the 20 years-old Energy Performance Building Directive (EPBD 2002, recast 2010, amendment 2018 and 2023), nowadays approximately 75% of the EU building stock remains inefficient, with low renovation rate.g. With the evolution of the EPBD, a progressive attention has been focused on the rehabilitation of the existing buildings, with even deeper renovations required to reach nearly zero-energy targets (referring to buildings requiring nearly zero or very low amounts of energy, covered by renewable energy sources).
In the framework of the EPBDirectives, the EU expresses the need and opportunity of public buildings to demonstrate their exemplary role in building renovation, in reaching ambitious renovation rates and stimulating local measures and policies for the private sector. The focus on the public sector is intended to facilitate the build-up of the necessary skills, expertise and workforce that will be required to renovate the larger privately owned stock.
In more recent years, in the context of the ambitious European Green Deal aiming to cut 55% of greenhouse emissions by 2030 and to reach climate neutrality by 2050, the EU Commission

launched the Renovation Wave strategy, requiring an anticipated revision of the EPBD to set out how to achieve a zero-emission and fully decarbonised building stock.

Renovation is the process of intervening on the existing building through the integration of strategies and mix-of-technologies in order to achieve, at first instance, energy efficiency.

The roadmap accompanies the proposed long-term strategy for the renovation of the national university building stock by defining renovation goals and desired outcomes (expressed in terms of measurable indicators and milestones) in time milestones needed to reach it.

The strategy aligns with the EU pathway towards 100% decarbonization of the building stock by 2050 and supports the need to develop and maintain long-term renovation strategies to achieve the final target of climate neutrality and raise their ambition for the reduction of the energy consumption as soon as possible. The EU requirement is to deliver at least 3% annual deep renovation rate by 2030, to reach the climate-neutrality objective by 2050.

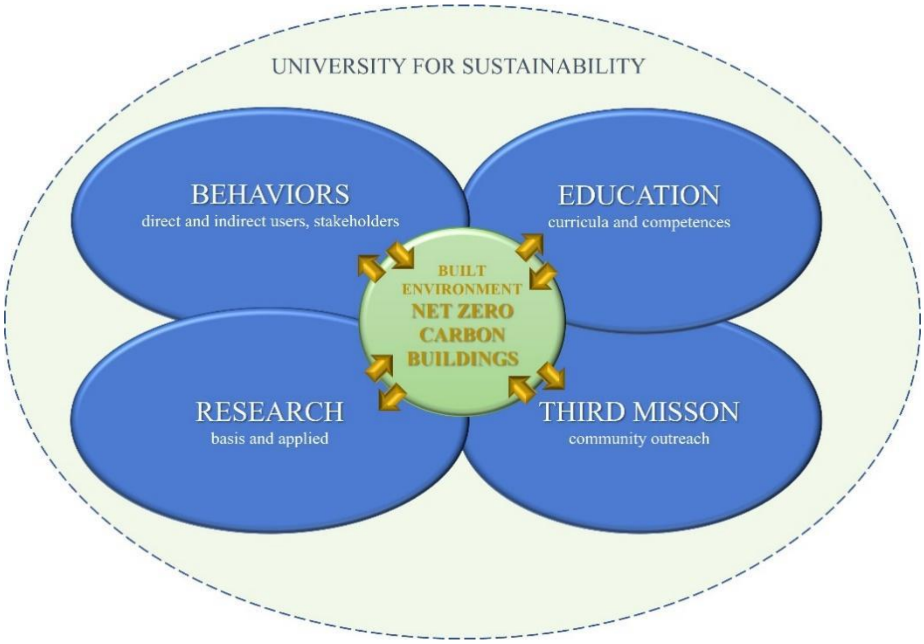
3.1 A long-term strategy

The proposed strategy emphasises the principle of "energy efficiency first", addressing the ambitious target of decarbonization posed by the European Green Deal.
In line with the EU approach to building renovations, the strategy valorises the possibility of taking the maximum contribution from energy rehabilitations, not only in terms of energy savings and environmental impacts (reduction of energy consumption and of greenhouse emissions), but also considering the wider benefits related to health and comfort for occupants, improved living conditions, promotion of more sustainable lifestyles and valorization of art and aesthetics. This approach also aligns with the New European Bauhaus initiative, which fosters creativity and transdisciplinarity in designing sustainable living spaces, inclusive and beautiful. Still in line with EU policies, the strategy also expresses the need, and opportunity, to tackle together the twin challenges of the green and digital transition, promoting digitally friendly renovations.
Last but not least, the proposed strategy derives from and capitalises the Med-EcoSuRe project, with its objective of valuing the role of universities as catalysts for the implementation of eco-sustainable and more collaborative renovation processes.
Considering universities as the most fertile background and appropriate testing space to raise open innovation, the project adopted a Living Lab approach to overcome the weak implementation and the fragmentation of retrofit processes in Mediterranean public buildings.
For their innate nature of education, research and technological transfer, universities are the ideal place for innovation, consenting to capitalise the academic knowledge, the know-how of the local network of stakeholders (companies, public administrations), and allowing the young generation of students the opportunity to take part in pilot renovation processes.
In this perspective, (public) university buildings can act as living laboratories to experiment innovative retrofitting processes, technologies and approaches, as an occasion to educate the university community (as a little city), as future citizens, towards the decarbonized sustainable buildings of tomorrow.

3.1.1 Mediterranean University buildings energy performance profiling*

Universities are the main centres where the drivers of innovation for sustainability and decarbonisation of the built heritage are investigated and developed. Universities have the primary task of investing in research and development of innovative technologies aimed to mitigate climate change. As centers where the drivers of innovation are studied and designed, they intrinsically have the role of demonstrators of the feasibility and effectiveness of policies for sustainability and decarbonization of the built environment.

From a scenario analysis to think structurally about the challenges that universities might face in the long run, an interesting characterization of the typological identity found emerges: there are universities with an orientation mainly close to society (open to life acting as a financially strong cooperative partner), universities rather distant from society (conservative maintaining a niche existence) and universities with a mainly instrumental role (market-oriented generating profitable knowledge). (Barth et al., 2011)



The Committee for International Cooperation (CIC) highlighted that universities' commitment to sustainability is academic and involves its three missions: Education, Research, and Third Mission, and it is not implementable separately by the interested actors. (Alonso-Almeida et al. 2015)
The scientific work carried out by the DADI-Vanvitelli and ANEA research groups as part of the Project "Mediterranean University as Catalyst for Eco-Sustainable Renovation" (MedEcoSuRe), funded by the European Union under the ENI CBC MED Program, focuses on the environmental aspects of sustainability, in particular the management of energy and natural resources in university buildings.
In WP4 - Policy and Project tools for Energy-Efficiency retrofit in Higher Education Buildings, DADI-Vanvitelli research group different analysed and compared some university sustainability assessment methodologies in order to extrapolate the most effective indicators to assess the environmental and energy performance of existing buildings, not only to highlight the truly virtuous buildings, but also to identify the strengths and weaknesses of the university building

stock in order to implement the most appropriate renovation strategies that would be able to make them sustainable in the fullest sense of the term. According to the Renovation Wave Strategy, these strategies are intended to improve not only the energy performance of buildings but also the quality of life of people who live in and use university buildings. This is consistent with what was already stated by the Stockholm Declaration (1972) and reiterated by the Talloires Declaration (1990), which advocated the direct correlation between people and their living/studying/working environment, giving university buildings a key educating role in achieving environmental sustainability.

3.1.2 Tools for assessment of sustainability in universities

The international strategies promoted by the European Green Deal and the New European Bauhaus lead us to question the environmental energy performance of the built heritage. If carbon neutral buildings are to be our goal in 2050, we need to understand: what is the current carbon footprint of university buildings? And how can we measure it? Almost all the investigated tools deal with the theme in a complex way, not separating the environmental energy assessment of the built environment from the ways of using it and from the awareness taught in these places of knowledge, giving strength to the concept that the habitat in which the human being lives, conditions in a biunivocal way his behaviours.

However, in many cases, there is a strong gap between the sustainability taught in the different courses of study, and the real performance (in terms of ecological footprint) of the buildings where they take place. For this reason, a series of operational tools, tested in different cultural areas of the world, have been studied in order to highlight not only the recurring non-negligible features, but also the strategies to enhance the best practices to implement a Cross Border Strategic Plan for University Building Retrofitting (WP 4.2). The research highlighted that several tools for assessing the sustainability of universities have been developed around the world over the past two decades.

Dalal-Clayton &Bass (2002) describe three main approaches to measure and analyse sustainability:

- Accounts (raw data that are then converted to a common unit: (monetary, area or energy),
- Narrative assessments (that combine text, maps, graphics and tabular data and might use indicators),
- Indicator-based.

