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A Regenerative Heritage Project with Sustainable Development Goals using the COPERNICUS Data Store: Advisable Conscious Quality Use from Assisi (A.C.Q.U.A.)

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A Regenerative Heritage Project with Sustainable Development Goals using the COPERNICUS Data Store: Advisable Conscious Quality Use from Assisi (A.C.Q.U.A.)

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Abstract: The A.C.Q.U.A. (Advisable Conscious Quality Use from Assisi) project, promoted by the Climate and Energy and Heritage Design courses of the Planet Life Design Master Program, addresses the theme of the recovery and regeneration of ancient wash-houses in the context of energy, environmental sustainability and innovation, a way of understanding cultural heritage in the wider sense of heritage community through the active participation of all the actors involved: universities, institutions, businesses, students and citizens. The proposal, tested in the municipalities of Assisi in Umbria and Ruviano in the Campania (ITALY), involves the creation of a "Community Wash House", a new way of carrying out the usual domestic act of washing clothes in the open air, next to the places where this rite was traditionally performed, in technologically innovative constructions that use renewable energy sources and encourage a reduction in household consumption of water and energy. This project is part of the training of professionals in the new inter-university course that combines knowledge of the tools of technical and scientific design with historical and cultural perspectives in a perspective of sustainable redevelopment of existing structures in the area and the use of alternative energy sources with low climate impact, calculated using the statistics of the Copernicus CDS.

Keywords: sustainable developments goals; cultural heritage; eco-design; climate education; COPERNICUS CDS; climate change impact; regenerative design; renewable energy resources

1. Introduction

The principles of sustainable development form the conceptual basis of the 2030 Agenda [1], a global program of action developed by the United Nations "for People, Planet and Prosperity." This agenda has been articulated by the United Nations into 17 Sustainable Development Goals (SDGs), which are to be achieved by 2030 and are listed in various targets. Among the global sustainable development purposes being advocated by the UN is the access for the world's population to clean and economically sustainable sources of energy (SDG 7) [2,3] and sustainable cities and community (SDG 11) ([4,5]).

Leaving aside the economic part of the problem, which has been dramatically brought to the fore by the recent global economic and geopolitical crises, the UN's target under item 7, "by 2030, to enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and clean fossil fuel technologies, and to promote investment in energy infrastructure and clean energy technologies", is currently far from being achieved ([6–8]).

In fact, climate neutrality with respect to mankind's greenhouse gas emissions is a topic of political debate and from a scientific point of view has no certainty of being achieved without a policy

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of reducing emissions and converting to non-fossil and renewable energy sources that emerging countries reject ([9–11]).

Moreover, by 2050, it is projected that 7 out of 10 people will reside in urban areas, contributing to over 70% of global greenhouse gas emissions ([12,13]). This rapid and poorly planned urbanization poses a significant threat to SDG 11 ([14].

It may result in inadequate infrastructure, including insufficient public transportation and limited access to essential services like equitable water distribution. Additionally, this unchecked urbanization can lead to unsafe levels of air pollution, reduced open spaces, and heightened climate and disaster risks. The profound inequalities highlighted by the COVID-19 pandemic and other cascading crises further highlight the importance of sustainable urban development. Strengthening the preparedness and resilience of cities, including high-quality infrastructure, and universal access to basic services, is crucial in the recovery phase and in our ability to respond to future crises. Among the reasons of crises, it must be listed the impact that climate change is having and will have on the European society. Finally, to address the problems posed by these critical issues, educational and training pathways must be built in an interdisciplinary way ([15,16]) capable of providing professional figures who have knowledge of these problems and possible solutions.

1.1. Teaching eco-design and heritage design as an approach to structure regeneration projects using renewable energy sources

The design project we are about to illustrate, starts by gathering elements that identify the surroundings and history of the environmental site that is to be reconstructed, its structural characteristics, proximity to an urbanized area, in the case of a preexisting historical/industrial building, the condition of the area, and the current functions of the building/site. Therefore, the general outline for teaching young people about these disciplines should encompass several key components. Firstly, providing them with a foundational understanding of the history and application of regenerative design for sites and objects. Secondly, offering comprehensive design knowledge relevant to civil engineering, including energy resource management and water-related aspects. Thirdly, equipping them with skills in computing climate data using reputable sources found on the internet. Finally, integrating other social disciplines that promote a holistic approach to addressing global societal issues. In addition, the related UN Urgent Action to Combat Climate Change and its Impacts (SDG 13) has target 13.3, which is closely related to this project: enhance education, awareness and human and institutional capacity for climate change mitigation, adaptation, impact reduction and early warning.

To this end, the Universities of Perugia and Campania Luigi Vanvitelli, have made a joint educational effort that starts from the teaching and research mission that is proper to the Universities and the promotion of third mission, the latter implies the promotion of scientific, technological and cultural transfer activities in the surrounding society and in the entrepreneurial fabric, with the creation of the Master's Degree Course in Design for Planet Life (PL&D).

1.2. Conceptual framework: cultural heritage, climate change impact and natural resource saving

The project considered in this paper is based on the wide concept of cultural heritage that represents the history, traditions, environment and historic buildings of a country or area, seen as something to be passed on in good condition to future generations (Bateman et al., 2005). The term heritage is usually associated with unique natural features and areas, as well as buildings of significant historical and/or architectural value. In the current era of global climate change, which is anticipated to impact urban living conditions and pose challenges to cities' capacity to adapt and address climate conditions while conserving resources such as water, there arises a necessity to impart in the younger generation the skills to conceive structures, objects, and architectural elements. These should not only preserve and potentially rejuvenate the historical legacy of these elements but also emphasize the revitalization of their functions and sustainability in terms of environmental impact and renewal of social and educational roles. This training becomes an educational and social equity and cultural protection goal that comes from preserving the monuments and the culture contained in them. On the other hand, the educational goal that we want to pursue is connected to the climate change the world is experiencing. The aspects involved in the urban and social heritage that it is intended to preserve need an integrated approach. If we want to protect and renew structures that maintain the various uses these structures had, we must do so without requiring consumption of (fossil) energy and water resources or land, but by recovering what already exists, and by integrating architectural design capabilities with the utilization of available natural and renewable resources. This paper firstly briefly outlines, in section 2, the need for an interdisciplinary and multisectoral scientific education to integrate design heritage and eco-design, which we have included in the broader theme of cultural heritage, with the scientific approach provided by the teaching of climate change and renewable resources. Section 3 will then present a list of arguments for the PL& D course, to highlight the objectives that the PL& D programme aims to achieve and how the field of design is part of these objectives. Section 4 describes the course development and its implementation in the design project as the final part of the course. Section 5 describes the design outcome as an elaboration of the project. Conclusions are then drawn from this work.

