Tenuta dello Scompiglio,
an utilisation of renewable energy sources in the heart of Tuscany

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ABSTRACT

The antique buildings that we now hold as monuments were constructed during epochs in which fossil fuels were not used as energy sources. For centuries, these buildings accomplished their tasks utilising only renewable energy sources. A contemporary method of restoration should stay true to the spirit with which the building was constructed. In projects that deal with the restructuring of energy systems, we must aim to reach modern standards of comfort in relation to temperature, acoustics and luminousity standards while keeping the production of harmful CO_2 gases to a minimum.

The Scompiglio estate is composed of the main villa, dating from the 17th century, gardens spanning about five hectares, eight auxiliary buildings and a 160 hectares of land with olive groves, vineyards, wooded foothills, mountainous areas, vegetables gardens and orchards.

The main villa is a registered (listed) historical building according to Italian conservation laws. The whole property is a conservation area with historic, architectural and natural interest.

The property was transformed, in 2003, into a research project with the goals of conservation and rehabilitation of the ancient agricultural uses and restoration of the buildings for residential use and as a setting for a cultural center that promotes the arts.

The main focus of the project has been environmental sustainability. All materials used are natural and bio-compatible and most of them come from local factories. The energy demand for each building is minimized and modifications were made with constant consideration for the preservation of their historic value.

The goal of the project has been to make the estate self-sufficient using only renewable energy sources. A photovoltaic system produces electrical energy. Thermal energy for heating and hot water is produced by a centralized system using a wood chip heater. The energy cycle is fully supplied by pruning and regular forest maintenance and is $C0^2$-neutral.

PREAMBLE

The Tenuta dello Scompiglio

The Tenuta dello Scompiglio (the Scompiglio estate) is a property of about 160 hectares which can be found in the village of Vorno, 7 km from the city of Lucca, in Tuscany. The estate consists mostly of land featuring typical Tuscan agricultural – olives, grapevines, and a vast wooded area. The heart of the property, consisting of about 40 hectares, includes a manor house, hear after called the villa, and a group of buildings intended for conducting farm business and activities.

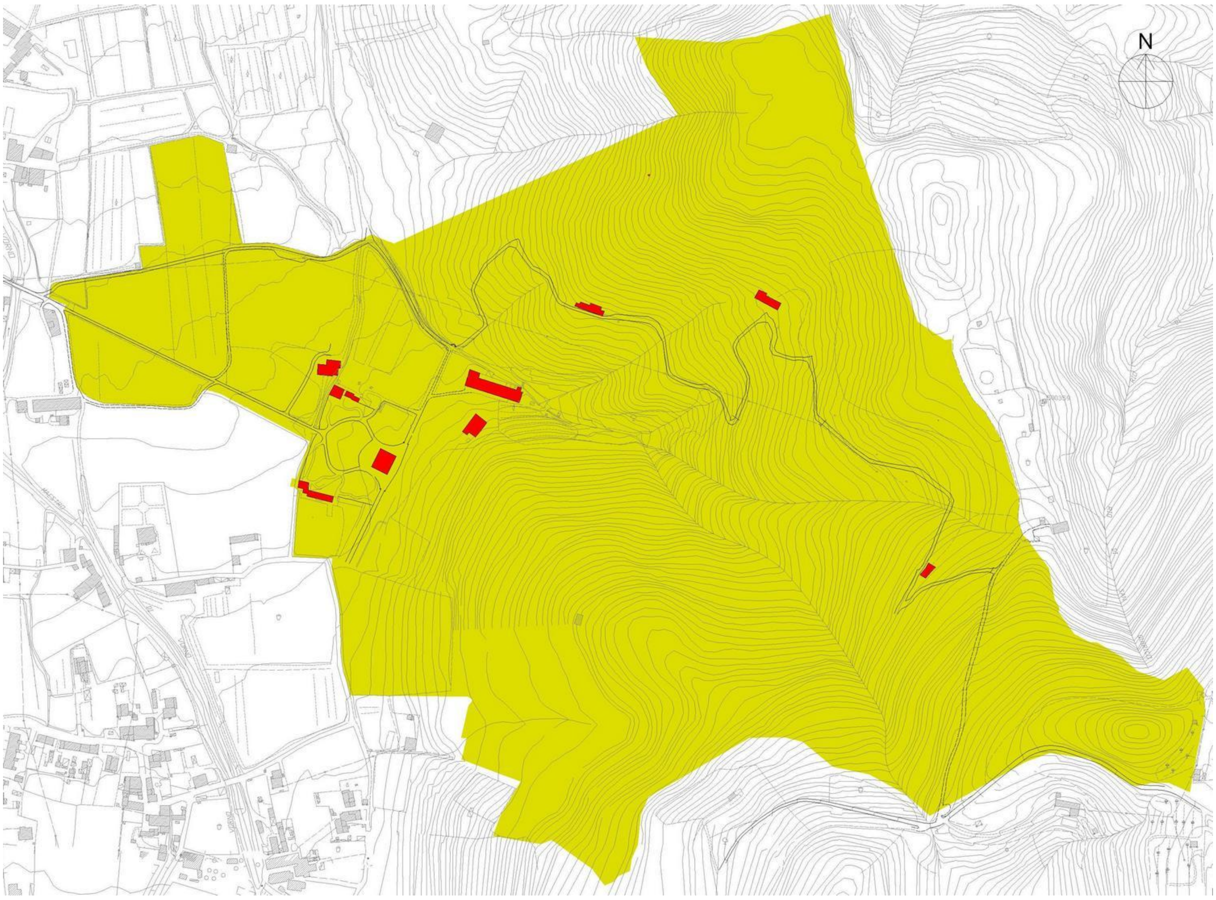

Figure 1.

In 2003, the estate was bought by the current owner who carried out a large restoration project on the buildings and re-established the farming activities utilizing, to an extensive extent, the criteria of bio-architecture and bio-dynamic agriculture.

The approach to this project, for the restoration of the buildings, included two different levels of work done contemporaneously: the specific level and the global level. The plan actively considered the characteristics and the requirements of each single building and the environmental conditions and resources of the estate. In this way, the plan for the project was included the entire estate on a global level: considering all of the energy resources available, along with the building jobs to be completed, currently and even in the future. Locally, the project of restructuring each single building kept in consideration all the specific particularities of each structure, dividing and optimising the jobs with respect to the characteristics of the existing building, its future purpose and how the building will be used, and the degree of heritage regulations and constrictions to which it is currently subject.

The purpose of this article is to illustrate the methods used throughout this project. In the following essay, attention is focused on the overall study of the use of energy resources on the estate and we analyse, in detail, the preliminary examinations and the project decisions made for the villa, the main building, which prominent both historically and artistically. The particular details of the jobs done to the other buildings, however, are not described at length.

Historical Introduction

The Tenuta dello Scompliglio was originally constructed in the first half of the 17th century. In this period, the noble family of Lucca, named the Tegrimi family, acquired the land in the area in the centre of which they constructed their summer home. The construction of this countryside manor followed a popular trend in Italy, which began around the late 1400s. The property was later inherited by Minutoli Tegrimi, with whom it remained until it was sold to the current owner in 2003.

