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1.- PREVIOUS STUDIES

1.1.- Multidisciplinary studies (historical, archaeological, etc.).

1.2.- Heritage and territory.

1.3.- Urban regeneration.

1.4.- Economical and financial policies.

1.5.- Social participation processes and socio-cultural aspects in rehabilitation projects.

1.6.- Construction pathology.

1.7.- Diagnostic techniques and structural assessment (no destructive testing, monitoring and numerical modeling).

1.8.- Guides and regulations.

2.- PROJECT

2.1.- Theoretical criteria of the intervention project.

2.2.- Traditional materials and construction methods.

2.3.- Novelty products applicable and new technologies.

2.4.- Sustainable design and energy efficiency.

3.- BUILDING INTERVENTION

3.1.- Intervention plans.

3.2.- Rehabilitation and durability.

3.3.- Reinforcement technologies.

3.4.- Restoration of artworks.

3.5.- Conservation of industrial heritage.

3.6.- Examples of intervention.

4.- MAINTENANCE

4.1.- Construction maintenance.

4.2.- Preventive conservation of built heritage.

5.- DIFFUSION AND PROMOTION

5.1.- Heritage and cultural tourism.

5.2.- Teaching and training.

5.3.- New technologies applied to the heritage diffusion.

5.4.- Accessibility to cultural heritage.

5.5.- Working networks in the cultural heritage.

CODE 141

A MULTI-LEVEL STRATEGY FOR THE SUSTAINABLE RECOVERY OF HISTORIC CENTRES

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ABSTRACT

The design process for the revitalization of historical city centers nowdays has to follow sustainable criteria and comfort objectives in order to rise the liveability and the opportunity of use of the built heritage. The study we propose illustrates a methodology for achiving the energy efficiency from a multilevel perspective, identifying three different dimensions -the territory, the urban context and the building-. For each dimension we move from a cognitive framework to a phase of plannnig, providing a series of operative indications. Case study of the present research is Arquata del Tronto, affected by the seismic activity starting in 2016. For research purposes we assume for Arquata a recovery of the original volumetric features. The territorial survey aims to evaluate the climatic and environmental conditions of the several districts of Arquata, scattered on both flat and mountainous areas. This leds to simplify the complexity of the territory and, by identifying similar conditions, to classify all the districts in five climatic zones. Deepening the research for each climatic zone, we outline areas with critical conditions of discomfort by analysing the facades shading and by performing a fluid-dynamic analysis of the urban fabric; we also provide the corresponding mitigation strategies at the urban level. The following step aims to improve the energy efficiency of the historical centers by working on the single buildings, in accordance to the guidelines provided by the Italian Ministry of Culture. As further deepening, the current study presents an estimation of the energy demand in the urban settlement, considering the different share of electrical energy, thermal energy for sanitary water and thermal energy for heating. After collecting these data, we studied how to supply all the demand with only renewable sources, so to minimise the need of fossil energy.
In conclusion, the project provides a multi-scale guideline text usable for supporting the reconstruction process and, in general, the recovery of the built heritage, orienting the design activities towards the sustainability requirements.

KEYWORDS: Sustainability; environment; recovery; guidelines.

1. INTRODUCTION

The energy efficiency of buildings has undergone an important evolution from a regulatory point of view, which was also matched by a satisfactory response from all the private players who invested in energy savings – thanks to political-economic strategies such as the 65% ecobonus. The achievement of the objectives of the European Action Plan for Energy Efficiency of 2011 (known as "Europe 20-20-20") is still far away though and by 2030 further targets are expected to be pressing with the scenarios developed at EU level, such as the Clean Energy Package. The most important challenge that the Italian building sector will have to set in order to get closer to these objectives is to intervene on the existing public and private building heritage. In fact, around 60% of the built fabric of the country is made up of

buildings characterised by the lowest energy efficiency class (G) and the 88% of Italian buildings are prior to 1991, when the first framework law came into force regarding the rational use of energy, energy saving and the development of renewable sources. That is why it is so important to consider the issue of energy improvement in the minor historic centres that widely characterise the national territory and on which the freedom of design is constrained by the need to preserve the original technical and architectural features. The current study arises from dramatic circumstances such us the earthquakes that struck Central Italy from 24 August 2016, which become the occasion to try out an operational mode to promote a reconstruction oriented to sustainability and energy efficiency criteria. An historical centre strongly affected by the earthquake is Arquata del Tronto, whose municipality commissioned the present research to the School of Architecture and Design of Ascoli Piceno. The aim was to provide public administrations and designers involved in the reconstruction phase with guidelines to suggest technological solutions for the energy improvement from the territorial scale to the single building.
The actual shape of an historic centre, characterised by several construction techniques and an irregular distribution of closed and open spaces, is the result of a series of successive transformations over the centuries. It is therefore the understanding of these transformations that allows to identify the historical values and the identity of the built areas, providing real indications on the elements needed to promote an active conservation of the urban-fabric. At the same time, in order to improve liveability and environmental comfort conditions, it is necessary to study the climatic context in which the historic center is located. This research starts from a climatic study of the territory of Arquata del Tronto and then goes on to provide the operational suggestions in order to support the project activities, both on an urban and building scale.

