Journal of Sustainability Perspectives: Special Issue, 2021, 165-174

Journal of Sustainability Perspectives

journal homepage: https://ejournal2.undip.ac.id/index.php/jsp/

Between Past and Future: The Mission of University of L'Aquila and Its Action on Energy and Climate Change

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Article Info

Received:
15 March 2021
Accepted:
25 May 2021
Published:
1 August 2021

DOI:

Presented in The 6th International (Virtual) Workshop on UI GreenMetric World University Rankings (IWGM 2020)

Abstract For the *University of L'Aquila*, sustainability and civic engagement are key commitments. Actions to enhance and safeguard the territory and to improve the community wellbeing are even more meaningful in a city that, after the earthquake of 2009, is re-thinking its social and economic backbone. The aim to provide buildings with a high level of seismic security, of energy efficiency and resources saving, has been particularly challenging, but that also offered an opportunity. The participation to the UI Green Metric WUR has been a natural consequence of this process of renovation. Moreover, throughout the data collection and analysis, UI GM rankings stimulates the cross disciplinary cooperation in research, innovation, social and civic engagement.Concerning "*Energy and Climate Change*" the University could take the opportunity to exploit the competencies of research teams worldwide known working in renewable energies production (solar, wind, hydropower), building efficiency and retrofitting, environmental impacts. The University is member of the Italian University Network for Sustainable Development, which offered guidelines to implement energy and climate change related politics. The improvements of building focused on: smart illumination appliances (61% of the area), smart automation of heating/cooling (90% of the area), renewable energy production (PV and solar thermal), and integration of climate action into the strategic plan.

Keyword:
Preservation, restoration, prevention, development, inclusiveness

1. Introduction

With 7 Departments displayed in three campuses (Roio, Coppito and City Center) the University of L'Aquila offers its about 20,000 students a wide range of first and second cycle degrees, and a vast array of PhDs and 3rd Cycles courses in the fields of Mathematics, Physics, Chemistry, ICT, Biology, Medicine and Life Sciences, Social Sciences and Humanities.

Excellence in both education and research is at the centre of University's policy. Teaching is designed to be interactive, stimulating and interlocked with research as closely as possible. Preparing the students for becoming global graduates in a global community and for a successful career is the core goal of the internationalization policy. Students can apply new knowledge to real problems drawn from working life and are embedded in an international environment thanks to the partnerships with universities in Europe and beyond, from Asia to America and Africa, in the framework of about 400 agreements in more than 60 countries.

Sustainability and civic engagement are key commitments of the University. To enhance and safeguard the territory, to improve community wellbeing, to promote a knowledge-based economy and to work effectively together for the common good, have a special meaning in a territory that after the 2009 earthquake is re-thinking its social and economic backbone.

The City of L'Aquila is one of the main cultural heritage centers in Italy, so the restoration of the damaged artistic heritage required the intervention of experts from several sectors. The University, with its multidisciplinary expertise, has been and is a key actor also in the physical reconstruction of the monuments and buildings, also stimulating new research in techniques, materials and devices. At present, the University has restructured almost all the buildings of its campuses including the ancient ones following the most accredited principles of sustainability and the strong commitment to reduce the impact on the environment, with special attention to high level of seismic security, energy efficiency and resources saving.

Thus, the participation to the UI Green Metric WUR has been a natural consequence of the long process of renovation and the way to measure its effectiveness as well as the range of possible improvements. Concerning "*Energy and Climate Change*" the University was able to take the opportunity to exploit the competencies of research teams worldwide known working in renewable energies production (solar, wind, hydropower), building efficiency and retrofitting, environmental impacts, and in the Research "*Center of Excellence Telesensing of Environmental and Model Prediction of Severe events*" (CETEMPS, focused on climate changes), and the Excellence Center "*Design Methodologies for Embedded controllers, Wireless interconnect and System-on-chip*" (DEWS, focused on disruptive technologies, IoT and AI), just to mention some examples.