The village of Vorno, thanks to its vicinity to the city of Lucca, its warm climate and the abundance of fresh water, was the ideal location for the construction of the summer homes where the most wealthy families could pass the months from April to October away from their city mansions. From the year 1500, many villas were constructed in the area of the former Minutoli villa, now called the Tenuta dello Scompiglio.

Description of the Property

The central unit of the property, consisting of nearly 40 hectares, is within an enclosure (a gated area encircled by high stone walls) which features the villa at its centre and is surrounded by gardens and various auxiliary buildings, which include the private chapel, the limonaia (lemon greenhouse) and the caretaker's house.

To reach the villa, you must travel a long street lined by cypress trees and surrounded by flat farmland. Directly behind the villa, begin the rolling hills of cultivated olive trees and grapevines and, higher up, begin the forested mountainous area.

Just outside of the gate of the villa's garden, lie the other large buildings that were, at one time, used for the farm business activities. Finally, the property includes a few cottages situated on the foothills which were, at one time, used as housing for the families who cultivated the same olive groves and vineyards which are found on the property today. The total surface area of the principle buildings is about 8’000 m^2.

The building typology corresponds with the style typical of agricultural construction in Tuscany - characterized by stone walls, some exposed without plaster finishing, wooden floor beams and joists and roof pitch covered in flat and rounded roof tiles.

The architecture of the main villa reflects its purpose as a summer house for nobility and its symbolic value as the linchpin of the property. The building has a square floor plan and is four stories high - including a basement level, ground floor, second floor and attic. On the south facade, facing the valley, there is a double staircase decorated with balustrades and mosaics and the main entrance door. On the north facade, facing the mountains, there is a portico supported by stone columns on the ground-floor exterior which opens toward the gardens. The door frames, window frames and the belt course are made of local grey stone which stands out against the plaster, giving a chromatic effect to the building's exterior.

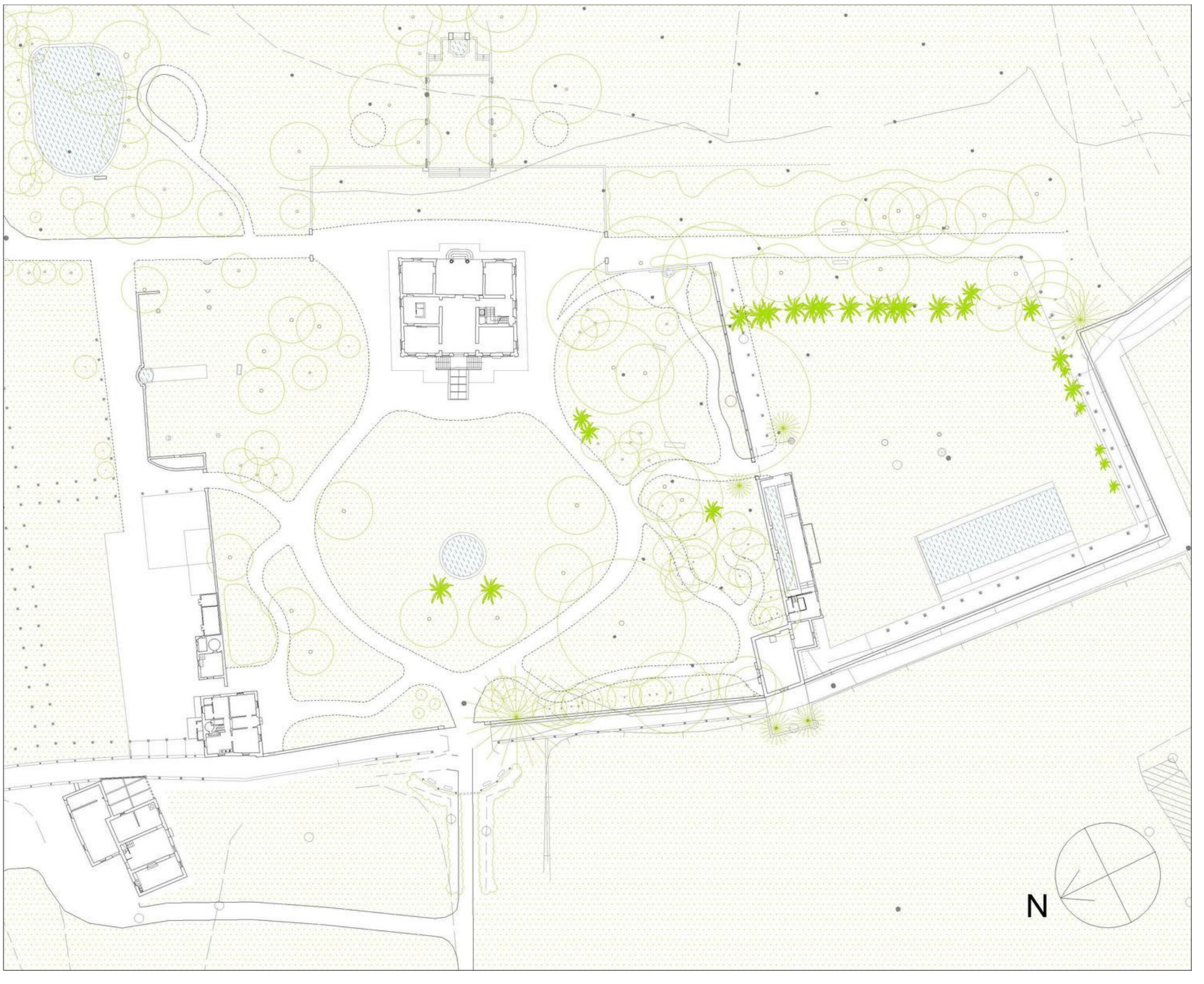

Figure 2.

Project
The "Tenuta dello Scompiglio" project consists of a series of works dispersed throughout the entire property, including the land and buildings.

The cultivation of olive groves and vineyards was re-established where these areas still existed and was reintroduced to the land where, by now, it had been abandoned. On the flatlands of the valley, a vegetable garden and an orchard were planted. The water drainage systems and the terracing of the hills were restored. All of the farming is conducted according the principles of bio-dynamic agriculture.

In addition to the farm business activities, the Tenuta dello Scompiglio is home to the Accademia Culturale which stages theatrical and musical performances and exhibits art sculptures and paintings.

The existing buildings have been restructured to be residential units for housing the employees connected to the above-mentioned activities.

Figure 3.

The villa was restored to its glory as a manor house. In the old lemon greenhouse, an indoor swimming pool was installed, along with a spa area. A large building named the “Casa Quadrata” ('Square House') was restructured to accommodate the new winery and wine cellar on the ground floor and offices on the upper floors. The cottages were restructured, or are in the process of being restructured, as lodging for employees of the farm and to accommodate the artists from the Accademia Culturale. An old agricultural building, situated opposite the west entrance of the estate, was torn down and reconstructed to create a cellar for the storage of the centralized hot-water heater while the upper levels now accommodate a restaurant.