2. CLIMATE ANALYSIS

The bioclimatic analysis of the Arquata del Tronto area started with the assessment of the parameters of sunshine, radiation, ventilation, humidity and consistency of precipitation, carried out in both summer and winter scenarios.
Combining the values obtained, it is possible to identify the critical environmental zones and the areas which are potentially predisposed to the introduction of renewable energy systems, through which we can maximise the comfort perceived by the inhabitants and minimise the use of fossil energy.
The case of Arquata del Tronto, whose urban context is notably widespread and fragmented within an altimetrically articulated territory, has required to adopt a cognitive path divided into successive levels of in-depth analysis. The research was therefore structured on different phases: the territorial climate, the urban climate and the climatic analysis on the scale of a single building.

2.1. Territorial climate analysis

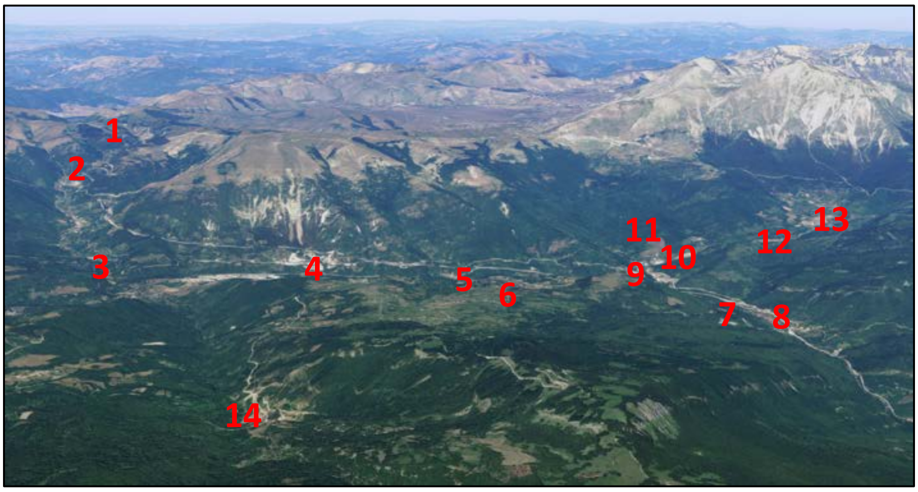


Figure 1: View of the land of Arquata del Tronto with its 14 hamlets

Arquata del Tronto is the last municipality in the province of Ascoli Piceno, on the border between Abruzzo and Lazio. It extends for 92 km square in a mountainous area and is the only municipality in Europe to belong to two national parks: the Monti Sibillini National Park and the Gran Sasso and Monti della Laga National Park. The territory is crossed by the Tronto river which runs along the flat area where the narrow and steep valleys of the northern and southern slopes converge. According to the Decree of the President of the Republic n. 412 of 26 August 1993, which establishes a subdivision of the Italian territory into climatic zones, the municipality of Arquata del Tronto falls within the climatic zone E.

The territorial location data (latitude, longitude and height above the sea level) were entered into the Meteonorm 7 software, using the climatic data reported in the UNI10349 standard. It was possible to obtain the files about the climatic data that characterise the 14 different locations in the municipal area of Arquata del Tronto (temperature, humidity, wind speed and direction, solar radiation). Using an additional software, Weather Tool, the outcomes have been reprocessed and it has been possible to obtain graphs and to conduct comparative evaluations which are useful for a more comprehensive understanding of the case study.

It was found, for example, that directionality and frequency of the wind are common to almost all the localities, with some differences which are more evident as the speed increases – since Spelonga, Colle and Forca Canapine differ from the other fractions. According to the parameters of temperature and humidity, Trisungo and Tufo, situated in the valley, differ from the centres at higher altitudes, like Colle and Forca Canapine. Focusing on rainy or snowy perturbations, we observed their distribution over time: it was found that the villages in the valley and those south of the Tronto river receive more precipitations, while those of medium height north of the river are less rainy.