Indicator-based appraisal is certainly preferable for tackling the sustainability assessment challenge of university buildings. This kind of approach involves a comprehensive process of

prioritisation and ensures better strategy advancement, performance follows up and genuine decision-making and most importantly describes strengths and weaknesses. (Adenle et al, 2020)
In most of the instruments analysed, the indicators are generally divided into thematic categories, which attempt to assess, through multi-objective (qualitative-quantitative) criteria, all the aspects that make a University more or less sustainable. Usually, the indicators should cover the entire system to address: Education (referring to Courses and Curricula), Research, Campus operations, Community outreach and Assessment and reporting. (Lozano, 2006)
In the MedEcoSuRe research project, net zero carbon buildings assume a central role in this quadrilateral of convergence towards sustainability, promoting cross-sector dialogue between institutions on sustainability and stimulating environmentally conscious behaviour and learning.
In the United States, for the past two decades, academics and environmentalists have sought to evaluate places of knowledge based on their sustainable practices and policies, primarily through the tools proposed by three organisations: Association for the Advancement of Sustainability in Higher Education (AASHE), The Princeton Review, and Sierra Club (Albis, 2017). Among the tools developed, the one proposed by AASHE (Sustainability Tracking, Assessment & Rating System™ - STARS®) is one of the most exhaustive, as well as being one of the first assessment systems specifically geared to assessing the sustainability of universities (Adenle, 2020). This is a voluntary and transparent self-assessment framework, active since 2006, based on a well-structured set of indicators and used to assess a wide range of actions from energy use to transportation, procurement to academic offerings in the field of sustainability, against six main categories: Institutional Characteristics, Academics, Engagement, Operations, Planning & Administration, and Innovation & Leadership. Instead, the Princeton Review, which publishes an annual green guide with rankings of America's sustainable universities (see https://www.princetonreview.com/press/green-guide/press-release-2022), assigns the score through a Green Rating. In the questionnaire administered to students, the questions regarding the energy-environmental performance of buildings are as follows:
1. Are school buildings that were constructed or underwent major renovations in the past three years LEED certified?
2. Does the school have a formal plan to mitigate its greenhouse gas emissions?
3. What percentage of the school's energy consumption is derived from renewable resources?
Therefore, Princeton Review includes more energy-related questions than any other topic (Albis 2017). Assessing the efforts made towards sustainable development by universities is also covered by the Global Reporting Initiative (GRI): a voluntary tool, born in a predominantly corporate environment (Hahn and Kuhnen, 2013), which offers a comprehensive set of standards for reporting impacts related to the three dimensions, economic, environmental and social, aimed at 40 different sectors, divided into 4 main groups. Universities belong to Group 4: Other services

and light manufacturing - Educational services Education services at all levels, including online education. This tool can also be used by universities (Lozano 2011), to communicate to the outside community how they address the dual mission of providing students with new skills to create a more sustainable society and reducing the environmental impact of their activities. In this second mission, the role of buildings and how they are designed, upgraded, and managed takes on strategic importance. Although at the global university level the adoption of reporting standards through the GRI framework is not yet sufficiently widespread, European universities can still be considered pioneers in the adoption of such standards (Alonso-Almeida et al. 2015)

How to evaluate the sustainability of a university ?

Three main approaches to measure and analyze sustainability

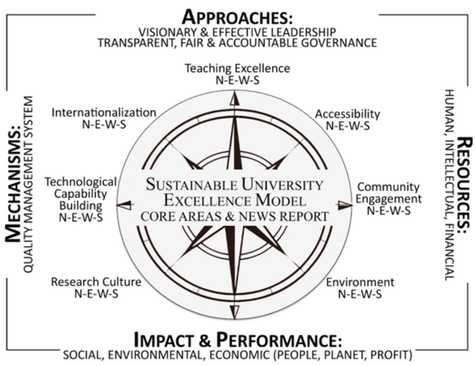
- ACCOUNTS

  raw data that are then converted to a common unit: monetary, area or energy, ...

- NARRATIVE ASSESSMENTS

  that combine text, maps, graphics and tabular data and might use indicators

- INDICATOR-BASED



Dalal-Clayton e Bass, 2002

Moreover, the influential and international UI GreenMetric World University Ranking has been considered, since it strives to account for the environmental sustainability of this peculiar building typology.

UI GREEN METRICS (link)

The ranking system was initiated by Universitas Indonesia in 2010, and today accounts for a total of 1050 universities participating with their data and their commitment to sustainability.

The purpose of the metrics is to value the role of universities in the joint effort between stakeholders and communities in combating climate change, promoting energy and water conservation, waste recycling, and green transportation, as a model for the society and a critical partner to the government.

Through 39 indicators in 6 criteria [Setting and Infrastructure (SI), Energy and Climate Change (EC), Waste (WS), Water (WR), Transportation (TR), Education (ED)] the ranking system led to comparisons on criteria considered to be of importance by universities concerned with sustainability.

Setting & Infrastructure

More space for greenery and in safeguarding environment, as well as the campus sustainable development budget.

Energy & Climate Change

Increase the effort in using energy efficiency appliances and develop renewable energy.

Waste

Some programs and waste treatments (i.e. recycling program, toxic waste, organic and inorganic waste, etc).

Water

Decrease groundwater usage, increase conservation program, and protect the habitat.

Transportation

Transportation policy to limit the number of private vehicles, pedestrian.

Education & Research

Courses, research, publication, website, report related to green and sustainability.

Key Indicators

- The ratio of open space area towards total area
- Total area on campus covered in forest vegetation
- The total open space area divided by total campus population

- Total area on campus covered in planted vegetation
- Conservation: plant, animal and wildlife, genetic resources for food and agriculture secured in either medium or long-term conservation facilities

- Total area on campus for water absorption besides the forest and planted vegetation

- Percentage of operation and maintenance activities of building during Covid-19 pandemic
- Campus facilities for disabled, special needs and or maternity care
- Security and safety facilities
- Health infrastructure facilities for students, academics and administrative staff's wellbeing

- Percentage of university budget for sustainability efforts

SETTINGS AND INFRASTRUCTURE (SI) (15%)

Basic information of the university policy towards green environment. Include space for greenery and in safeguarding environment, as well as developing sustainable energy.

Key Indicators

- Energy efficient appliances usage
- Total electricity usage divided by total campus population (kWh per person)

- Smart Building implementation
- Elements of green building implementation as reflected in all construction and renovation policies.

- Number of renewable energy sources in campus
- The ratio of renewable energy production divided by total energy usage per year

- Greenhouse gas emission reductions program
- Total carbon footprint divided by total campus' population (metric tons per person)

- Number of innovative program(s) during covid-19 pandemic
- Impactful university program(s) on climate change

ENERGY AND CLIMATE CHANGE (EC) (21%)

The university's attention to the use of energy and climate change issues. Universities are expected to increase the effort in energy efficiency on their buildings, nature and resources.

Among the criteria, the following key indicators has been considered:

- Total area of campus covered in planted vegetation;
- Energy efficient appliances usage;
- Total electricity usage divided by total campus population

3.1.3 Results: analytical, propositional and debate aspects

The literature review of the major tools indicated that the most comprehensive tool for assessing building performance is Sustainability Tracking, Assessment, and Rating Systems (STARS®). Only Sustainability index Model - DPSEEA (Waheed et al., 2011), Sustainable Campus Assessment System (SCAS) (Hokkaido University, 2013), and STARS® have extensively included spatial indicators at both indicator and sub-indicator levels. (Adenle et al, 2020).
The indicators used by STARS® to assess the energy-environmental performance of university buildings, and the use of renewable energy, are contained in the Operation category and are listed in Table 1, where for each credit are indicated Points available, Applicable to, Minimum requirement.

Table 1. Credit, Applicability, Criteria and scoring in STARS ® 2.2 Technical Manual

Credit, Number and Title	**Points available**	**Applicable to**	**Minimum requirement**
OP3 Building Design and Construction	3	Institutions that have new construction and/or major renovation projects completed within the previous five years	Own new or renovated buildings that were designed and built in accordance with a published green building code, policy/guideline, or rating system.
OP4 Building Operations and Maintenance	5	All institutions	Own buildings that are operated and maintained in accordance with a sustainable management policy/program or a green building rating system focused on the operations and maintenance of existing buildings.
OP5 Building Energy Efficiency	6	All institutions	Have data on grid-purchased electricity, electricity from on-site renewables, utility-provided steam and hot water, and stationary fuels and other energy products.

OP6 Clean and Renewable Energy	4	All institutions	Support the development and use of clean and renewable energy sources.

