Proposal for an Energy-Environmental Retrofit and Planning Procedure for Historical Centres by Means of an Energy Analysis on a Technological Scale

Application to the castelvecchio Calvisio (Aq) suburb, in Italy

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ABSTRACT: The aim of the present study is to define a methodology for the recovery of historical centres, directed at the energy-environmental upgrading of the patrimony itself.
The study case concerns the Castelvecchio Calvisio (Aq) historical centre in Italy, inside the Gran Sasso National Park and the Monti della Laga, which presents typical characteristics common to all the small centres situated in the Abruzzo mountain area, both from a typological and technological point of view. The study has been structured in three phases:

- *1) knowledge of the territorial system, by means of a check on external factors (physical and environmental) and the anthropic system, by means of a check on the residual performance of the actual state;*
- *2) configuration of the most appropriate strategies and the planning application with the assessment of the solutions adopted;*
- *3) comparison between the indications furnished by the present Italian regulations on the subject of energy saving (Dlgs 311/2006) and the indications drawn from the experimentation carried out on the study case, which can be extended to the great patrimony of historical tradition.*

The study concludes with the systematization of the results and the new ecological-environmental requirements which contribute to the improvement of the planning organization of physical space and the introduction of processes of energy-environmental upgrading of the existing building patrimony by means of an improvement of morphological, fruitive and ecosystem qualities, by means of a qualitative adaptation of building structures and the neighbourhood to which they belong.
Keywords: energy, comfort, daylight.

ENERGY UPGRADING OF SMALL HISTORICAL VILLAGES TOWARDS A SUSTAINABLE CITY

One of the fundamental problems to be faced today from the point of view of sustainable development is attention to consumption starting from energy consumption. At a building level, energy consumption is measured both in the building phase (from the production of materials and components to the setting up of a building site – construction and maintenance – and to demolition) and the use phase (for the production of comforts, internal microclimate, and working support as well as entertainment, electrical appliances and various equipment).

As far as the building shell is concerned, one should reutilize the rules (already present in the first architectural treatise – Vitruvio – and only recently – a little less than 100 years – completely ignored in proportion to the availability of fossil fuels and easy transport of components and materials) that range from reflection on the location and orientation of the building in relation to the distinctiveness of the place (physical and climatic) and choice of the most appropriate morphology and technology to the demands of the beneficiary and environment. This means that the planner must assess in detail the type of shell – thickness and materials – and the empty-full ratio that may achieve the best closures for that specific situation relating to a habitation settling.

Further attention must be given to the choice of materials not only as to the usual supplies to provide but also regarding the preservation of the environment and thus the source (environmental and energetic weight of transport) and quality (level of reproducibility and recyclability of the resources). The definition of a "zero emission" building with energy consumption satisfied from renewable sources is a possible reality which already boasts numerous examples above all in countries in the north European area. However, planning requires a wider approach and a deep multidisciplinary awareness. Furthermore, political sensitivity is necessary to provide incentives for such actions by sustaining the greater initial costs (often due to the present-day inadequacy of the market) and the reassessment of building and town planning regulations. But even if it is possible (as it has been demonstrated by some projects and achievements) to obtain buildings reducing energy consumption drastically to establish the living comforts required today, it is not so simple to upgrade the existing building park, in particular architecture in the 1950s, when building followed rules that were far from concerns over environmental and energy saving.

Summing up, we find ourselves faced with a delicate situation. On the one hand, theoretical studies have stated clearly methods and technologies for the construction of new, zero impact buildings as well as planning methods of new sustainable cities; on the other, we are aware that the actual sustainability of the territory cannot disregard a shrewder use of the same, which tends to minimize its occupation. As regards the problems we have just set out, the reality of our territory (Abruzzo, but the rest of Italy is not dissimilar) presents some peculiarities which suggest interesting reflections for actions towards sustainable development. On the one hand, an unused or underused building patrimony of notable figurative value in places where the landscape is particularly pleasant; on the other, areas which are overcrowded, overpopulated and of dubious environmental quality.

The analysis of the population distribution in the Abruzzo territory highlights the presence of a considerable number of historical, town nucleuses, mountain and hill nucleuses, which are little occupied or on the way to abandon; such a built patrimony, however, constitutes a cultural and economic resource to which reference is made in sustainable, regional development strategies; in the first place, thought is given to occasional residences for tourism (see the case of S. Stefano di Sessanio) with the aim, however, of also sparking off interest in the conversion to stable dwellings where, for example, work at a distance is allowed (see the case of Colletta thought out by G. De Carlo). The size of these small villages emerges dimensionally more or less like a typical town district.