2. Cultural heritage and climate change teaching through COPERNICUS

Protecting Europe's cultural heritage from the effects of climate change is vital, and research and innovation play a crucial role in achieving this. Researchers have been studying the effects of climate change on cultural heritage since 2003, when the European Commission launched the world's first call for research projects on the protection of cultural heritage. However, while progress has been made, more research is needed to identify the most serious threats and their impacts, as well as innovative measures to protect Europe's cultural heritage from climate change. In fact, while climate has always changed at geological scales since the emergence of Homo sapiens, it is only in the recent past (i.e.,the last 10,000 years) that humanity lived in a stable climate. A stable climate has enabled the development of human society as we know it. Recent anthropogenic change, as documented by the Intergovernmental Panel on Climate Change [17] as a result of ever-increasing CO2 emissions from burning fossil fuels, is causing global warming with an increasing number of extreme climate events such as heat waves, extreme low and high precipitation, and high storm surges. These extreme events pose huge risks to livelihoods and threaten cultural heritage. As education is the basis for understanding the profound role that cultural heritage plays in European societies, it is of paramount importance to include the link between cultural heritage and climate change in the educational pathways of European Member States, in order to also provide information on climate change and its impact on societies. The lack of interdisciplinary and multisectoral scientific training is a major obstacle. Without adequate training, it will be difficult to effectively integrate cultural heritage and climate science. The complex nature of climate change and its link to cultural heritage conservation requires an improvement in interdisciplinary science education. Education plays a crucial role in highlighting the importance of cultural heritage and protecting it from the threats of climate change. It also addresses the lack of knowledge sharing and collaboration between different sectors. Currently, heritage professionals have limited understanding of climate change policies and strategies, while energy, climate and urban planning professionals lack knowledge of cultural heritage and design. This lack of constructive interdisciplinary collaboration results in ineffective strategies. To address these issues, the Master programme in Planet Life Design used the European Commission data platform for European citizens, the COPERNICUS CDS. The CDS includes observations, historical climate data sets, estimates of key climate variables derived from Earth observations, global and regional climate reanalyses of past observations, seasonal forecasts and climate projections. Access to the data is open, free and unrestricted. Along with the data, the CDS includes a set of tools for analysing and predicting the impacts of climate change. Students of the PL& D course can access the CDS tools online to develop their own applications.

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The main purpose for which the COPERNICUS Data Store is used here is to reconstruct the climate at the sites where it is intended to make a compatible and sustainable design for the renewal of the sites under consideration. The Climate Data Store provides easy access to a wide range of climate data sets through a searchable catalogue. Part of the Master is devoted to a general explanation of the problem of climate change and how climate data are fundamental to understanding the consequences of climate change on structures, sites and basic parameters necessary for the well-being of society. Many different phenomena can be illustrated by data and their statistics over a space-time interval covering the definition of climate (30 years, WMO). The statistics calculated by COPERNICUS CDS can then be used to design the renewable energy resources needed to upgrade the sites, buildings and structures designed in the course. Designing sustainable structures involves incorporating renewable energy resources to reduce environmental impact and increase energy efficiency. Combining multiple renewable energy resources and implementing energy efficient technologies can help design sustainable structures that minimise reliance on non-renewable energy sources and reduce environmental impact. Having assessed the life cycle of traditional materials and old and new conservation materials, this class should explore opportunities for the reuse of building materials with quality controls for recycled materials. Finally, the teaching of this Master class has considered the contribution of the aesthetics of cultural heritage to well-being and livelihoods.

3. Climate and Energy and Heritage Design courses

The field of design has recently evolved from designing products to designing scenarios of life and relationships between people and the planet. The ethical and critical nature of design has led to debates about development limits and environmental changes. Design has become a means of affecting the planet's future and an affirmation of humanity's existence in the world. The Master class in "Design for Planet Life/PL&D" aims to prepare professionals who can critically operate in the field of design for the planet's well-being, taking into account necessary environmental adaptation. This multidisciplinary approach integrates technical, scientific, and creative skills, focusing on four specific educational areas to provide necessary skills for emerging leaders in this field.
The Master in PL&D proposes an innovative educational pathway that fits within the national educational framework, but does not overlap with other undergraduate or Masters programs in the proposing universities. The teaching of Climate and Energy aims to give an innovative outline of how to combine in design strategies, products, systems, and services aimed at coping with the changes taking place at the environmental level. This includes considering current settlement conditions and possible future scenarios, with a particular focus on adaptation and the evolutionary characteristics of life on the planet.

The training specifically addresses eco-design for quality of life, understood as a design approach devoted to sustainability and minimization of environmental impact, combining this design field with the issues of climate change and the use of energy from renewable sources. The program of the Climate and Energy and Heritage Design classes is summarized into the following 4 modules.

3.1. Heritage Design module

Heritage Design course is divided into three parts. The first part focuses on the historiography of design, exploring its origins and recent developments. The second part examines Design on a global scale, analyzing its role from conflicts in the late 19th century to post-war scenarios. The third part delves into the national design history, highlighting the cultural impact of design in Italy and worldwide throughout the 20th century. Special attention is given to design archives as valuable cultural resources, with students engaging in the collection and analysis of information for research purposes.

