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OBJECT PROGETTO ENERGIE UND BAUDENKMAL (ENBAU)

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Foreword

The National Information Centre for Cultural Heritage Conservation in Switzerland (NIKE, www.nike-kultur.ch) estimates that 3% of the Swiss built heritage is protected. Most of these buildings were built between the 19th and the beginning of the 20th centuries, and lie in old city centres.

The construction standards to which these buildings were built differ from those in place today, and their energy requirements are typically high. Although it is not always possible to achieve compliance with current energy standards, it is considered necessary and important – with a view to environmental sustainability and a prudent use of energy resources - to try to improve their **energy efficiency** as much as possible. The lofty objectives affecting all energy efficiency regulations, in Switzerland and abroad, seem difficult to achieve when renovating historical monuments. However, careful assessment of the benefits and feasibility of each case, together with the exploitation of the technological innovations currently available on the market, may lead to a number of potential solutions. The aim is to always look for a compromise.

“Le risorse naturali e culturali, fundamentalmente insostituibili, devono essere preservate e gestite con cura. Ciò riguarda sia la gestione dei fondamenti naturali della vita, come la produzione o il risparmio energetici, sia la gestione dei valori culturali, come la conservazione e la cura delle testimonianze di epoche culturali passate. Nell’ambito di un progetto di restauro, le istanze specialistiche devono dunque soppesare accuratamente, insieme ai proprietari, gli interessi della modernizzazione energetica degli edifici, della tutela dei monumenti e dell’utilizzo degli edifici, per trovare insieme soluzioni appropriate.”¹

Designing solutions aimed at improving the energy efficiency of protected buildings must involve a high level of cultural content: uncontrolled alterations, even if minor, to the envelope, windows, facings or installations may thwart the desire for conservation. **By “cultural approach”, we mean close collaboration between those appointed to execute the work, under the careful direction of the institutions responsible for protecting the building. Numerous technological elements have already been successfully installed on monuments (for example, fire protection systems and fire escape notices). The objective of this paper is to raise the awareness of restoration experts regarding energy efficiency issues, providing them with potential operating solutions.**

Only rarely is it possible to alter the envelope elements of protected buildings, since the aesthetic appearance would be affected, but these elements perform a fundamental role in ensuring a good level of thermal insulation.

High performance window frames, well-insulated opaque surfaces and facings, efficient thermal installations and passive techniques for heating and cooling the interiors are all interventions aimed at reducing the consumption of the building, and which must be assessed in the early stages of the design. The objective of this project is to evaluate the feasibility of these changes also for building renovation or redevelopment work executed in order to improve the global energy balance as much as possible.

Systems for the production of **energy from renewable energy resources** play a fundamental role in solutions that improve the energy performance of buildings and that allow a rational use of energy.

“È evidente inoltre che su un patrimonio a basso fabbisogno energetico il valore delle fonti alternative ha grandissimo significato e incidenza”²

¹ Federal Energy Office – Federal Commission of Historical Monuments. “Energia e monumento. Raccomandazioni per il miglioramento energetico dei monumenti”. Berne, 16 July 2009

² AUGELLI Lionello, Saint - Gobain Isover Italia S.p.a. “Soluzioni per l’involucro verticale opaco”
Atti del Convegno del 22 settembre 2009, Villa Erba Cernobbio VI:
“LA PROGETTAZIONE DELL’EDIFICIO ENERGETICAMENTE EFFICIENTE Pareti, Coperture e Serramenti”

Solar energy systems are now widespread. The situation may become slightly problematic when the thermal solar collectors and / or photovoltaic panels are to be installed on a historical building, although they can be legally mounted onto buildings close to monuments of Cantonal or National cultural / environmental importance, provided they are perfectly integrated and do not disturb the historical buildings.³

Integrating renewable technologies into an urban context, or into existing buildings, can improve the architectural and technical quality of the building in terms of economic and environmental sustainability. It is also important to consider that future action in our cities will involve the redevelopment of pre-existing buildings, with the aim of reducing the extent of land coverage. There are worthy examples, based on meticulous research aimed at appropriate integration, and that demonstrate the enormous potential of integrating these elements into historical buildings.



Fig. 1 – Some examples of building integrated Photovoltaic system on historical buildings:

- a) Hotel Industrial, Parigi (Francia), 2008 . Fonte: Tina Roach AIA
- b) Turist office, city of Alès (Francia). Source: CLER, Solerte
- c) Sala "Nervi", Città del Vaticano (Italia) - Premio Solare europeo 2007. Source: Eurosolar Italia.

By defining an implementation methodology, exemplified by means of three unique case studies, this project provides a valid **decision-making tool**, the outcome of discussion and consensus between all the parties involved in the process of redeveloping a protected architectural structure. This tool must provide an approach to adopt when selecting **inter-disciplinary solutions**: the architects, energy consultants, specialist engineers will be carefully supervised by the restorer, they will understand their areas of competence and will therefore be able to set their respective targets. On the other hand, the heritage specialists will be able to assess the efficacy and feasibility of the solutions proposed. The final objective is that, already during the preliminary phase, it will be possible to choose a renovation project with a high level of sustainability.

Since there are divergent, and at times almost irreconcilable, opinions regarding the need to intervene "energetically" on historical buildings, it is necessary to **develop a working method** that is as objective as possible and that can reduce the possibility of contradictions based on personal and arbitrary considerations. The primary aim of the project is therefore to facilitate communications and understanding between the various actors participating in the renovation and energy redevelopment of a historical building, and is achieved by preparing charts with concrete examples. In addition to this, public administration bodies can use the results of the project as input for new legislation related to energy improvement solutions for buildings of historical significance.

The aim of this project is to identify appropriate solutions for reducing energy requirements by making alterations to the envelope and installations, trying to achieve an optimal result by exploiting the very features of the building and of the surrounding environment.

Dalla corretta progettazione all'esecuzione dei componenti dell'involucro come status dell'equilibrio tra abitazione ed ambiente. Cenni d'interventi di Casa Passiva. <http://www.convegnovillaerba.com/atti.html>

³ (art. 18a LPT - Legge sulla pianificazione del territorio)

1. Introduction

When designing an intervention aimed at improving the energy performance of a historical building, the project development process must take into account a number of factors: the historical features to be protected, the final use of the building as a whole and of its various rooms, the energy requirement. Questions must be asked regarding how it might be possible to reduce consumption in function with conserving the historical identity, and the feasibility and advantages of each solution proposed must be carefully assessed.

Each design solution has specific objectives and requirements which must be considered and assessed in a logical manner:

1. Objectives to reach.
2. Needs of the client and of all the stakeholders.
3. Features of the historical building (external envelope, internal structure, surrounding environment, current energy assessment, final use)
4. Analysis of the critical aspects, restrictions and regulations
5. Feasibility analysis of the solutions proposed (impact on the building, effect on the environment, reversibility, costs etc.)

Protection demands and **energy savings** requirements are two factors that must both be satisfied since they are important for the sustainable use of resources and for quality of life. So it is important to find customized solutions that can integrate these two requirements in a harmonious fashion, limiting the strain that undoubtedly arises if the work is planned without having been thought out in an integrated manner.

With regard to work executed on the envelope installations of the building, a carefully designed renovation project would not only make it possible to comply with current energy requirements, but would also safeguard the historical/construction features of the building, ensuring its conservation. However, since opinion is divided regarding the need to intervene “energetically” on historical monuments, it is necessary to develop a working method that enables the project, and its development phases, to be discussed and agreed on with the partners involved, and that makes it possible to minimize the possibility of conflicting opinions based on personal or arbitrary beliefs.

It will be important to design the project in accordance with a methodological procedure that provides the opportunity not only for the various proposals to be presented and discussed, but also for the environmental, architectural, operational and administrative consequences to be evaluated. This methodology must allow the potential solutions to be rationalised and the priorities to be ranked, clarifying the potential advantages and disadvantages of the solutions with regard to the features of the intervention proposed. The choice of solution is therefore based on understanding, the higher or lower environmental performance, and other aspects, of the solutions to be executed.

Three tangible cases have been analysed, making it possible to define a series of solutions aimed mainly at improving the energy features of the building and the level of comfort inside. The measures proposed vary in accordance with the various levels of priority and feasibility, depending on the need to protect and conserve the building, and are defined, in order to achieve a sustainable compromise between the various requirements.

Collaboration between the various stakeholders is essential if an assessment methodology and optimal solution is to be decided and established for each case. The aim is to define a series of interventions, single or cumulative, that will be of unquestionable interest to the client and the designer, but also to the local bodies, Cultural Heritage offices and the community, since it will be an example of good practice contributing to global environmental sustainability. The most important factor involves the development of a methodological approach that is generic but applied to the individual case studies, based on easily interpreted charts that can be used to identify the main parameters on which to work, and a set of different solutions that can be selected depending on the execution possibilities.

1.1.Objectives

The main objectives of the project can be summarised as shown below:

- Develop a **working method** that considers how the project is affected by various aspects (surrounding environment, architectural and decorative features of the building, existing installations, new additions, use of renewable energy resources..), and by the various parties involved (owner, heritage protection office representatives, architects, system engineers..), who often hold opposing views. Working to the same method should help these players to obtain a global vision of the problems, allow them to discuss their opinions and therefore avoid the possibility of reverting to proposals aimed at specific and ready-made solutions (window replacements, for example) that have not been carefully thought through and that are not always necessary.
- Assess the possibility of **integrating solar installations**. In order to achieve these objectives different types of historical buildings were selected, and the **materials and envelope** problems analysed, providing a basis for the development of technologically appropriate solutions;
- The aim was to try and understand how it might be possible to **reduce the energy requirements** and **improve the level of interior comfort** by means of minimum, non-invasive interventions (eliminating draughts, dampness, low surface temperature of the walls), respecting the historical, artistic and material features of the building, and deciding whether to introduce high-efficiency technological systems. .

1.2. ENBAU research project development: methodology

The project priorities will be focussed in function with the feasibility of each intervention, with the aim of defining a methodology that is uniform and easily re-applicable to other protected buildings.

The project objectives listed above have been developed in accordance with an innovative methodology identified and proposed in the course of the project. The project activities are structured as shown below:

Phase A: Data collection

- Analysis of the problems and of the objectives to reach;
- Requirements of the client and of the Bodies involved;
- Consideration of all the cultural heritage protection restrictions, and of the provisions and regulations related to energy and construction efficiency, in order to develop and execute retrofit solutions on protected historical buildings;
- Energy assessment of the building in its existing state.

Phase B: Design proposals

- Energy improvement proposals for the existing situation, taking into consideration the historical and cultural value of the building.

Phase C: Evaluation of the results

- Check of the effective energy and environmental benefit of the solutions proposed.

The Department of Environment, Construction and Design (DACD) of the University of Applied Sciences and Arts of Southern Switzerland (SUPSI) is the project referent for the entire process, exploiting the expertise of its various research units (see Chapter 2). With the contribution of all the stakeholders (the experts, cultural heritage office representatives, local authorities and owners of the buildings), DACD participates in the various phases, contributing to the final result and ensuring that the initial objectives are achieved.

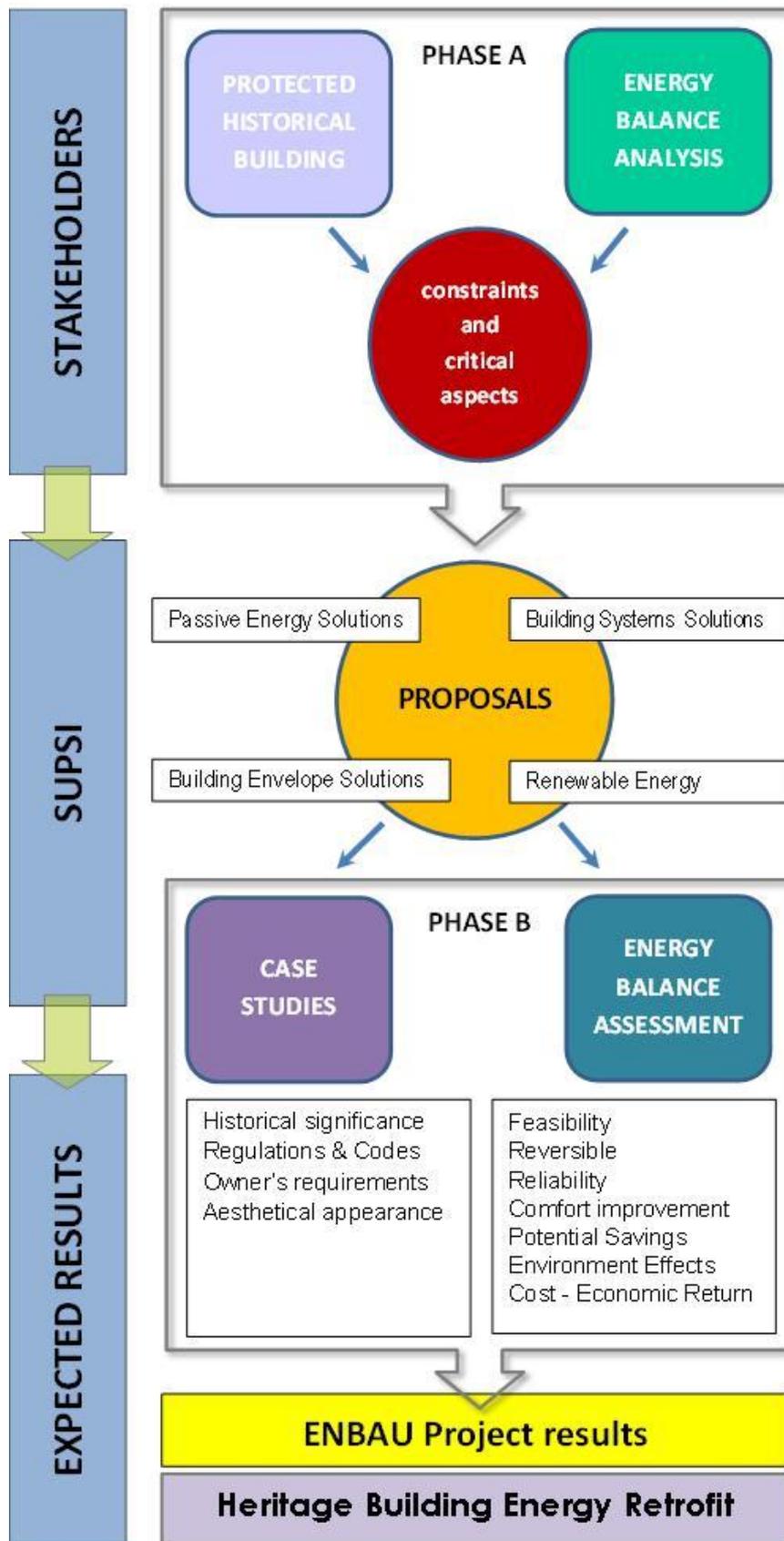


Fig. 2 – Identification of the adopted methodology.