This first general climatic analysis allowed to organise the localities of Arquata del Tronto in homogeneous climatic zones, grouping them according to similar climatic and geomorphological conditions.

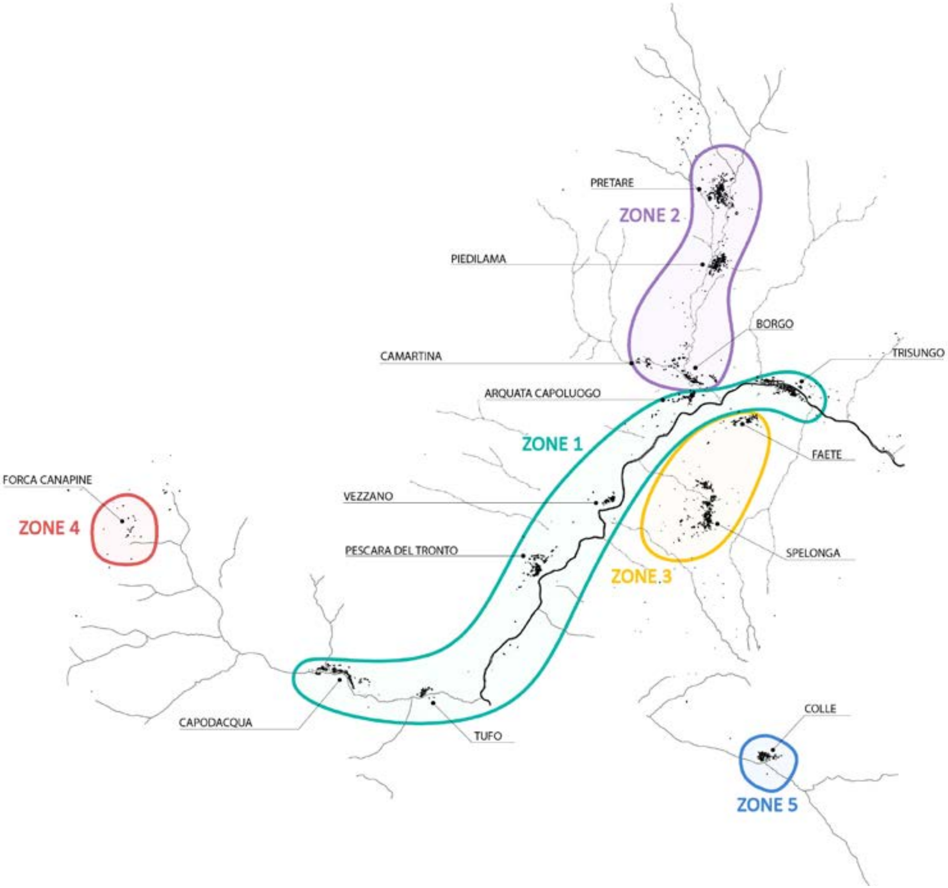


Figure 2: Homogeneous climatic zones grouping the 14 hamlets of Arquata del Tronto according with climatic and geomorphological similarities

The territory is in fact characterised by multiple exposures and environmental situations, since there is a short distance between the valley floor and the mountain ridges, passing from an altitude of 600 m (Trisungo) to 1500 m (Forca Canapine). Five distinct climate zones were outlined (Fig.2):

Zone 1. Villages on the valley floor and on the first hills (Trisungo, Vezzano, Pescara del Tronto, Tufo, Arquata e Capodacqua)
Zone 2. Piedmont villages north of the Tronto river (Pretare, Piedilama, Camartina e Borgo)
Zone 3. Piedmont villages south of the Tronto river (Faete e Spelonga)
Zone 4. Mountain villages north of the Tronto river (Forca Canapine)
Zone 5. Mountain villages south of the Tronto river (Colle)