The course aims to familiarise students with the history of design, with a particular focus on projects related to sustainability and the formation of cultural identities in different regions. Students will learn methods and tools for analysing design heritage, taking into account the shift in lifestyles

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from individual objects to environments at different scales, from homes to cities to the planet. By developing these skills, students will be able to navigate the complexities of cultural aspects related to design heritage and propose strategies for its preservation.

3.2. Eco-design module

Eco-design refers to the practice of developing tangible and intangible processes and products while considering ecological and environmental factors ([18,19]). It involves utilizing methodological, critical, and operational tools to create eco-oriented strategies and solutions at various scales. The goal is to enhance the quality of life by understanding the main causes of alterations and implementing design practices that promote environmental sustainability. This includes both theoretical knowledge of eco-strategies and practical knowledge of good practices, including those outside Europe.

The main knowledge gained from studying eco-design includes an understanding of the factors that affect quality of life, the theoretical underpinnings of eco-orientated strategies and knowledge of design practices related to environmental sustainability. In addition, the following skills will be acquired:

- Ability to identify the theoretical and formal frame of reference: Students will develop the ability to recognise and understand the theoretical principles and frameworks relevant to eco-design.
- Ability to select and critically analyse case studies: Students will develop the ability to select and analyse case studies related to eco-design, critically evaluating their requirements and characteristics.
- Ability to read, interpret identified needs and define possible solutions: Students will learn how to assess and understand identified needs and then propose possible solutions that address these needs within an eco-design framework.

By acquiring these knowledge and skills, students will be able to contribute to the development of eco-designed processes, products and services, taking into account sustainability and environmental considerations.

3.3. Climate Change module

Climate change refers to the long-term alteration of the Earth's climate patterns, including variations in temperature, precipitation, wind patterns and atmospheric conditions ([20]). The course aims to equip students with the skills necessary to understand the fundamental concepts related to the Earth-atmosphere system and its climate, and the processes that influence it, such as chemical composition, vertical structure, winds, convection, precipitation and radiation. Students will learn the conservation principles and equations governing the general circulation of the atmosphere and ocean, which are essential for understanding climate processes. Students will gain knowledge of the theoretical principles governing climate and its feedback mechanisms, as well as a brief history of the Earth's paleoclimate, understanding its composition and its role in shaping climate patterns. The Earth's carbon cycle and its relevance to climate dynamics are examined, as are climate sensitivity, forcings and feedbacks. Students explore the influence of past climatic conditions (paleoclimate) on current and future climate trends. They also gain an insight into the global energy balance and its impact on the Earth's climate.

The course emphasizes the development of skills in selecting and analyzing numerical climate models output and observations. Given the aim of the module that is to finalize a project using renewable sources of energy, students will also become familiar with mathematical methods like statistical analysis used to access and use climate data to estimate the amount of renewable energy available to sustain the equipment used in the project, in particular students:

- learn to access and utilize climate data from the Copernicus CDS, a comprehensive resource for climate-related information.

- are introduced to global reanalysis datasets, such as ERA5 reanalysis, and learn basic statistical analysis techniques for climate data (EDA).

3.4. Renewable Energy resources module

In the context of PL&D course, renewable energy resources play a crucial role. Renewable energy refers to energy sources that are naturally replenished and have minimal environmental impact. This course aims to provide students with knowledge and understanding of various renewable energy resources and their applications within the broader Earth-Atmosphere system.

Students explore the energy balance of the Earth-Atmosphere system and delve into specific renewable energy sources such as solar energy, wind energy, geo-thermal energy, hydropower, energy from waste, and biomass. These resources offer sustainable alternatives to conventional energy sources, reducing dependence on fossil fuels and mitigating environmental impacts. The course also covers the wood energy supply chain and explores methods for offsetting carbon dioxide (CO2) emissions, focusing on renewable fuels for sustainable transportation. Students learn about systems for storing electricity and thermal energy, crucial for optimizing the utilization of renewable energy sources.
Additionally, the course addresses mechanisms and incentives aimed at supporting and disseminating the use of renewable energy sources. This includes exploring policies, regulations, and financial incentives that encourage the adoption of renewable energy technologies at individual, community, and national levels. Students also gain knowledge in conducting energy, economic, and environmental impact analyses of systems based on renewable energy sources. This understanding is essential for evaluating the feasibility and sustainability of renewable energy projects. By incorporating these topics, students develop a comprehensive understanding of renewable energy resources and their application in sustainable design practices. They acquire the knowledge and skills needed to integrate renewable energy systems effectively, assess their environmental and economic impact, and contribute to the development of sustainable and energy-efficient designs.

4. Course learning and implementation

The programme of Climate and Energy and Heritage Design courses, summarised in the four illustrated modules, is divided into a first part of theoretical study which is then tested with regard to the subjects' understanding and ability to present content clearly and coherently, in intermediate tests to evaluate students' learning and growth. These tests consist of both oral discussions with lecturers and intermediate workshops in which the concepts studied are applied to design workshops in preparation for the final project.

The purpose of the intermediate test is to assess the level of knowledge that students have acquired in relation to the theoretical content of the course. Through this test, students demonstrate their ability to express ideas clearly and coherently by using appropriate vocabulary relevant to the course topics. In addition, the oral test aims to determine the student's ability to engage in a dialectical relationship during the interview, fostering a constructive conversation about the whole design project, starting from the historical and cultural background of the design ideas.

To this end, the course includes test workshops that explore the application of the concepts studied in the initial projects from which the final test project is derived. These workshops aim to assess students' project management skills through the presentation of work, including descriptive, graphic/technical work and a prototype of the artefact.

4.1. Workshops in preparation for Design Project

The A.C Q,U A. project, aims to recover, and regenerate ancient washhouses with a focus on energy and environmental sustainability. It involves the active participation of universities, institutions, organizations, companies, students, and citizens. The project focuses on the municipalities of Assisi and Ruviano, where innovative "Comity Washhouses" will be established. These washhouses will

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be technologically advanced buildings utilizing renewable sources, reducing household water and energy consumption.

Assisi is known for the fraternity of St. Maria del Vescovado, now called the Residences of San Crispino, while Ruviano has an ancient washhouse near a water source used by washerwomen in the past. The project involves workshops, where students conducted surveys, mapping the areas, visiting historic washhouses, and learning from elderly women who used them. Practical insights are gained by exploring the surrounding natural areas.