2. Resources and organization of the project

There are a number of different research units in the SUPSI Department of Environment Construction and Design (DACD).

Institute for Sustainability Applied to the Built Environment (ISAAC)

ISAAC reports to the University of Applied Arts and Sciences of Southern Switzerland (SUPSI). The research activities and services conducted by the institute fall basically into two fields: renewable energy, particularly solar and geothermic energy, and the rational use of energy in constructions, in accordance with ecological and financial criteria.

Swiss Centre of Competence BiPV – Building integrated PhotoVoltaic

The Swiss Centre of Competence for BiPV was established at ISAAC with the aim of sharing the expertise of the SUPSI Department of Architecture and ISAAC, in order to provide a new approach geared toward architects.

Building Management Group

The Building Management Group focuses on all the aspects involved in properly maintaining cultural heritage elements, including the principles of sustainability, and of energy and functional efficiency.

In addition to its research and didactic work, the group also provides a variety of services, such as conducting check-ups on the conservation and maintenance condition, processing redevelopment scenarios with financial assessments or providing technical assistance and consumption monitoring.

Building Energy Efficiency Group

This group deals with all aspects associated with the energy efficiency of buildings and with the promotion of renewable energy resources.

It is located in the Energy sector of the buildings occupied by the Institute for Sustainability Applied to the Built Environment (ISAAC) and focuses on research, didactics and various services in the field dedicated to the energy efficiency of buildings.

Institute of Materials and Constructions

The Institute of Materials and Constructions studies the materials and construction structures in various areas of competence, and is divided into five work groups: materials and structures, technology and durability, construction diagnostics, conservation and restoration, survey of the historical and built environment.

The conservation and restoration sector conducts diagnostic investigations on materials and on historical structures, identifying stratifications, features and state of conservation, existing degradation phenomena and the environmental and anthropic factors causing them. The collaborators work in the research field and in the provision of services, playing the role of scientific guide on renovation work sites during the phases dedicated to identifying and diagnosing the problems, developing the conservation solution, assessing the results, and checking the work executed.

Partner

Assisted by ISAAC, the Cantons identified the buildings to be analysed. Whenever possible, a Cantonal representative attended the on-site inspection, contributing ideas and suggestions.

Canton Vallese

Département de l'économie, de l'énergie et du territoire - Service de l'énergie et des forces hydrauliques SEFH.

Département des transports, de l'équipement et de l'environnement - Service des bâtiments, monuments et archéologie SBMA.

Canton Graubünden

HTW Chur - Hochschule für Technik und Wirtschaft
Prof. Dipl. Arch. ETH/SIA Christian Wagner

Canton Ticino

Department of the Territory – Nature and Landscape Office (*Dipartimento del Territorio - Ufficio della natura e del paesaggio*)

Client

Stiftung zur Förderung der Denkmalpflege

This project was financed by the Stiftung zur Förderung der Denkmalpflege (Foundation for the Promotion of the Conservation of Historical Monuments), a charitable organisation in compliance with Article 80 of the Swiss Civil Code. The aim of the Foundation is to promote scientific and technological education, research and consulting services in the field of historical conservation, and to operate in these same sector institutions at the national and international levels.

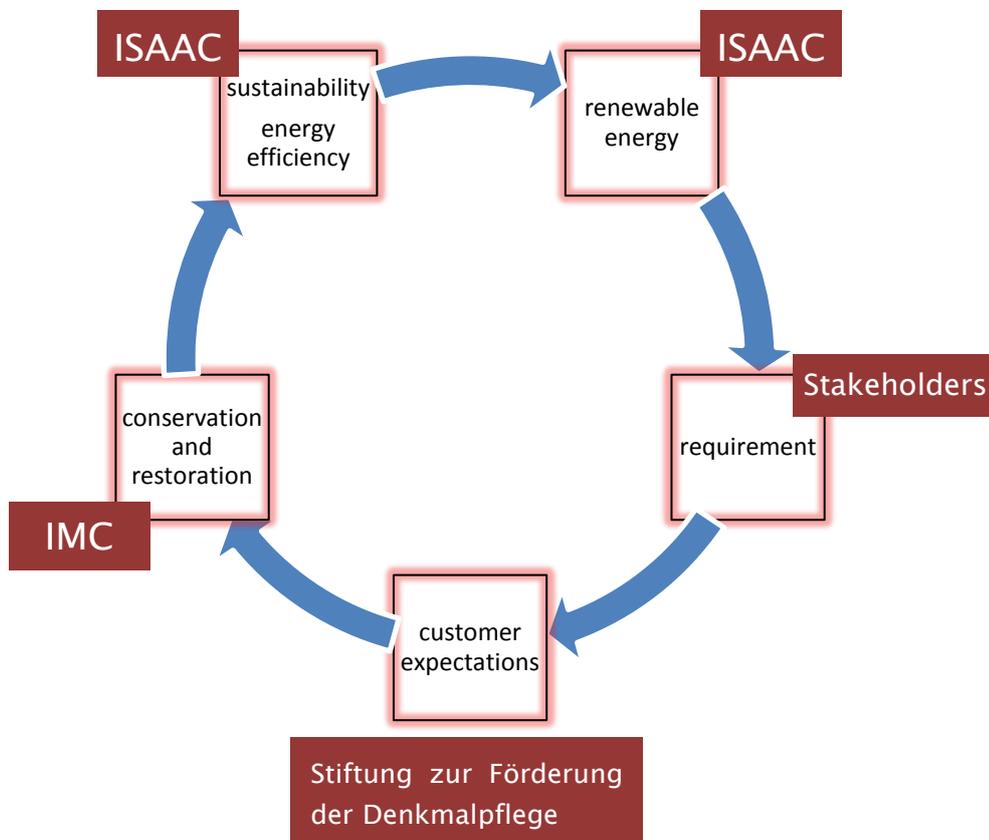


Fig. 4 – Area of competence.

3. Guide for the energy redevelopment of cultural heritage buildings

3.1. State of the art

It is often indispensable and necessary to develop or renovate a historical building, not only in order to conserve its structure but also in order to ensure an acceptable level of comfort inside. The quality of a conservation and renovation project for a historical building depends on the capacity to reach a compromise between the many, and often divergent, requirements of current legislation on static safety, accessibility, levels of environmental hygiene and energy savings, set against the architectural and material features of buildings designed and constructed in accordance with other criteria.

Studies conducted in the last few decades, particularly on static safety and on overcoming architectural barriers⁴, have shown instead that it is possible to reach a compromise between these apparently irreconcilable requirements, and how, by specifying some legislative derogations on the one hand, and by adopting equivalent safety solutions on the other hand, historical buildings can be brought close to meeting these requirements without radically altering the very features that make them unique, distinctive and irreplaceable.

One aspect that has been little studied until now, and which is the focus of this work, is instead related to finding a balance between energy consumption reduction, improved levels of comfort and protection of the historical and artistic features of our cultural heritage. Cultural heritage items are fragile and can be compromised easily and irreparably unless they have been studied meticulously and fully understood prior to any internal changes altering the stratifications and balances that have been established over the course of time.

Federal energy policies developed in Switzerland emphasise the importance of incrementing the supply of energy from renewable resources, while also reducing the energy demand in consumption sectors, with specific focus on the construction sector. These objectives, which in Switzerland are summarised in the concept of “Società 2000 Watt” [2], have become much more relevant since the 2011 Fukushima nuclear station accident, after which principles were defined for a new “2050 energy strategy” [3, 4]. At the same time, the European Union has also developed international political strategies and directives aimed at achieving greater integration between energy and the construction section (for example, EU Directive on the net zero energy of buildings [5]). The need for greater energy autonomy and for a reduction in greenhouse gas emissions has led to imagining new models of society, marked by distributed energy generation and by substantial energy savings in all consumption sectors [6, 7].

The various energy policies are all directed toward these objectives, promoting energy consumption reductions in existing buildings, and covering the residual requirements by means of renewable resources, supporting sustainable development.

All the actors involved in a renovation project (architects, renovation experts, owners, technicians, protection officers) must therefore carefully consider the new technological developments, and understand how they can be introduced and integrated into existing buildings. Adopting a sustainable philosophy also involves taking existing resources into consideration, and understanding how to make them work as effectively as possible, avoiding useless replacements and wastage.

From a theoretical aspect, the Guidelines for the Preservation of Built Heritage in Switzerland (2007) maintain that *“the principle of sustainability is to be observed when intervening in built heritage”* (p.89), while from a technical aspect various recent articles and studies show how solar and photovoltaic panels can be mounted onto historical buildings or in their vicinity [8]. English Heritage has also made a substantial contribution to the activities conducted in this area [9, 10]. The

⁴ For further information see: Linee guida per la valutazione e riduzione del rischio sismico del patrimonio culturale, Ministero per i Beni e le Attività Culturali, 2006 e le Linee guida per il superamento delle barriere architettoniche nei luoghi di interesse culturale, Ministero per i Beni e le Attività Culturali, 2008.

documents and guidelines provided by English Heritage have been written in order to help avert conflicts related to the interpretation of the energy efficiency requirements of building regulations, and the conservation of historical buildings, with the aim of establishing appropriate energy performance standards for redevelopment projects involving historical buildings.

For now, and for the near future in the construction field, it will be increasingly necessary to execute work on the existing heritage, in order to use the ground in a sustainable manner by means of more effective use of zones that have already been built. In order to slow down the process of messy city expansion, the issue of densification is now under discussion. The need for high-quality densification of urban settlements is also gaining ground in public opinion, as recently stated by the Schweizer Heimatschutz [11] and in various newspaper articles [12].

“L’obiettivo di frenare l’espansione disordinata degli abitati è ampiamente condiviso. La densificazione delle zone già edificate diventa viepiù importante. La nuova presa di posizione dell’Heimatschutz Svizzera indica come i futuri processi di densificazione possono e devono venir attuati.”⁵

There are key examples, national and international research and development projects that are currently promoting the effective and low-energy-consumption renovation of existing structures and of historically significant buildings [13,14,15,16,17,18,19]. The final aim of these projects is to reduce primary energy consumption as much as possible, to optimise the integration of solar energy, to ensure and improve the level of comfort (thermal and acoustic conditions, quality of the internal air and natural lighting conditions), guaranteeing a high-quality and cost-competitive construction process.

The topical nature of the energy issue has recently attracted attention to the possibilities provided by the local climate and by the conditions of a site, in order to exploit these resources in a passive manner (architectural treatises – from Vitruvio to the 19th century – invite architects to understand and take advantage of the orientation of the building lot, in terms of sun and prevailing winds), and, with a view to limiting the consumption of heating and air conditioning systems, further research is also being conducted into creating construction solutions that can satisfy environmental comfort requirements.

Historical buildings often represent interesting construction models associated with the local area, the financial use of materials and local building methods. Their construction shows how, using a limited number of materials, which are often also not ideal, the technological result can be optimised in terms of geometry, wastage and durability.

From an energy aspect, these buildings often have high levels of thermal dispersion, while on the other hand they provide a positive inertial mass effect. Nowadays, the utilisation of high-quality insulation materials makes it possible to safeguard internal heat in winter and restrict summer heat from entering, while in the case of historical buildings we must try to understand how to exploit the thermal inertia of the envelope, the aero-illuminating ratios and the possibility of achieving passive control over the microclimatic parameters. A passive solution may sometimes effectively provide a design solution that, in conservation terms, is less invasive than incorporating a technological system into the building.

These solutions are already being explored in a number of pilot projects, as in the case of Castello di Valère near Sion [20, 21], where rooms are air-conditioned by means of passive strategies using a low-consumption air-conditioning system based on Geocooling and on natural ventilation, which can ensure the high-performance microclimatic control required for the conservation of the wooden structures and of the objects on display.

Studying and thinking about the environmental qualities of historical architecture, the bio-climatic features and the climatic qualities of the site, can be an important starting point for an energy

⁵ L’aménagement du territoire face à de grands défis/Raumplanung vor grossen. Herausforderungen. Schweizer Heimatschutz, Positionspaper “Verdichten braucht Qualität” November 2011.

adaptation project aimed at minimizing consumption and facilitating energy savings in a building. In fact, improving the well-being and sanitary conditions of these buildings represents an opportunity for reconsidering “tradition”, by adopting an analytic and critical outlook of the capacity expressed by the historical building in solving the microclimatic problems.

In effect, the objective of a historical building energy adaptation project is to improve the levels of comfort and to reduce the energy consumption required for heating, lighting and other purposes. When considering energy savings, it will also be advisable to evaluate the contribution of renewable energy resources. Integrating these resources into existing structures is a challenge that cannot be ignored, and this aspect will be discussed in greater detail below.

With a view to supporting sustainable development, the Cantonal and Federal energy policy for climate protection in the construction sector also has the recurring theme of reducing energy consumption levels in historical buildings, and meeting residual energy requirements by means of renewable energy resources. Many international projects aim to promote the integration of renewable energies and energy efficiency technologies into historical buildings, with the objective of helping surmount the lack of information regarding these technologies, which is still one of the greatest obstacles preventing their diffusion. [22,23,24,25]

In terms of integrating solar technology into historical buildings, the Swiss Centre of Competence for BiPV – Building integrated PhotoVoltaic, part of the Institute for Sustainability Applied to the Built Environment (*Istituto di Sostenibilità Applicata all’Ambiente Costruito* - ISAAC), has matured significant experience as a result of a number of specific projects [26,27,28,29]. The project entitled SOLNUC - PV and Solar Collectors in Historical Centers, where, as a result of the proposal made by the Office of Nature and the Landscape, the Canton Ticino State Council commissioned ISAAC to define the architectural and landscape criteria for the installation of solar and photovoltaic panels in old town centres. The aim of this study was to formulate evaluation criteria proposals to adopt when examining projects for the installation of panels in visually sensitive positions. The project was entitled SURHIB - Sustainable Renovation of Historical Buildings, and the objective was to develop, test and promote solutions for the sustainable renovation of non-protected historical buildings. The task of ISAAC was to draw up guidelines for integrating solar installations into buildings of this type.

Many of these studies have shown that it is not impossible (and often with minimum cost) to execute energy-related work on buildings of this type, and that comfort levels improve significantly. When deciding solutions for historical and traditional buildings, the correct balance can be determined by understanding all the details related to the building, its conservation condition and its intrinsic features. A reasonable energy efficiency improvement compromise must be reached by considering all the critical aspects, in order to avoid damaging the nature of the building and to preserve the appearance and significance of the protected structure.

4. The macro areas of implementation - Methodological approach

A project aimed at achieving energy improvements compatible with the historical, construction and material features of an existing building, the very features that make the building unique and a non-renewable asset, entails the involvement of an inter-disciplinary work group.