Mountain territory is characterized by this built presence, alternated with vast wood and agricultural areas, the result of a pre-industrial subsistence economy but of present-day interest for a reading of its sustainability. In fact, the size of the small villages is proportionate to the agricultural productivity as far as food demands are concerned; to the presence of a wood for energy and building necessities; to the further locating of local stone for building needs. In short, a system of small villages and a "subdued" territory are highlighted, for the production of goods necessary for the maintenance of the town centre itself.

It is, therefore, a sort of planning, a town project based on an "ecological imprint" ante litteram.

Figure 1: The Gran Sasso Park subdivided into districts. The dividing of the area into districts is conceived for a use of the territory which is in harmony with its environmental and landscape qualities in every area identified.

Figure 2: The "Terre della Baronia" district. Besides Castelvecchio Calvisio, the district has another seven communes.

THE ANTHROPIC SYSTEM OF MOUNTAIN AREAS AS SUSTAINABLE PARK CITIES

The question was if it was possible to bring the existing system up to date by superimposing on it a pattern of a sustainable town-district derivable from "ecological imprint" studies to provide new cities, without further erosion of the territory, useful also for relieving overcrowded areas. Subsequent analyses have contributed to sustaining the hypothesis of a system already planned according to the parameters of a sustainable project, from which it turns out that the organization of town road network is already the result of particular attention to the place, both as far as the orientation of the roads and lots are concerned, and in the relationship with the specific climate; in fact, in the case of Castelvecchio Calvisio, for example, the particularly harsh climate suggested a covering system for the roads in winter, also to minimize the hardships which derive from abundant snowfalls. The biomass coming from agricultural residues, care of woods and seasonal pruning can become an interesting source of energy renewable also in relation to the small dimensions of the modular housing units, which can be easily heated by a "hearth". The movability among the "districts" of the widespread city should be assured by a virtual network and an alternative public and private transport system (electric means of transport and car sharing).

The upgrading of villages, or rather the transition from the present-day small villages to the "sustainable park city" provides for an integrated management of the system built as districts of a widespread city in which its internal wood territory may also have the function of absorbing the CO2 produced by the different town actions.

In short, the research aims at identifying a strategy to recover and upgrade small, ancient villages for which the intervention is not limited to the mere preservation of the historical document, but intends implementing an active strategy for the protection of the territory and management policies which sustain it, associating the intervention on the building scale with a programme on a wider scale, which integrates the settling system under consideration within the available economic and cultural resources. From a methodological point of view this study aims at testing, in the first instance, the potentialities of the patrimony built for residential and/or tourist purposes starting from the peculiarities of comfort offered and the possible (technical and economic) difficulties to achieve them. Furthermore, one aims at assessing regulatory references to test the suitability and possible necessity of reviewing/adapting to unforeseen situations. Further developments will follow concerning the defining of approach criteria to the recovery project oriented to the defining of appropriate upgrading strategies, re-use, maintenance.

Finally, the reading of the productive and energy potentialities tied in with the revitalization of each centre will be referred to a wider field of interest which views the single built-up area as belonging to a network, local and regional, intent on pursuing a pattern of sustainable development.

Figure 3: map of the historical centre of Castelvecchio Calvisio

Figure 4: view of the remains of the structures of the covered road

THE HISTORICAL PATRIMONY AND ADAPTATION TO ENERGY REGULATIONS.

Many of the energy upgrading interventions arise more from a legislative obligation, to which it is necessary to adapt oneself forcedly, than from an awareness of the real problems both environmental and economic tied in with them.

The present-day Italian energy regulations (D.Lgs 311/2006), presents quite a few limits precisely on the subject of energy upgrading. The most outstanding one concerns the modes of calculation and checking of the energy supplies of the buildings. The regulations concentrate exclusively on the checking of the primary winter energy needs (EP) by proposing a calculation method based on stationery regulations, thus limiting the buildings' energy behaviour to the values of just the thermal transmittance. For the checking of energy needs in the summer period, the indications of the regulations are rather vague and are not exhaustive in that just an inferior limit of superficial mass is considered to be respected, based on the reference locality. A similar method, if generalized to all the existing building patrimony, would lead to hypothesizing upgrading interventions that may turn out to be damaging both to buildings and to its inhabitants. It is known that thermal wellbeing is also established, besides by appropriate insulation, by the thermal inertia of the shell, which is capable of attenuating and putting the thermal wave between the inside and outside out of phase, thus reducing the internal temperature peaks. As will be demonstrated subsequently, much of the historical patrimony presents such conformations of a space and technological type that it makes them energetically valid already in their present-day state and it will be demonstrated how, with simple, targeted solutions of a detailed type, standards of energy efficiency can be reached which are able to satisfy fully comfort conditions in obedience of regulatory limits.