The information provided in that section gives a clear overview of both the obtained results and the policies underlying them, and, in several cases, also the "*evidence*" that justify the provided answers. The good performance of UNIVAQ in this sector cannot be disconnected by the other items of the questionnaire since it is the result of several coherent and concurrent factors:

1. The establishment of objectives that were concrete and feasible
2. The appointment of people motivated and provided with the power to implement the needed actions
3. The monitoring and assessment of the results
4. The adoption of corrective and integrated measures for improving the number and the quality of the results

2. Policies and Methodologies

2.1. University of L'Aquila and Sustainability

University of L'Aquila started its approach to sustainability by joining the RUS – the Italian University Network for Sustainable Development – in late 2017 [1] and included several sustainability issues in its strategic plan since 2015. In 2018 the University participated for the first time to the GM ranking and the questionnaire proved to be a valid tool for self-assessment and for starting a systematic and sound collection of data and reports in the six dimensions investigated: infrastructure, energy, water, waste, transportation, education. The consequent reorganization of the flow of information between different administrative offices and the quality enhancement of the documents and methodologies, as well as a cross disciplinary approach to sustainability issues, allowed the improvement of the performance in 2019 (in the global rank: 147 on 719 participants in 2018, 105 on 780 participants in 2019).

The University is displayed in three main campuses: City Center (Rectorate, Human Science and Economics), and the suburban areas Roio (Engineering), on the top of a hill totally covered by a pine forest, and Coppito (Sciences and Medicine), within a large area with planted vegetation.

The total campus area amounts to 490197 m^2, of which >35% is covered in forest vegetation, between 20–30% is covered in planted vegetation, with a ratio of open space to total area >90-95%.The total campus ground floor area of buildings is 27285 m^2, and the total campus buildings area is 94228 m^2 for a population of about 20.000 people (>40 m^2 of open space per person).

After the earthquake of 2009, all the buildings of the University had to be reconstructed. Some belong to the architectural historical heritage of the City which is one of the most important art centers in Italy. The restoration of the sites has been one of the main challenges in the reorganization of the academic and scientific activities, but also offered an opportunity to reorganize all the spaces and to restore both the recent and ancient buildings taking into consideration all the European and National Directives as well as to propose innovative solutions and exploit new technologies for ensuring sustainability. Energy efficiency has been one of the key goals and the efforts done during the reconstruction provided the University with competence and tools for achieving good results in the GM metrics, not only in the "*Energy and Climate Change*" sector.

To boost energy performance of buildings, the EU has established a legislative framework that includes the Energy Performance of Buildings Directive 2010/31/EU (EPBD) [2] and the Energy Efficiency Directive 2012/27/EU [3]. Italy, as an EU country, has transposed these rules into national laws. In particular, the former was adopted through the Law Decree 63/2013 [4]; while the latter through the Law Decree 102/2014 [5]. Both Directives mentioned above were amended, as part of the '*Clean energy for all Europeans*' package, in 2018 and 2019. In particular, the Directive amending the Energy Performance of Buildings Directive (2018/844/EU [6]) introduces new elements and sends a strong political signal on the EU's commitment to modernize the buildings sector in light of technological improvements and to increase building renovations. EU countries need to transpose the new and revised rules into national laws.

2.2 The UNIVAQ approach to "Energy and Climate Change" indicators

The University of L'Aquila is also member of the RUS Working Groups "Energy" and "Climate Change", so that several issues measured by the "*Energy and Climate Change*" indicators were considered and assessed in the national context. Integrations and improvements in the decisions and policies implementation are in a continuous process.

GM question 2.1: Energy efficient appliances usage

The renovation of the buildings provided the opportunity to replace the majority of the appliances with energy efficient ones. In three buildings of UNIVAQ campuses, Human Science (new building – 7,608 m^2), Blocco "0" (new building) of 'Coppito' sub-campus (consisting of three buildings - 46,191m^2) and Palazzo Camponeschi (renovated building – 3,685 m^2), all the lighting fixtures are based on the LED low-energy technology according to the European directives [2,4] and Italian laws [3,5]. In addition, in the two other existing buildings of 'Coppito' sub-campus, conventional lighting fixtures have been replaced with LED lamps according to central administration policies of sustainable development (SD) [7], thereby permanently reducing electrical energy consumption. For this reason, the percentage of LED lamp used currently in the total UNIVAQ building area is into the range of 50 – 75 %. In fact

$$\frac{\text{LED-lamp equipped building area}}{\text{total building area}}\times 100=\frac{(7,608+3,685+46,191)\ \text{m}^2}{94,228\ \text{m}^2}\times 100=61\% \quad (1)$$

Also, bearing in mind that the energy performance of buildings does not focus only on the building envelope, but include all relevant elements and technical systems involved in a building, such as passive elements that participate in passive techniques aiming to reduce the energy needs for heating or cooling [1-4], all the old and inefficient appliances installed in Palazzo Camponeschi have been replaced with the highest energy saving ones (e.g. boilers, local space heaters, air heaters) based on stand-by mode and inverter technology. Energy efficient appliances are also used in the new buildings of Human Science and Blocco "0" of 'Coppito' sub-campus according to [2 -5].