With a view to establishing a common procedure that will provide instructions for improving the energy efficiency of historical buildings, and after having analysed three case studies, survey charts with differentiated investigation steps will be prepared.

The methodological approach adopted for the preliminary analysis specifies three phases:

- First phase: Data acquisition and analysis of the requirements.
- Second phase: Development of a design proposal that, based on the data acquired in Phase 1, can be used to evaluate which objectives and procedures (actions and methods) can be implemented in order to alter the existing situation, with a view to improving the energy requirements of the building while respecting its historical features.
- Third phase: evaluation of the proposals and of the results achieved

The project must consider various aspects that can be classified into four macro categories (points 1-4) and it must correctly balance a set of often divergent requirements.

FIRST PHASE - PHASE A: Data acquisition and analysis of the requirements

1. Understand the building - identify the transformation potential and limits

1.1. The building in relation to the surrounding environment

The background conditions of the environment surrounding the building, and the climate of the site, make a strong impact on the project design, in terms of both volume and ground plan (arrangement of the rooms, typological and construction solutions, the presence or absence of solar protection devices etc.) in order to ensure **optimal conditions of well-being and a higher level of indoor environmental quality**. These aspects prevail in the case of historical buildings built solely on the basis of construction experience matured over the course of many centuries and using only the resources available.

The most fundamental **macro-climatic and micro-climatic factors** (topography, vegetation, solar radiation features, humidity, rainfall, cloud cover, wind strength and direction, etc.) must be considered since they may often have affected the form, the use of the building and its defining construction elements. The features of the forms or of the construction elements of a traditional building may have changed over time, in order to respond to new expectations of the users or the change of uses. In many cases, placing confidence in the most advanced technological progress, air conditioning systems and installations available at the time, some aspects will have been neglected, such as the form and position, the construction material used, the definition of the spaces, the positioning and dimensions of the windows and shutters, the form and slope of the covering materials, the dimensions of the sloping roofs.

A correct approach to **“eco-sustainable” building**, not simply in terms of environmental issues but also in terms of energy, is one that combines two aspects, namely installations (such as HVAC system) and passive gains (summer and winter), without ever disengaging the building from the site on which it lies.

An accurate **climatic and bio-climatic study** based on this data can provide the basis for the various passive technologies to be applied in an informed manner, which may generate environmental advantages as well as general energy savings.

Bio-climatics focuses on controlling the parameters moulding the environmental physical well-being, by means of design choices that tend to ensure a sufficient level of quality, transferring some environmental regulation functions to the building itself. The term “bio-climatics” denotes the relationship between man, “bios” (the party utilising and benefiting from the architecture), and the external environment, understood to mean the “climatic” force field. Bio-climatic strategies can substantially improve the efficiency of a building, lowering consumption levels and helping it to become energetically sustainable.

Bio-climatic diagnostic tools can be used to study the environment comfort levels of buildings, taking into consideration a series of parameters (the metabolic activity conducted (met), people’s clothing (clo), the average radiant temperature of the internal environment, the external climatic conditions, the ventilation air velocity, etc.) in order to identify the strategies to adopt in order to obtain thermal hygrometric well-being in the building. Well-being diagrams use a typical day for each month of the year to show the environmental well-being comfort zones for summer and winter, and the local climate. These graphs and diagrams can be used to identify the times of the day when various strategies are required in order to benefit passively from the climate, and to achieve optimal levels of environmental comfort.

Improving the energy efficiency of a building cannot be disassociated from factors such as the **internal comfort** of the rooms. All solutions must be designed with a view to exploiting the benefits deriving from the external environmental conditions and from the construction features of the building, minimising consumption levels by implementing passive strategies whenever possible. The building must be interpreted as an active element that collaborates in maintaining internal comfort conditions. In order to achieve this, it must be able to collect, repel and store “heat”, while constantly taking into consideration the limitations set by its location.

1.2. Construction features and state of conservation

The building on which work is to be executed must be understood in order to comprehend its **historical features, transformation phases and state of conservation**. Understanding these aspects makes it possible to decide which areas or parts of the building may be more suited to alteration work, and which, on the other hand, require higher levels of protection. The existing potential must be exploited attentively and perceptively.

1.3. Existing installation systems

Since the dawn of history humankind has interpreted the features of the location and the climatic resources in order to ensure comfort and well-being by means of the technologies available. The **installation systems in historical buildings are part of the architectural heritage**. Their operation and performance are rooted in the customs of the time, and satisfy various models of water, thermal or utilization balance. At the same time, these systems provide unique evidence of historical developments and of the construction techniques then in use, and that can often still be used, albeit with some appropriate supplementary elements or adjustments.

In historical buildings there was a very tight bond between the materials used to construct the building and the installations initially designed. For example, the presence of elements with high levels of thermal inertia, with the function of stabilizing the internal temperature and de-phasing the thermal peaks, are factors tied to the climate and to the installations in the building. Equally, internal wood-panelled rooms responded to the requirement to heat rooms quickly using systems suited to achieving this objective. By the same token, local materials used in construction were largely selected **on the basis of availability and durability**.

It is important to comprehend the building and understand how comfort-related problems are resolved now and how they were resolved in the past, know the history of the building and of its installations and understand their relationship with the environmental and climatic features of the site. All these aspects must then be used as a basis on which to work. The information available, both official and descriptive (historical / manual resources, surveys and direct analyses), must be gathered together and processed; the technical reports recording the changes that have taken place

over time, and the contributions of authors, architects and technical experts all play a role in the cognizant choice of the new design solutions.

1.4. The cultural value of the building

One further decisive factor affecting the decision-making process consists of establishing the **cultural value of the building, and the elements by means of which this is conveyed**. This is important in order to ensure that the transformation design does not harm the values identified. The existing installation systems may also possess some cultural value (rarity, significance for technical history) and it is therefore important to understand how they may also contribute to the cultural meaning of the building.

2. Intended use: analysis of the requirements and needs

2.1. Intended use

The intended use of a building may change over time. At this point it is important to consider if **the building is intended for public or private use**, and if it **houses museum collections**, if it is **used regularly or occasionally**, if **there are attendance peaks** that might affect the air conditioning strategies for the rooms, or if the intended use has not changed over time (private or public use).

2.2. Client expectations (in terms of comfort and aesthetics)

In a building renovation process it is vital that the owner or the final users are consulted with regard to their final expectations in terms of aesthetics (evaluate the presence of external installations that do not affect the historic walls) and regarding the expected levels of comfort, particularly in the case of a residential building. The final design solutions must consider the **utilisation conditions and the suitability for specific types of users**.

The impact made by installation solutions, both active and passive, on achieving greater energy efficiency are very constrained for those who must administer and live in the building. The **final benefit often depends on the rational and mindful use of the solutions proposed**.

2.3. Requirements of the collections and heritage items in the building

“Fra le condizioni e gli strumenti utili a conservare e fruire il patrimonio culturale, il clima interno degli edifici e i sistemi che lo controllano giocano un ruolo rilevante”⁶

“Indoor climatic control is a crucial aspect for artifacts conservation in museum environments to prevent damages. Last year’s development of technologies and equipments aimed at continuous monitoring the indoor environmental parameters (temperature, relative humidity, air speed, lighting, air pollutants, etc.) allowed the collection, elaboration and analysis of indoor environmental data in order to avoid any deterioration processes on works of art: preventive control programmes are nowadays widely applied in museums.”⁷

Historical buildings may sometimes house **objects or works of art that require specific micro-climatic conditions**. It is sometimes necessary to find a balance satisfying the requirements of the

⁶ Davide Del Curto e Maria Fratelli . “Edifici storici e destinazione museale”. Conservazione degli edifici e delle opere d’arte. Progetti per il restauro e l’integrazione di impianti esistenti. Marzo 2010. Casa editrice: Il prato.

⁷ Corgnati S.P., Fabi V., Filippi M. , “A methodology for microclimatic quality evaluation in museums: application to a temporary exhibit”, BUILDING AND ENVIRONMENT, Elsevier, pp. 8, 2009, Vol. 44, Issue 6, pagine da 1253 a 1260, ISSN: 0360-1323, DOI: 10.1016/j.buildenv.2008.09.012.

building, the occupants and the exhibited objects, also considering that the “well-being” of people does not usually correspond with the “well-being” of objects and collections.

Scientists and researchers in the museum field follow opposing schools of thought on this issue. Some studies consider a compromise between the optimal level of comfort reached [30, 31], while others consider each factor individually, focussing particularly on ensuring a solution appropriate for the conservation of the objects and artefacts found in the building [32,33,34].

Relative humidity and temperature are the most important parameters for the conservation of artefacts: excessively low or high levels can create risks and foster further development of the degradation agents (biological agents, mechanical, chemical and physical damage) that cause deterioration.

The environmental quality level in museums is specified by various international technical regulations, such as the ASHRAE Applications Handbook, Chapter 21; European Regulations, European Standard: Conservation of Cultural Property (prEN15898, prEN15759-1, prEN16095, prEN15999 and prEN161419) and the Italian Standard UNI 10829/1999 and UNI 10969/2002. [35, 36, 37]

Indoor air quality is not regulated by binding and comprehensive legislation in Switzerland; the Swiss Parliament has not acknowledged the need for this and has rejected a law bill on the issue. The only regulatory measure is found in work legislation, in the document entitled “Valeurs limites d'exposition aux postes de travail 2012”. Other specific provisions refer solely to radon, and are found in the Federal Ordinance on Radioprotection (ORaP), 22 June 1994 in force. [38, 39]

3. Energy features

This data collection phase is very important in order to be able to estimate and further calculate the energy balance of the building, which can highlight the elements that are most dispersive or compromised, and on which it is worth intervening in order to improve the energy performance.

It may be difficult to analyse the construction elements of buildings of this type because the building details are usually not available. So if it is not possible to conduct surveys or visual inspections directly, the stratification of the envelope must often be hypothesised (walls and covering materials), also based on the year of construction and building type. These hypotheses can make a negative impact on the accuracy of the energy balance calculation.

The Lesosai 7.0 software programme was used for the energy balances calculated in the project. This software was developed with the support of EPFL.⁸ Laboratoire d'énergie solaire et de physique du bâtiment.

4. Regulations and laws

4.1. Cultural Heritage Protection Office (Local Office, Principles of protection)

In Switzerland, cultural heritage protection is delegated to the Cantons, which have adopted very diverse laws and provisions. A document providing guidelines, with the aim of inspiring and coordinating - at the Federal level - the various types of action, was recently edited by the Federal Commission for Historical Monuments (*Commissione Federale dei Monumenti Storici* - CFMS): “Principles for the protection of Historical Monuments in Switzerland” (“*Principi per la tutela dei Monumenti Storici in Svizzera*”)⁹ [40, 41]. This document is aimed at all the actors involved in the

⁸ <http://www.lesosai.com/>

⁹ “*Principi per la tutela dei Monumenti Storici in Svizzera*”. Commissione Federale dei Monumenti Storici (CFMH). ISBN10: 3-7281-3089-3; ISBN13: 978-3-7281-3089-1.”

administration of built heritage, and invites them to establish measures ensuring the long term conservation of the construction.

Paragraph 3, entitled “*Working on a historical monument*” specifies a number of fundamental points :

- *Principles of sustainability must be observed when working on historical monuments;*
- *Appropriate use facilitates the long term conservation;*
- *Regular maintenance work is the least invasive measure for the conservation of historical monuments;*
- *Preventive measures must be implemented in order to safeguard a historical monument that is fundamentally compromised;*
- *An correct understanding of the object is a fundamental condition for deciding which protection measures to adopt;*
- *Various specialist areas must be involved in order to provide answers to heritage protection issues;*
- *Before starting work, a binding plan of measures must be defined;*
- *For future protection measures, priority must be given to the conservation of the existing structure;*
- *Appropriate documentation regarding the unique aspects of the structure must be prepared for all work executed.*

Regarding the application of construction regulations for heritage buildings (paragraph 4.12), it is noted that:

- *Building regulations must not be applied to historical monuments without having first conducted an in-depth investigation. In each case, it must be decided whether a regulation can be ignored fully or partially, or if the objective of the regulation in question can be reached by means of other appropriate measures.*

In a document entitled “*Protection of the context of historical monuments*” (“*Tutela del contesto dei monumenti storici*”¹⁰), the CFMS also asks that the significance of the context also be considered, and not simply that of the individual building, and how the surrounding environment is often the element that undergoes more frequent and more rapid changes. The features of the spaces adjoining the monument must therefore also be protected, since this spatial context is a fully-integrated and fundamental part of the monument; monument and context interact inseparably, forming one single spatial unit. Context can also include the neighbouring buildings, the surrounding road space, town squares and gardens.

Changes to the context must be evaluated:

- *analysing the field of action, specifying the determinant perimeter and the protection objectives;*
- *studying the potential repercussions of the proposed changes on the monument and on the context;*
- *considering structural changes and measures compatible with the protection measures, in order to enhance the general situation;*
- *proposing high-level design construction work so that the new elements do not clash with the monument.*

Although these principles have no legal value, they stand as a fundamental and shared reference point at the Federal level, with the objective of guiding the strategic vision behind diverse work programmes conducted on the protection of the built and environmental heritage.

¹⁰ “*Tutela del contesto dei monumenti storici*”. Documento di principio. Riferimento/codice della pratica 362.64

4.2. Cantonal energy regulations, based on Federal law

On 4 April 2008 the Conference of Cantonal Energy Directors (*Conferenza dei direttori cantonali dell'energia* - EnDK), which represents the Cantonal joint centre of competence on energy issues, approved the new "Model of Cantonal Energy Regulations" ("*Modello di prescrizioni energetiche dei cantoni* - MoPEC)", further highlighting the need to reduce energy consumption in buildings. These provisions take into consideration the changes made to the Federal Energy Law in Summer 2007 .

In Canton Ticino, in January 2009, the "Regulations for energy utilisation" ("*Regolamento sull'utilizzazione dell'energia*" - RUEn) replaced the 2002 "Executive Decree on measures for energy savings in buildings" ("*Decreto esecutivo sui provvedimenti di risparmio energetico nell'edilizia*". The RUEn regulates the application of chapter IV (Measures for buildings and installations - *Provvedimenti sugli edifici e gli impianti*) of the Cantonal Energy Law of 8 February 1994, in compliance with the new "Model of Cantonal Energy Regulations" ("*Modello delle prescrizioni dei Cantoni*) MoPEC", adopted by the EnDK Conference on 8 April 2008.

The Regulations specify the framework conditions and control the application of the measures to buildings, installations and the related apparatus that must be designed and managed in such a way as to ensure both a frugal, rational use of energy in buildings and the utilisation of renewable energies. It is therefore necessary to re-evaluate the requirements of the various construction elements, the features of the materials, and, more generally, the global construction approach to adopt both for new buildings, but particularly also for redevelopment projects. The RUEn articles define the specific requirements of the various components of a building: the thermal envelope, the installations, the energy vector utilised, in relation to the typology and category of a specific construction (both new buildings and redevelopment projects).