APPLIED METHOD

Starting from a global knowledge of the external climatic conditions, the method followed in this work is thus structured:

- *Analysis of the site;*
- *Checking of the residual supplies in their actual state;*
- *Defining the aims;*
- *Project and checking of the solutions.*

The checking of the climatic and environmental conditions of the places, up to the knowledge of the real "efficiency" conditions in which the buildings which are the subject of assessment are today, represents un indispensable passage for defining solutions which are able to improve the energy efficiency of the buildings and the context of origin.

The analysis of the site, carried out over all the historic centre, was carried out by means of a checking of the environmental and climatic factors which characterize the place; the results obtained represent the basis for the setting up of operative instruments that are able to guide the planner in defining optimal intervention strategies. Among the elements considered, climatic factors represent proper project data, which are able to affect the planning solutions in a decisive manner in order to obtain an improvement in the conditions of comfort both inside and outside the confined spaces.

CASE STUDY AND CHECKING OF THE RESIDUAL SUPPLIES IN THEIR PRESENT-DAY STATE

The small village of Castelvecchio Calvisio (Aq) was chosen because, rightly, it can present itself as an emblematic case useful for carrying out reflections to be transferred to analogous situations. This presents almost all the characteristics typical of the small centres situated in the Abruzzo mountain area, with living typologies of one or two rooms of limited dimensions and a simple technological system integrated with the place of origin, both for materials and building techniques. The living typology is realized in a modular system; it is characterized, in fact, by elementary cells of a compact form, with storeys ranging from 2.1 to 2.6m high, with a maximum of three levels.

These can be subdivided into two main typologies: terraced houses. The construction of the built-up area springs from the close relationship with the territory from various points of view, which range from the availability of the material, to the climatic aspect, to the planimetric course of the terrain, etc. Almost all the building have been realized with the use of two main materials:

- Stone – for defining the walls or vertical elevation structures;
- Wood – mainly for setting up intermediate horizontal or covering structures, or rather for the horizontal elevation structures.

This particular architectonic conformation makes the dwellings a system of well-balanced energy control, which lends itself well to an experiment of this type. For the checking of the residual supplies in their present-day state, three dwellings in particular were chosen and admitted as a case study which, from the analysis of the site, turn out to be the most disadvantaged in the direct relationship with the environmental and climatic factors of the place. In this phase, one tries to verify the real condition of energy function of the dwellings in their present-day state. The results of the check, which were carried out by means of detailed analyses on the various parts that make up the building, are indispensable to identify appropriate intervention strategies aimed at improving the conditions of thermo-hygrometric wellbeing of the living spaces.

The three dwellings chosen as case studies are developed on two levels with a planned surface of about 25 s.m. for each storey; the shell is formed by supporting walls in plastered stone of a total thickness of about 80 cms; all the dwellings have a covering structure of wooden beams with a closure of pantiles without thermal insulation and a percentage of "windowed" surface of about 11% of the opaque surface. This particular conformation, characterized by massive opaque surfaces, compact volumetries and reduced "windowed" surfaces, lends itself well to an experiment whose purpose is to define an intervention strategy for the energy upgrading of these particular contexts.

Figure 5: identification of the case study

Castelvecchio Calvisio (Aq) falls into the climatic area F. Belonging to a climatic area (classified from A to F) is based on some specific parameters of the project area as, for example, the geographic position (41° 18' latitude north, 13° 41' longitude east), the height above sea level (about 1161m) and the number of Day-Degrees (GG=3206). The regulations assign to each climatic area supply reference values tied in with both the energy behaviour of each single building component (thermal transmittance values) and the global energy behaviour (index of winter energy supply EP). The latter is deduced from the relationship of form S/V, that is, the relationship between the dispersing surface which delimits the heated volume (S) and the gross heated volume (V) delimited by S. In the specific case of Castelvecchio Calvisio, the supply reference parameters are:

vert. sup.	**Orizz. sup.**	**windows**
0,44 W/m^2K	0,41 W/m^2K	2,4 W/m^2K

For the purpose of this article, the results of only one typology of the three identified are reported and in particular of the B typology. The building which is the subject of assessment is characterized by a relationship of form S/V=0.78 from which the EP limit value is extracted which must be ≤98 kWh/m² a year. Both for the summer and winter seasons, the checks were carried out with a calculation in a transitory system (utilizing Energyplus software) considering a whole series of parameters which condition the energy function of a building, as, for example, the thermal inertia of the walls. The check of the residual supplies has the following purpose:

- check of the energy supplies of the single, architectonic components in their actual state;
- check of the internal comfort.