With respect to indicators OP3 and OP4, the score is attributed, according to STARS ® 2.2 Technical Manual, to the buildings that were constructed or underwent major renovations (in the previous five years) were designed and built in accordance with a published green building code, policy/guideline, and/or rating system.
Green building codes, policies/guidelines, and rating systems may be:
Multi-attribute
Single-attribute: focusing predominantly on one aspect of sustainability such as energy/water efficiency, human health and wellbeing, or sustainable sites.
Third-party certification under a multi-attribute green building rating system developed/ administered by a WorldGBC member Green Building Council (GBC) is weighted more heavily for scoring purposes.

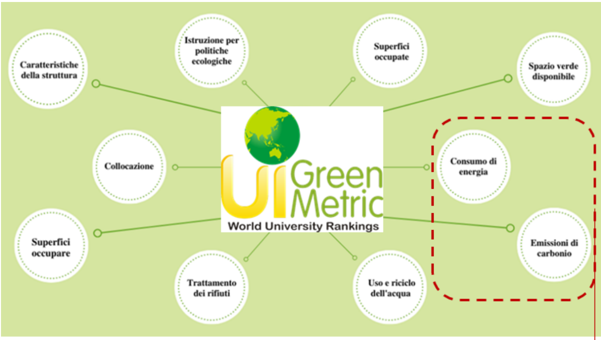
Table 2. Relation between credit ad rating system in STARS ® 2.2 Technical Manual

Credit	Type of rating system	Rating system
OP3 Building Design and Construction	Multi-attribute GBC rating systems	BREEAM, CASBEE, DGNB, Green Star, LEED BD+C, LEED ID+C, Living Building Certification, Parksmart
	Multi-attribute non-GBC rating systems	Green Globes NC
	Single-attribute rating systems	EDGE, Fitwell, Living Building Petal Certification, Net Zero Energy, Passive House / Passivhaus, WELL, ZCB-Design
OP4 Building Operations and Maintenance	Multi-attribute GBC rating systems	BREEAM-In Use, CASBEE for Existing Buildings, DGNB, Green Star Performance, LEED O+M, Parksmart Pioneer
	Multi-attribute non-GBC rating systems	BOMA BEST, Green Globes EB
	Single-attribute rating systems	EDGE, ENERGY STAR, Fitwell, TRUE, WELL, ZCB-Performance

“Each rating system also has criteria related to LEED/sustainable certified buildings. STARS and Sierra Club go as far to measure the percentage of certified sustainable building space” (Albis 2017).
Global Reporting Initiative (GRI) uses the following indicators to assess energy sustainability:
GRI 302-1 Energy consumed within the organisation.
GRI 302-2 Energy consumed outside the organisation
GRI 302-3 Energy intensity
GRI 302-4 Reduction in energy consumption
GRI 302-5 Reduction in the energy requirements of products and services
The Green Metric, promoted in 2010 by the University of Indonesia and whose reference for Italy is the University of Bologna, was also studied as part of the research. This tool groups indicators into six macro-categories to which a specific weight is attributed:

1. Setting and Infrastructure (15%)
2. Energy and climate change (21%)
3. Waste management (18%)
4. Water use (10%)
5. Means of transport (18%)
6. Education and research (18%).

Within the Italian Network of Sustainable Universities (RUS), a simplified methodology based on the verification of some minimum requirements related to automation, energy, water, indoor comfort, lighting and security, developed by the Energy Working Group of RUS, coordinated by the Polytechnic of Turin, has been adopted.



2. Energy and Climate Change (EC)

- 2.1. The use of energy-efficient appliances that replace conventional ones (lighting and household appliances)
- 2.4. Electricity use per year Total energy used for all purposes such as lighting, heating, cooling
- 2.6. Presence of green solutions in all construction and renovation policies
  - [1] None
  - [2] Natural ventilation
  - [3] Natural lighting throughout the day
  - [4] Existence of a building energy manager
  - [5] Green building
- 2.8. The total carbon footprint (CO2 emission in the past 12 months)

Field		Requirement		Description
B	Automation	B1	BMS	Presence of Building Management System (BMS) / Building Information Modelling (BIM) / Building Automation System (BAS) / Facility Management System (FMS) **(recommended requirement)**
		B2	APP	Interactive support for users via APP or online service
S	Safety	S1	Intruder Alarm System	Intruder alarm system (recommended: interfaced with BMS)
		S2	Fire-fighting	Fire-fighting system (recommended: interfaced with BMS)
		S3	Video surveillance	Video surveillance system (recommended: interfaced with BMS)
		S4	Anti-flooding	Anti-flooding system (recommended: interfaced with BMS)
E	Energy	E1	Monitoring	Automatic acquisition and logging system of energy consumption (recommended: interfaced with BMS)
		E2	Management	Automatic management system for energy supplies and production (recommended: interfaced with BMS)
A	Water	A1	Monitoring	Automatic acquisition and logging system of water consumption (recommended: interfaced with BMS)
		A2	Recovery	Rainwater recovery system for covering the flushing and irrigation
I	Indoor environment	I1	Thermal comfort	Monitoring (recommended: interfaced with BMS) of environmental parameters related to thermo-hygrometric comfort (e.g. air temperature, relative humidity, air velocity, etc.)
		I2	Air quality	Monitoring (recommended: interfaced with BMS)of pollutants (e.g. VOC, PM, CO2 ...)
		I3	Real-time	Programming and management in real time according to the occupancy profile of the premises (recommended: interfaced with BMS)
		I4	Passive system	Passive cooling and/or exploitation/limitation systems for free supplies
L	Lighting	L1	LEDs	High-efficiency luminaires (LEDs)
		L2	Sensors	Automatic lighting control (recommended: presence/illuminance sensors interfaced with BMS)
		L3	Shielding	Shielding adjustment and solar control
		L4	Natural light	Passive systems for natural light exploitation

Adapted from 'UI GreenMetric 2018: Guidelines for compiling energy and climate change', by RUS Energia, 2019.

Assessing the sustainability of university buildings has to take into account multiple aspects that relate not only to the environmental and functional performance of buildings, but also to direct user satisfaction (providing a safe, healthy, comfortable environment for students, teachers, and staff).

The evaluation of environmental and functional performance of educational buildings should ensure that the effectiveness of buildings is maximised not just in terms of occupancy costs but also with respect to user satisfaction (Ekekezie et al. 2021).

However, the analysis of the analysed tools showed that the centrality of the direct user and his perception of sustainability and comfort is not among the evaluation indicators. Moreover, the evaluation of the green potential of the building, that can be defined as the "capacity to refurbish a conventional building into a green building (green refurbishment) through architectural interventions" (Ben Avraham & Capeluto 2011) is delegated to other assessment tools.

In the light of these considerations, in the MedEcoSuRe research we see the need to investigation of direct users: identification of critical issues in relation to specific modes of use verification phase of the green potential of buildings.

*The three paragraphs and relative contents have been elaborated by University of Campania L. Vanvitelli

3.2 Long-term Renovation Goals

Long term renovation goals are intended to reduce/remove the existing barriers/bottlenecks slowing down building renovation processes of public buildings at EU and Italian level.

- Financial barriers: access to finance, payback expectations, investment horizon, competing expenditure, adequacy of price signals;
- Institutional and administrative barriers: regulatory and planning issues, institutional, structural, multiple stakeholders;
- Awareness, advice and skills: information, awareness of benefits, professional skills.

In line with the EU framework of ambitious environmental and energy targets, the proposed strategy exploits the primary objective of improving the energy performance of existing university buildings, as an occasion to to valorise the wide range of collateral benefits linked to building energy renovations.

- Economic benefits: energy cost saving, economic stimulus, impact on GDP, property value, research and developments (competitiveness and export growth), impact on public finance, energy import bill;
- Societal benefits: reduce fuel poverty, health, increased comfort and productivity;
- Environmental benefits: carbon saving (reduced by between 730 and 930 MtCO2/a in 2050 (a reduction of between 71% and 90%), reduced air pollution;
- Energy System benefits: energy security, avoided new generation capacity, reduced peak load. [BPIE]

From an architectural point of view, going beyond the imperative of "energy efficiency first", the strategy looks at the great opportunity of improving, through renovations, at least three more building-related aspects:

- Human comfort and wellbeing (indoor environmental quality, perception of the building as comfortable)
- Environmental impact (environmental sustainability in the life cycle)
- Architectural quality (aesthetic, liveability, sociality, quality of the living spaces).

The strategy addresses four long-term renovation goals:

1) ENERGY: Reduction of energy needs

Renovations strive at first instance for the reduction of the building's energy needs, so that the low energy demand can be fully satisfied by renewable energy.

2) ENVIRONMENT: Reduction of environmental impact

Ambitious renovations minimise the carbon footprint of buildings, reduce the environmental impact of existing buildings, starting from the integration of renewable resource.g.