Students are required to choose an area for project implementation based on energy resource availability and the impact on the resident population. Historical research is conducted in both Perugia and Caserta, identifying significant sites such as fountains and washhouses. Notable examples include the washhouse in Nocera Umbra near medieval walls, the Lavatoio dell'Accolta in Bevagna, the Paciano washhouse sourced from the Fonte di San Bartolomeo, and the Lavatoio della Posterna and Lavatoio delle Felici in Spoleto.In Assisi, the Moiano fountain near one of the city gates and the Oliviera fountain in the historical center are of interest (see Figure 1a).

(a) Assisi, Perugia

(b) Ruviano, Caserta

Figure 1. Historical research. The province of Perugia with Assisi and its washhouses of special historical significance and value. The project's choice fell on Caserta province in whose municipality the Ruviano springs are located.

The workshop held in Ruviano in December 2022, included visits to the public washhouse "Vallone le Serole", the ancient Ruviano mill and the slave well (Figure 1b). Students also took part in roundtable discussions with local institutions and businesses. These workshops provide students with hands-on experience and help them to apply their knowledge in real-life scenarios. Overall, these interim results demonstrate the students' progress in understanding theoretical concepts, analysing case studies and actively participating in design initiatives related to sustainable energy, environment and innovation with the participating cities. The focus of the project was Caserta, including Ruviano, thanks to the immediate response of the municipal institutions and citizens.

4.2. Comity Washhouse App

The second workshop also presented the results of the design of the Washhouse app (Figure 2). Washhouse App is the application that allows the user to book laundry services and get to know the washhouse world. Inside, thanks to its simple interface it is possible to select the nearest washhouse location, the day, the time slot and the type of washer and dryer that the user wishes to use for washing. As with any type of reservation application, registration is required. In the user profile section, you can see how many liters (gallons) of water and electricity the user has saved on their bill, based on the number of washes they have done at the washhouse.

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Figure 2. Comity Washhouse app.

The choice of the name Comity Washhouse is closely linked to the system of equipment designed for washing and drying laundry proposed to the municipalities of Assisi and Ruviano. Comity - adjective related to a friendly, cooperative, social atmosphere- washhouse conveys the community's sense of reappropriation of spaces, natural rhythms and interpersonal relationships, as well as the renewed relationship of intimacy with the 'environment'. These are the defining characteristics of the project and its development.

On the first day, the results of the project were presented to the Mayor of the Municipality of Ruviano and other local and regional authorities involved in the defence of the environment, the soil and the ecosystem in various fields. On the second day, the 200 photographs taken by local secondary school students were viewed and awarded prizes. The peculiarity of the A.C.Q.U.A. project lies not only in the proposal of an innovative eco-design product, the "washing house", which uses climate and renewable energies, but also in the sustainable creative processes. In such a context, it is worth of notice the "soap coin action", for the recovery of unused soap as currency for the purchase of a common washing machine, and the awareness of young students on the issue of energy saving through the enhancement of architectural, cultural and landscape resources.

Many public washhouses, some of very ancient origin, have been built around the famous springs of the province of Caserta. Near San Potito Sannitico stands the Aulecina washhouse, recently decorated with murals and graffiti. Roccamonfina, famous for its springs, is home to the Fontana and Lavatoio dell' Acquarotta (Figure 3). A short distance away, near Ruviano, is the washhouse, the focus of the workshop.

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Figure 3. Public washhouses of the Caserta Province

4.3. Design of the Project

4.3.1. Focus Area

At this point in the project, the students have completed the section on the sources of Ruviano.

A map of Ruviano and the surrounding area is shown in Figure 4a, where the demarcated area is the area of intervention where the project is concerned. The demarcated area extends along Via Mulino and the provincial road leading to Via Municipio, where the medieval tower is located. The same area has been identified on a historical map of Ruviano dating back to the Bourbon era. These two main spots of the project are visible in Figure 4b where the intervention area is enlarged, in red for the washhouse, and in yellow for the laboratory part. In Figure 4b, the main areas of intervention are highlighted, where the public washhouse is located between "Vallone le Serole", near which the washhouse project will be developed, and the building adjacent to the stream, which could be redeveloped to become a workshop and laboratory area related to the world of laundry and washing.

(a)

(b)

Figure 4. (**a**) Highlighted in yellow the main areas of intervention in the Ruviano area. (**b**) The Workshop's focus washhouse: in red the washhouse area, in yellow the laboratory area.

The area to be rehabilitated will have a car park and a pedestrian path. Users will walk along this path to reach the washhouse. This path will then continue along the waterway to the bridge connecting the two banks of the stream. This connection between the washhouse and the bridge could become a strong point of the project, as it would not only enhance the surrounding area and the waterway that crosses it, but also emphasise and strengthen the link that unites people with nature and water.

The proposed design solutions are therefore intended to further develop the relationship between man and the landscape of the site. After choosing the two areas of the project, the students have to evaluate the type amount of renewable energy sources available on average in these two spots.

4.4. Evaluation of renewable energy sources: climate data statistics

The Copernicus CDS platform used in this project is built on a supercomputer (ATOS, EuroHPC supercomputer, based on Atos' BullSequana XH2000) which, through global networks of instruments, collects climate parameters of the earth-atmosphere system measured worldwide and, after processing these data with a series of physical-mathematical models, provides many types of climate data of assured quality. This platform has an interface, (Figure 5), that gives all students easy access to climate datasets through a freely searchable, free catalogue that allows statistical data processing of the aspects of climate that were of interest for the project through an online toolbox. In the context of the course, solar energy, precipitation and temperature are the climate parameters whose available statistics are desired to enable design that maximizes the use of renewable resources and their exploitation from the perspective of environmental sustainability.