Another agricultural building, which housed the barn and stables, is currently being renovated and will accommodate a small theatre and a few spaces for art displays and exhibitions.

Preservation Constraints

The constraints related to historical, aesthetic and environmental heritage preservation in Italy are currently regulated by the Decreto Legislativo (federal law) num. 42, 2004 *"Codice dei beni culturali e del paesaggio”* (code of cultural and environmental heritage) which combines two laws, in existence until 2004: law num.1089, 1939 which covers 'artistic objects' and law num. 1497, from the same year, which covers 'natural beauty.'

Figure 4.

The former Minutoli villa, along with the gardens and their pools and fountains, is subject to the constrictions directly related to cultural heritage. The buildings included in the gated area surrounding the villa are subject to a special regulations and restriction due to their association to the villa and are considered together, as parts of a consort, a single monument. The entire area of the Tenuta dello Scompiglio is subject to the Vincolo di Tutela paesaggistica (the environmental heritage constrictions).

Based on the above-described constrictions, any work done involving modifications to the exterior of the buildings on the Tenuta dello Scompiglio is obliged to first procure the appropriate permits of Autorizzazione paesaggistica (environmental authorization). The villa and the surrounding buildings, additionally, are subject to authoritative bodies even for work done to the interior, with limitations more or less restrictive in relation to the various levels of the constrictions.

ENERGY REQUIREMENTS

Microclimate

Lucca is located in a geographical area in which the climate is generally similar to that of the Mediterranean region, with the association of dry summers and rainy winters. Local climate is strongly influenced by its geographic formation: the sea to the west and the Apennine ridge, which closes around and protects the area on the north-east side.

Vorno is located in this context, in a small valley nestled among the arch of the Monti Pisani (Pisa mountains), south of the city of Lucca.

The property, therefore, is mostly closed on the east, south and west sides, surrounded by forests and wooded areas and rich in water. The valley, in fact, is outlined by the Maestro di Vorno river, the river which collects all of the water coming from the various streams in the area. The result is that, with respect to the city of Lucca, this region has a higher level of humidity affecting both the winter temperatures, which drop lower then the averages throughout the province, and on the summer temperatures, which during the day are always slightly lower.

It is this type of climate that made the area all the more inviting for those wealthy families from Lucca looking to move out of the city during the summer months.

On the estate, there has been a meteorological station (accessible on the internet at www.fieldclimate.com) set up on the higher area of the estate since 2008, installed at the request of the clients.

This station has provided rather interesting data that was useful in designing the project and making the energy plans and will be utilized even in the long term, providing important information for the agricultural technicians. The data is collected, monitored and used year by year.

This data is reported in figure 5, the table of output from the meteorological station relative to one solar year (year 2010).

Date	Solar radi [W/m²]	Wind direc [deg]	Precipitat [mm]	Wind speed [m/sec]		Leaf Wetne [min]	HC Air te [°C]			HC Relativ [%]	Dew Point [°C]	
	medi	ulti	somm	medi	mass	temp	medi	mini	mass	medi	medi	mini
2009-02-01 00:00:00	96	88	166.2	0.48	6.90	12290	6.26	-3.28	14.94	73	0.91	-15.10
2009-03-01 00:00:00	152	67	251.6	0.70	6.60	11710	9.70	1.23	18.80	72	4.05	-13.60
2009-04-01 00:00:00	194	108	106.2	0.62	7.40	11540	13.80	7.19	24.01	75	8.88	0.80
2009-05-01 00:00:00	300	106	10.4	0.53	3.80	1580	18.93	9.20	32.47	61	10.29	0.20
2009-06-01 00:00:00	283	80	38.0	0.70	4.10	4480	20.62	11.93	32.27	70	14.34	4.00
2009-07-01 00:00:00	323	92	22.6	0.84	5.30	2280	23.57	14.80	35.60	65	15.60	2.30
2009-08-01 00:00:00	239	108	1.0	0.70	3.80	1085	25.31	16.78	37.57	60	15.93	5.80
2009-09-01 00:00:00	133	84	121.4	0.47	5.90	6845	20.78	13.26	32.64	65	13.01	2.20
2009-10-01 00:00:00	88	97	109.8	0.28	3.50	12080	14.27	2.01	26.56	77	9.65	-3.20
2009-11-01 00:00:00	71	260	140.2	0.59	5.40	6415	9.68	4.14	17.40	82	6.27	-6.70
2010-02-01 00:00:00	49	286	43.8	0.84	8.40	2950	10.43	3.96	14.85	81	6.85	-1.80
2010-03-01 00:00:00	74	229	58.0	0.83	7.50	8770	9.00	-2.27	19.70	76	4.50	-13.80
2010-04-01 00:00:00	119	96	149.4	0.73	6.90	8230	13.07	3.62	25.05	71	7.27	-1.50
2010-05-01 00:00:00	111	71	187.4	0.66	3.80	16325	15.71	8.82	27.01	79	11.41	3.30
2010-06-01 00:00:00	130	76	96.4	0.65	4.00	10700	20.10	11.78	32.71	76	15.15	7.50
2010-07-01 00:00:00	134	52	186.6	0.50	3.90	5225	24.65	13.74	34.27	67	17.33	5.20
2010-08-01 00:00:00	105	81	103.4	0.52	4.40	2325	21.86	10.33	33.39	75	16.57	4.00
2010-09-01 00:00:00	76	61	70.0	0.42	3.20	8010	18.67	9.42	28.95	74	13.27	2.70
2010-10-01 00:00:00	44	218	219.6	0.37	4.50	15025	13.75	4.29	25.73	77	9.31	-2.60
2010-11-01 00:00:00	22	304	358.6	0.40	6.50	26540	10.21	-0.46	21.67	91	8.47	-1.90
2010-12-01 00:00:00	18	89	238.2	0.52	6.30	21435	5.68	-5.89	16.12	82	2.40	-13.10
2011-01-01 00:00:00	22	117	84.6	0.31	3.10	12425	6.16	-2.43	15.08	79	2.49	-12.10
2011-02-01 00:00:00	44	103	0.0	0.49	2.30	245	7.63	2.09	16.58	56	-2.17	-16.40