3) COMFORT: Improvement of indoor comfort and wellbeing

Renovations improve the indoor environmental quality of existing living spaces, contributing to occupants' health, comfort and wellbeing, also stimulating more sustainable behaviours

4) ARCHITECTURE: Improvement of architectural quality

Renovation is the occasion for a functional/aesthetical requalification of the existing university buildings, contributing to the co-creation of beautiful and vibrant buildings communicating sustainability, where people are stimulated in study, work and dialogue.

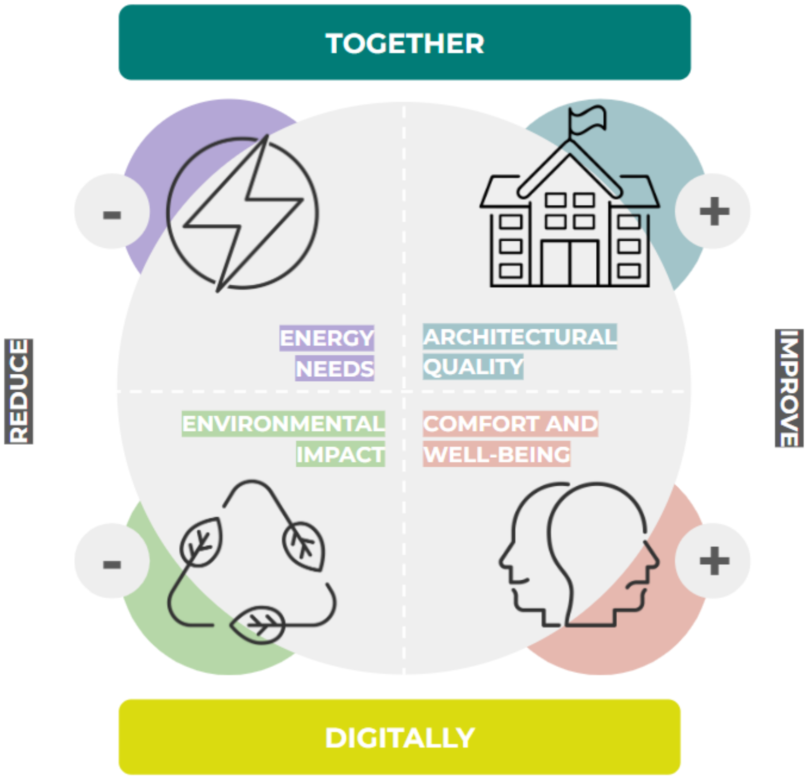
Transversal to the long-term goals, the strategy suggests two interrelated approaches, more related to processes than to buildings, supporting inclusive and innovative processes as fundamentals to approach the complexity of contemporary renovation challenges:

a. TOGETHER: boosting the proactive role/behaviour of people

promotion of more collaborative approaches between renovation stakeholders, and engagement of end users in co-design/"aware use" of sustainable university/public buildings, as the best approach;

b. DIGITALLY: untapping the digital potential

adoption of digital technologies to sustain more collaborative, reliable and sustainable renovation processes, as the best path.



3.3 Indicators and milestones

The evaluation of the proposed renovation strategy is based on the assessment of the defined long-term renovation goals, deriving and aligning with the state of art of EU policies and targets.
If for energy efficiency the EU normative body and policies provide for appropriate indicators, other aspects are needed to encompass all the four long-term goals.
Addressing the defined four long-term goals, the proposed strategy for the renovation of university public buildings is based on measurable indicators, allowing to assess the progressive implementation and fulfilment of the strategy.
The strategy considers a set of quantitative and qualitative indicators aligned with the defined long-term goals, as well as indicative milestones to take track of the improvements in the medium and long period (2030-2040-2050).

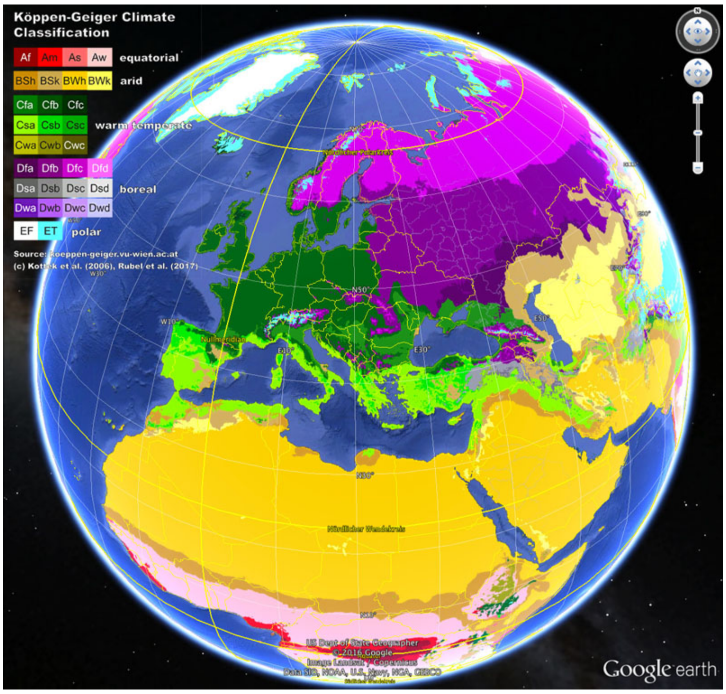
Aspects	n.	INDICATORS	UNIT	MILEST. 1 - 2030	MILEST. 3 - 2050
ENERGY	1	Energy savings	%		
	2	Renovation rate	%		
	3	Deep renovation rate	%		
	4	Share of nZEBs	%		
	5	Share of buildings in the lowest energy classes	%		
ENVIRONMENT	6	Share of renewables	%		
	7	PV installed	KW		
	8	CO2 emissions reduction	Kg CO_2 eq./person		
	9	New green areas	m^2		
COMFORT & WELLBEING	10	Number of questionnaires on environmental quality	n.		
	11	Evaluation of PMV	-3 to +3		
	12	Evaluation of PPD	%		
ARCHITECTURAL QUALITY	13	Renewed opaque facades	m^2		
	14	Renewed roofs	m^2		
	15	Renewed interiors	m^2		
	16	Renew/new opened transparent surfaces	m^2		
	17	Renewed external green spaces	m^2		
	18	New covered external spaces	m^2		
	19	New shading devices	m^2		
PEOPLE	20	Number of Living Lab activated	n.		

LIVING LAB	21	Number of people involved in co-design processes	n.		
	22	Number of people involved in the monitoring processes	n.		
	23	Number of actions (e.g. guidelines) promoting user engagement	N.		
DIGITAL Smart building	24	Number of building with BIM models	%		
	25	Smart metric Level			
	26	Number of buildings with BMS	%		
	27	Number of monitoring ICT, platform, dashboards			

4. Technical Appraisal

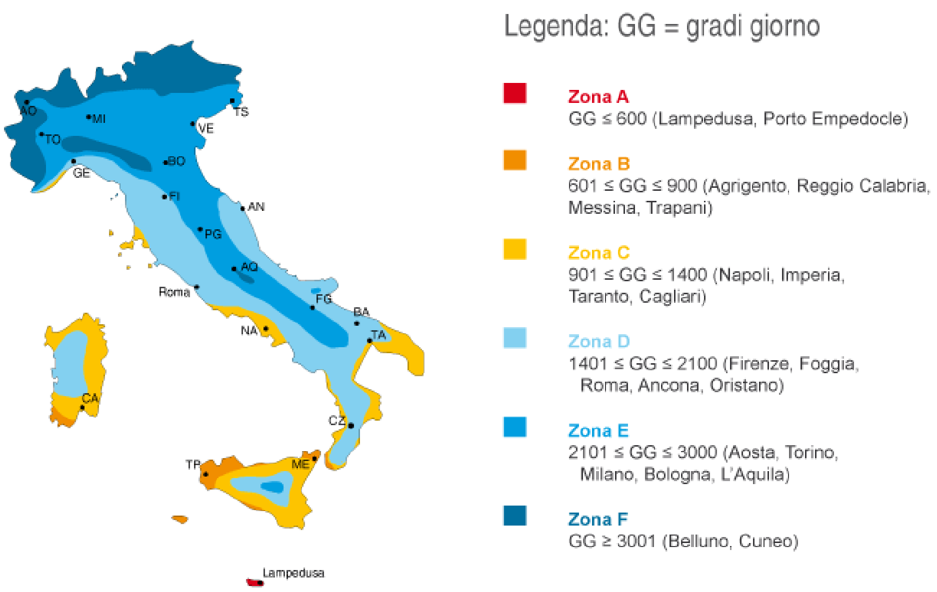
4.1 Climate and microclimate

UNIFI is located in Tuscany, a region in the centre-north of the Italian peninsula overlooking the Tyrrhenian Sea.
According to the Köppen climate classification (classifying the major climatic types on the basis of patterns of average precipitation, average temperature, and natural vegetation), the territory of Florence belongs to the class Cfa of "**humid subtropical climate**", referring to climate with (C) the temperature of warmest month greater than or equal to 10 °C, and temperature of coldest month less than 18 °C but greater than −3 °C, (f) precipitation more evenly distributed throughout year; criteria for neither s nor w satisfied and (a) temperature of warmest month 22 °C or above.