The new, and substantially more restrictive, criteria required for both the thermal envelope and the installations imply radical design changes.

The legislators are aware of the fact that historical monuments must be protected at the expense of meeting existing energy standards. Current legislation therefore provides some general exceptions (see Art 5, Chapters 1 and 2 of the RUEn).

Art. 5 ¹ Se delle condizioni straordinarie rendono eccessivamente difficoltoso e sproporzionato il rispetto delle disposizioni del presente regolamento, possono essere accordate delle deroghe alle esigenze, ma solo nella misura in cui viene meglio salvaguardato l'interesse pubblico, in particolare nel restauro dei beni culturali.

² Le deroghe possono essere condizionate al rispetto di condizioni particolari, degli obblighi e/o delle compensazioni definite a seconda delle specificità del caso.

³ Il richiedente può essere chiamato a fornire delle verifiche e dei giustificativi in relazione all'economicità, alla fisica delle costruzioni, ai bilanci energetici ed ecologici, o al rilievo dei fabbisogni di energia.

This is therefore an agreement between the Office for the Protection of the Air, Water and Soil (*Sezione della protezione dell'aria dell'acqua e del suolo* – SPASS, Territory Department, Environment Division, UACER Office – Office of Air, Climate and Renewable Energies - *Ufficio dell'aria, del clima e delle energie rinnovabili*) and the Cultural Heritage Office (*Ufficio dei beni culturali* – UBC) – Service for Monuments, Territory Department, Section for Territorial Development).

Art. 4 ² Qualora la Legge sull'energia o il presente regolamento non dispongano altrimenti, valgono quale stato della tecnica» le esigenze e i metodi di calcolo delle vigenti norme e raccomandazioni edite dalle associazioni professionali o dalla Conferenza dei direttori cantonali dell'energia (in seguito EnDK) o dalla Conferenza dei servizi cantonali dell'energia (in seguito EnFK). La pubblicazione di tali normative è curata dall'UACER.

From a technical and regulatory aspect, MoPEC (and therefore also the RUEn) refers to various regulations and technical documents issued by the SIA, which is a fundamental organisation in the field of energy and technical installations. Particular reference is made to regulation SIA 380/1 (2007 edition) on thermal energy (energy balance in buildings), SIA 382/1 (2007 edition) on the installation of ventilation and air-conditioning apparatus, SIA 380/4 on electrical energy (2006 edition). Some of these regulations have now been updated: SIA 380/1 (edited in 2009) and SIA 382/2 for calculating the energy requirement for air-conditioning in buildings.

The MINERGIE® standards provide a valuable reference point in this context asking that buildings meet standards that are more exacting than legal provisions and than the regulatory minimums for new buildings and redevelopment projects. MINERGIE® buildings, both new and redeveloped, therefore have higher than average construction standards and comfort performances .

From a practical aspect, reference must be made to the energy regulations in force in the Canton in which the building is located, because, although the objective is to achieve uniform energy regulations in compliance with the Model of Cantonal Energy Regulations (MOPEC), in some areas of the Country the regulatory requirements may be different as a result of potential delays in passing revisions to laws or Cantonal regulations.

4.3. European energy requirement assessment legislation

At the international level, on 16 December 2002 the European Parliament (persuaded by demands related to environmental protection) passed Directive 2002/91/CE [42, 43] on energy savings, ordering Member States to pass the relative national laws and implementation regulations in such a way as to make it operational by 2005. The implementation process of European Directive 2002/91/CE on Energy Performances of Buildings is generating significant changes in Public Institutions and in the construction industry.

4.4. Integration of solar installations in Switzerland

In Switzerland the **integration and installation of solar systems (Photovoltaic and Solar Thermal)** in the built environment is regulated by current legislation, which mainly considers compliance with Article 18a, included in the revision to the Federal Law on Territorial Planning [44]. This law states that, in residential zones, carefully integrated (on roofs and facades) solar installations are permitted provided they do not ruin the heritage structures or natural sites of some Cantonal or National importance. It is also necessary to consider all the existing Cantonal guidelines¹¹ related to the integration of solar energy in buildings.

Art. 18a Legge sulla pianificazione del territorio (22 giugno 1979, stato 1 agosto 2008)

700 Legge federale sulla pianificazione del territorio – LPT

Titolo secondo: misure pianificatorie - Capitolo 3: piani di utilizzazione – Sezione 1: scopo e contenuto.

Art. 18a Impianti solari

Nelle zone edificabili e nelle zone agricole è accordata l'autorizzazione per l'installazione di impianti solari accuratamente integrati nei tetti e nelle facciate, sempre che non ne risultino pregiudicati monumenti culturali o naturali d'importanza cantonale o nazionale.

700 Loi fédérale sur l'aménagement du territoire – LAT

Titre 2: mesures d'aménagement - Chapitre 3: plans d'affectation - Section 1: but et contenu

Art. 18a Installations solaires

¹¹ Ticino – February 2010

“Pannelli solari nei nuclei storici. Criteri di posa e di valutazione paesaggistica”

Set of criteria and recommendations which focus on the installation of solar technologies in historical centres.

Dans les zones à bâtir et les zones agricoles, les installations solaires soigneusement intégrées aux toits et aux façades sont autorisées dès lors qu'elles ne portent atteinte à aucun bien culturel ni à aucun site naturel d'importance cantonale ou nationale.

700 Bundesgesetz über die Raumplanung – RPG

Titel 2: Massnahmen der Raumplanung – Kapitel 3: Nutzungspläne – Abschnitt 1: Zweck und Inhalt

Art. 18a Solaranlagen

In Bau- und Landwirtschaftszonen sind sorgfältig in Dach- und Fassadenflächen integrierte Solaranlagen zu bewilligen, sofern keine Kultur- und Naturdenkmäler von kantonaler oder nationaler Bedeutung beeinträchtigt werden.

SECOND PHASE - PHASE B: Design proposal

The data acquired in the first phase will provide the basis for finalising a design proposal that can be used to evaluate which objectives, procedures and means can be implemented in order to alter the existing situation, and to assess the impact of these transformations on the building and on the energy balance.

1. Changes to the building

A number of fundamental aspects should be considered:

- What to conserve? Which parts of the building? Which parts of the existing installations?
- If the existing installations cannot be put back into operation but are considered to be interesting, should they be preserved in situ in any case, and not removed or altered?
- It is often advisable to evaluate mixed solutions (old - new);
- Highlight which elements (construction and technical) are best suited to energy improvement solutions;
- Evaluate the use of renewable energies and how the aesthetic configuration of the building would be altered.

2. Changes to the intended use

Check if it is possible:

- Lower some temperatures (mainly for heating);
- “Heat the people” and not the buildings;
- Tell the users how to manage the building. Highlight the most correct conduct associated with using the building (ventilate properly, only heat rooms that are used, etc.).

Building management and maintenance becomes a fundamental parameter for extending its useful life. To be successful, the transformations proposed, in terms of either active or passive changes to installations, depend largely on making correct management of the utilities. It is often necessary and extremely helpful to provide an operating manual for the building and for its infrastructures.

3. Changes to the energy requirement

Appropriate thermal insulation is often required in order to improve the comfort level in this type of building. Improvements of this type are expressed by higher superficial internal temperatures and hygrometric control over of the internal rooms, generating a significant and immediately perceptible improvement in the level of well-being. The energy requirement of a building depends chiefly on these factors, but also on some others that must also be considered, such as:

- Structural or volumetric changes to the building
- Changes to existing installations

- Introduction of new installations or generation systems
- Adequately air-tight windows, and support from external shading devices in order to reduce nocturnal losses and to guarantee adequate shading;
- Utilisation of appropriate, high-yield heating and cooling systems (even passive);
- Control of the electricity consumption and of the equipment in the building (also for lighting purposes);
- Natural lighting.

Even minimum procedures can enhance the potential of existing installations, and it is advisable to try to improve existing installations rather than replace them (mount thermostats, change valves, boilers ...).

On the other hand, if it is felt that they should be replaced, alternative types of installations must be investigated for each case, how they operate and if they can be integrated with a system using renewable energies. Financial aspects (installation and running costs), environmental sustainability ("grey" costs), maintenance over time of the proposed solutions, the environmental impact and the technical benefits must also be evaluated and codified (although these aspects are not the focus of this paper). The capital value of the property establishes an energy yield that can be measured by means of management economics: lower energy maintenance bills will increase the real estate value of the asset, in a way that can be certified.

The final aim of the proposals will be to minimise the consumption costs, complying with current building regulations and provisions, and aim at achieving maximum profit by exploiting the features of the building and of the environment, following the principles of minimum action, compatibility, reversibility, maintenance. The most effective solutions are those that allow the installations to operate in an optimal manner.

THIRD PHASE - PHASE C: Evaluation of the results

The design proposals made in the above phases will be evaluated on the basis of criteria that make it possible to analyse the solutions on the basis of both the cultural value of the building and the energy benefits obtained.

Based on the effective reduction in the energy requirement of the historical building being redeveloped, and based on the points criteria established by the methodology proposed (see Chapter 6), the global assessment of all the solutions proposed (in terms of passive strategies, envelope, installations and the integration of renewable technologies) provides an immediate indicative assessment of the energy – environmental benefits corresponding to the solutions considered in PHASE B. Having specified the solution scenarios for each case study, and having assessed the energy savings forecasting models obtained for all the proposed solutions, during the project execution phase it should then be checked that the forecasting models correspond to the real situation.

The financial feasibility of the proposals is another factor that must be considered. The financial aspect is probably the most problematic factor for the redevelopment of historical buildings. The type of solution selected, together with a more complex implementation procedure, generate higher costs. The client, either public or private, is interested mainly in the investment costs. However, in projects of this kind, aimed at improving the energy efficiency of the building, in addition to the running costs it is also possible to consider potential government incentives and subsidies that can reduce the initial impact of the higher costs for the work. These higher investment costs mean that government incentives provide significant support. Nevertheless, although the financial factor is important in the decision-making process, it is essential to remember that the objective of the final choices is to improve the energy efficiency of the building. A frequent concern is that the owners or investors of the heritage structure focus exclusively on solutions related to heating the building, or

increasing its insulation, often choosing solutions that are not compatible with the features of the monuments.

In recent times there has been growing awareness that degradation phenomena must be opposed by means of appropriate programming strategies and by technical-financial building **maintenance** management. The objective underlying these new maintenance strategies is to rationalize the technical and financial management of the work required in order to maintain the quality and efficiency of buildings over time. In order to implement this type of change, the traditional approach to maintenance must be developed; instead of considering maintenance as action limited to the operating level and with short-term prospects, it must instead be assigned a strategic role based on an overview of the entire life cycle. Maintenance programming strategies are established on a system of procedures that regulate the deadlines, the frequencies and the types of work to be executed. The programming procedures first of all specify understanding the features and conditions of the building, in order to then be able to schedule an appropriate distribution of “renovation cycles”. This entails writing maintenance plans aimed at maintaining the structural components and installations in an optimal functioning condition by controlling the degradation, preventive action and work executed. The maintenance programme constitutes the main management tool for schedulable maintenance. The approach will therefore increasingly become one of **scheduled preventive maintenance**, or, in other words, planning in accordance with a scheduled series of deadlines corresponding to the renovation cycles planned for the various parts of the building, and aimed at reducing the probability of damage or degradation [45].

5. Case Studies

Three historical buildings were identified and analysed during the project, with particular focus on their features, their needs and the requirements of the most distinctive construction elements. It was decided to analyse only buildings that had originally been residential, constrained by increasingly restrictive levels of conservation protection, and with different intended purposes.

The three case studies were selected in order to have three diverse construction typologies, with differing unique features, so that the solutions identified could be replicated and generalised. The following buildings were selected:

- Casa Anatta: early 20th-century building which over time has undergone various transformations, both spatial and functional (originally private residence, now a museum).
- Casa Manetti: typically residential building, with one part used as a veterinary clinic and a restaurant. This prestigious structure is part of a group of buildings which lie on the Monte Verità.
- Hotel la Sage: a protected building that over the years has undergone transformations and volumetric extensions, so the appearance has changed together with its use.

The three case studies therefore provided the opportunity to apply the methodology proposed in the course of the project to examples with diverse features and problems, and, in particular, with varying levels of freedom in terms of permissible solutions.

The three buildings are described in greater detail below¹².

5.1. Casa Anatta

This building was built at the end of 1904. Despite its relatively homogeneous appearance, marked by single-story wooden structure set on a commanding stone base, Casa Anatta has undergone various cycles of building work, largely coinciding with changes to its ownership and use.

The name of the architect is not known, and there are no documents available in terms of graphic documents, plans, sections or elevations of the original design, or of the subsequent modifications.



Fig. 5: Casa Anatta, Front (sud-est) view.

The information available in the historical documentation and in the technical report provided by Studio Geronzi, Lugano shows that the current condition of Casa Anatta corresponds to the building phase that began in 1926, executed by Barone von der Heydt. Little work has been done since then, and there are numerous signs that minor parts were removed subsequently. The importance of this

¹² Consult the assessment and proposal charts for a more detailed analysis.

work precludes any possibility of returning the structure to its previous phases without distorting the historical value of the artefact.

The building is not in a good state of conservation, mainly due to the lack of maintenance. However, there are some original construction defects, associated mainly with the work phase that began in 1926 and that is still contributing to the inexorable degradation process, particularly in the joints between the flat roofs and vertical walls above, and in the points of contact with the ground. One very critical point is on the north side, where the water-channelling system no longer operates properly, causing the live rock to drain all the meteoric water against the perimeter walls.

Some solutions, such as the gravel laid to protect the water-proofing coat of the flat roof, but without a gravel-grate round the edges, have made the gutters inoperative, causing the woodwork to rot.

Some technologies are particularly subject to wear-and-tear, particularly the sliding windows, which, unlike the traditional swing-type model, require constant maintenance and strong metalwork for the wide-opening windows. The installations are very old and the modernisation work executed has always been periodic and sketchy, besides failing to respect the details of the original models, and in any case cannot contend with current energy and museological requirements.

The construction materials used for the various parts of the structure, particularly inside, have the advantage that they can be maintained or restored the need to make any painful replacements. On the other hand, the paintwork has largely degraded since, due to partial re-painting of the base, various layers of different colours have been applied and the effect is so obvious that it must be harmonized. Most of the woodwork, which is not original but which was added in 1926, is seriously compromised and will be replaced. The same can also be said for the covering materials, which were also all re-done or built in 1926, where the same operational techniques and the same materials will be maintained, compensating for the original defects with solutions that are more correct from a construction aspect but that do not alter the original aesthetic appearance.