The results of the analyses on the shell show how the values of thermal transmittance both of the walls (k=1.78W/m²K) and coverings (K=2.03W/m²K) do not satisfy supply reference values at all: these are about four times above the limit values. At the same time, however, the good inertial properties of the walls, characterized by a value of the surface mass equal to 1270 Kg/m², are highlighted. To verify the conditions of thermo-hygrometric wellbeing inside the living areas, precisely the contribution of the thermal inertia of the shell was considered, which, in these conformations, could be decisive: in summer, the internal operative temperatures are always at least 2°C lower than the radiant temperatures, even with the air-conditioning plant turned off; in winter, the energy supply EP index is equal to 115kWh/m² a year, a slightly higher value than the limit value of 98kWh/m² a year. From this latter result, it is noted how, although in the presence of a building characterized by very high thermal transmittance values, the EP value is slightly higher than the regulatory limit value. This result underlines the real contribution of the shell's thermal inertia, and highlights the importance of an energy check in a transitory system which allows us to consider not only the shell's thermal transmittance but also a whole series of parameters which affect the thermal behaviour of the buildings in a decisive way.

In this way, the results that are obtained come as close as possible to a real condition, giving us, therefore, the possibility of hypothesizing the right ameliorative solutions. Instead, if we had used the checking procedure advised by the D.Lgs 311/2006 for the EP calculation, considering therefore only the thermal transmittance of the shell, we would have had as a result a value equal to 212kW/m²a year, which is decidedly above the regulatory reference limit. This result would lead to hypothesizing intervention solutions which may turn out to be pejorative for this type of structure, as, for example, the increase in thermal insulation, which would "suffocate" the structure, with the real possibility of the forming of interstitial condensation to the detriment of not only the energy function of the same, but above all of the salubrity of the internal spaces.

table 6: analysis of the opaque vertical structures

RESULT			
THICKNESS TOTAL	S	*0,8*	m
SUPERFICIAL MASS	M	*1760*	Kg/mq
CAPACITY THERMAL FACADE	C	*774*	KJ/mqk
THERMAL INERTIA	D	*8,2*	adim
PROBABLE TRANSMITTANCE	Kp	*2,1*	W/mqK
TRANSMITTANCE	K	*1,78*	W/mqK
DAMPING	m	*0,018*	adim
PHASE-DIFFERENCE	y	*16,5*	h
HEAT OF I ACCUMULATE	Ca	*9346*	KJ/Mmq
MASS FACTOR	Mf	*0,8*	adim

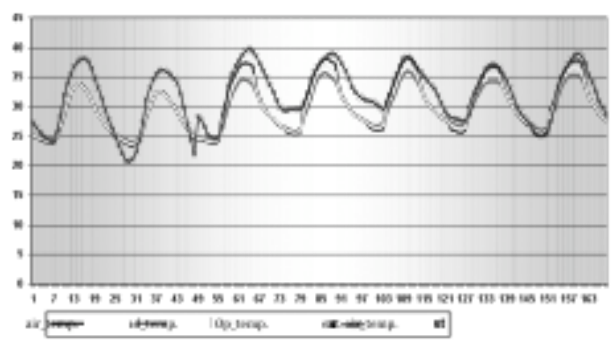

Figure 6: energy check in the summer system. Present-day state

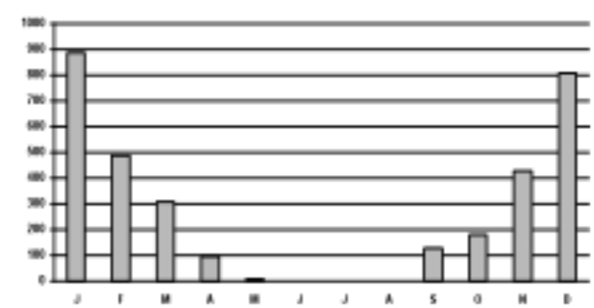

Figure 7: energy check in the winter system. Present-day state

HYPOTHESIS TO IMPROVE WHAT ALREADY EXISTS

In the hypothesis to improve what already exists, it was decided to intervene only on the covering (the element which turned out to be demanding as far as summer thermal loads and winter thermal dispersal are concerned), envisaging a ventilated wooden roof with cork insulation 7 cms thick, which allows us to verify the regulatory transmittance limits (0.37W/m²K).