For its geographical and orographic position in the Tuscan hinterland, the climate of Florence is characterised by more polarised temperatures than along the Tuscan coast (resulting in Csa-Mediterranean climate), without benefits from the thermo-regulator action of winds blowing from the Tyrrhenian sea. This behaviour is also determined by the territorial morphology characterised by the valley of the Arno river, crossing the historical city centre. For these reasons, the Florentine

territory is characterised by very hot and humid summers, with perceived temperatures in some days near to 40°, and very humid and cold winters, with perceived temperatures in some days reaching some degrees sub-zero.
According to UNI (Italian Standardization Body), the climatic reference climatic zone of Florence is D (between 1401 and 2100 degree days) accounting for 1.821 dd requiring 12 hours/day of heating from the 1st of November to the 15th of April).



The wide territorial distribution of UNIFI buildings corresponds to very different locations in terms of altitude and urban context, influencing the relative microclimatic conditions.
For example, buildings in "Polo Centro Storico" are characterised by an exasperation of humidity conditions, determined by the presence of the Arno river and by the compactness of the urban tissue of the mediaeval city centre, determining a heat island effect. Other locations, such as "Polo Careggi", are characterised by higher altimetries and more diradated urban contexts, consenting a better ventilation and more tempered conditions. The different microclimatic conditions can be appreciated by comparing the data of the different weather stations across the territory (link).

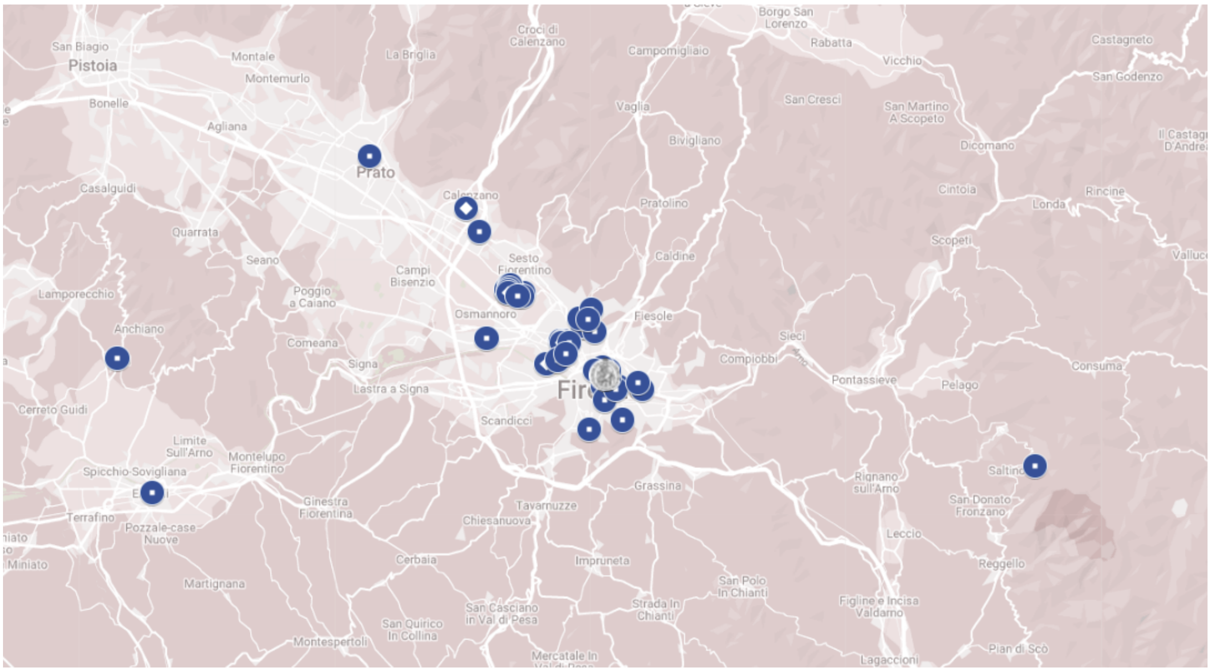
4.2 Composition of the building stock

The building stock in use by the University of Florence consists of about 90 buildings and 140 hectares, distributed across the Florentine territory and beyond.

First university buildings have been settled since the Middle Ages in the historical city centre of Florence, still representing the location of a high number of university activities, hosted in a wide range of heritage buildings originally dedicated to other functions (e.g. convents, public buildings), but also enlarged across time in new buildings.

In order to shrink the research and analysis field, the study focuses on buildings hosting the most representative educational and research activities (at least). Not considering buildings specifically dedicated to university related services, accommodations and other services (e.g. sport, culture and leisure), the sample is composed of **75 buildings for education and research (from now defined as "university buildings").**

This choice also derives from the consideration that the UNIFI building park is characterised by some very special historical buildings, such as museums and botanical gardens, whose peculiarities require an ad hoc attention.



UNIFI (link)

4.2.1 Urban level analysis

The building stock of the University of Florence is mainly settled in the territory of the municipality of Florence (70%), with some buildings located in the territory of other municipalities (30%).
Due to its ancient roots, most representative buildings are still hosted in the city centre (32%), with more recents expansions spreaded out in more peripheral areas of urban expansion (e.g. the urban axis connecting Florence-Prato-Pistoia).
It is possible to distinguish three main "university urban types" describing the university settlements in terms of distribution of the different university buildings in the urban context:

- **Polo**: set of university buildings distributed in a relationship of proximity (walkable distance);
- **Campus**: set of university buildings concentrated in a defined area developed for the scope;
- **Single building/complex**: single building/building complex without a continuity solution with the other university buildings (not walking distance).

A high number of UNIFI buildings is located in the UNESCO protected historical centre of Florence, with educational and research activities still performed in heritage buildings. The set of university buildings located within the historical centre of Florence is called "**Polo Centro Storico**"; accounting for a total **24 university buildings**, it is the biggest UNIFI polo.
Other UNIFI buildings are distributed in various "polo" scattered across time throughout the city and beyond, in different urban development areas and municipalities.

→ **Polo:**
- Centro Storico (32%)
- Novoli (8%)
- Careggi (2,5%)
- Morgagni (10,5%)

- Calenzano (2,5%)
- Empoli (1,5%)
- Prato (1,5%)

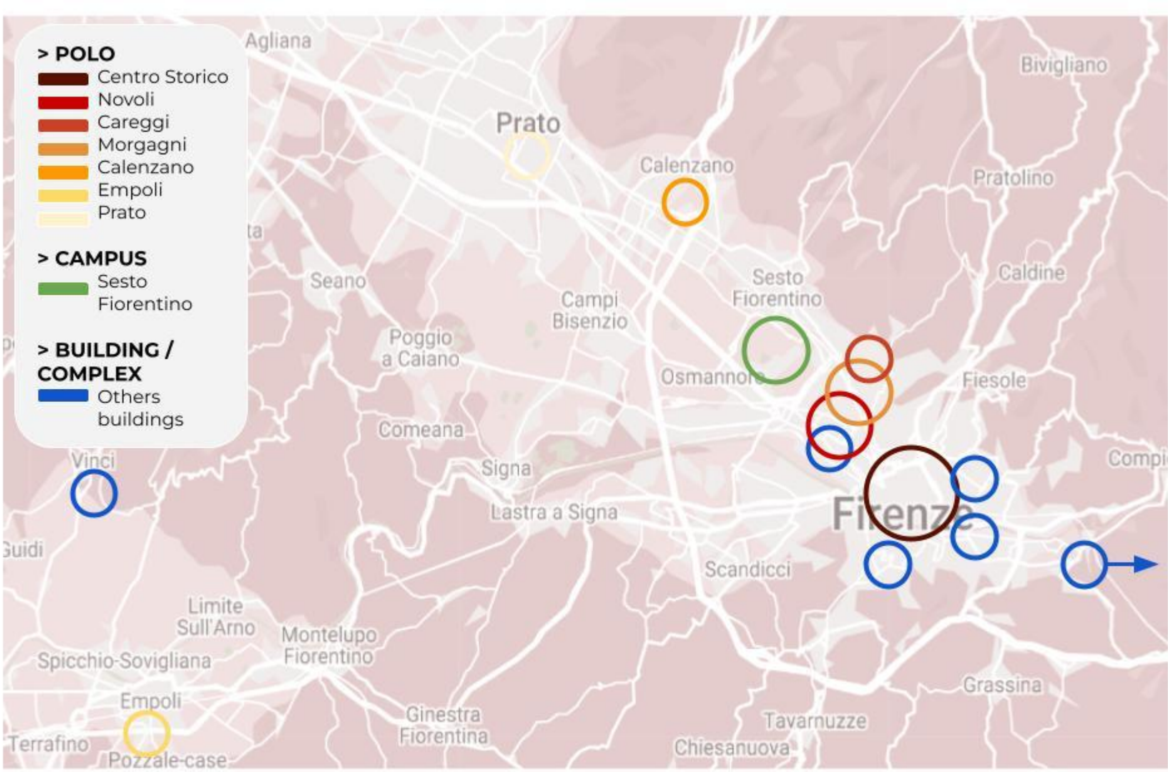
The University of Florence has one only campus (Sesto Fiorentino), located in the north-east expansion from the historical city, in the plain geographical area connecting with the productive areas of Prato-Pistoia (5 km from the city centre). It is only university buildings' concentration which can be defined as a "campus": here in fact, all the functional spaces characterising universities (education and research, administrative and management services, accommodation and other services) are present in a defined area designed for the scope.
The "Sesto Fiorentino Campus" covers a surface of 70 hectares, where today **16 buildings** are distributed for education and research activities.
The campus is the object of future expansion projects, since large and unused lots are available. The more consistent (as reported in the UNIFI STRATEGIC PLAN, see above)