Students learned how to construct monthly climate statistics using two meter temperature, precipitation and solar radiation data extracted from COPERNICUS global data over the areas considered. Climate statistics are by definition (WMO) averages over 30 years of data. So the climatology was calculated for all gridded parameters on COPERNICUS data set from 1991 to 2020. The data were averaged over that time period by month or by year and over the area of Europe and Italy, showing the climate oscillation over the two areas of Europe and Italy (see Figure 5 a) vs. c) and b) vs. d)), and then the data needed for the project were extracted at the point corresponding to the position at surface in latitude and longitude of the washes considered both for the solar downward monthly climatology (from 1991-2020, in W/m^2) and for the maximum surface solar downward radiation in Ruviano, (see Figure 8 a) and Figure 8 b)), and in Assisi, (see Figure 8 c) and Figure 8 d)). Using the online toolbox, students were able to create trough Python programming, total averages, anomalies (defined as the difference from the 30 years average, or baseline) standard deviations, and trends to suit the project. Figure 6 and Figure 8 show the main variables related to the project, but these tools allowed the students to understand how to manage the data in latitude, longitude, height and time within the COPERNICUS CDS with a very large set of applications to calculate climatologies and anomalies of all types of data contained in CDS using the access to the ATOS online servers.

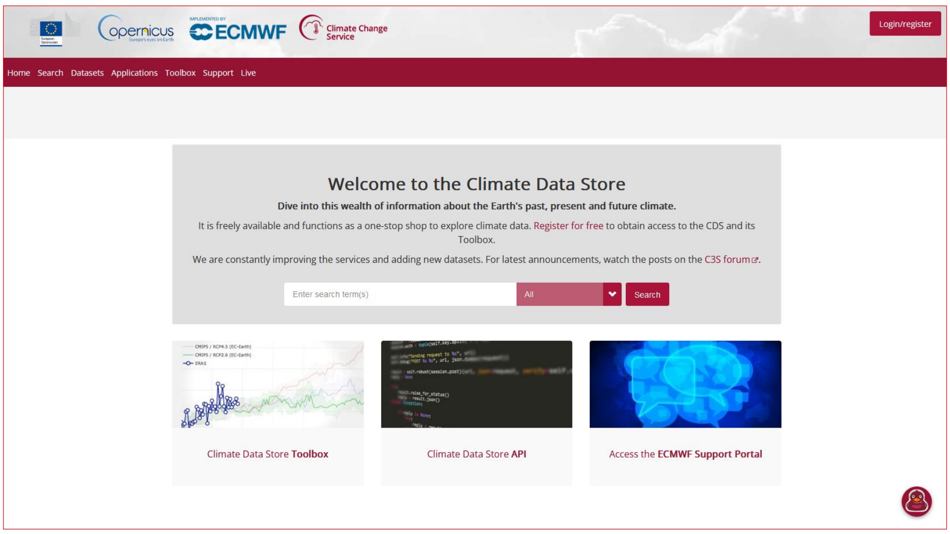

Figure 5. COPERNICUS CDS interface (https://cds.climate.copernicus.eu/).

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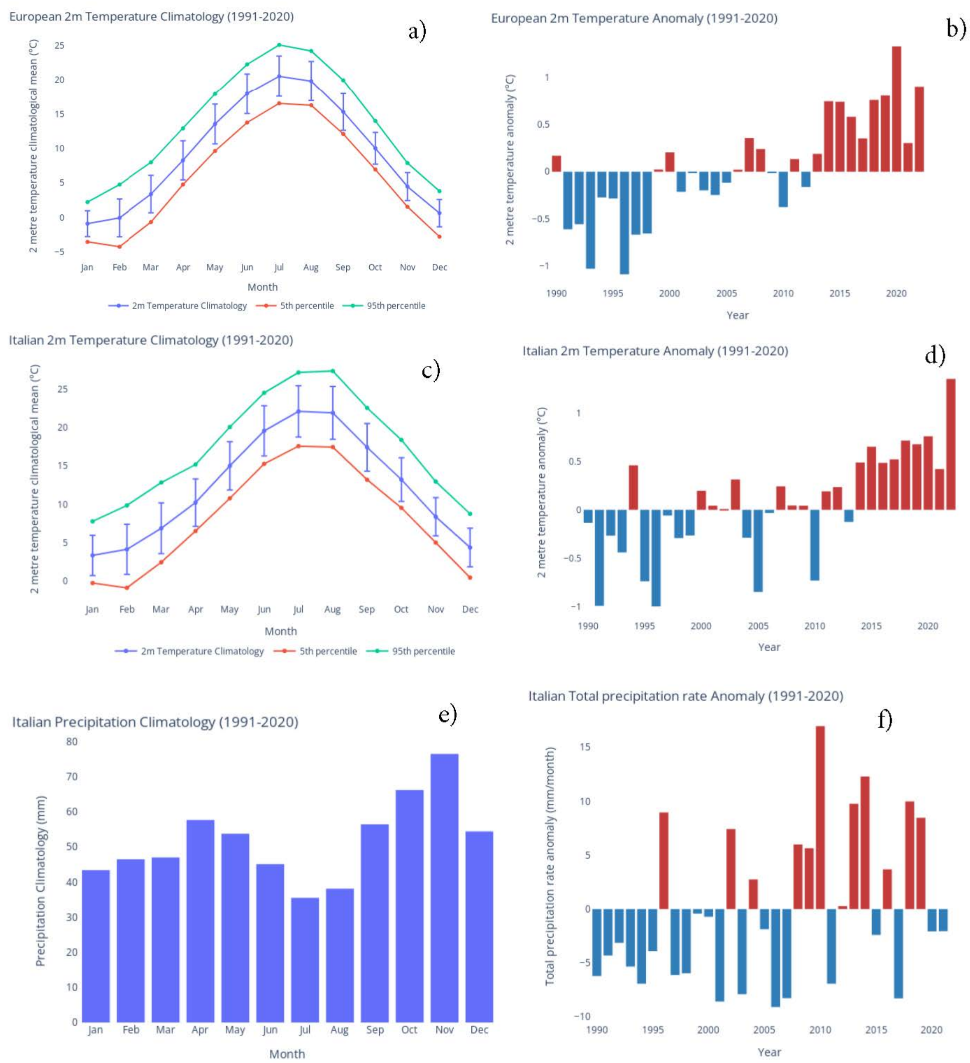

Figure 6. Climate temperature statistics (2 m; °C) from 1991-2020 of ERA5 data, COPERNICUS CDS: a) Europe $2mT$ climatology (mean ± stn. deviation); b) Europe $2mT$ anomaly; c) Italy $2mT$ climatology; d) Italy $2mT$ anomaly; precipitation statistics in mm; e) Italy climatology and f) total precipitation anomaly.