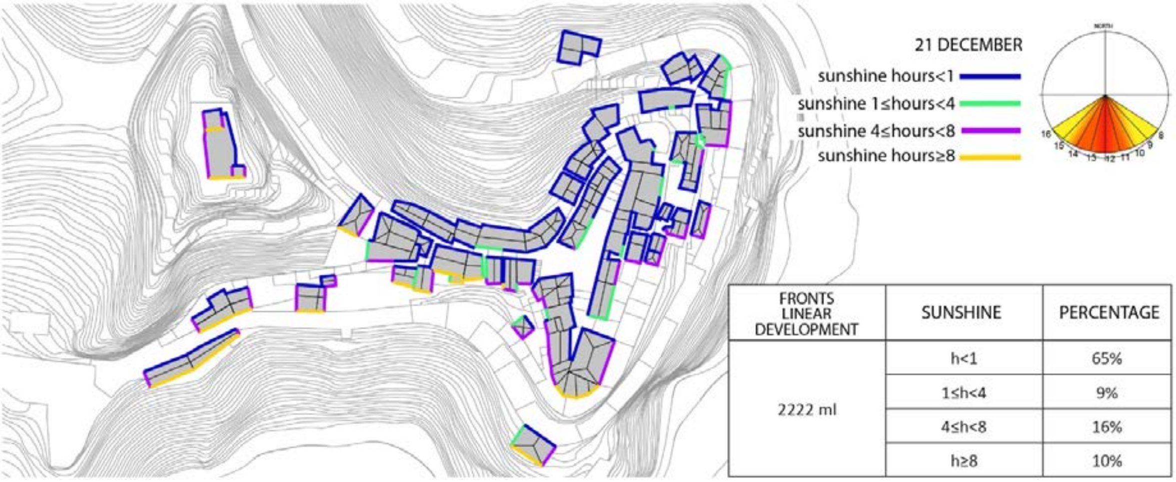
2.2. Urban climate analysis

After identifying the climatic zones, we assumed some fractions as representative case studies for the three central homogeneous zones of the territory: Trisungo for the zone 1, Arquata Capoluogo for the zone 2 and Spelonga for the zone 3.
Under the assumption that the buildings will be reconstructed preserving the original volumes, the climatic study was deepened, aiming to obtain indications strictly related to the relationship between soil and buildings. A fluid dynamics analysis was then carried out using the ENVI-met software[1] (the results are described in sub-chapter 3.1) while the climatic data relating to solar geometries and psychrometric diagrams were elaborated.
On the three localities assumed as case studies, we simulated the distribution of the shadows and the lighting of the building fronts. Since they are located in three distinct areas, the fractions differ in exposure. In the mountain villages, a mountain or a woodland area can be a barrier to the winds but also an obstacle for a correct daytime lighting. The 3D solar path was then simulated through the Ecotect software. It allows to provide a study of daylight during standardised periods of the day and year: morning, noon and afternoon on the days of summer solstice (21 June), winter solstice (21 December) and equinox (21 March). Once the simulations were completed, critical situations have been noticed: persistent shadow in winter and continuous sunlight in summer. After evaluating the degree of illumination of the fronts in the different locations it was possible to quantify the average duration with which the fronts of the buildings are hit by the sun's rays.
According to the calculated sunshine we can consider four types of building fronts:

Fronts with less than 1 hour of sunshine
Fronts with 1÷4 hours of sunshine
Fronts with 4÷8 hours of sunshine
Fronts with more than 8 hours of sunshine

Observing the maps obtained, we note that in the village of Arquata, located on the hill, the north-facing parts present a critical situation, because they are significantly shady, especially in winter (Fig.3).

[1] ENVI-met is a three-dimensional, non-hydrostatic and microclimatic model, able to provide simulations with a spatial resolution of 0.5÷10 meters and a temporal resolution of 10 seconds. The software is based on the fundamental laws of fluid dynamics and thermodynamics.



FRONTS LINEAR DEVELOPMENT	SUNSHINE	PERCENTAGE
2222 ml	h<1	65%
	1≤h<4	9%
	4≤h<8	16%
	h≥8	10%

Figure 3: Map regarding the sun exposure of the building fronts. Arquata Capoluogo. 31 December

For Arquata del Tronto we wanted to carry out a study on the pre-earthquake situation in order to understand the critical points of the urban-fabric currently destroyed and to provide useful suggestions for a possible reconstruction. In fact, some fronts could be lowered to allow the illumination of the secondary streets, in order to improve internal comfort both from a luminous and thermal point of view. In general, considering the reconstruction or reconfiguration of the existing villages, a study of this type is useful to reorganise the distribution of interior spaces by dedicating more illuminated areas to day use destinations.

The study of the sunshine follows the reading of the psychrometric chart. Normally the psychrometric diagram is used during the design phase of a building but the same can also be used for the assessment of the thermo-hygrometric comfort of an existing building.