Figure 5. Table of output from the meteorological station, year 2010

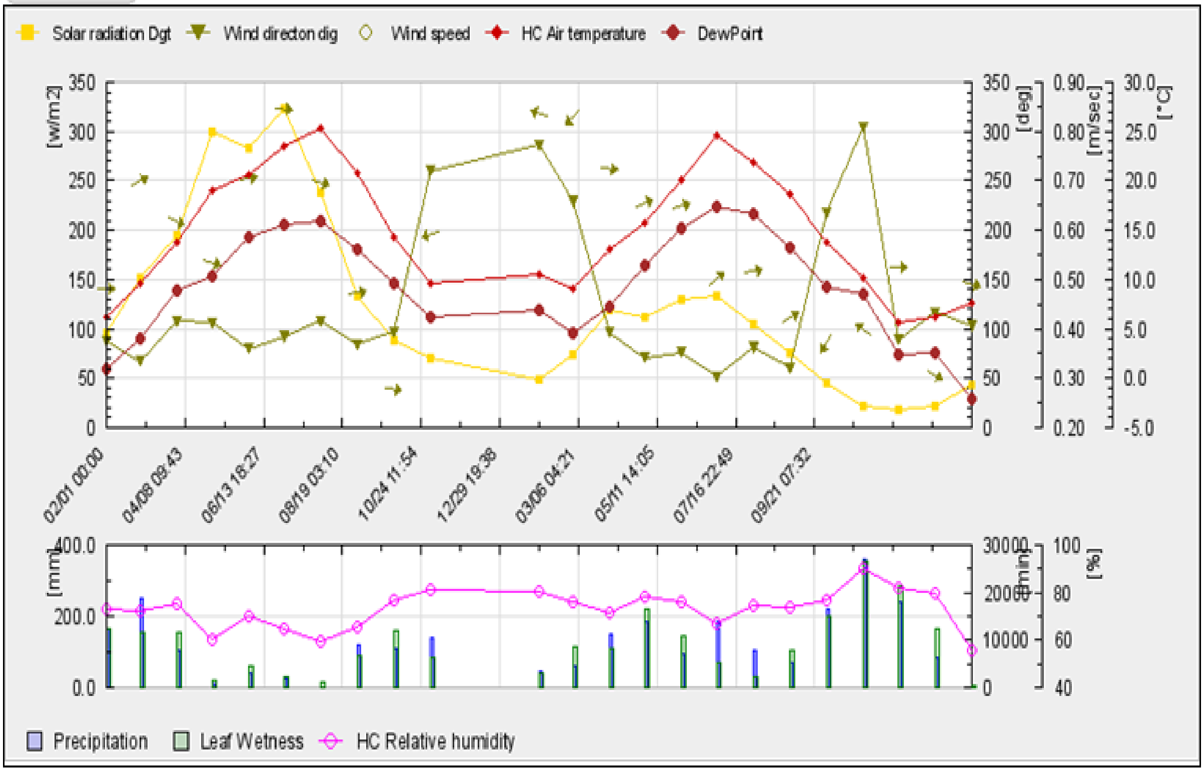

Figure 6. Diagrams of the output from the meteorological station, year 2010

During the modeling phases, it was possible to manage input conditions of the data more precisely and with more detail by modifying the parameters responsible for the largest diversion from the normative standards, therefore obtaining more exact results. In Table 1, a short comparison conducted in 2010 is reported. It compares the climactic data from the flat-land area of Lucca and the foothills where the meteorological station is located.

	Avg. daily external temperature		Annual precipitation 2010		Realitve external humidity	
	UNI 10349 LUCCA [°C]	**WEATHER STATION 2010 [°C]**	**LUCCA 2010 [mm]**	**WEATHER STATION 2010 [mm]**	**LUCCA 2010 [%]**	**WEATHER STATION 2010 [%]**
February	7.2	10.4	70	43.8	71%	81%
March	10.1	9	77	58	70%	76%
April	13.3	13.1	80	149.4	72%	71%
May	17.1	15.7	61	187.4	72%	79%
June	21.2	20.1	43	96.4	70%	76%
July	23.8	23.7	24	186.6	67%	67%
August	23.6	21.9	57	103.4	68%	75%
September	20.9	18.7	88	70	71%	74%
October	15.8	13.8	120	219.6	72%	77%
November	10.9	10.2	122	358.6	74%	91%
December	7.3	5.7	85	238.2	76%	82%

Table 1. Comparison of the standard data and that from the meteorological station

In particular, a notable difference is observed with respect to the precipitation, caused by its proximity to the Monti Pisani and the humidity levels, especially during the winter period.
With respect to the temperature, it is notable that the average daily temperature is constantly lower, by about one or two degrees Celsius. It should be emphasized that this climactic phenomena would be amplified in the area where the main buildings stand because it is lower, in the valley, and more shaded with respect to the weather station, located on a hill and decisively more exposed to the sun's rays.

Water on the Estate

The Tenuta dello Scompiglio has ample availability of water, present inside the historical gardens, as a natural and architecturally aesthetic element and as an important natural resource.

The area of the principle buildings is enclosed by two streams which converge in the valley of the small river named Rio Maestro di Vorno and in the included area, emerging at various points, is a network of natural springs situated upon a system of hydraulically well-structured cliffs.

This strong presence of water is consistent throughout the entire year, favoured by the previously described microclimate, characterized by high humidity levels.

The estate has transformed this natural element into an important source of energy, useful during the summer period. A network of fountains stretches from behind the villa and circles around its two sides, ending in a small pond that also collects the water from the cliffs behind the villa.

The survey analyses of the hydraulic system in the gardens showed that the series of fountains was supplied by a natural spring located to the north of the estate. The entire uptake of water for the system comes from two sources – natural springs and drainage wells. There are four natural springs that surge from fissures in the rock layers. The other type, man-made, is a network of three drainage wells, further down in the valley. From both of these sources, the water is first collected in a storage tank and then distributed downstream, starting from the area behind the villa, branching off towards the other buildings.

The monitoring and examination phase, lasted a year. The averages from a year's worth of data showed that, of the four natural springs, the majority of the water was supplied by one single spring. The other three springs showed a largely variable amount of water, probably because they collect only surface water. The data showed that average amount of water collected by the principle spring was about 1 lt/sec. The temperature of the water exiting remained fairly constant at 16°C.

Orientation of the Buildings

The estate complex is a system of buildings that functions like organs, in which each building has a particular use and purpose and they were constructed and positioned accordingly.

In particular, we found that the principle building, the villa, was positioned in a way to take advantage of natural air-conditioning. Located directly at the bottom of the foothills, it is therefore protected by the hills from the winter winds blowing from the north-east. The main facade faces the west valley and the south and west facades feature many windows that allow ample sunlight to enter in the winter season. On the ground floor, there is a system that allows the building to be opened up along the east-west axis, creating a natural flow and movement of air in the summer and recycling the fresh air from the surrounding heavily shaded areas.

In fact, the villa is bordered on the north-east by the wooded foothills and the valley has been proficiently filled by beautiful plants, which not only have aesthetic function but also accomplish the important function of cooling the air and the horizontal surfaces. The cooling affect is also increased, as we have already shown, by the constant presence of water.

Building Envelope Materials

The buildings on the estate are all completely built of stone walls using large, thick stones, with traditional wooden floor beams, including the double-layer roofing with beams and joists and terracotta tiles.

Both the exterior and the interior of the villa are rich with decorative elements, including stone window and door frames on the exterior, painted flooring, plaster frescos and rooms with vaulted ceilings on the main living floors (the ground floor and the second floor). These are all elements that place strong constraints, stemming from the necessity to restore and preserve them, on the eventual project decisions.