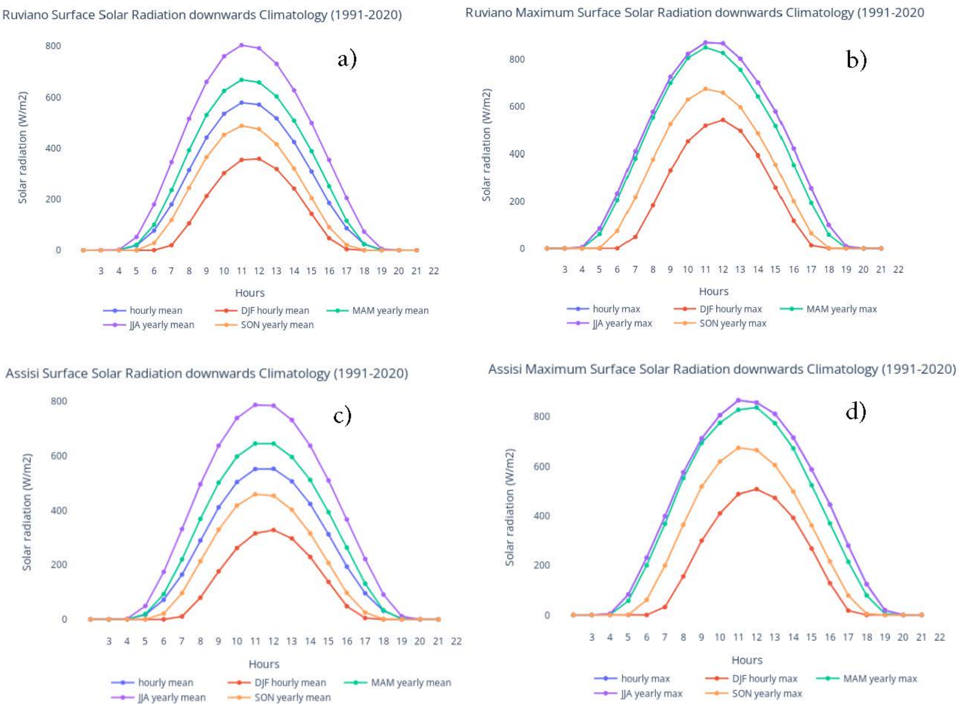

Figure 7. Climate average from 1991 to 2020 of surface downward radiation in W/m^2 (ERA5 data, COPERNICUS CDS see text): a) Ruviano: climate surface monthly downward radiation ; b) climate maximum surface solar downward radiation ; c) Assisi: climate surface monthly downward radiation; d)climate maximum surface solar downward radiation.

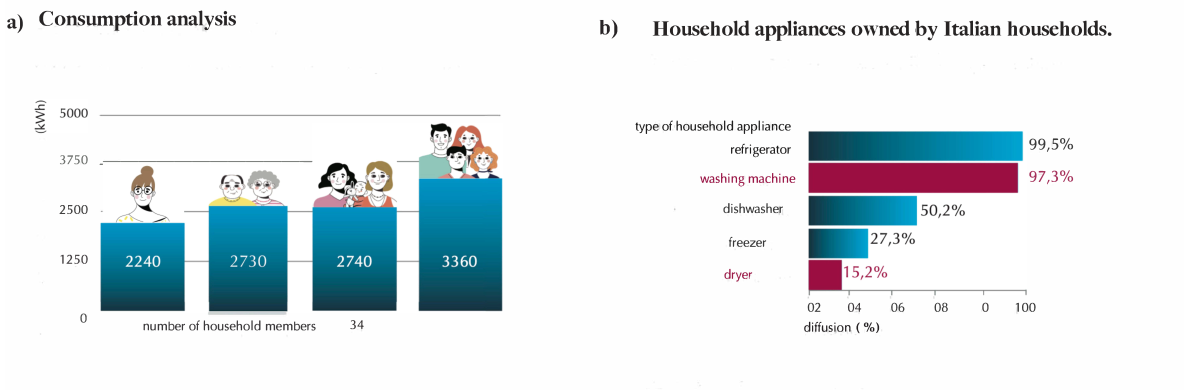

Figure 8. a) Annual consumption analysis of Italian households classified based on the number of household members. Italian households with a 4-member household consume an average of 3360 kWh/year. Electricity consumption of the households consisting of 1, 2, and 3 components is reduced by 18%, 19%, and 33%, respectively; and b) Household appliances owned by Italian households. Among large household appliances, the most common are refrigerators and washing machines, present in almost all households (99.5% and 97.3%, respectively), 15.2% of households also own Ia dryer (separate from the washing machine).

4.5. Renewable energy: plant study, cost and consumption type

How are renewable sources used? What energy is needed for the project? Students highlighted the following characteristics of renewable energy within the project:

4.5.1. Photoelectric plant

Solar energy is by definition renewable. It produces direct power through the photovoltaic effect, which is then converted into alternating power using the photovoltaic effect produced by the

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photons of the sun's short-wave radiation in the photovoltaic panels installed in the washhouse. In fact, photovoltaic panels produce electricity where it is needed, do not harm the environment and offer the advantage of being "made to measure" according to the actual needs of the user.