It starts with the construction of the psychrometric chart with reference to the climatic characteristics of the place. Everything within it could in a first instance determine a specific standard comfort area (pink line) and observe the graph offering us a rate of reasoning on intervention strategies that contribute to widening the initial comfort area. As can be seen from Fig.4, the best and most effective intervention strategies that prolong comfort in both winter and summer are of four types:

- *Passive solar heating,* interventions that provide for the heating of the premises through passive solar systems such as solar greenhouses, large windows, or natural air heating systems;
- *Thermal mass effects*, interventions in which we tend to use building materials that store the heat produced by the sun rays that hit the building and slowly release it over time;
- *Exposed mass and night purge ventilation*, the most used strategy for the summer period with which it’s possible to cool in a building using the insertion of opposing openings of the casing, so as to move from a cooler area to a warmer one. Both for day and night time.
- *Natural ventilation*, it can be used for passive cooling systems, called dissipative, which requires considerations with respect to the characteristics of the local winds and the vertical distribution of the communicating internal environments.

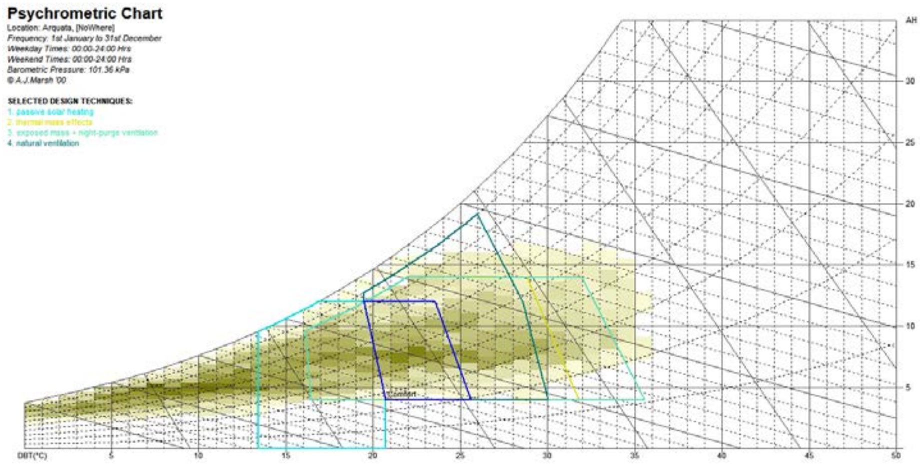


Figure 4: Example of psychrometric chart. Arquata Capoluogo – Annual scenario

In case of restructuring operations, it is possible to reduce the energy consumption for heating or cooling by extending the internal comfort area without focusing on plants, but using passive technologies (solar greenhouses, solar air collectors, exploitation of the thermal mass and optimal arrangement of the openings so as to guarantee natural internal ventilation). The analysis of microclimatic aspects on an urban scale was performed using the ENVI-met software, capable of simulating surface-plant-air interactions in an urban environment. ENVI-met is particularly useful in assessing the impact of new urban-design interventions, because it provides numerical forecasts on the environmental impact of new structures or green areas. It also simulates the flow of wind between buildings, heat exchange processes and steam at ground and wall level, atmospheric turbulence, some vegetation parameters and bioclimatology. The parameters calculated by the software are:

1. Atmosphere: wind, temperature, steam, turbulence, pollution; soil - temperature, water flow, water concentrations;
2. Vegetation: leaf temperature, heat exchange, steam exchange, water transport, water interception;
3. Surfaces: ground level flows, wall and roof flows, heat transfer through the walls;
4. Biometeorology: PMV *(Predicted Mean Vote)* value.

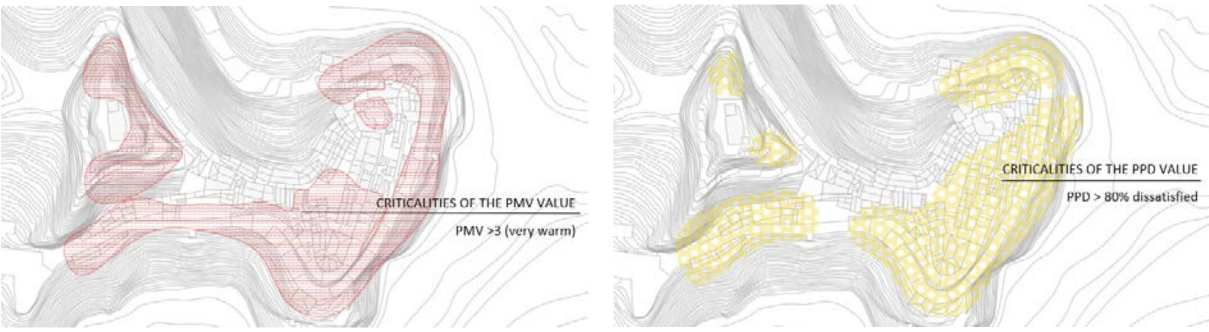


Figure 5: Example of graphic representation for critical areas: PMV *(Predicted Mean Vote)* and PPD *(Predicted Percentage of Dissatisfied)* parameters. Arquata Capoluogo – Summer scenario

In particular, the mapping of the PMV and PPD *(Predicted Percentage of Dissatisfied)* parameters allows to identify the most critical areas of the urban context. The maps show, as an example, the criticalities outlined through the fluid-dynamic analysis conducted on the Arquata Capoluogo case study (Fig.5).