GM questions 2.2. Total campus smart building area and2.3. Smart building implementation

The total area of smart buildings in UNIVAQ campus is of 84,827.00 m^2. In this context a smart building is described as one that is well designed, has low intrinsic energy demand, is comfortable (and has a healthy indoor environment), has the right materials and equipment, and can ultimately empower the consumer to take the best decision for them and their situation. But, above all, it has to be supported by active control systems such as automation, control and monitoring electronic devices that aim to save energy for the heating, cooling, ventilation, hot water, lighting or for a combination thereof.

Five buildings/sub-campus of UNIVAQ can be classified as smart buildings according to the definition of UI GreenMetric 2018, that adapted the RUS indicators [11]. In fact, building automation and electronic monitoring of technical building systems are installed in new buildings such as Human Science (7,608 m^2), Blocco "0" of 'Coppito' sub-campus (46,191 m^2) and in renovated buildings such as Palazzo Camponeschi (3,685 m^2) and Roio sub-campus (24,806 m^2) according to the European directives [2,4] and Italian laws [3,5]. They are also installed in existing buildings such as "Acquasanta" (2,537 m^2) for Economics courses and in the two other existing buildings of 'Coppito' sub-campus according to central administration policies of sustainable development [6]. The Facility Management System (FMS) used in UNIVAQ is Infocad.FM.

The energy needs for space heating, space cooling, domestic hot water and ventilation are monitored and managed by a Building Automation System (BAS) in order to optimize indoor environmental quality (e.g. air quality, humidity) and ensure high levels of occupant thermal comfort defined by the Italian standard UNI 10339. In particular, the BAS software used at Human Science building is 'CONTROLLI'; while the one utilized at Palazzo Camponeschi is 'SIEMENS'. For this reason, self-regulating devices for the regulation of indoor air temperature within the building and indoor air quality sensors and ventilations have been installed in the buildings stated before. Thus, the percentage of the total floor area of the smart building to the total all floors building area of UNIVAQ is greater than 75 %. In detail,

$$\frac{\text{total smart building area}}{\text{total building area}} \times 100 = \frac{(7{,}608 + 3{,}685 + 46{,}191 + 24{,}806 + 2{,}537)\ \text{m}^2}{94{,}228\ \text{m}^2} \times 100 = 90\% \tag{2}$$

GM questions 2.4. Number of renewable energy sources in campus and 2.5. Please specify renewable energy sources in campus and provide capacity produced in kWh/hour

The use of energy from renewable sources in the buildings sector constitutes important measures needed to reduce the UNIVAQ's energy dependency and greenhouse gas emissions [2-5]. Till now the number of renewable energy sources used at UNIVAQ is two: The Photovoltaic power plant has a capacity of 83,374 'electrical' kWh/year, the Solar thermal plant the capacity of 97,000 'thermal' kWh/year.

As regards the PV power, five three-phase inverters of 15 kW each are used to convert D.C. in A.C. electricity. The delivered electrical energy is used on-site or, if not needed, is provided to the grid. The capacity of the PV power plant is of about 85 MWh/year, while the energy consumption of electrical energy at the Human Science building is of about 510 MWh/year. Therefore, the solar power plant can cover at most 17% of the electricity demand as energy demand-response not always match each other.

Regarding the solar thermal plant, it is not used for domestic hot water needs, but only for integrating the space heating. In fact, two boilers of approximately 2,000 liters each are connected both to the 27 solar thermal collectors (each delivering 3,600 kWht/year) and to the gas furniture and deliver hot water to the radiant panels to heat up part of the building. An HVAC system heats up the part not served by the radiant panels using hot air with appropriate humidity heated by two natural-gas powered condensing heat generators (boilers). As a matter of fact, the solar collectors are also used to cool down part of the building. In fact, an absorption refrigerating cycle machine of 45 kW is connected both to the solar thermal collectors and to the gas furniture and deliver cold water to the radiant panels to cool down part of the building. The HVAC system mentioned above cools down the part not served by the radiant panels by means of cool air with appropriate humidity cooled by two electrical-energy powered chillers. In this system, the unique manifold is connected both to the chillers and to the condensing boilers, so the system can either heats up or cool down. The manifold is connected to 4 different air handling units (AHUs) that serve different zone of the building via VAV boxes. Post heating batteries are connected to variable air volume (VAV) boxes and can be used to slightly heat up the rooms recovering the heat produced by the chillers.