The key component for converting solar radiation into electricity is the photovoltaic cell, a thin plate of semiconductor material and small in size. The photovoltaic cells are connected in series to form a stable and manageable structure called photovoltaic module. The photovoltaic panels are connected in series and connected to an inverter, an electronic device that converts the incoming direct power into alternating power so that it is immediately available to households. In order to optimise production, the PV panels, should be positioned as close as possible to the geographical south and with an optimum tilt angle towards the ground, which varies according to the geographical location of the installation. The off-grid photovoltaic system combines the ability to store the energy produced in batteries (Stand Alone), connected to the national grid to feed in and be compensated for the energy produced and not consumed (Grid Connected), with the current technological innovation that combines these two features, where the energy produced by the system is stored in batteries. When they are fully charged, the extra energy is fed back into the grid to be compensated later (Storage).

For the final project of the PL&D course, the SunPower Performance 5 UPP was chosen as the PV panel, which is designed to meet the specific needs of solar power plants. The double-sided power generation and G12 (210mm) cell technology combine to maximise power density, while the framed glass/glass structure provides increased durability for longer panel life, ensuring an estimated 35 year life span. The choice of battery characteristics is critical to the operation of the washhouses.

4.5.2. Storage Batteries: Types, costs and lifetime

Storage batteries are used to store electrical energy that is generated but not immediately consumed. The energy stored in the batteries can be used at any time, such as at night or during periods of low solar irradiation, when the system does not produce enough energy to meet its energy needs. Batteries can be unidirectional, charging only from PV, or bidirectional, charging from both PV and the grid.

In terms of technology, there is only one type of photovoltaic storage battery powerly on the market: the lithium-ion one. The lifetime of lithium-ion batteries for photovoltaic storage is about twice as long as the old batteries in circulation, with short charging times. The main difference between lithium-ion batteries for photovoltaic storage and the previous lead-acid batteries is mainly the cost (900-1,200 euros per kWh). Lithium-ion batteries have a higher purchase price, but have a longer life and excellent energy efficiency. In general, the storage power is 50-100% higher than the peak power of the PV system. An important aspect to consider is the lifetime of PV storage batteries. This characteristic depends on a number of factors, such as the technology used and the quality of the modules, but it is measured in terms of full charge cycles, similar to that for the lithium batteries in modern smartphones. For this reason, the lifespan of solar storage batteries is related to the number of charge cycles, so the more you charge and discharge the battery, the shorter the lifespan of the storage system. Most batteries on the market today have a manufacturer's warranty of 7 years, so they are guaranteed to work for at least 84 months from the date of installation. However, in terms of number of charge cycles, the best quality products can last up to 10,000 cycles, or about 15 years of use. The Tesla Powerwall unit selected for the project is an AC battery system for use in smaller residential or commercial properties. Its rechargeable lithium-ion battery pack provides energy storage for direct solar power consumption, load management and back-up power.

The washers and dryers selected for the final design of the washhouses meet the project's criteria for energy efficiency and reduced consumption of water resources. In this regard, the students analysed the expected consumption for the different types of customers and users of the WashHouse world.

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4.5.3. Consumption analysis and Ruviano case study

After a general estimation of the annual electricity consumption of Italian households and the types of appliances used shown in Figure 9 a) and Figure 9 b) as well as of the water consumption (not shown), the students focused on the use and consumption of electricity by each household in the chosen site where were analyzed the hypothetical families living in Ruviano: what are their habits with respect to the action of doing laundry, which washer and dryer they use and what are their respective consumption in energy and water consumption. In particular, four types of households were analysed, from one to four members per household, with ages ranging from 2 years to 79 years, see Figure S2. The energy and environmental analysis carried out in the case of Ruviano first identified the need for renewable energy (100% solar) and water resources (source water from the washhouse). Then the analysis identified the performance of the washhouse and the benefits associated with its use by households as shown in Table 1.

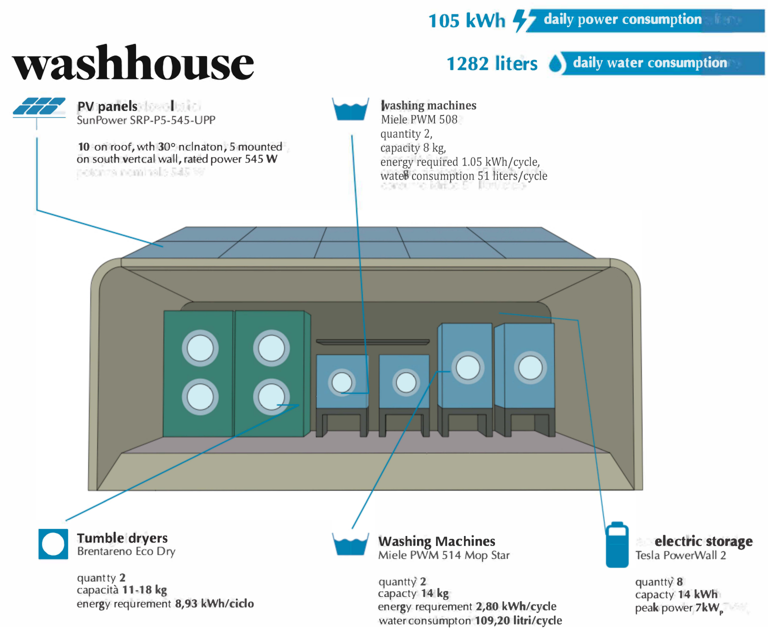

Figure 9. General schematic of the washhouse area. General characteristics of all the washing and drying equipment and the electrical storage units selected on the basis of consumption and possible savings.

Table 1

Performances	
Total washing cycles	1856 cycles/year
Total drying cycles	1856 cycles/year
Quantity of washed laundry	14.080 kg/year
Quantity of laundry dried	18560 kg/year
Benefits	
electricity savings	12.158 kWh/year
water saved	148.666 liters/year
emissions avoided $CO_{2,eq}$	3.818 kg$CO_{2,eq}$ / year

5. The Washhouse design

The washhouse design starts from the calculated optimization of energy and water resources and appliances used in collective areas. Figure 10 summarises the electricity generation equipment, the photovoltaic panels, with their technical characteristics and their location on the laundry structures. The energy and environmental analysis carried out for the Assisi and Ruviano case studies identified

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the following two possible design solutions, taking into account the performance of the washhouse and the benefits associated with its use by households.