2.3. Climate analysis of the building

This last level of in-depth analysis in the thermal analysis of the building can be achieved both instrumentally (thermography, thermoflowmetry - Fig.6), and analytically, through the knowledge of the construction characteristics that characterize the building envelope and the systems. In particular, to have a reference picture of the energy-environmental performance of the building, it’s necessary to consider further factors such as energy consumption, thermal insulation, attenuation and phase shift, air permeability, passive solar thermal loads.

Fig. 6: Example of a thermographic survey

The data obtained from the analysis of the energy-environmental behavior are to be considered together with those deriving from the environmental analysis, in order to choose which type of intervention to operate. In addition to the analysis of the energy-environmental behavior of the building, it is essential to proceed with the analysis of the "building-plant system", through which the specific technical-construction and technological characteristics of the building envelope and of the energy supply systems are identified. This will make it possible to evaluate the possibility of maintaining its presence in the new project solution, to evaluate their integrability, or to declare its age and therefore its ineffectiveness with respect to new energy performances.

3. WORKING SUGGESTIONS

If the current legislative framework requires an unconditional adjustment to the regulatory obligations, undoubtedly the pursuit of energy efficiency objectives for the architectural heritage needs to be regulated by a careful evaluation of the possible impact that the interventions would entail on historical buildings: any type of intervention, if not calibrated through conservative criteria, could lead to a transformation and to the distortion of the buildings and the areas where they are located.
Therefore the present research intends to introduce, in the reconstruction process of the analysed centre, a technological and energy sustainability method based on evaluative and critical steps. In this way it is possible to place the interventions that can be implemented in relation to the pre-existing urban-fabric and the landscape. The “improvement” logic so adopted does not lead to a mere adaptation of regulatory standards and minimum requirements, but is focused on the assessment of the landscape compatibility, in respect of a territory that bears witness to the millennial balance of man and nature.
In the following paragraphs some strategies used for the energy efficiency improvement of historical centers will be showed. The research aims to reduce energy consumptions in the historic center and integrate renewable energy sources (active and passive systems for energy production), by direct actions on individual buildings or by urban-design applications on collective open spaces.

3.1. Urban-Design for the common spaces

Resuming the assessments described in sub-chapter 2.2 and after a cognitive stage, which allowed the identification of the areas with the greatest critical environmental comfort, we arrived at a proposal phase, in which the same ENVI-met software was used to prove the effectiveness of the hypothesised interventions as the introduction of new vegetation, the use of appropriate materials (low albedo and emissivity values) for exterior pavings or the realization of fountains, green roof and little pools of water. ENVI-met provides quantitative forecasts on the impact of newly designed green areas or structures, supporting the urban-design process in order to achieve the following objectives: reducing the summer temperatures by making outdoor spaces more accessible, protecting buildings from direct sun radiation, avoiding excessive heating of the interior and improving comfort even in the winter season. The graphic representations regarding Arquata Capoluogo are reported below, showing the comparison made between the energy simulations before and after interventions (Fig. 7, 8).

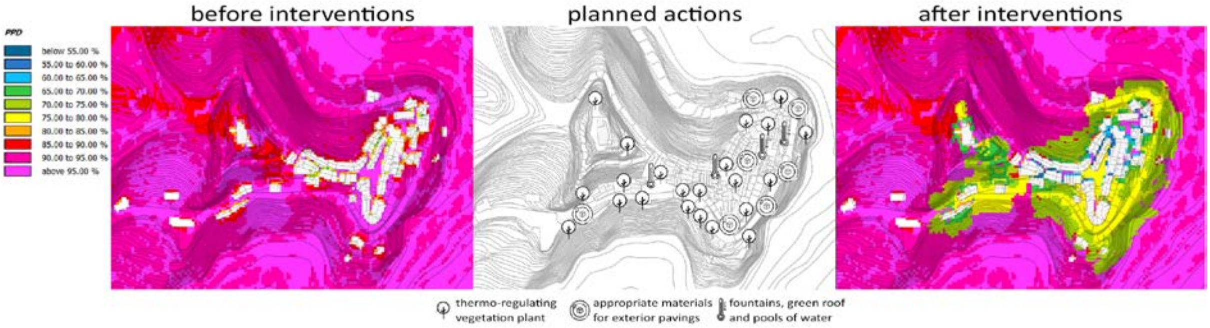


Figure 7: Example of comparative evaluation for the PPD value: before and after the interventions. Arquata Capoluogo – Summer