➔ **Campus:**
- Sesto Fiorentino (21%)

A third category of UNIFI's urban types refers to isolated buildings or building complexes, not in relationship of proximity with other university buildings, where university activities of education and research are performed. The majority of the university buildings included in this urban type are historical, since they are mainly located in little towns on the hills surrounding Florence, such as former religious building complexes (e.g. convents), and/or Renaissance villas.

➔ **Single building/complex:**
- Santa Marta
- Vinci
- Arcetri
- Torretta
- Ponte di Mezzo
- Gore
- Donizetti
- Maragliano
- Pieraccini
- Quaracchi
- Il Paradisino

- San Salvi
- Cascine
- Palagi



All the UNIFI buildings related to the main representative function of "education and research" have been analysed at urban level, in reference to the following categories of analysis:

- Urban type (defined above)
- Urban pattern (urban density and settlement period)
- Age band (period of construction)
- Geographic position (valley, plain, hill and mountain)

Such categories of analysis have been selected in the light of their influence on micro-climatic conditions, as well as on the building energy and environmental performance.

Med-EcoSuRe

Buildings	Urban Type	Toponym	Urban Pattern	Age band	Geographic Position
AOUC Azienda Ospedaliero - Universitaria Careggi	POLO	Careggi (Medical centre)	Recent settlement	After 1996	Plain
AOUC Azienda Ospedaliero - Universitaria Careggi	POLO	Careggi (Medical centre)	Recent settlement	1956-1978	Plain
Aula Battilani	POLO	Centro Storico	Historic core	Before 1897	Valley
Borgo Albizi	POLO	Centro Storico	Historic core	Before 1897	Valley
Campus Morgagni A	POLO	Morgagni	Recent settlement	After 1996	Plain
Campus Morgagni B	POLO	Morgagni	Recent settlement	1897-1956	Plain
Campus Morgagni C	POLO	Morgagni	Recent settlement	1897-1996	Plain
Campus Morgagni D	POLO	Morgagni	Recent settlement	1956-1978	Plain
Campus Morgagni E1	POLO	Morgagni	Recent settlement	1897-1956	Plain
Campus Morgagni E2	POLO	Morgagni	Recent settlement	1897-1956	Plain
Campus Morgagni F	POLO	Morgagni	Recent settlement	1956-1978	Plain
Campus Morgagni G	POLO	Morgagni	Recent settlement	1956-1978	Plain
Campus Novoli C9	POLO	Novoli	Recent settlement	After 1996	Plain

Campus Novoli D1	POLO	Novoli	Recent settlement	After 1996	Plain
Campus Novoli D4	POLO	Novoli	Recent settlement	After 1996	Plain
Campus Novoli D5	POLO	Novoli	Recent settlement	After 1996	Plain
Campus Novoli D6	POLO	Novoli	Recent settlement	After 1996	Plain
Campus Novoli D14	POLO	Novoli	Recent settlement	After 1996	Plain
Cascine - Campus di Agraria	single BUILDING / COMPLEX	Cascine	Sparse settlement	Before 1897 + 1897-1956	Plain
PALAGI	single BUILDING / COMPLEX	Palagi (Medical centre)	Recent settlement	1956-1978	Hill
La Pira	POLO	Centro Storico	Historic core	Before 1897	Valley
[Arcetri]	single BUILDING / COMPLEX	Arcetri	Sparse settlement	Before 1897	Hill
Orbatello	POLO	Centro Storico	Historic core	Before 1897	Valley
Palazzo Fenzi	POLO	Centro Storico	Historic core	Before 1897	Valley
Palazzo Nonfinito	POLO	Centro Storico	Historic core	Before 1897	Valley
Palazzo Vegni	POLO	Centro Storico	Historic core	Before 1897	Valley
piazza Brunelleschi	POLO	Centro Storico	Historic core	Before 1897	Valley
San Clemente	POLO	Centro Storico	Historic core	Before 1897	Valley
San Salvi padiglione 26	single BUILDING / COMPLEX	San Salvi	Sparse settlement	1956-1978	Plain
Santa Marta	single BUILDING / COMPLEX	Santa Marta	Sparse settlement	1897-1956	Hill

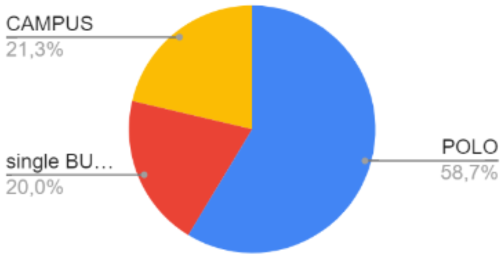
Santa Teresa	POLO	Centro Storico	Historic core	1897-1956	Valley
Santa Verdiana	POLO	Centro Storico	Historic core	Before 1897 + 1897-1956	Valley
Torretta (la)	single BUILDING / COMPLEX	Torretta	Compact settlement	1897-1956	Plain
via Alfani (1) - CLA	POLO	Centro Storico	Historic core	Before 1897	Valley
via Alfani (2) - CLA	POLO	Centro Storico	Historic core	Before 1898	Valley
via Alfani (3) - CLA	POLO	Centro Storico	Historic core	Before 1899	Valley
via Capponi (1)	POLO	Centro Storico	Historic core	1897-1956	Valley
via Capponi (2)	POLO	Centro Storico	Historic core	Before 1897	Valley
via Capponi (3) - facoltà di lettere e filosofia	POLO	Centro Storico	Historic core	Before 1897	Valley
via Cesare Battisti	POLO	Centro Storico	Historic core	Before 1897	Valley
via del Ponte di Mezzo	single BUILDING / COMPLEX	Ponte di Mezzo	Compact settlement	1897-1956	Plain
via delle Gore	single BUILDING / COMPLEX	Gore	Recent settlement	1956-1978	Plain
via Donizetti	single BUILDING / COMPLEX	Donizetti	Compact settlement	1897-1956	Plain
Via Laura - facoltà di scienze della formazione	POLO	Centro Storico	Historic core	Before 1897	Valley
via Maragliano	single BUILDING / COMPLEX	Maragliano	Compact settlement	1897-1956	Plain
via Micheli (1)	POLO	Centro Storico	Historic core	Before 1897	Valley
via Micheli (2)	POLO	Centro Storico	Historic core	1897-1956	Valley

via Micheli (3)	POLO	Centro Storico	Historic core	1897-1956	Valley
via Santa Reparata	POLO	Centro Storico	Historic core	Before 1897	Valley
viale Pieraccini (1)	single BUILDING / COMPLEX	Pieraccini	Recent settlement	1897-1956	Plain
viale Pieraccini (2)	single BUILDING / COMPLEX	Pieraccini	Recent settlement	1978-1996	Plain
Villa Rucellai - Quaracchi	single BUILDING / COMPLEX	Quaracchi	Compact settlement	Before 1897	Plain
Villa Ruspoli	POLO	Centro Storico	Historic core	1897-1956	Valley
Calenzano / Design Campus	POLO	Calenzano	Recent settlement	After 1996	Plain
Calenzano	POLO	Calenzano	Recent settlement	1988-1996	Plain
Empoli / San Giuseppe	POLO	Empoli	Tessuto compatto	Before 1897	Plain
Prato / Polo "Città di Prato"	POLO	Prato	Tessuto compatto	1897-1956	Plain

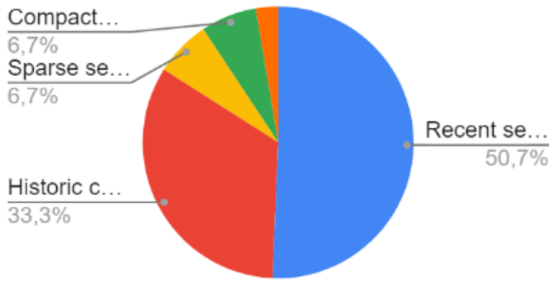
Reggello / Il Paradisino	single BUILDING / COMPLEX	Il paradisino	Sparse settlement	1897-1956	Mountain (sub-sistema montagna)
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	1988-1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	1988-1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain

Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	1988-1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	1988-1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Sesto Fiorentino / Campus Sesto	CAMPUS	Sesto Fiorentino	Recent settlement	after 1996	Plain
Vinci	single BUILDING / COMPLEX	Vinci	Historic core	1897-1978	Hill

The analysis revealed that the majority of UNIFI buildings belong to the urban type of “polo” (58%), while half are located in recent settlements (50,7%), immediately followed by locations in historical centres (33, 3%).