(a) General schematic of the washhouse PLUS.

(b) General schematic of the washhouse ONE.

Figure 10. The two design solutions based on consumption analyzed at the sites considered-Assisi and Ruviano.

In the map of Ruviano, as mentioned above, the intervention area of the laundry rehabilitation project is delimited, see Figure 4b where you can see the area with the public washhouse between "Vallone le Serole", near which the washhouse project will be developed, next the stream that in the elaboration carried out during the course it was assumed could be the subject of redevelopment to become a workshop and laboratory area related to the world of laundry and washing. The affected area will be provided with two car park, see Figure 4b, and a footpath for users to walk along to reach the washhouse. This path will then continue along the waterway to the bridge that connects the two banks of the stream. This connection between the washhouse and the bridge, through the use of street furniture design interventions that incorporate the acquired skills, could become a strong point of the project, as it would not only enhance the entire surrounding area and the waterway that crosses it, but it would also emphasise and strengthen the bond that unites man, nature and water. The proposed design solutions are therefore intended to further strengthen the link between man and the landscape of the site.

 doi:10.20944/preprints202308.0271.v1

5.1. Washhouse Traditional

For the washroom area, the addition of shelves and basins has been planned, which are always available to the users, see Figure S2 in the su . Selected EverDrop detergents are suitable for all types of garments and offer excellent washing results. These detergents have a common feature that makes them special-they are adapted to the actual hardness of the water. Depending on the region, the water has a certain degree of hardness, so the use of unnecessary fillers is avoided. The ingredients are vegan and easily biodegradable, and once empty, the packaging can be recycled into paper or be used as a wet bag.

5.2. Washhouse PLUS

Starting from the regeneration of the washhouse, Washhouse PLUS is a modular solution consisting of several modules that can be declined in its morphology in any natural or urban context. The materials used for its conformation are all environmentally friendly. The space can contain a variable number of washing machines and dryers powered by energy from the use of photovoltaic panels. Figure 10a shows the various features of the washhouse PLUS. topology materials

5.3. Washhouse ONE

washhouse ONE is one-module solution that is transportable and easily placed in any natural or urban setting. The topology of the washhouse depends on the location and user, which in the specific case was designed for the washhouses that are available for redevelopment. In the case of Ruviano, the optimal dimensions is that of washhouse ONE. The space contains four washing machines and two dryers powered by energy from the use of photovoltaic panels as shown in Figure 10b. This is the solution chosen in the project for application in the Ruviano area. .

5.4. Urban design

The last chapter contains street furniture designed for the area between the washhouse and the bridge, as seen on the site map in Figure 4b e S1. Figure S2 shows how the washhouse was rethought in the design to make it functional for the new facility.

The artefacts are designed to be in harmony with the environment and, through the use of some technologies, to evoke the typical smells and sounds of laundry. All the objects will be placed on the part of the bridge to create a relaxation area that users can use once they reach the end of the green path, or simply as a waiting area to wait for the end of the washing machine cycle.

5.4.1. Parking

In the affected area there are two parking lots and a pedestrian pathway that users can walk along to reach the washhouse and washhouse. This path will then continue along the watercourse until it reaches the bridge that connects the two banks of the creek as shown in Figure 4b e S6.

5.4.2. Stair, Flooring and balaustrade

The project also consists of the design of the staircase that connects the bridge to the river below, see S7, the floor of the entire area under consideration see S8, and the recreation, seating and decoration area, see S10.

The project consists of the creation of a wall composed of fabric threads reminiscent of the strands that companion clothing and those used to lay cloth. The wall is an integral part of the balustrade and allows the end user to "peek," to look through the threads at nature overlooking the waterway below.

5.4.3. Clothes trolley

The WashCase folding bucket,shown in S9, is made of recycled PVC, which is extremely sturdy and has a solid base. Equipped with wheels and an extendable handle, it allows laundry to be transported with the utmost convenience. Made of water-resistant material, it is capable of carrying any liquid, as well as heavier items. Recycled PVC retains its physical-mechanical properties, remains a stable and chemically inert material, safe in processing and use.

6. Discussion

The SDGs encompass universal, transformative, and inclusive objectives that outline significant development hurdles for humanity. Among the SDGs, the SDG 13 "Climate Action: Urgent action to combat climate", involves teaching action to make people understand the main ecological, social, cultural and economic consequences of climate change locally, and globally and understands how these can themselves become catalysing, reinforcing factors for climate change. Moreover teaching about prevention, mitigation and adaptation strategies at different levels (global to individual) is a further goal. Given the concept of cultural heritage and its association with historical buildings, traditions, and the environment, which are passed on to future generations, and with the challenges posed by global climate change, there is a need to teach younger generations how to conceive structures that not only preserve the historical legacy but also emphasize sustainability and environmental impact. The educational effort that the Master course in PL&D here described makes, involves an integrated approach to preserve the urban and social heritage, utilizing natural and renewable resources without relying on fossil energy or water consumption. The paper outlines the need for an interdisciplinary and multisectoral scientific education to integrate design heritage, eco-design, climate change, and renewable resources. The PL& D course its development and implementation, and the design outcome, is here presented as a mean to achieve these objectives. The ultimate aim is to protect cultural heritage while addressing contemporary challenges and promoting social equity.

7. Conclusions

This section is not mandatory, but can be added to the manuscript if the discussion is unusually long or complex.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org

Data Availability Statement: The Climate Data Store python based language codes used to produce the results produced in this work are available at https://cds.climate.copernicus.eu/toolbox-editor/40924/radiazione and https://cds.climate.copernicus.eu/toolbox-editor/40924/precipitazione-1 upon free login into the Climate Data Store.

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Abbreviations

Abbreviations

The following abbreviations are used in this manuscript:

COPERNICUS CDS	COPERNICUS Climate data store
WMO	World Meteorological Organization
MDPI	Multidisciplinary Digital Publishing Institute
DOAJ	Directory of open access journals
SDGs	Sustainable Development Goals
UN	United Nations
EDA	Exploratory Data Analysis
PV	photovoltaic effect

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