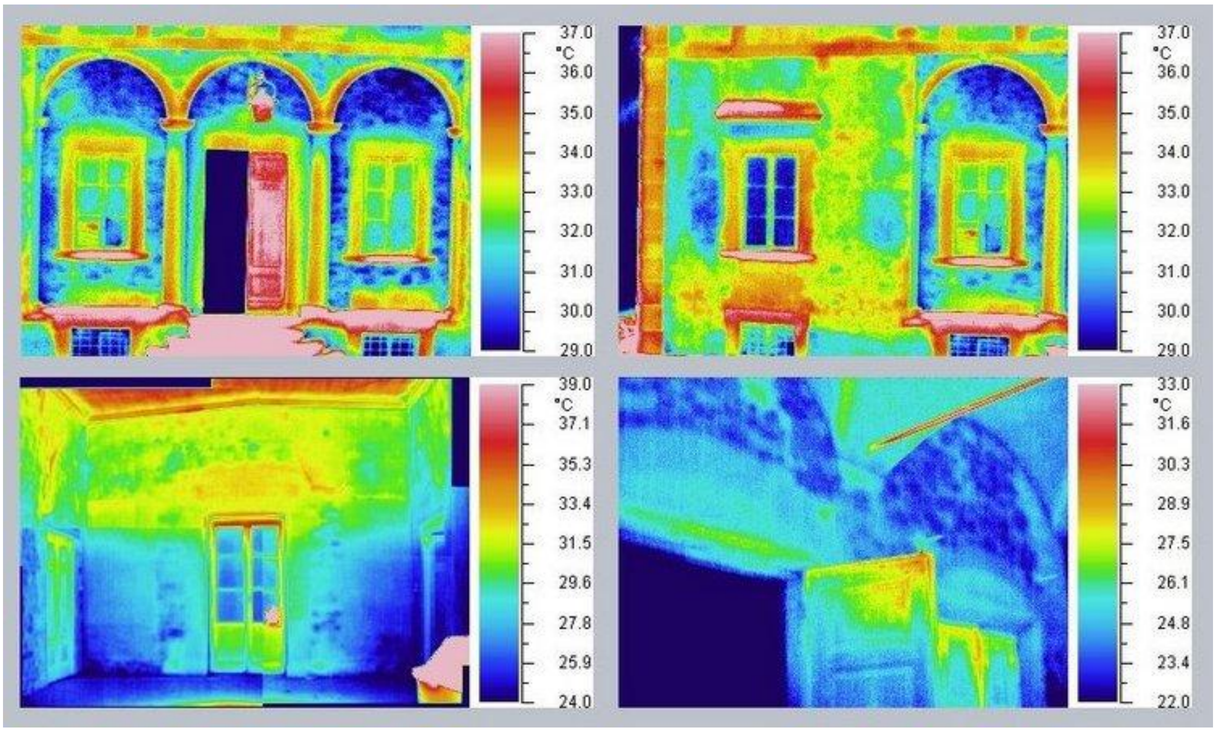

Figure 6.

According to the traditional building plan, the building structure is characterised by an overall prevalence of closed surfaces rather than of windowed space. For that reason, the various wall elements become very significant from the perspective of the general thermal balance.

For this reason, and the fact that the villa is considered historically important, in-depth examinations were done on the walls in order to better understand both their thermal and structural characteristics.

With the composite survey analysis executed, the cylindrical samples taken and the examinations and instrumental tests employed (such as thermo-graphic analyses) we collected the data useful in understanding the building and how to best capitalize on it. In the end, we are able to not just preserve the walls, but optimise this particular property.

The average thickness of the walls checked was 40 cm, with a maximum thickness on the basement floor where they reached a thickness of 55 cm, for an average surface mass of about 800 kg/m².

The creation of a precise model allowed the study of the relationship between the walled surfaces and glass surfaces and, most importantly, the position of the building, and its windows, in relation to the sun. In the end, the model showed that it was possible to avoid overly invasive modifications to this historical, such as the substitution of the wooden window frames and single-pane glass windows, the installation of insulation in the walls and the insertion of an air-conditioning system.

Thermal Inertia for the Buildings

Along with the cylindrical samples of the walls, a climactic surveillance was also performed on the interior of the villa in the period before the projects began. This confirmed the dimensional data of the walls that was mentioned above.

From the results obtained, in fact, it is evident that the characterizing element of the global behaviour of the building is thermal inertial, which makes it possible to surpass the problem of the inability to insulate the building envelope.

In theory, a wall of stone 40-cm thick has a mass four times greater than a wall of the same thickness made in bricks and, despite the much lower thermal resistance, it guarantees the same time shift.

It is observable here on the experimental diagram, in fact, that the law thermal resistance, caused by the higher surface mass of the wall, has a retarding affect on the transmission of heat (time shift). In the end, thermal inertia perfectly stabilises the internal microclimate (see Figure 8).