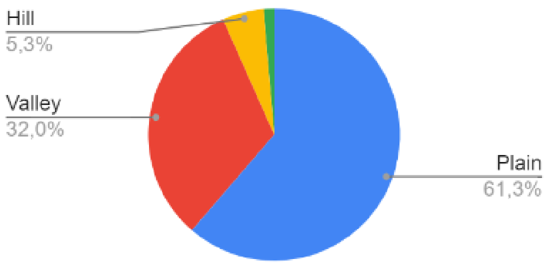


URBAN TYPES

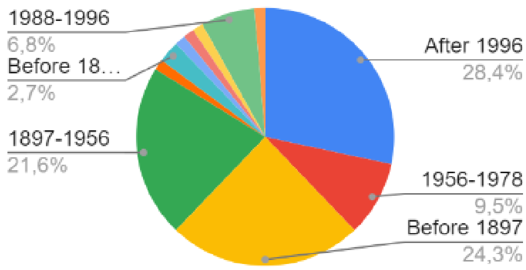


URBAN PATTERNS

According to the geographical position, plain is over-represented (61%). Regarding the age band, only a minority of buildings (28,4%) has been built after 1996, while most represented sector dates before 1987 (24,3%).



GEOGRAPHICAL POSITION



AGE BAND

4.2.2 Building level analysis

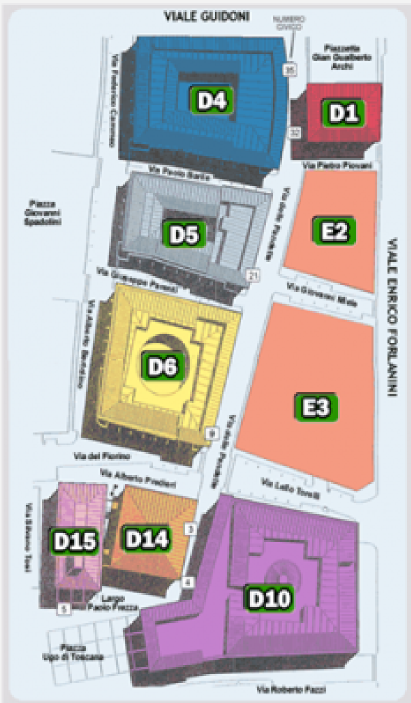
On the basis of the classification adopted at urban level, it was possible to select the most representative buildings, allowing to start a reflection about energy-environmental performance and impacts, and the prefiguration of renovation strategies.

Reference Buildings	Urban Type	Toponym	Urban Pattern	Age Band	Geographic Position
group 1. **Santa VERDIANA**	POLO	Centro Storico	Old compact settlement	XIV sec.	Valley (sub-system Arno)
group 2. **NOVOLI**	POLO	Novoli	Recent compact settlement	2002	Plain (sub-system plain)
group 3. **Santa MARTA**	single BUILDING complex	Santa Marta	Scattered urban fabric	XIV sec.	Hills (sub-system hill)
group 4. **SESTO Fiorentino**	CAMPUS	Sesto Fiorentino	Recent large settlement	after 1996	Plain (sub-system plain)

Each one of the four representative university buildings has been described in depth, in terms of:

- Specific building typology
- Energy carrier
- Energy use per building type and age
- Energy consumption
- Energy performance (energy classes)
- Occupancy
- Ownership and tenure status

GROUP 1. Santa Verdiana	
Original building typology	Monastery
Image	
Energy Carrier	Natural gas and electricity
Energy use per building type and age	Heating, cooling and lighting, hot water
ENERGY CONSUMPTION MWh	147 MWhe 244 MWht
EPC BAND / ENERGY PERFORMANCE	label G
Occupancy	Total seats > n° 1300 - Occupancy > 70% (900 persons)
Ownership	Comune di Firenze

<table>
<tr><th colspan="2">GROUP 2. Novoli</th></tr>
<tr><td>Original building typology</td><td>University</td></tr>
<tr><td>Image</td><td>

</td></tr>
</table>

Energy Carrier	Natural gas + Electricity
Energy use per building type and age	lighting, heating, cooling, hot water
ENERGY CONSUMPTION MWh	4358 MWhe 1251 MWht
EPC BAND / ENERGY PERFORMANCE	label E
Occupancy	Total seats > n° 5800 - Overage occupancy > 70% (4000 persons)
Ownership	Comune di Firenze

GROUP 3. Santa Marta	
Original building typology	Private Residence
Image	
Energy Carrier	electricity and natural gas
Energy use per building type and age	lighting, heating, cooling, hot water

ENERGY CONSUMPTION	1269 MWhe 1319 MWht
EPC BAND / ENERGY PERFORMANCE	label G
Occupancy	Total seats > n° 1600 - Average occupancy > 70% (1000 persons)
Ownership	Comune di Firenze

GROUP 4. Sesto Fiorentino	
Specific building typology	University
Image	

Energy Carrier	Natural gas + Electricity
Energy use per building type and age	lighting, heating, cooling, hot water
ENERGY CONSUMPTION MWh	14705 MWhe 4939 MWht
EPC BAND / ENERGY PERFORMANCE	label E
Occupancy	Total seats > n° 1500 - Occupancy > 70% (1000 persons)
Ownership	Comune di Sesto Fiorentino

4.3 Identification of worst-performing segments of the building stock

Considering the analysis of the building stock, and the focus on the four identified reference buildings, it is possible to affirm that Group 1 is the worst-performing segment, due to the different aspects:

- low energy class (G)
- construction age band (before 1897): the presence of heritage constraints impedes deep renovations. Moreover, also the integration of new plant systems is more complex than in more recent buildings;
- Urban districts: historical centre in compact settlement, with heat island effect, without the possibility of integration of Nature-based solutions.

4.4 Identification of cost-effective approaches to renovation

The identification of cost-effective approaches to renovate the university building stocks, relevant to building type and climatic zone, can be supported by the Med-EcoSuRe TOOLKIT, and in particular the ABACUS, guiding the selection of the best strategies, technologies and materials for energy renovations in the Mediterranean area.

Considering the four reference buildings identified (representative of the whole group), and their peculiarities in terms of age band and urban context, it was possible to identify the best strategies to adopt for renovation.

Reference Buildings	Renovation Strategies
group 1. **Santa VERDIANA**	STRATEGY 1. Valorise daylight STRATEGY 3. Integrate shading devices STRATEGY 8. Integrate renewable energy
group 2. **NOVOLI**	STRATEGY 8. Integrate renewable energy
group 3. **Santa MARTA**	STRATEGY 4. Upgrade the opaque envelope STRATEGY 8. Integrate renewable energies
group 4. **SESTO Fiorentino**	STRATEGY 7. Regulate outdoor microclimate STRATEGY 8. Integrate renewable energies

4.5 Renovation opportunities and expected benefits

For each reference building, a set of renovation strategies and technologies have been identified and evaluated, in order to appreciate the benefits of renovations.