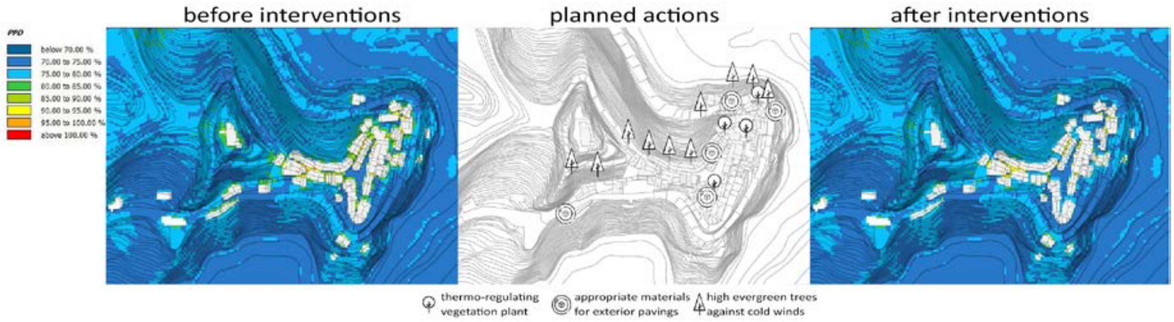


Figure 8: Example of comparative evaluation for the PPD value: before and after the interventions. Arquata Capoluogo – Winter

To solve problems related to temperature and humidity values of the summer scenario, it is advisable to introduce specific deciduous vegetational plants, which lower the air temperature and shield the solar radiation. Considering the PMV values, that are not optimal during the summer seasons, the third frame shows also the positive effect of introducing pools and fountains, as well as using materials suitable for paving open spaces (stone, gravel and porous materials). The effectiveness of the interventions is clear observing the yellow and the green colours that appear in the final scenario and that correspond to a lower percentage of dissatisfied.

To improve temperature and ventilation values of the winter scenario, it is advisable to introduce high evergreen trees that act as a barrier to the strong and cold winter currents coming from the north/north-west. As proof of the correctness of the actions planned, the third frame of the winter scenario shows that the yellow and the green colours have been reduced, in favour of a lower percentage of dissatisfied.

3.2. Use of renewable energies to cover urban energy needs

Assuming the use of renewable energies to cover the energy needs, the understanding of the territorial resources becomes necessary to suggest reconstructive solutions consistent with the characteristics of the place. Considering the village of Arquata del Tronto as a case study, we imagined to cover all the energy needs with renewable energy sources only. We assumed to have installed photovoltaic and thermal solar panels according to the features of the study area and to have used the territory's own resources. We referred to the electricity supplied by small hydroelectric generators fed by watercourses and the zero-mile thermal energy generated by the combustion of biomass collected in the territory. A significant amount of energy is added as a result of a possible geothermal system. The verification of the total coverage through the sources mentioned above was carried out starting from the buildings' square meters and the average needs of the users, using pre-dimensioning calculation charts. The objective of the calculation is the minimisation of the energy losses, in order to reduce the consumption of fossil energy.

Hamlet			ARQUATA		
ACTUAL PRIMARY ENERGY DEMAND (GWh/year)		PARTIAL	Electrical energy	Thermal energy for sanitary water	Thermal energy for heating
			0,081	0,052	0,399
		TOTAL	0,532		
PRIMARY ENERGY SAVINGS	COVERAGE	photovoltaic system	50%	-	-
		solar thermal system	-	84%	-
		actions on building envelope	-	-	35%
		biomass	-	-	50%
		geothermal system	-	-	15%
	RESIDUAL NEED (GWh/year)		0,041	0,008	0
POST PROJECT PRIMARY ENERGY DEMAND (GWh/year)			0,049		
TOTAL ENERGY SAVING (GWh/year)			0,483		

Figure 9: Calculations of energy savings through the use of renewable sources

3.3. Energy improvement of individual buildings

In the case of historical buildings, which characterise the urban settlement of Arquata del Tronto, improving the energy saving does not mean reaching the legislative parameters established for the new constructions. However attention must be paid to the technical-design solutions in order to identify those that make a more conscious and rational use of energy resources.
Looking at a conscious use of energy-environmental resources, it is possible to list a series of actions according to the indications collected in the guidelines of the Italian Ministry of Cultural Heritage.
These have been systematically reorganised, following three aspects:

1) the elements of the building on which the intervention is applied (opaque and transparent surfaces);
2) the type of action carried out;
3) the impact that the intervention produces on the historic building.