Therefore, the solar collectors are used to heat up during the winter and cool down during the summer part of the building. During the rest of the year, the solar thermal plant is switched off. As the capacity of the solar thermal plant is of about 300 MWh/year, while the consumption of natural gas is of about 80,000 Sm^3/year to which corresponds an amount of thermal energy of about 900 MWh/year, the percentage covered by the solar thermal plant to the total consumption of energy (1200 MWh/year) is of about 25%.

GM questions 2.6. Electricity usage per year (in kilowatt hour) and 2.7. The total electricity usage divided by total campus population (kWh per person)

The total electrical energy used in 2018 by UNIVAQ was of 5,292,804.00 kWh to which correspond about 5.3 GWh. This means less than 279 kWh/person.

Electrical energy is mainly used for space cooling, ventilation, domestic hot water, lighting, building automation and control, laboratories, as space heating and domestic hot water make in general use of natural gas in UNIVAQ campus. Concerning this, the total amount of natural gas used during the 2018 year at UNIVAQ was of about 1,500,000.00 Sm^3 to which correspond 16,500,00.00 'thermal' kWh = 16.5 'thermal' GWh (as the gas LHV is of about 11 kWh/Sm^3). Bearing in mind that the efficiency of the Italian electrical grid is of 0.37, the total amount of electrical energy used during the 2018 year was of about 14.5 'thermal' GWh that is comparable with the numerical value of the natural gas usage.

Thus, the total amount of energy used at UNIVAQ during 2018 was of 31 'thermal' GWh. As regards the consumption of electrical energy, Tables 1-2 show this consumption per month and compares it with the one of the corresponding months of the 2017 year.

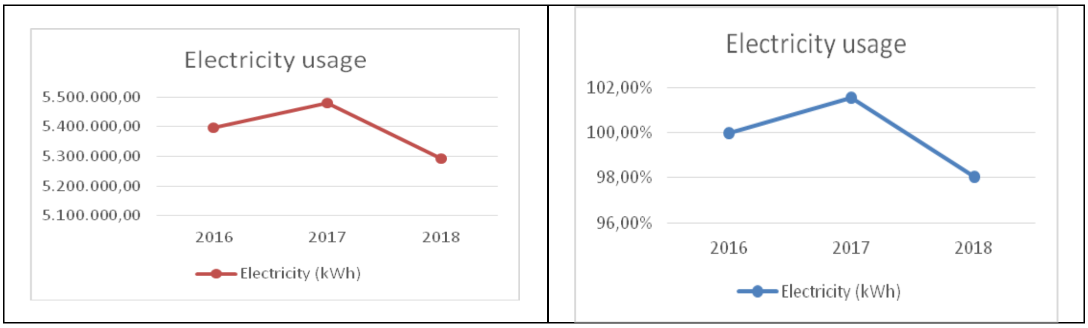

Figure 1. Total electricity usage (all locations) in 2016-2018 (UNIVAQ, Italy)

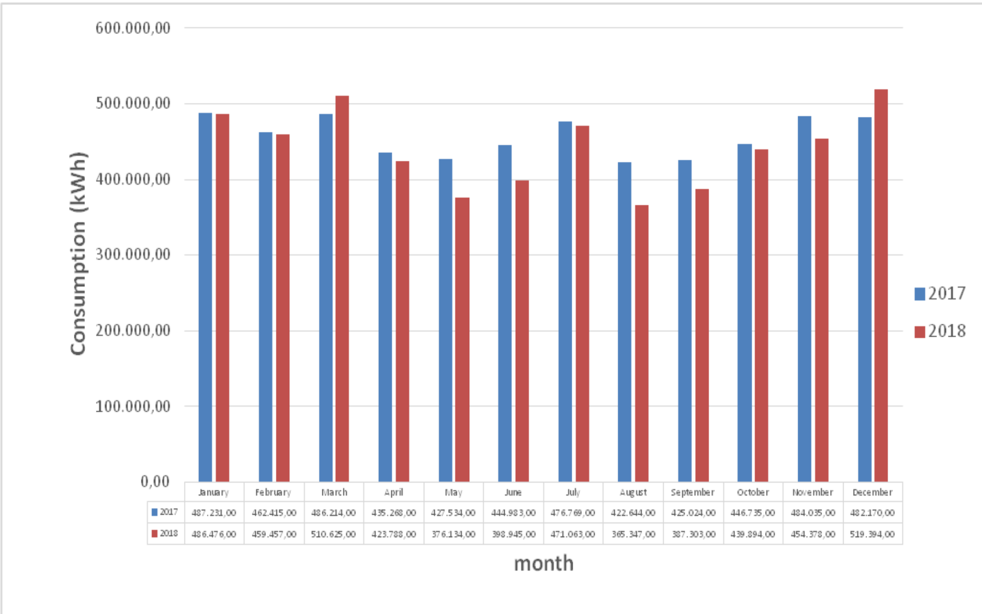

Figure 2. Electricity usage (kWh) (UNIVAQ, Italy)