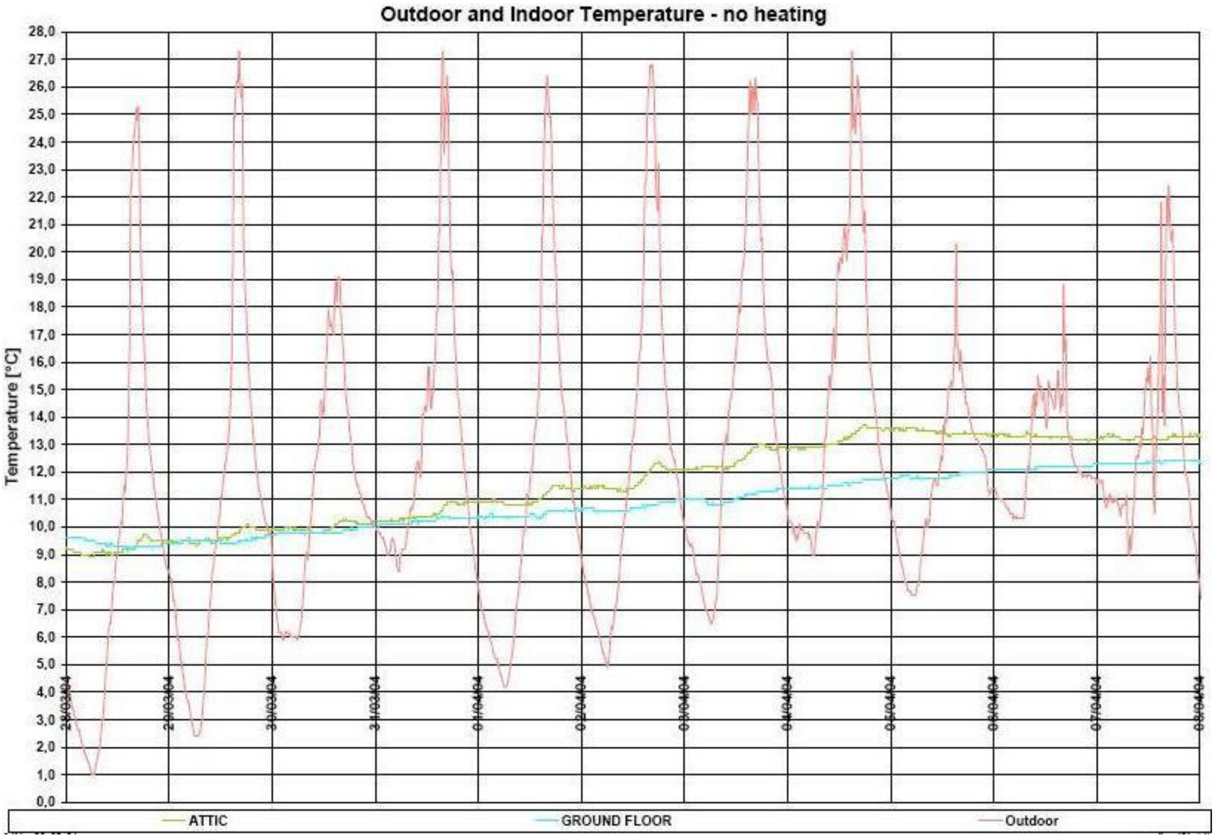

Figure 8. Diagram of the internal temperature compared to the external temperature

The red line in the diagram is for reference purposes. It represents the temperatures in one month. The light blue and green lines represent the temperature trends inside the ground floor and the attic floor.

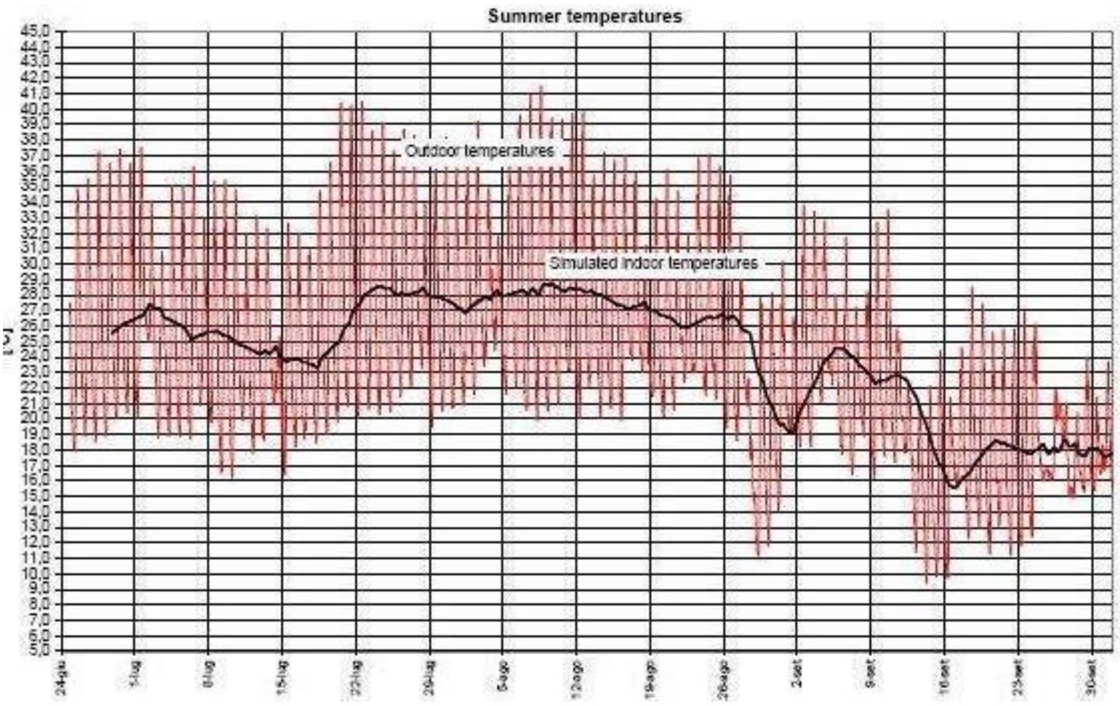

Figure 9. Summer temperature trends

It is clearly observable how even the largely exposed attic floor responds with very stable temperatures independent from the large swings in the external temperature.

We had executed a simulation of the internal climactic behavior during the summer period. In the graphic of Figure 9, you can see that, during the hotter months with the maximum external temperature reaching 40°C, the internal environment does not exceed the temperature 28°C. This information impacted the project planning phase and the jobs carried out; in particular, the installation of an air-conditioning system on the buildings' interior was deemed unnecessary during the planning phase.

WORKS INCLUDED IN THE PROJECT

Water

In the spirit of restoration on the estate, it was decided that the water management system would also be brought back to life, to restore the fountains in the historical gardens. Additionally, and most importantly, they would be restored to take the full advantage of this precious resource, for domestic uses and for irrigation purposes, and to avoid the need for external supply of water by means of an aqueduct.

This is why, a complete reconstruction of the network of springs was employed to optimise both the collection and distribution of water.

The preliminary surveillance done supplied the data for determining the most important supply points where sealed manholes were then installed to protect the water from contaminated run-off (it is an area inhabited by many wild animals).

In substitution of the three drainage wells, a system of trenches was created and proved much more efficient, without changing the position and areas of interest for water collection.

We sought to minimise the dispersion and channel all of the collected water in the valley, with new lines placed in the existing tracks.

A collection reservoir just below the collection system, made of a pre-existing cistern, adequately waterproofed and cleaned out to, allowed the balancing of the influxes and out-flows of the water.

At this point, two distinct distribution systems begin. There is the supply system that goes to the historic fountains and the system supplying the sanitary water for the entire estate. The systems are also able to store their surplus separately, in order to manage the consumption in relation to the availability of water in every period of the year, such as the dryer period, about a month during the summer season. In the case of a drop in the supply, all of the water becomes utilized only for sanitary purposes.

The sanitary sewers converge in the central hydraulic station where there is also the security connection to the aqueduct, from which the distribution towards the buildings on the estate begins.

Additionally, an interesting fact emerged from the examinations – that the temperature of the water from the natural spring stays, almost constantly throughout year, around 16°C. The project planned to utilise this resource as a means to cool the buildings throughout the entire property.

The thermal system, featuring hydronic radiant floor heating panels, has an optimal result in that it takes advantage of this thermal resource in the summer period. A cooling pipe, supplying the radiant panels with the cool natural spring water, was laid from the hydraulic station extending to each of the buildings.

Employing this type of system and considering the walls' thermal inertia, which has been analyzed above, in the buildings on the estate allowed us to avoid installing an air-conditioning system, limiting the necessity to the installation of small dehumidifiers.

To complete the water supply system, the project dedicated a few of the buildings to the collection of rainwater, with the installation of special tanks (5000 lt. for each building). The water that is accumulated, using these tanks, feeds into the non-potable hydraulic system that serves the bathrooms of the buildings.

Even the water which squirts from the fountains is not wasted, but is recycled. Even in this case, collection tanks were designed into the project to store the water for agricultural use – to irrigate the fields located on the estate.