1.ACTIONS ON OPAQUE PARTS OF THE BUILDING ENVELOPE

	ACTION	WHAT IT DOES			IMPACT		
		INSULATES	STORES	DISSIPATES	COMPATIBILITY	REVERSIBILITY	INVASIVENESS
1	EXTERNAL INSULATION OF UNVENTILATED ROOF	x	x		•	•	••
2	EXTERNAL INSULATION OF VENTILATED ROOF	x	x	x	•	••	••
3	INTERNAL INSULATION OF THE ROOF	x	x		•	••	••
4	EXTERNAL INSULATION OF THE WALLS	x	x		•	••	••
5	EXTERNAL HEAT-INSULATING PLASTER	x	x		•	••	••
6	INTERNAL INSULATION OF THE WALLS	x			•	••	••
14	EXTERNAL INSULATION OF THE FLOOR ON UNHEATED ROOMS	x	x		•	••	••
15	INTERNAL INSULATION OF THE FLOOR ON THE GROUND	x	x		•	••	••
16	PHYSICAL BARRIERS TO CAPILLARY RISE			x	•	••	••
17	CHEMICAL BARRIERS TO CAPILLARY RISE			x	•	••	••
18	SYSTEMS TO DELETE HUMIDITY			x	•	••	••

2.ACTIONS ON TRANSPARENT PARTS OF THE BUILDING ENVELOPE

	ACTION	WHAT IT DOES				IMPACT		
		INSULATES	PICKS UP	TRANSFERS	DISSIPATES	COMPATIBILITY	REVERSIBILITY	INVASIVENESS
7	HIGH PERFORMANCE WINDOWS FRAMES	x	x	x	x	•	••	••
8	HIGH PERFORMANCE GLASSES ON EXISTING FRAMES	x	x	x	x	••	••	••
9	SECOND STAINED-GLASS WIDOW ON THE INTERNAL SIDE	x	x	x	x	••	•••	••
10	SECOND LAYER OF GLASSES ON THE INTERNAL SIDE OF THE WINDOW	x	x	x	x	••	•••	•
11	FRAME INSULATION AND AIR TIGHTNESS	x	x	x	x	•••	•••	•
12	INSULATING FILM ON THE EXISTING GLASSES	x	x	x	x	•••	•••	•
13	WINDOW MECHANIZATION				x	••	•••	•
19	SOLAR CONTROL FILM ON THE EXISTING GLASSES				x	•••	•••	•
20	INTERNAL SCREENS				x	••	•••	•
21	EXTERNAL SCREENS				x	•	••	•••

Figure 10a: List of the eligible actions on historical buildings and their description in terms of aim and impact

3.ADDITIONAL ACTIONS

		WHAT IT DOES						IMPACT		
	ACTION	INSULATES	PICKS UP	DELIVERS	TRANSFERS	STORES	DISSIPATES	COMPATIBILITY	REVERSIBILITY	INVASIVENESS
22	OUTDOOR SHADING SYSTEMS						x	•	••	••
23	LIGHTSHELF		x	x				•	••	•••
24	SOLAR GREENHOUSE	x	x		x	x		••	••	••
25	SUNTUBE		x	x	x			•	•	•••
26	VENT STACK						x	••	••	••

Figure 10b: List of the eligible actions on historical buildings and their description in terms of aim and impact

4. CONCLUSION

The research conducted verifies the methodological, operational and technological complexity of the theme, but also its centrality for the identification of the strategies for a sustainable and energetically oriented enhancement of the existing historical building heritage.

Starting from the territory and the knowledge of the historical values, it is necessary that the intervention projects safeguard the identity and the global functioning of the building and its context. Therefore, knowing the territory and understanding the complex historical and architectural stratification in which the buildings are located, it’s vital to promote an increasingly efficient energy management.

The study carried out on Arquata allowed us to outline a hierarchy of operational suggestions, which go from the territorial scale to the individual buildings, by proceeding through successive levels of in-depth analysis. These suggestions provide cues for an appropriate recovery process in respect of environmental issues.

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