The total electricity usage may be normalized by dividing it (i.e., 5,300,000.00 kWh) by the total campus population, that is, the total number of regular students (19,800.00 in 2018) and the total number of academic (540 in 2018) and administrative staff (460 in 2018). Therefore,

$$\frac{5,300,000.00 \text{ kWh}}{(19,800 + 540 + 460) \text{ person}} = 255 \text{ kWh/person},$$

(3)

that is less than 279 kWh/person during 2018. The electrical energy consumption in 2018 was 2 % lower than the one in 2016.

GM questions 2.8. The ratio of renewable energy production divided by total energy usage per year

As stated in Subsections 2.4/2.5, the photovoltaic power plant has a capacity of 83,374 'electrical' kWh/year, while the solar thermal plant has a capacity of 97,000 'thermal' kWh/year to which correspond 36,000 'electrical' kWh/year according to an efficiency of the Italian electrical grid of 0.37. As the total amount of electrical energy used per year is of about 5,300,000.00 kWh, the ratio of renewable energy production divided by the total energy usage per year is given by

$$\frac{(83,374 + 36,000) \text{ kWh/year}}{5,300,000.00 \text{ kWh/year}} \times 100 = 2.25\%$$

(4)

that falls into the range 2 – 25 %.

GM questions 2.9. Elements of green building implementation as reflected in all construction and renovation policies

More than three elements of green building are implemented at UNIVAQ. As already said in Subsections 2.2/2.3, five buildings/sub-campus of the whole UNIVAQ campus can be classified as smart buildings according to the definition of UI GreenMetric 2018, for a total floor smart building area of about 90 % to the total all floors area. According to European directives [2,4] and Italian laws [3,5], UNIVAQ is reorganizing the energy consumption in its campus by providing each building with automation (sensors and remote controllers for a constant monitoring of energy consumed). This produced a reduction of energy consumption of 2% in 2018 (see Subsections 2.6 and 2.7). Also, the new restored buildings have only led lamps and the total replacement of obsolete lamps is ongoing as well as the replacement of obsolete appliances with energy efficient ones.

One important issue is the reduction of energy for space heating purposes according to the Italian law [4] that requires for both new and renovated existing buildings to meet the minimum energy performance requirements through constant monitoring of temperature on the rooms with automatic switch off of the heat emitters, thermal insulation of building envelope, and major technical system modifications. Concerning this, an energy performance certificate (EPC) of a building is required, where EPC means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes energy used for heating, cooling, ventilation, hot water and lighting. For only new buildings, as was done for Human Science building at UNIVAQ campus, alternative high-efficiency systems such as heat pumps combined with radiant panels and district/decentralized solutions based upon renewable energy were considered.

GM question 2.10. Greenhouse gas emission reduction program

We reported the number of initiatives put in place by the University aimed at decreasing the carbon footprint. These are related to the planning and implementation of energy efficiency measures concern Scope 1 (Direct greenhouse gas (GHG) and fugitive emissions), Scope 2 (indirect GHG emissions) and partly Scope 3 (better organization of commuting and wisdom in air travels of students and staff). However, these were not conceived in a holistic and uniform approach, because of the lack of an official and detailed emission inventory. The latter was now approved in April 2020 and it will be the starting point for the discussion and drafting of the Climate Change Mitigation Plan with a horizon up to 2025. The effort will be coordinated the with a Climate Change Adaptation Plan.

GM questions 2.11. Please provide the total carbon footprint (CO2 emission in the last 12 months, in metric tons) and 2.12. The total carbon footprint divided by total campus population (metric tons per person)

Using the methodology suggested by UI GM, the total footprint in 2018 amounts to 6790 metric tons, that means < 0.42 - 0.10 metric ton per person.