Building Envelope

The set of examinations and samples done on the walls became the basis for numerous project decisions, establishing and evaluating the properties of each individual building. In the end, this reduced the number of the works to only those that were strictly necessary and less invasive.

In general, the works done were to improve the thermal resistance of the building envelope, reducing the humidity present. The restoration works and the introduction of insulation, chosen from the various available forms (panels, plaster) are all based on natural and bio-compatible materials.

With respect to the main villa, how we have already described, it presented many constrictions both on the external facade and on the internal surfaces. It was necessary to proceed without the use of insulation, in accordance with the heritage constrictions. Consequently, the restoration was limited to smaller, local restoration projects. These included a general cleaning of the wall surfaces, chemical cuts were made on the foundation level to reduce the rise of humidity from the ground, and a highly breathable natural plaster with a base of 'cocciopesto' (a material from brick fragments) was applied.

On the upper floors we executed a significant job of cleaning and restoring the existing plaster and restoring the surfaces, with the support of restoration technicians for areas in which the principle existing frescos were to be salvaged.

For the external walls above ground, therefore, the design considered their thermal inertia, allowing the focus of the project to shift to the decision of the type of system to install and making it functional.

Figure 10.

The insulation, on the other hand, was used to improve the thermal resistance of the roof and floors. On the roof, in order to gain the highest degree of comfort in the attic areas, reducing energy consumption, an insulated and ventilated roof, a natural convection roof, was constructed. Specific detail was paid to the eaves of the roof to ensure that there was no alteration to the aesthetic aspect and architectural elements of the roofing. In the flooring between levels, hydronic radiant floor panels and insulation panels made of cork were installed. This was made possible despite the minimal thickness of the wood floor beams. We took advantage of the existing differences in height, using a precise study of the division of the levels, examining the specific sections of the flooring, room by room.

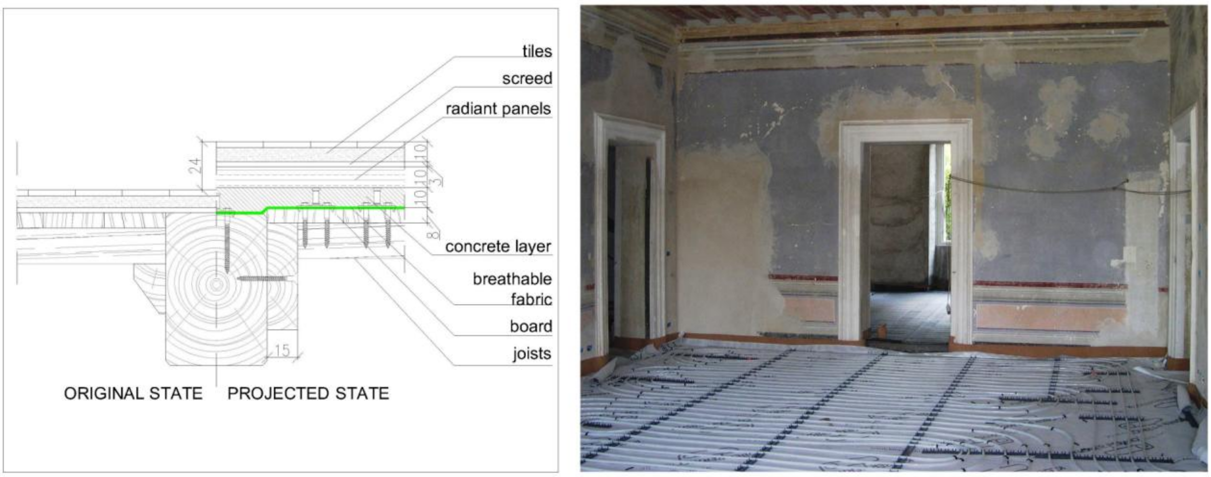

Figure 11.

For the insertion of new utility systems, the tracing of the pre-existing tacks and shafts was very useful. The existence of these tracks and their position was pinpointed with precise surveying and thermographic camera. Using this methodology, we were able to minimise and avoid the weakening of the structural and thermal resistance of the walls that would have been necessitated by creating new shafts. The installation of the new utility systems, and their distribution between floors, was accurately studied using all of the passages, shafts and chimneys already present, which were then skilfully re-closed and insulated.

Thermal Energy on the Estate

The Estate is organised in two parts: the system in the valley, with the centralized energy management supplied by the wood-chip water heater, and the mountain houses that, given their distance from the valley nucleus, were treated separately and for which we aimed to make them self-sustaining.

The design of each building and the heating plant station were created using 3-dimensional finite-element models for each building serviced, in order to determine the appropriate size for the boiler in relation to the power's need. In the same way, the annual energy demand for heating the sanitary water was estimated.

In Table 2, the estimated consumption data obtained is reported.

ESTIMATED THERMAL CONSUMPTION		CASE 1 gas [m3]	CASE 2 wood chips [ton]
VILLA	radiant panels	26,351	84
CARETAKER'S HOUSE	radiant panels	5,270	16
LEMON GREENHOUSE	air-conditioning + heated pool	7,972	25
EXTERNAL POOL	Heated pool	2,657	8
'CASA QUADRATA'	radiant panels + fan coils + laundry room	6,695	21
RUSTICO	fan coils + heat recovery + kitchen fan system	7,569	24
Total demand for the estate		56,515	179
Total demand in euro		**48,603**	**11,606**
		ESTIMATED YEARLY SAVINGS	***76%***

Table 2. Estimated consumption of the projected thermal system

Included in the project was a centralized heating system. The water is distributed from the boiler in the thermal station, through insulated tubes, providing district heating which serves all of the buildings in the valley nucleus. With this configuration, the result was that each building became completely self-sustaining in relation to thermal regulation.

The boiler is supplied by wood chips continuously throughout the year. In the winter, the hot water is used for central heating and, during the summer, it is used to heat the swimming pools.

From Table 2 reported above, it becomes apparent that for the consumption, estimated following the legal energy indications plus the hypothesized increase in consumption, the use of the wood-chip water heater would permit an annual energy savings of about 37,000 euro.

The choice of energy source, the wood-chip heater, was also given special consideration in that it was to be installed in a heavily wooded area.

With the scope of making the estate as self-sufficient as possible, the resource of wood is a great choice from the perspective that it is bio-compatible and sustainable. In fact, proper annual maintenance of forest area, anyway necessary, is able to provide the same quantity required to run the wood-chip heater for the thermal station.

Figure 11.

The wood-chip boiler is supported, regardless, by a gas boiler of the same power. This was necessary both to satisfy eventual periods of suspension for the other boiler (maintenance or malfunction) and to integrate it during the peak times when the highest power is required. In the plans, the dimension of the water heater was decided based not upon the peak energy requirements, but on the average estimated power required to keep the system to working at a consistent pace, with a high efficiency.

The actual amount of energy consumed, with respect to the estimated amount, is composed of a quantity of cubic meters of gas and a quantity of tons of wood chips.