5.2. Hôtel de la Sage

The hotel was built in 1890 and then progressively extended until the 1930s. The building consists of a main wing with five floors, and a secondary wing with three floors. The main wing is served by a central corridor and holds the reception, the public areas (including a sauna), various service rooms (on the ground and basement floors) and the bedrooms. The secondary wing, built at right-angles to the main wing, holds the ground-floor dining room (connected to the kitchen at the semi-basement level), and the lounge/library on the first floor. In the 1960s (an architecturally debatable extension) was built onto this structure.



Fig. 6: Hôtel de la Sage, main façade, entrance.

The original structure is intact, the maintenance and transformation work has been limited, and executed without any concern for the quality of the building (particularly the addition of the extra floor on the secondary wing, and the replacement of the balconies and of some of the original windows).

In 2005 the hotel was purchased by the current owner, who did some work aimed mainly at improving the comfort of the bedrooms (the shared bathrooms were eliminated, and en-suite

bathrooms put in all the rooms, the flooring was phonically insulated). Almost all the windows on the north facade, and those of the attic floor (wood-frame, single-glazed) were replaced with new, double-glazed wood-frame windows.

The attic was converted into an apartment for the owners, who thermal-insulated the roof with approximately 80 mm of glass wool (the owner did this job in person). Some parts of the perimeter walls were also insulated with approximately 80 mm of insulating material (the insulated part is negligible, however).

As a result of the extent of the work executed (particularly the extension, the reconstruction of the internal areas and the replacement windows), the interior of the building can no longer be considered as protected. The external situation is ambiguous: unless the terrace-solarium is renovated, it will be difficult to consider the hotel as a protected historical building. One compromise might be to protect at least some elements (the lounges on the ground and first floors, the windows on the main facade). The original wooden “roller” shutters were eliminated in 2005, and the boxes were filled with insulation material.

The hotel is open all year round (12 rooms + 1 apartment), and the current envelope means that it is quite difficult to heat in winter, particularly the rooms with single-glazed windows. All the radiators have thermostats that are adjusted manually by the owner. In order to improve the level of comfort, the dining room and library have been equipped with wood-burning stoves that compensate for the thermal dispersion caused by the large windows.

The kitchen (gas-powered) was originally in its current position, but in 1954 was moved to the ground floor (to the area currently used as games room). In 2005 the basement (originally accessible from outside) was re-converted into the kitchen, so direct access to the dining room had to be created. The boiler-room, with naphtha boiler installed in 2005, lies between the kitchen and the store-room.

A store-room was built below the external terrace, probably in 1954. Regarding the safety of the building, the owner personally designed the fire-alarm system, which has not been inspected by the appropriate authorities but which has been approved on the basis of the plans and information provided by the owner.

The lack of information is a particularly serious problem: neither the construction plans nor the energy consumption tables are available.

5.3. Casa Manetti

Casa Manetti (Antica Osteria Manetti) is an enormous, rectangular building with an extensive stone-slab roof, perhaps dating back to the 17th century. It is known to have existed in the early 1600s, when it was a refreshment point for travelling merchants and the last horse-changing station for the St. Gothard mail-coach. The most recent renovation work was executed in 1979.

The building is registered on the Confederation PBC- Protection of cultural heritage inventory (status 01.04.2011). “B objects” are specified, cultural heritage items of regional importance.



Fig. 7: Casa Manetti, main facade facing Est and north facade..

No particular degradation problems have been recorded for the major construction elements of the thermal envelope, apart from some flaking in the skirting board area, particularly in the veterinary clinic. The facades of the main body are in natural stone, 50-60 cm thick without any thermal insulation. The facades of the secondary body (veterinary clinic part) have a total thickness of 50 cm and are made from cement-type bricks.

Work was done on the roof in 1979: replacement stone-slab covering, wooden rail-work, counter wooden rail-work and the attic, while the battens were preserved. The loft was insulated with a layer of insulating material (glass wool). The attic area is enormous, divided by stone fire-proof walls, and is used as a store-cupboard/archive. The intended use cannot be changed.

The most recent renovation work dates back to 1983, when almost all the windows were replaced (PVC, double-glazing, internal shutters).

The building does not have a centralised heat generator, creating problems for many designs. All the units are heated by electricity (with storage or bar radiators), and the hot water is also heated electrically. A centralised solution would be desirable so further study should be conducted in this area.

6. The structure of the assessment and work charts

All the information, the analyses, and the potential energy solutions will be summarised and processed in summary charts for each structure. The charts have been designed as support tools for the project director (usually the restorer) and for her/his team of experts. They can also be used in order to conduct a final check (by means of scores) of all the improvement proposals, and will help in the process of drawing up a balance sheet of the advantages and disadvantages of each solution. Each category of charts corresponds to the methodological approach described in Chapter 4, divided into the three phases: first phase – Phase A; second phase – Phase B; and third phase – Phase C.

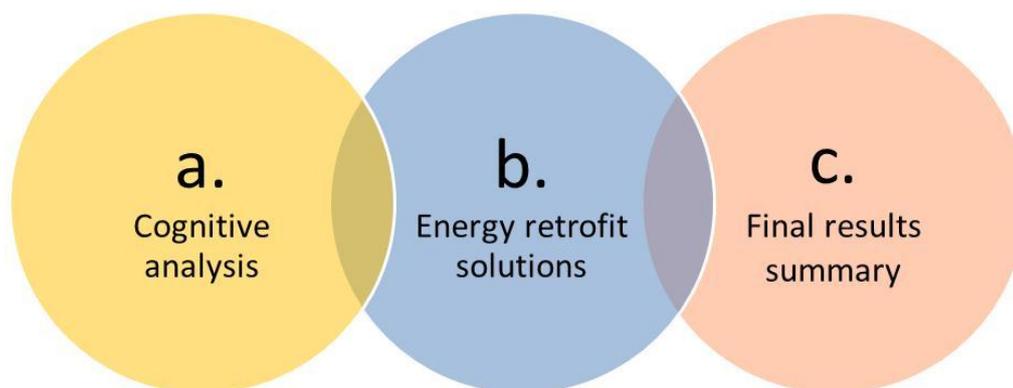


Fig. 8 – Main structure of the charts and methodology

a. Registration and descriptive charts (PHASE A)

The registration charts contain the description of the building and the historical survey documents summarising the value of the structure. The descriptive charts, with attached design report provided by the architect or by the client, contain the survey report of the current condition of the building, highlighting the strong points and the critical aspects of the structure, and inspiring the re-development solutions that will be proposed for the building, from an energy, construction and design aspect.

The charts are divided into four parts:

a.1 Registration Charts – Description of the historical value

- Identification of the building
- General information about the location of the building and about the construction
- Features related to the function and use of the buildings
- Age
- Changes made
- Photos and diagrams of the building (plans, elevations, construction details, etc.)
- Attached documents

a.2 Descriptive Charts – Analysis of the critical aspects

- Re-development plan for the building
- Structural typology
- State of conservation
- Problems and critical aspects
- Attached documents – technical reports, inspections, thermography reports

a.3 Initial energy assessment charts

a.4 Climate and site analysis charts

b. Assessment charts and solutions proposed (PHASE B)

Based on the previous analysis, these charts highlight the solutions that, from an energy aspect, can be executed immediately or in the immediate future, taking into consideration all the critical aspects emerging from the descriptive charts and proposing the work required for these problems to be resolved.

This section is divided into four parts:

- b.1 Charts analysing the exploitation of passive energy solutions
- b.2 Charts proposing work on the envelope of the building
- b.3 Charts proposing work to be executed on the installations
- b.4 Charts for the integration of renewable technologies

Measures “b.1 *Charts analysing the exploitation of passive energy solutions*”, show the action or work to improve the energy efficiency and that can be considered when it is not possible to work actively on the building. Passive strategies are often not considered or exploited fully. Measures b.2, b.3, b.4 illustrate action or work making a greater impact on the building, since they are active solutions. The combination of both these typologies is always possible and desirable.

C. Global energy assessment summary charts (PHASE C)

These charts summarise the final results obtained in the charts described above, in order to obtain a global, tangible and clear view of the benefits brought to the building by the proposed solutions.

c.1 Global energy assessment summary chart

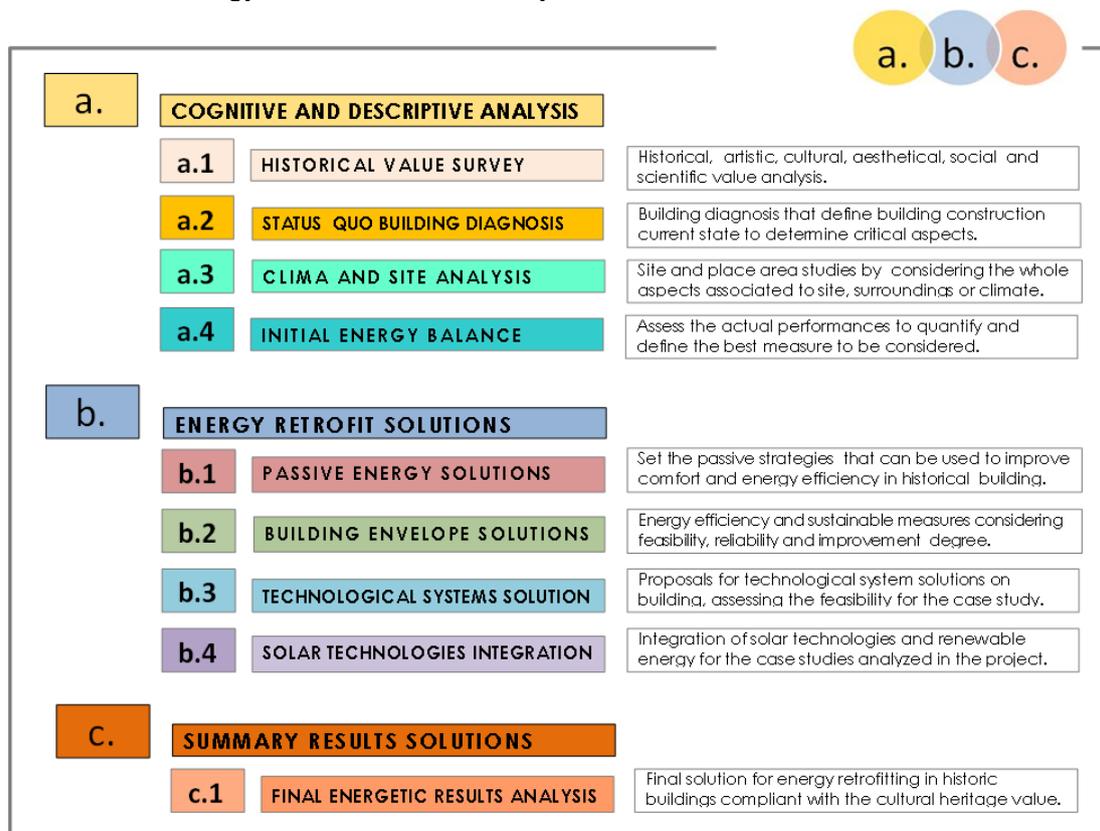


Fig. 9 – Technical charter format, typology of work , criteria.

6.1. Description of the charts

Each chart is identified by a colour (Fig. 9). The assessment charts, divided by topic area, contain all the systems related to the topic, grouped together by development macro-area. Each topic is assessed by means of an analysis that considers the potential of the solution, the limits and the levels of action. Each sub-system could in turn be subdivided into further sub-categories, therefore expanding the level of information of the general matrix.

All chart typologies have summary charts and charts of attachments providing further details about the information; at the end of each category there is a brief summary of the main aspects considered.

Identification codes

The areas of interest, into which the charts are subdivided, were defined in the previous chapter. Each action measure is then classified by means of a 6-character alpha-numeric code:

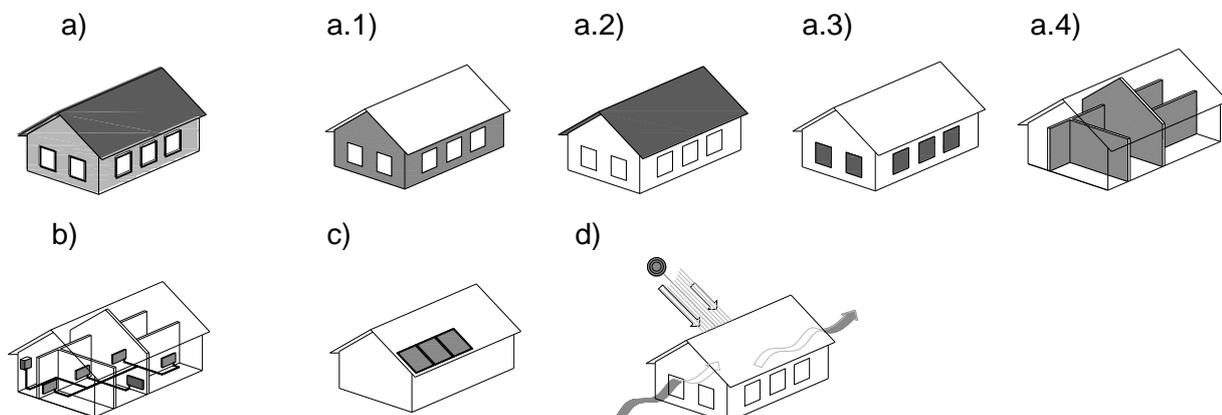
- The first letter **a.**, **b.**, **c.** refers to the area of interest
- The second number **a.1**, **a.2**, **a.3**, **a.4**, **b.1**, **b.2**, etc.) refers to the order of study for each sub-category (climate, passive solutions, action, etc.);
- The following letters refer to the element studied (a.1.**HV** Historical Value; a.2.**BD** Building Diagnosis; a.3.**CL** Climate Analysis; a.4.**IE** Initial Energy Balance; b.1.**PS** Passive Solutions; b.2.**BE** Building Envelope Solutions; b.3.**TS** Technological Systems; b.4.**RS** Renewable systems; c.1.**FR** Final Energy Results);
- The final two numbers constitute a progressive sub-division for sub-categories.

For example, the code **b.4.RS.01** identifies the job of installing a photovoltaic solar installation. The purpose of the colour-coded identification is to make it easy, and fast, to understand the potential for action in each category and in each sub-system, in such a way as to inter-relate the categories with each other.

The identification symbols

These symbols denote the areas of the building that are involved in the proposed solution:

- a) Envelope (external/internal):
 - a.1 Opaque envelope _ Facades;
 - a.2 Opaque envelope _ Covering materials (roofs) / Basements; Transparent envelope;
 - a.3 Windows (glass / frames)
 - a.4 Internal cladding elements
- b) Installations (electrical /thermal / AC)
- c) Renewable systems/resources (photovoltaic / thermal / other)
- d) Passive bio-climatic solutions



6.2. The descriptive and action charts: contents and indicators

a. Registration and descriptive charts (PHASE A)

These charts consist of two parts: the first describes the historical value and the second describes the current status of the building, highlighting the more critical aspects.

a.1 Registration Charts – Description of the historical value (a.1.HV Historical Value)

- Identification of the building
- General information about the location of the building and about the construction
- Features related to the function and use of the building
- Age
- Changes made
- Photos and diagrams of the building (plans, elevations, construction details, etc.)
- Attached documents

A **summarising chart** summarises the main aspects of the building in question, and introduces the attached documents.