Until 2020 the University did not have an officially approved greenhouse gas inventory to support calculations and evidence for the Carbon Footprint delivered to Green Metric. We thus relied on the methodology suggested Appendix 3 of the UI Green Metric Guideline, i.e. we used the http://www.carbonfootprint.com/ online tool to estimate CO_2 yearly emissions from electricity usage and transportation (bus, cars, motorcycles; flights were neglected as requested in the Guideline). The methodology neglects the emissions from the part of the heating systems which use methane as fuel, even if in efficient systems.

We calculated the emission flux from electricity using information on the electricity billing system, which provides the total energy in kWh consumed over the year (5,292,804 kWh for 2018) For homogeneity with Appendix 3, however we used the suggested emission factor of 840 tonCO_2/kWh.

For transport we also used the emission factors suggested in Appendix 3, namely 200 gCO_2/km for cars and 100 gCO_2/km for buses and motorcycles. The one-way distance travelled was estimated from average distance between the main campus sites. The number of vehicles (cars and motorcycles) accessing the campus sites was estimated from the parking area available and considering it fully occupied.

The participation to the UI Green Metric ranking and the involvement of the University into the Italian network of Universities for Sustainability (RUS, https://sites.google.com/unive.it/rus/eng?authuser=0) promoted internal work for a refinement of the Appendix 3 methodology in order to (1) account for direct emissions from the heating system, (2) improve accuracy of the estimate, (3) have a more detailed vision of the potential area of improvements (e.g. particular energy-consuming buildings or high-emitting transport modes). This new information will be confronted with that obtained from the Appendix 3 and will be used for the 2020 questionnaire.

3. Lessons learnt

The participation to the UI GM**,** has represented for University of L'Aquila a very important tool for carrying on a self-assessment of the policies adopted, and the methodologies applied for achieving the sustainable goals established in the strategic plan.

By trying to reach the criteria and performance measures of the questionnaire, the University was pushed not only towards a stronger commitment for sustainability but also towards a global approach to the issues concerned. This means a reorganisation of the flow of information between different administrative offices and a "green" vision in all the activities, both academic (teaching and research) and administrative (from governance to maintenance). Furthermore, the need to extract the data in a transparent and easy way forced the revision of the methods used for uploading data, providing all of them with specific recognisable "labels" referable to the different sustainability sectors.

The results obtained by UNIVAQ in the UI GM ranking offered also a media visibility, that, even though not so strong in Italy, proved to be useful to strengthen the impact of the accomplished and planned sustainability actions.

The contemporary participation of UNIVAQ to the Times Higher Education Impact ranking "the only global performance tables that assess universities against the 17 United Nations' Sustainable Development Goals", with good results, increased the impact and the general interest on such important issues.

4. Summary / Concluding Remarks

According to the current Strategic Policies [8] of the University of L'Aquila, the sustainable development in the topic of Energy and Climate Change (EC) is one of the main goals. It also follows the last European Directive 2018/44/EU [5] on the energy performance of buildings and energy efficiency in general, which amends the previous ones [1] and [2]. For example, Member States shall lay down requirements to ensure that, where technically and economically feasible, non-residential buildings with an effective rated output for heating systems or systems for combined space heating and ventilation of over 290 kW are equipped with building automation and control systems by 2025.

The first goal is to perform an energy audit of the existing and non-renovated buildings of UNIVAQ campus applying the European standards [9] and [10]. This regards the systematic inspection and analysis of energy use and energy consumption of a building with the objective of identifying energy flows and the potential for energy efficiency improvements. Once the energy audit is performed, the energy improvement solutions for UNIVAQ campus are [8]: a) no cost (set-point and time schedule adjustment, switching off lights, closing doors, etc.); b) low cost (adding or improving controls, etc.); c) high-cost investments (thermal insulation of building envelope, major technical system modifications, relamping, renewable energy, CHP, etc).

As regards the relamping, 5,000 low-efficiency lamps will be replaced with LED lamps by the end of 2021. The relamping will be concerning with buildings located mainly at 'Coppito' subcampus and 'Roio' subcampus, with the exception of laboratories and some offices. As far as renewable energy is concerned, an economic analysis was recently performed in [12] for installing a photovoltaic plant at 'Roio' subcampus.

Concerning 2.4 and 2.5, a recent study on the solar energy potential of roofs of the University buildings has proved that the number of renewable energy sources in the campuses can be increased with a relevant production of energy and reduction of operating costs. Actions aimed at tackling Climate Mitigation and Adaptation are also effectively taking place and will be a main guidance for the strategic plan over the next years.

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