The annual consumption in 2010, the first year with the system working at full stretch, with all the buildings up and running, is as follows: the quantity of wood chips totalling 230 tons at the price of 65 euro/ton equalling 14,950.00 euro/year, plus the quantity of natural gas totalling 12,616 m^3 costing 10,724.45 euro per year (of which 9,054 m^3 went to running the gas boiler and the rest to powering the kitchen).

In Table 3, the consumption is reported, comparing three different hypotheses. Case 1 shows the consumption under the condition that natural gas would be the only energy source, thus the situation of a standard system. Case 2 represents the consumption under the hypothetical condition that wood chips would be the only energy source employed, and therefore represents the situation that is theoretically ideal. Finally, Case 3 is the representation of the actual situation, combining both wood chips and natural gas.

ACTUAL THERMAL CONSUMPTION (YEAR 2010)			
	CASE 1 only gas [m3]	CASE 2 only wood chips [ton]	CASE 3 wood chips + gas mixed system
TOTAL CONSUMPTION	79,572	260	Gas 9054 m3 wood chips 230 ton
TOTAL euro/year	**€ 68,432.00**	**€ 16,869.00**	**€ 22,736.00**
ACTUAL ANNUAL SAVINGS (COMPARED TO USE OF ONLY GAS)			***67%***

Table 2. Comparison of three different hypotheses applied to the consumption in the year 2010.

It is shown in Table 2 that, already in year 2010, the savings connected to the energy solution employed, when compared to the standard, is quite large.

It should be noted that this comparison was a simulation in which the estimated cost was based on purchasing the wood chips from an external provider. The overall project for the estate and the agricultural business, however, predicted the eventual internal supply of its own wood chips. This would result in further savings, as internal supply would have a much lower cost than that of its market value.
Starting in 2011, the wood chips necessary for the heater will be internally produced from the pruning and regular forest maintenance done on the estate.

Going further into detail with respect to each individual building, each building was studied in relation to the various input data collected and, obviously, in relation to their various intended uses in order to determines the energy solution.

In the case of the main villa, the higher level of thermal inertia of building envelope resulted in two notable benefits: In the winter period, the necessary power for central heating was calculated on the average daily demand. In the summer period, it was deemed unnecessary to install an air-conditioning system.

Electrical Energy

Even for the supply of electricity, the estate is divided between the buildings in the main nucleus in the valley and the mountain houses. The electrical system in the valley can be controlled by a single, medium-voltage, electric meter. The mountain houses are serviced by their own low-voltage electric meter. The electrical station is found in the vicinity of the caretaker's house, which has, through the use of particular computer software, the ability to control the consumption throughout the entire estate and of each single building.

The total electrical consumption for the year is 211,608 kWh per year (data for year 2010, the first year in which the peak was reached), with the cost of electricity totalling about 36,000 euro per year.

Further, the estate established a system of general supervision from the energy station, with Siemens technology and computers, which allows the management and monitoring of the consumption and function of the utilities for all of the buildings. The purpose, and result, of this supervision is to increase the total energy savings.

Photovoltaic System

Included in the project plan was the installation of a total of four photovoltaic fields, of which one services the principle complex of the estate, and three with a smaller surface area to service the individual mountain houses.

The main field, that has 389.7 m² of polycrystalline silicon photovoltaic panels, have a nominal power capacity of 58.8 kWp (kilowatt-peak) on the ground, resulting in the annual estimated production of 1,145 kWh/kWp, equal to 67,326 kWh. Therefore, the field will be able to provide about 32% of the internal energy demand of the complex, which consumes about 211,000 kWh yearly.

The three fields servicing the houses disconnected from the internal area of the complex, in the wooded mountain area, are predicted to each have a total surface area of 20m², for a production capacity of 5.55 kWp each. The photovoltaic system will be a grid-connect system and the energy produced will be sent through a low-voltage steel wire.

ELECTRICAL CONSUMPTION – ESTIMATED AND ACTUAL – FOR YEAR 2010		*ESTIMATED ELECTRICAL DEMAND* [kWhe]	*ACTUAL ELECTRIC CONSUMPTION* [kWhe]
VILLA	Residentiale	21,303	23,278
CARETAKER'S HOUSE	Residentiale + laundry	5,513	6,523
LEMON GREENHOUSE	Swimming pool + spa	3,657	3,579
'CASA QUADRATA'	Cellar + walk-in refrigerator + offices + gym	7,940	13,364
RUSTICO	restaurant + kitchen	57,241	66,889
THERMAL STATION		50,000	49,664
TRASFORMER		26,218	48,312
TOTAL CONSUMPTION		17,1872	211,608
TOTAL euro/year		**€ 34,374.00**	**€ 35,973.00**

PHOTOVOLTAIC SUPPLY (kWh)	6,7326
PHOTOVOLTAIC SUPPLY IN PERCENTAGE	**32%**

AMORTIZATION PERIOD [YEARS]	10

Table 4. Sums of electrical consumption

CONCLUSION

The presented project illustrates a case of specific study which also exemplifies a methodology that is more generally applicable to projects of Energy Restoration for existing historical and architectural monuments.

The starting point for the optimization of the project and planning decisions was a careful set of examinations and preliminary studies. In the works on the local level, on the buildings' envelopes, the current heritage preservation constrictions for the various building types were respected. Thanks to the preliminary surveys of the walls, the installation of new technological utility systems was executed without alteration to the external and internal aspects of the buildings. In fact, existing shafts and passageways were found and traced, finding even those that were hidden deeply inside the walls and floor beams. These existing passageways were used to install new utilities.

Each single building was subject to careful surveying of its structural characteristics, their local microclimates, the characteristics of the materials and thermal characteristics of the building envelope. This made it possible to create numerical models with which to calculate the specific energy demands of the buildings and find the actual data relative to both the environmental conditions and the characteristics of the materials. The reference parameters provided in the manuals were corrected based on the actual data recorded, allowing the project to be refined. In the end, this brought about notable savings in terms of the energy demands and consumption.

For the supply of energy, we evaluated the various sources of *renewable* energy available on location: sun, water and wood. Each of these resources was fully utilized for specific uses. Solar energy was used to produce electrical energy by means of photovoltaic panels. Water was used in the sanitary water system and to cool the buildings during the summer. Wood was utilized as biomass for the central heating system.

The priorities and prerequisites guiding this project were environmental sustainability and bio-compatibility. The use of renewable energy sources was maximized in order to minimize the production of harmful CO^2 emissions and reliance upon fossil fuels. All of the materials used were natural and the works were performed delicately to preserve the historic value of the buildings and the natural beauty of the environment. In the end, the data related to the consumption revealed that in addition to confirming the feasibility of these project goals, it demonstrated that a notable economic savings can be achieved by choosing to extensively utilizing the sustainable energy resources available on location, in particular the wood chips derived from pruning and regular forest maintenance.

The antique buildings that we now hold as monuments were constructed during epochs in which fossil fuels were not used as energy sources. Now, these great pieces of architectural history can be restored to their original glory and return to an era independent from fossil fuels while moving toward a brighter future of sustainability and bio-compatibility.

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