Scuola universitaria professionale della Svizzera italiana

01

Casa Anatta

Monte Verità – Ascona Ticino (Svizzera)

a.1.HV.01

Indagine anagrafica

Latitudine: 46° 09' 60" N
 Longitudine: 8° 45' 47" E

Indirizzo: Monte Verità, Via Collina 84
 CH-6612 Ascona (Svizzera)
 Anno costruzione: 1904
 Progetto originario: H. Gonenkoven
 Proprietà: Fondazione Monte Verità

Tipologia d'edificio

Residenziale

a.1. NOTIZIE GENERALI SULL'UBICAZIONE DEL FABBRICATO E SULL'EDIFICIO

1.1 Codice identificativo

Sistema Informativo dei beni culturali (SIBC):

Percorso museale Monte Verità - Albergo, parco, case e percorso museale Monte Verità

KGS_Nr = 8434

78-84 Via Collina Ascona (TI)

Inventario PBC, Protezione Beni Culturali

Categoria Oggetto A, importanza nazionale TICINO 337

Costruzione: Oggetto multiplo

Collezione: Museo

x 702.377 / y 112.710

1.2 Proprietà dell'edificio

Cantone: Anno di costruzione:

1.3 Tipologia dell'edificio

Villa indipendente Anno di costruzione:

1.4 Uso dell'edificio

Museo Altri:

1.5 Presenza di collezioni e oggetti di valore

Esposizione permanente

1.6 Morfologia architettonica

Edificio singolo

1.6 Trasformazioni

Ampliamento

Restauro integrale

Manutenzione straordinaria

2011 - 2014

1.7 Superficie costruita (m²)

444 Superficie Utile (m²)

1.8 Altezza dell'edificio totale (m)

10.26 Numero di piani

1.9 Volume dell'edificio (m³)

1.933 rapporto S/V

ML_rapporto-Pro PV v2 3/65

Scuola universitaria professionale della Svizzera italiana

01

Casa Anatta

Monte Verità – Ascona Ticino (Svizzera)

a.1.HV.01

Indagine anagrafica

Latitudine: 46° 09' 60" N
 Longitudine: 8° 45' 47" E

Foto/Grafiche

MAIN FLOOR

SOUTH ELEVATION

RASEGNA STORICA

Il complesso del Monte Verità ad Ascona è composto di un parco e di edifici di grande valore architettonico, quali l'albergo Bauhaus del 1926-1928 e la casa Anatta, la casa Selma, la casa dei Russi e al Museo Ellarion.

La casa Anatta data del 1904 ed rappresenta letteralmente l'anima - anatta significa infatti "anima" in sanscrito - delle esperienze spirituali, filosofiche e artistiche dei vegetariani e, in particolare, della coppia formata da Henri Oedenkoven e Ida Hofmann, fondatori del "Sanatorium del Monte Verità" una colonia che consisteva in una comunità improntata su un sistema di vita alternativo che cercava il ritorno alla natura e professava una dieta vegetariana, lunghe esposizioni al sole, il naturismo e l'adesione alla filosofia teosofica, l'avamposto meridionale del movimento della Lebensreform. La proprietà venne acquistata nel 1926 dal barone Eduard von der Heydt che la lasciò in donazione al Canton Ticino, divenutone proprietario nel 1964.

La casa è impostata su una pianta a L; la chiara volumetria dell'esterno caratterizzata da una terrazza e da un tetto piano, contrasta con l'interno, rivestito in gran parte in legno marcato da forme curvilinee e organiche di matrice liberty.

Dal 1981 vi è stata allestita l'esposizione permanente "Le mammelle della verità", ideata e realizzata da Harald Szeemann. La mostra, raccoglie gli oggetti e le testimonianze di una riforma della vita iniziata e mai compiuta fino in fondo, utopia fra le utopie, e allarga il campo di ricerca a quella storia universale che per qualche tempo sembrava essersi concentrata intorno al magnetismo del Monte Verità.

FONTE: <http://www.monteverta.org/museo/content.cfm?id=66>

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Fig. 10 – Example of a registration chart (a.1.HV Historical Value).

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a.2 Descriptive Charts – Analysis of the critical aspects (a.2.BD Building Diagnosis)

- Re-development plan for the building
- Structural typology
- State of conservation
- Problems and critical aspects
- Attached documents – technical reports, inspections, thermography reports

More details in Figure 12

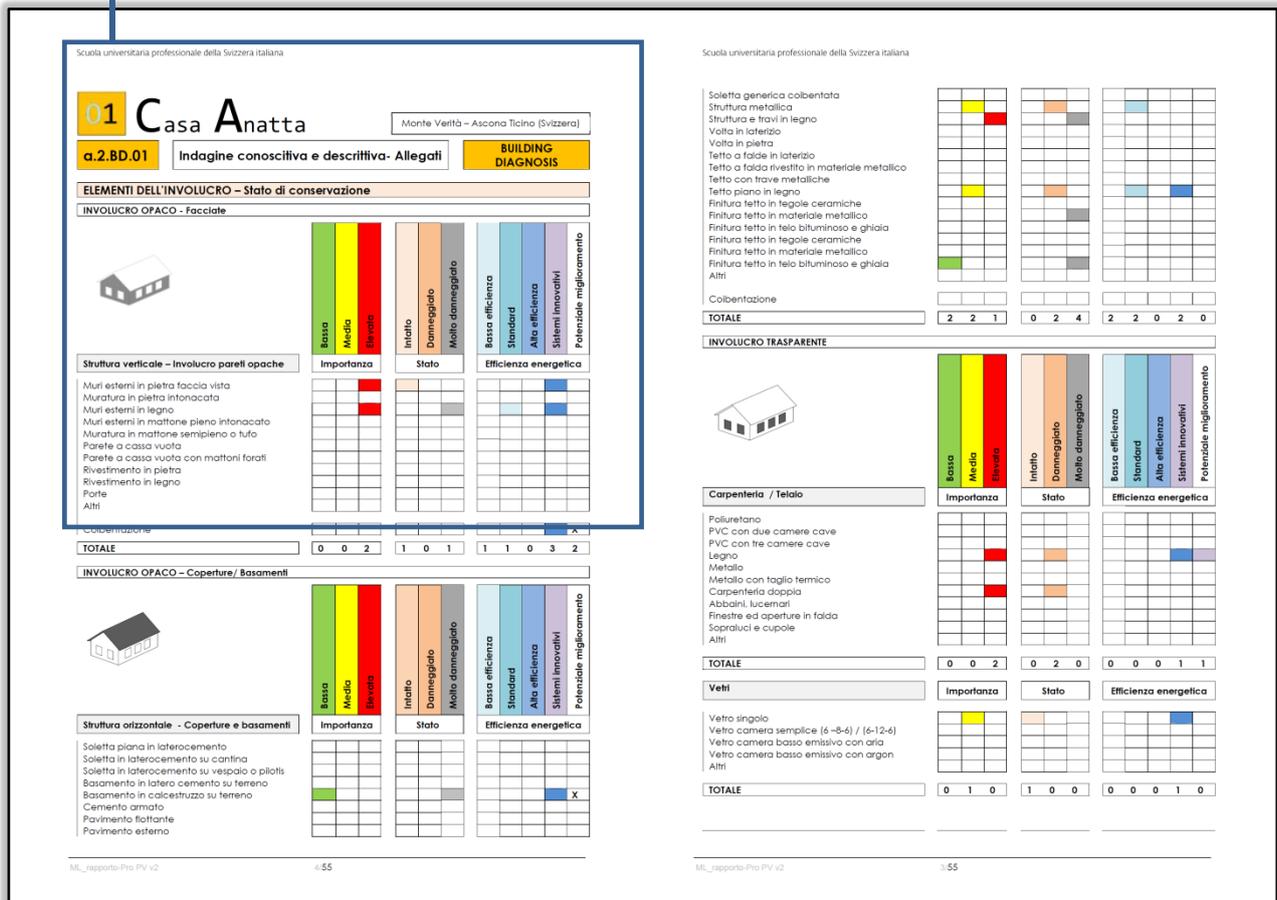


Fig. 11 – Detailed of a state of the art chart: indoor and outdoor elements (a.2.BD Building Diagnosis).

These charts define the current status of all the sub-systems of the building (envelope and technical installations). In order to specify the critical aspects, the following indicators have been defined:

The indicators

When specifying the indicators it is necessary to distinguish between the part corresponding to the building envelope (opaque envelope and transparent envelope and the internal cladding elements) and the part referring to the installations. During the preliminary investigation phase a code must be established to evaluate the level of criticality and to set the potential alteration limits; the sum of the scores for each indicator quickly gives us a global overview of the most important aspects on which to conduct the proposed work.

For the part corresponding to the building envelope / installations, the table is structured as shown below:

A code is defined as follows:

- Historical value, importance from a historical point of view
 - Low, not important, high possibility of transformation;
 - Medium, low potential for transformation;
 - High, transformation is very difficult.
- Preservation state
 - Intact - Undamaged;
 - Damaged;
 - Very damaged, repaired only through refurbishment or replacement;
- Energy efficiency - Factors that affect the energy efficiency of the construction
 - Low efficiency, element that could be upgraded;
 - Standard – normal situation not so efficient;
 - High efficiency, energy-efficient element or system;
 - Innovative, highly efficient systems with high technological content;
 - X Potential for improvement - High potential for improving energy efficiency in the building.

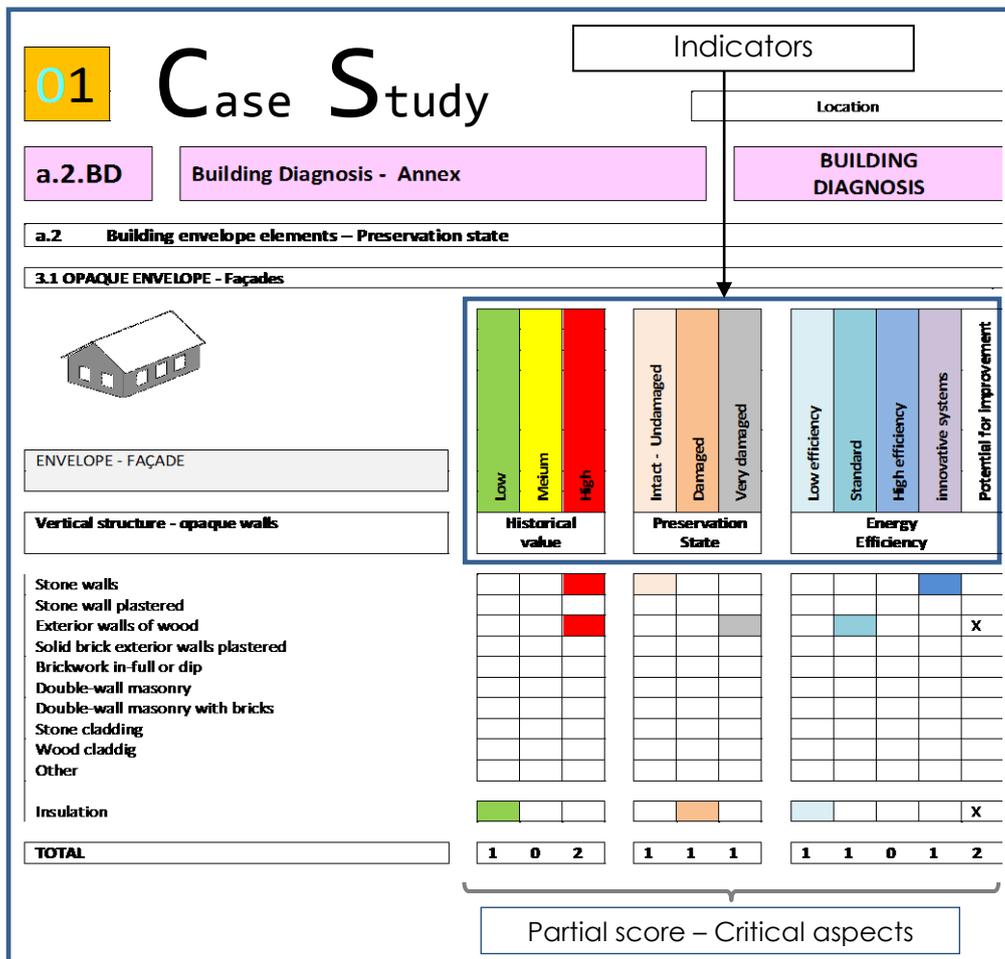


Fig. 12 – Building diagnosis chart (Fig. 10) (a.2.BD Building Diagnosis).