GROUP 1. Santa Verdiana	
Renovation Strategy	STRATEGY 1. Valorise daylight STRATEGY 3. Integrate shading devices STRATEGY 8. Integrate renewable energy
Renovation Technologies and Materials	The realised renovation project (Med-EcoSuRe pilot), insisting on a building block, provided the integration of a skylights in order to improve the indoor visual quality and reduce the adoption of artificial light; the project also regarded the integration of a 3d external steel structure hosting innovative PV panels (amorphous silicon and monocrystalline) located in the south façade of the building block, consenting not only to shade the overlighted façade (reducing energy need for cooling and avoiding overlit), but also for the production of clean energy.
Improvements and results	The analysis of the improvements starts with the energy dynamic simulation of the state of art for what concerning the block involved in the renovation process. Consequently, energy saving was evaluated, updating the model with the integrated solution. The results are followings: ● State of art consumption: 114 kWh/m^{2}y ● Effect of the shading by the PV structure and relamping with LED: 65 kWh/m^{2}y (reduction for cooling and lighting) ● Effect of the energy production from PV panels: 50 kWh/m^{2}y (7000 kWh year) Finally the overall amount of energy saving for the investigated block is -56%.

Image	

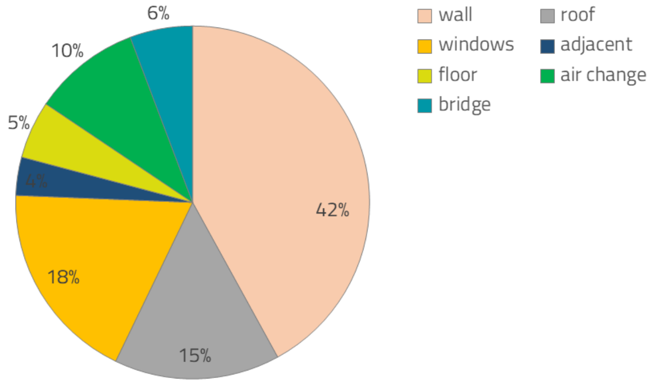
GROUP 2. Novoli	
Renovation Strategy	STRATEGY 8. Integrate renewable energy
Renovation Technologies and Materials	Mono-crystalline silicon panels integrated on roof
Improvements and results	Since the site was built in the '90, the blocks are designed with modern standards materials and technologies. Optimisation could be achieved pushing on the contribution from renewable energy sources. The new PV plants are supposed to be installed on the available part of the roof for an overall net area of 3088 m^2. The layout of the roof limits its exploitation due to the presence of many vertical/horizontal gaps and other services, so a coverage factor of 70% also was considered. That leads to a peak power of about 670 kW with an yearly energy production of 908 MWhy (21% of the demand).

Image	Suitable area for PV installation (east-south-west orientation) 

GROUP 3. Santa Marta	
Renovation Strategy	STRATEGY 4. Upgrade the opaque envelope STRATEGY 8. Integrate renewable energies
Renovation Technologies and Materials	Exterior Insulation and Finishing System Fixtures substitution Mono-crystalline silicon panels integrated on roof and parking shelter
Improvements and results	Since the Santa Marta complex is an ancient site (not protected by Sovrintendenza office) the envelope is characterised by very low performance from an energy point of view, in respect with the standard reference values (see table below).

Thermal transmittance [W/m²K]	Santa Marta	reference
wall	1.52	0.32
roof	1.73	0.26
floor	0.92	0.32
fixtures	5.23	1.8

According to the building certification (APE), the weight of energy dissipation for each component can be evaluated during the winter season and shown in the next diagram: the external walls result to have the major impact.



Therefore, the retrofitting process in this specific case must include a strong intervention on the envelope before considering plants and the integration of renewable energy sources. Depending on the overall area of each component, some evaluations have been carried out, aiming at the contribution for the amount of energy saving with the renovation of a mix of them. The results are reported in the table below with a target of -38% for heating consumption with a complete refurbishment.

<table>
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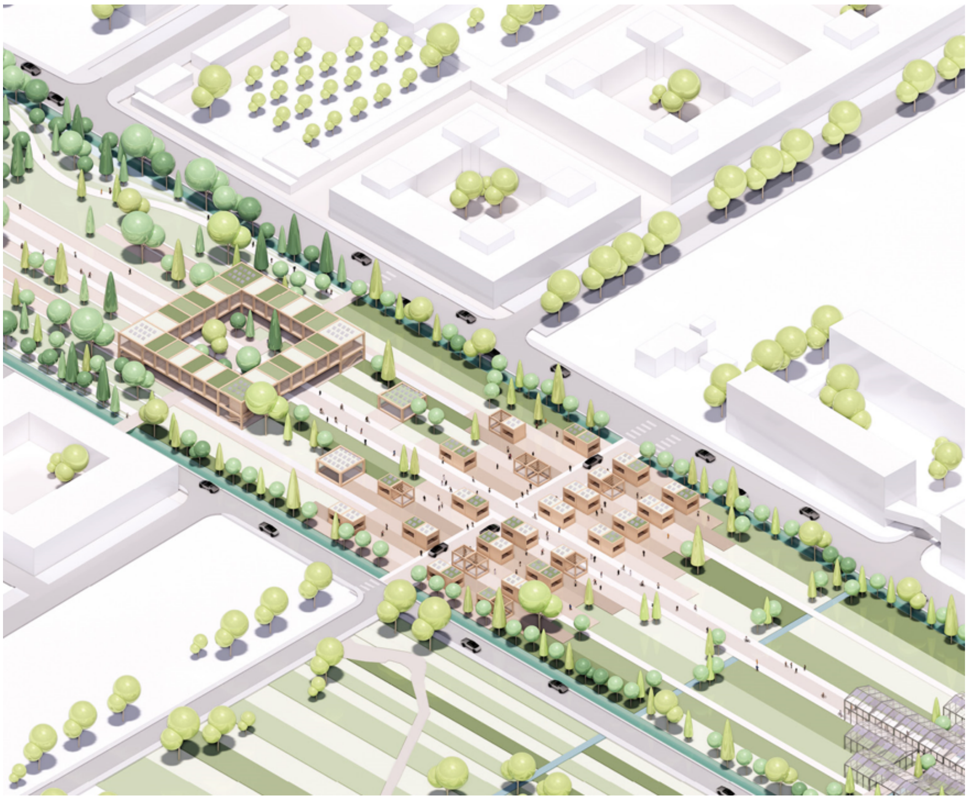
intervention	energy savings
envelope	-14%
roof	-13%
windows	-12%
envelope+roof	-26%
roof+windows	-25%
envelope+windows	-25%
full retrofitting	-38%

For what concerning the integration of renewable energy sources, the roof was investigated together with the parking area in this site, choosing the suitable zones facing east-south-west orientation for a total surface of 3162 m^2. In this configuration a global peak power of 677 kWp with PV panels is achieved, obtaining an annual energy production of 776 MWh (61% of the demand). Electric energy consumption (more than 50% for lighting) will be also reduced thanks to a relamping intervention. Finally, a further optimization could be addressed converting standard gas boilers for heating in more efficient plants avoiding the needs of fossil fuels. 1319 MWht from natural gas corresponds to 377 MWhe through the installation of high efficiency heat pumps.
All the proposed interventions must be evaluated not only from the energy point of view but also from an economical one, quantifying the cost/benefits ratio.
</td></tr>
<tr><td>Image</td><td>Suitable area for PV installation (south orientation)
</td></tr>
</table>

GROUP 4. Sesto Fiorentino	
Renovation Strategy	STRATEGY 7. Regulate outdoor microclimate STRATEGY 8. Integrate renewable energies
Renovation Technologies and Materials	Nature-based solutions Mono-crystalline silicon panels integrated on roof and parking shelter
Improvements and results	The outdoor unfinished spaces of the campus have been redesigned in order to integrate green solutions and small infrastructures, intended to improve the microclimatic conditions of the site (reducing the heat island effect), with a positive influence both on building performance and on the perceived quality of comfort by occupants. From an energy point of view, as already mentioned for the Novoli site, also Sesto Fiorentino is recent and the blocks are designed according to updated standards (for material characteristics and services). For this reason, only the maximisation of the contribution of renewable energy was taken into account. Looking at the available surfaces (roofs and parking areas), 5989 m^2 could be used for the installation of PV panels reaching a peak power of 1300 kW and a production of 1564 MWhy that correspond to the 4.2% of the entire electric demand of the University of Florence.

Image	Strategy 7  

4.6 Final considerations about renewable energy sources integration

The integration of renewable energy represents a renovation strategy that is transversal for the different site typologies and it could be applied transversally. The maximum exploitation of the available free areas for installing PV plants increases the contribution of clean energy in respect to the demand.

A preliminary analysis was carried out on the complete building stock in order to predict the potential of the technology: 220 complexes were considered quantifying the roof area with a coverage factor equal to 50% to be conservative.

Starting from the datasheet of a mono-crystalline silicon panel from the market (efficiency 21%), we obtained that operating on about 95 buildings (137274 m^2), it would be possible to install 29758 MW of peak power with a production of 36.79 GWh per year from the Sun.

This represents such an important result since the yearly demand rises 37 GWh: it is to say that we would be able to avoid totally the energy consumption for electricity, at least.