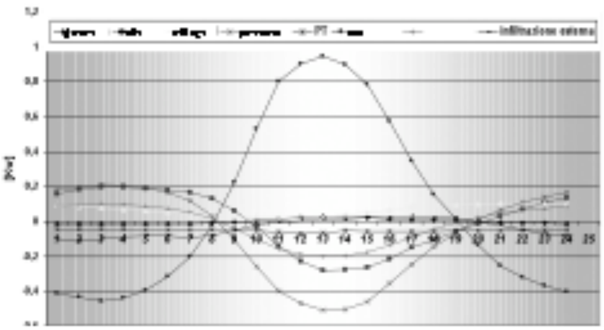

Figure 8: energy behaviour of the building shell in the summer system. Present-day state

The vertical walls were left in their original state, so as to make good use of, and verify, the real contribution of thermal inertia. The result is the following:

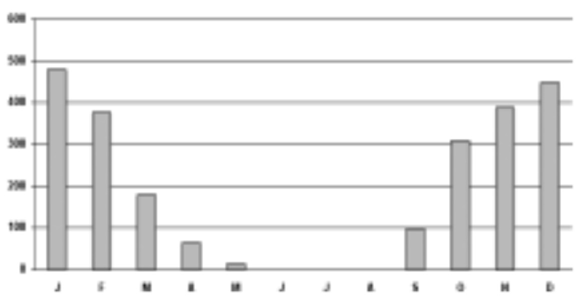

Figure 9: energy check in the winter system. Planning state

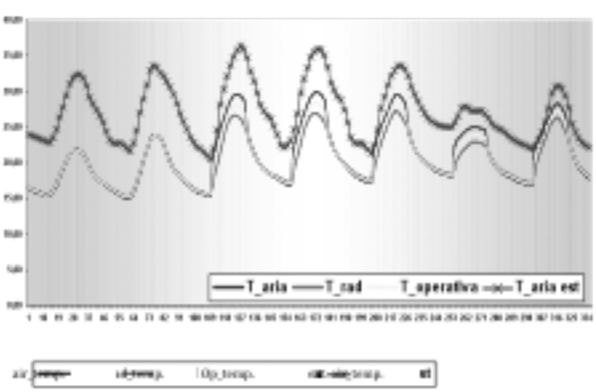

Figure 10: energy check in the summer system. Planning state

In summer, a lowering of internal temperatures of about 5°C respecting the present-day state was discovered; in winter we obtain an EP value equal to 71kWh/m² a year, a value which fully verifies the regulatory reference limit. The results thus obtained underline the urgency of a reassessment of present-day regulations on the matter of energy, above all concerning the upgrading of the existing building patrimony. Basing ourselves on methods which connect the global energy function of a building to only the thermal transmittance values of the shell, a whole series of interventions which may present enormous problems concerning both summer overheating and the hydro-hygrometric checking of the structures are made acceptable. In the presence of particular living structures with good inertial properties as in this case, the results obtained from a similar approach may turn out to be partial and non referable to real situations.

Reassessing energy checking methods precisely on the matter of the upgrading of the historical patrimony is today necessary and urgent. Introducing new parameters as, for example, thermal inertia which often characterizes these particular contexts, leads to hypothesizing intervention strategies of a detailed type with a real improvement in global energy efficiency.

CONCLUSIONS

Through the recovery and re-use of the existing building patrimony it is possible, in synthesis, to assume a first sustainable and measurable attitude respecting some demands which are not of secondary importance.

The "protection of naturalistic systems" and landscape systems can be assured by the "maintenance" of the historical-anthropic patrimony to which an artistic and environmental quality has been widely acknowledged. The "protection of the environment" is satisfied primarily by the lack of further use-occupation of the territory, as well as by the use of materials and components of a low environmental load, both of use of primary energy and emissions of CO_2 for the production of materials and components; parallel to this, the demands of a rational use of resources are satisfied for the prevalent presence of recyclable and lasting materials (stone) and materials from resources which are renewable (wood) as well as used with dry assembly systems and therefore easily maintained and managed at the end of their life. The "Rational use of climatic resources" and "Thermal wellbeing" are finally checked by means of thermal inertia – useful for establishing that thermal difference for the improvement of internal comfort as well as for reducing the contribution from installations.

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