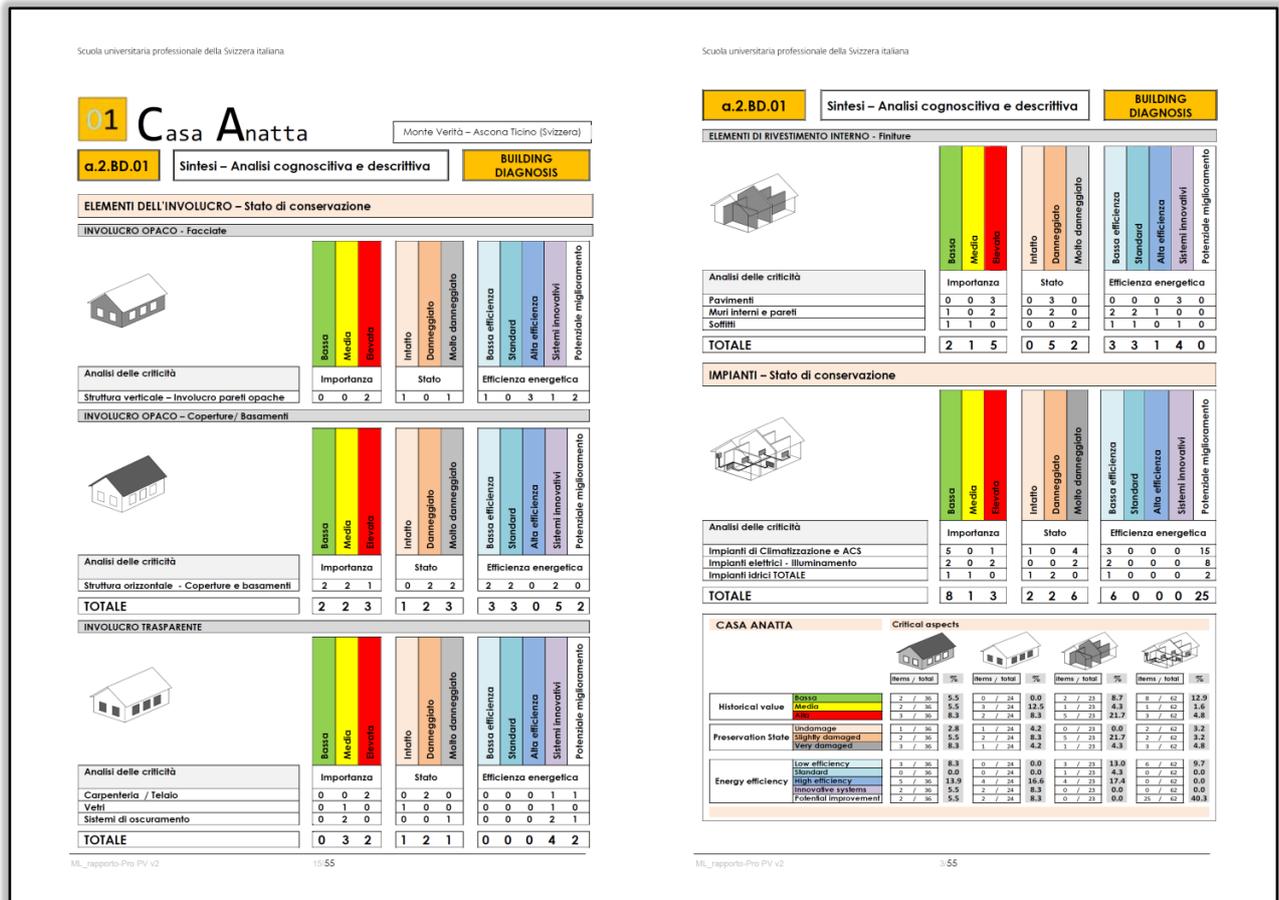


Fig. 13 – Resume chart, critical aspects of the building (global score) and result of the evaluation of the historical building.

The summary chart gives the total numeric scores for the envelope and installation elements recorded in the building diagnosis phases (attachment a.2.BD), and which are evaluated by the group of experts collaborating in the energy redevelopment project for the building. The table below (Fig. 14), which is given at the end of the summary chart, shows the percentage of elements by sub-category (opaque and transparent envelope, internal cladding and installations), assessed on the basis of the indicators previously established on the total number elements analysed.

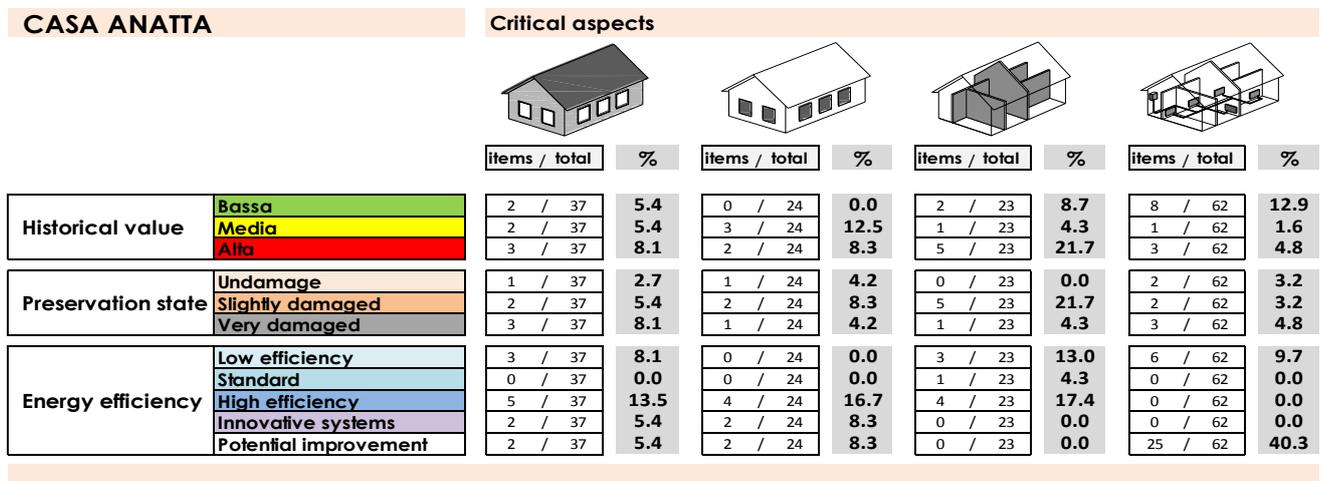


Fig. 14 – Resume chart all the type of intervention are here classified and rated. a.

a.3 Climate and site analysis charts (a.3.CL Climate and Site Analysis)

Projects for improving the efficiency of heating and air-conditioning systems require preliminary studies on the climatic conditions of the area. The data from these studies are used for specific bi-climatic studies in order to establish correct project criteria that fully exploit the external environmental conditions. The data refer to the meteorological station closest to the building.

The meteorological parameters studied are related to the external air temperature, relative environmental humidity, precipitation, solar radiation (the graphs and climatic data were processed using average statistical data from the Federal Office of Meteorology and Climatology – MeteoSvizzera – based on data measured in the 1961-1990 and 1981-2000 periods for irradiation, in the meteorological station close to the site on which the case study building stands.

This chart is summarised as shown below:

- Description
- Processed results
- Summary and analysis

- Codification of the options
- Potential for energy exploitation
- Considerations

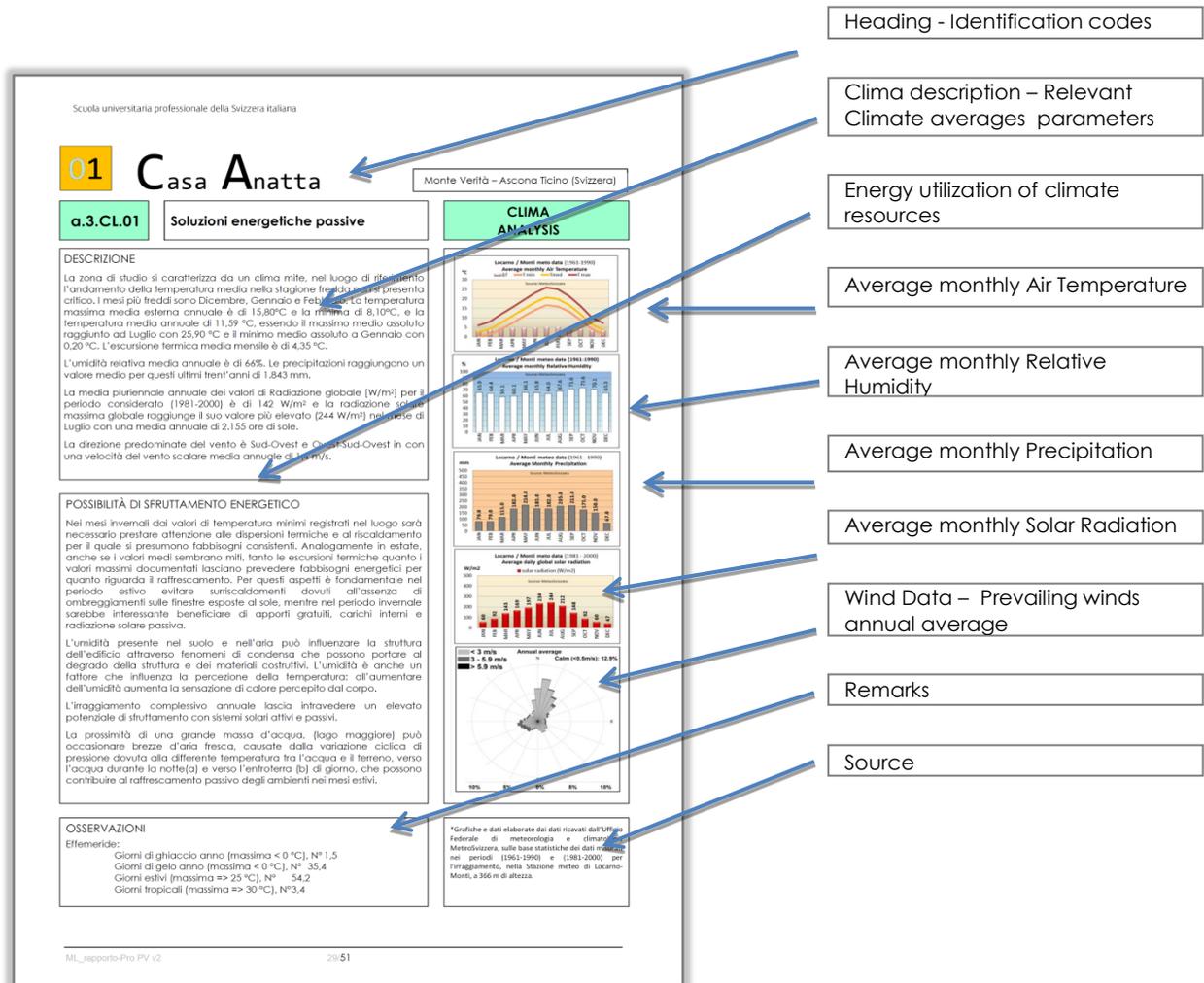


Fig. 15 – Climate and site analysis chart (Sezione a.3.CL.01).

b. Assessment charts and work proposed (PHASE B)

These charts analyse and propose solutions that will improve the energy performance and that can be executed immediately or in the future, taking into consideration the individual critical aspects.

b.1 Charts analysing the exploitation of the passive energy solutions

b.2 Charts proposing work on the envelope of the building

b.3 Charts proposing work to be executed on the installations

b.4 Charts for the integration renewable technologies

The solutions proposed in both the descriptive and action parts will also be assigned ratings and subdivided into three categories: maximum impact, medium impact and minimum impact, identified by three different colours. This initial assessment of the measure (which affects the entire building, the element or the system) is classified as, or corresponds to, the three possible alternative solutions in terms of the greater or lesser level of **impact** on the building:

Maximum	
Medium	
Minimum	

Red: Major impact, feasible but requires a significant level of study and specialist expertise in order to comply with the protection constraints on the building;

Yellow: Medium impact, the measure is coherent with the protection constraints on the building;

Green: Low impact, the measure is feasible, without conflicting with the preservation of the building, and is not invasive;

All these charts are organised as shown below:

Structure of the chart

The assessment charts will be applied to each case study, and, for each topic area, solutions and potential solution proposals will be specified.

Each chart has been divided into different sections,:

1. Heading;
2. Descriptive part;
3. Energy and environmental benefits;
4. Score section;
5. Identification symbols;
6. Considerations.

1. Heading

Includes: the identification code; the name of the measure; the rating of this measure (impact, applicability, scheduled maintenance requirements);

2. Descriptive part

Description of the issue in question and the most important parameters to consider for each case study. Brief description of the proposed solution or element. It may include photographs, diagrams, graphs (plans, sections, elevations, general blueprints), technical data, tables or any information that is thought might make the chart more fully comprehensible.

3. Energy and environmental benefits

Description of the benefits/disadvantages of the proposed measure, from an energy and environmental aspect, taking into consideration the critical aspects involved.

4. Score section

This section takes into consideration other final assessment criteria of the proposed solution, expressed as a rating divided into five categories that can be identified in the diagram and that are described here below:

- **Feasibility**

Further indications on feasibility of the work.

- Maximum feasibility: no special skills are required for this solution, there is no major impact on the building and it does not conflict with the protection constraints applied to the building;
- Good feasibility: normal solutions without the need for special skills, but more detailed study is in any case required for the case study;
- Moderate feasibility: it will be difficult to implement this solution at present but technical developments mean that it might be possible in the long term;
- Not feasible

- **Reversibility**

Specifies the extent of reversibility of the measure, which therefore makes it possible to keep the protected element intact.

- High reversibility: maximum reversibility with solutions that are not binding and with no impact on the element
- Normal reversibility: maximum reversibility with averagely binding solutions and/or with minimum impact on the element
- Low reversibility: low reversibility with highly binding solutions and with impact on the element
- Minimum reversibility: non-reversible work

- **Reliability**

Specifies the extent to which the measure remains effective and reliable over time.

- High reliability: the performance of the measure is guaranteed for a duration equal to that of the building;
- Good reliability: the performance of the measure is guaranteed although regular (but limited) maintenance work must be executed;
- Average reliability: the performance of the measure is guaranteed with frequent maintenance operations;
- Poor reliability: the measure is unlikely to perform effectively over time because it requires costly technical skills.

- **Comfort Improvement**

This criterion specifies how the measure improves the internal comfort of the building, improving the thermal conditions (work on insulation, installations etc.) or the lighting conditions (shading, lighting installations, direct glare, etc.).

- High comfort: the measure substantially improves the internal comfort of the building;
- Good comfort: adequately improves the internal comfort of the building;
- Moderate comfort: moderately improves the internal comfort of the building;
- Low comfort: the measure is unlikely to improve the internal comfort of the building, or does not affect this aspect.

- **Potential savings**

This criterion specifies the annual percentage reduction in final energy consumption in comparison with the current situation (initial energy assessment), for each proposed measure.

- > 70%
- 40 – 70%
- 20 – 40%
- < 20%

- **Environment effects**

This criterion specifies the potential mitigation of polluting CO₂ emissions in the environment, in metric tons of CO₂, also considering the energy saved or generated by renewable resources.

- > 10 tn CO₂
- 5.tn – 10 tn CO₂
- 1 tn – 5 tn CO₂
- < 1 tn CO₂

- **Maintenance and management**

Specifies the assessment of the maintenance requirements of the chosen measure.

- Does not require any special operational or maintenance action
- Limited maintenance, without any particular operational costs
- Maintenance required
- Extraordinary operations requiring a greater amount of maintenance

- **Rating**

Each grey dot is worth 25 points. Zero is the lowest possible value, while 4 grey dots amount to 100 points, which is the maximum score possible for each assessment criterion considered. The maximum number of possible points, for all seven criteria, is 700.

These rating elements assess the following aspects:

- FEASIBILITY MEASURE
- REVERSIBILITY MEASURE
- RELIABILITY MEASURE
- COMFORT IMPROVEMENT
- POTENTIAL SAVINGS
- ENVIRONMENT EFFECTS
- MAINTENANCE AND MANAGEMENT

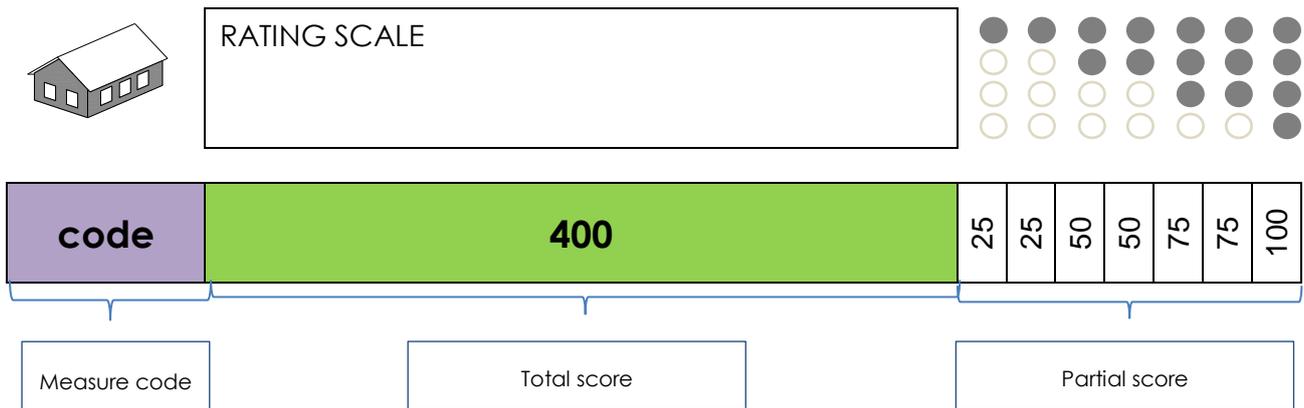
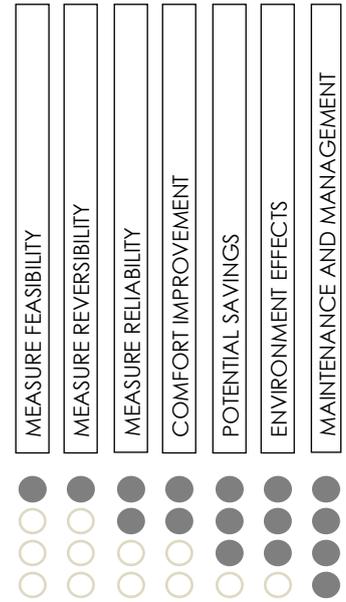


Fig. 17 – Rating scale and criteria assessment.

5. Considerations

This section specifies the parameters that must be considered as information supplementing that given in the chart. It refers to the documents attached to the project, the source of the information and where to find further additional information.

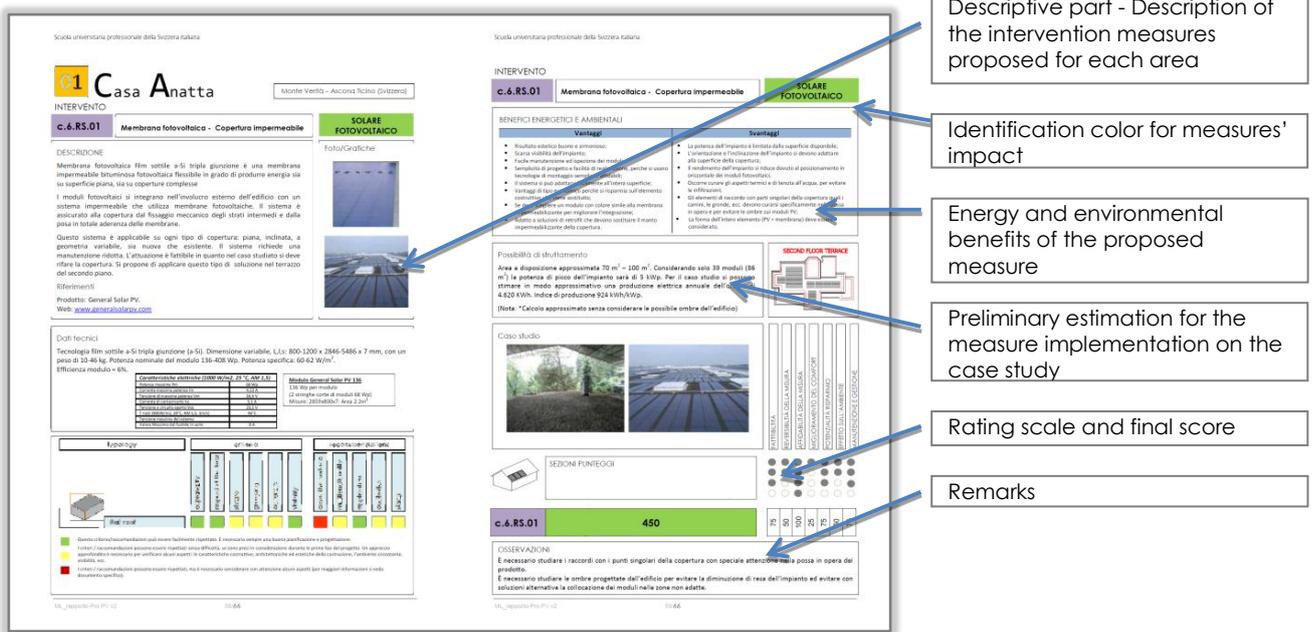


Fig. 18 – Example of chart type and application of the evaluation criteria (Section b).

The charts for this section are described below:

b.1 Analysis charts of the exploitation of the passive energy solutions (b.1.PS Passive Energy Solutions)

These charts highlight the possibility of exploiting passive energy solutions and strategies without having to execute invasive work on the building (not always possible). In any case, these considerations do not exclude the fact that all solutions, both active and passive, may be considered in order to improve the general energy efficiency of the building.

In the last few years, having relied on the environmental control capacity of mechanical installations, there has often been a lack of sensitivity toward historical constructions when buildings were constrained by the climatic, environmental and social contexts of their locations. Traditional construction typologies, intuitive and historical architecture representing past eras, exploited mainly the natural resources available (climate, construction materials easily found on-site), and have therefore survived the passage of time, enhancing and refining their intrinsic features.

This chart proposes a bio-climatic analysis methodology that can supplement and enhance the considerations related to the passive exploitation of the climate and location, regulated by the reference Swiss provisions (by means of calculation sheets or formulae). This type of analysis for existing buildings, and particularly for historical buildings, can be utilised to study and analyse the construction procedures and the original energy functioning of the structure, to study its relationship with the climate (sunlight, wind, temperature, humidity, light, etc.), revealing the energy and functional qualities of each element of the building.

For example, a healthy environment may be ensured by means of effective ventilation and changes of air in the rooms, although this must be controlled in order to avoid making a negative impact on the thermal comfort and/or energy consumption. In order to guarantee effective ventilation, it is possible to exploit either natural systems (nocturnal or transversal natural ventilation), or ad hoc installed devices (forced ventilation).

Reduce over-heating in summer and facilitate adequate protection or correct solar control in the hot months in order to avoid excessive energy consumption or wastage when cooling down rooms, or, in general, in order to improve the natural lighting and therefore reduce the use of artificial lighting. Architects have solved this problem for some buildings by making small adjustments, such as adding pergolas, windowsills, overhanging roofs, shutters, elements existing in the original structure of the building and that should be studied in order to see if they adequately meet current energy redevelopment objectives.

However, in some climates it is not possible to ensure conditions of adequate comfort by means of passive systems alone (solar gains, thermal inertia, internal loads), and active systems must be implemented to air-condition the rooms. In order to ensure conditions appropriate for the conservation and preservation of the building and of its immovable contents, the “indoor” environmental conditions must often also be controlled. In this case, the air-conditioning systems of the building play an important role, but energy consumption must be taken into consideration.

In order to identify the passive bio-climatic strategies that be used to most effect in the buildings examined in this project, the Givoni-Milne diagram was used. Since this diagram has not been assimilated into the calculation or certification system used in Switzerland, and has therefore not been integrated into the regulatory system, it is described in greater detail in the next pages.

Givoni-Milne bio-climatic design chart

The Givoni-Milne (Milne and Givoni, 1979) diagram uses a psychometric diagram to represent the zones of environmental well-being, zones of hygrometric thermal comfort, for summer and winter; other zones identify the various potential passive design strategies that can be implemented in order to achieve the desired level of comfort.

The input data of the chart consists exclusively of the external air temperature and relative humidity values.

The comfort area is 21°C - 26°C of dry bulb temperature, with a permissible well-being margin of 20°C - 27°C. The relative humidity limit is 75-80% in the upper part, and 20% in the lower part. Small lines of specific humidity or effective constant temperature close off the area. Various numbered zones around this area represent the potential strategies to implement simultaneously.

This diagram shows the temperature and humidity conditions of typical days in each month of the year (horizontal coloured lines). When these lines representing the temperature and relative humidity conditions of a typical day for each month of the year overlap the comfort zones or the numbered zones, various conclusions can be drawn.

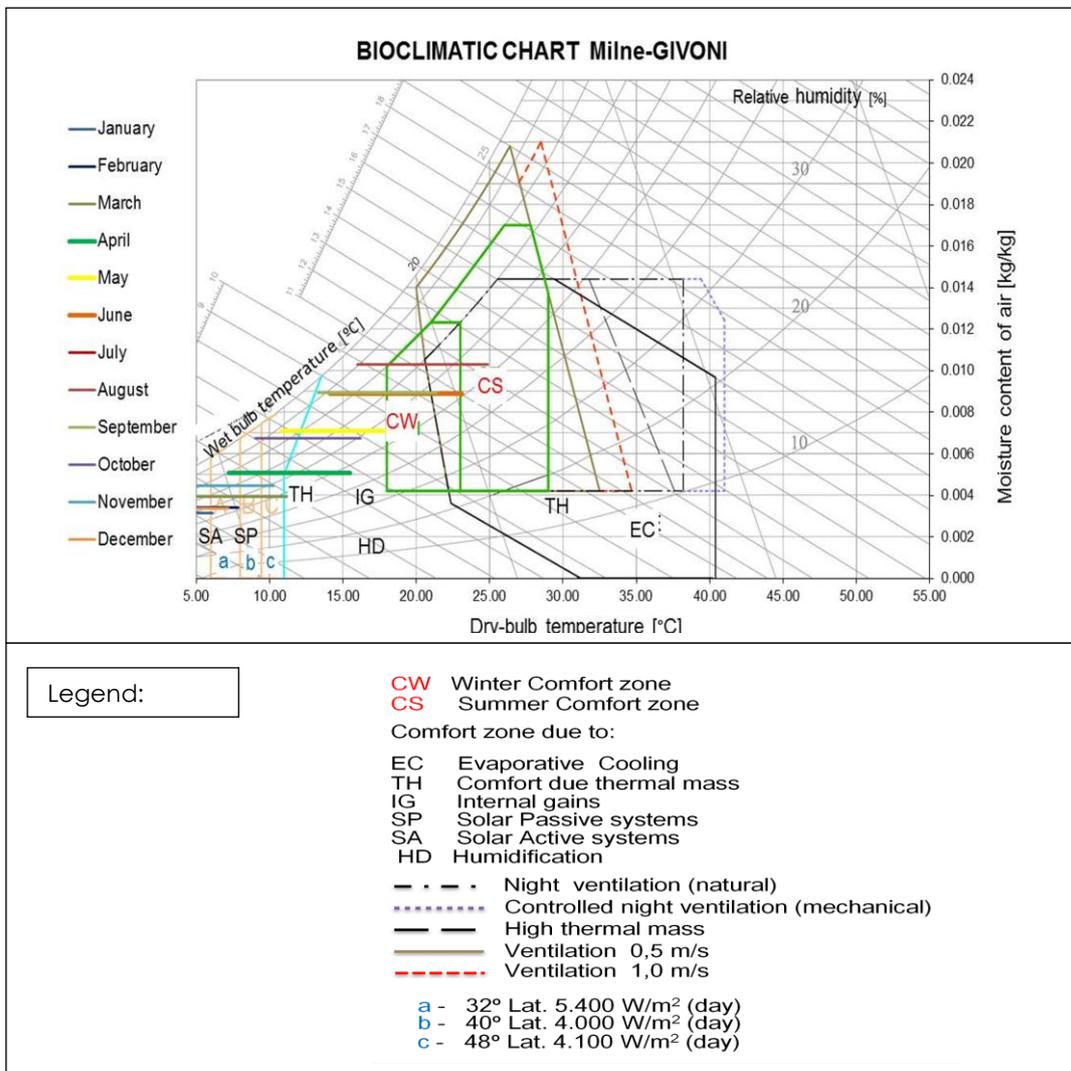
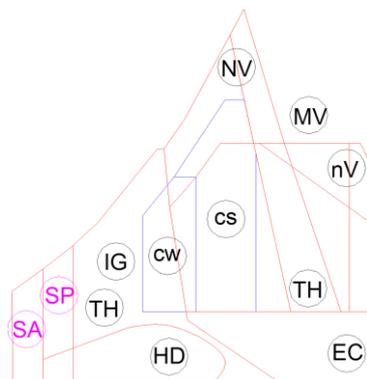
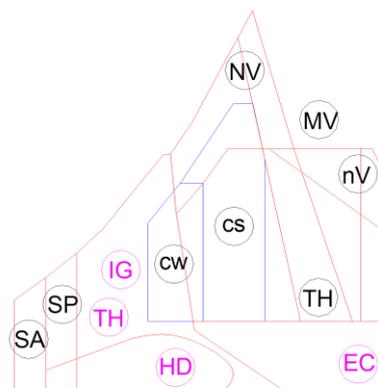


Figure 19 – Givoni-Milne bioclimatic design chart.

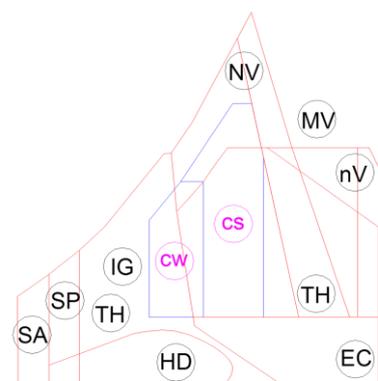
Zone SA shows the conditions of intense cold. The climatic conditions in this zone cannot be controlled by means of passive techniques, and active systems, conventional heating systems must be used in any case. In **zone SP** we can control the internal conditions by means of passive solar systems since we are in a moderately cold zone. When in this thermal zone, it is important to consider the thermal inertia of the building.



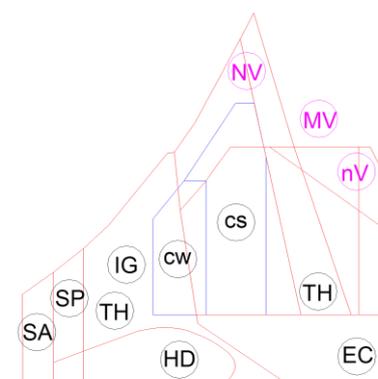
Zone IG represents the zone controlled by means of the internal loads (people, lighting, electric appliances, computers, etc.) and is a moderately cold zone. Comfort can be achieved by means of the heat generated exclusively by the internal loads. **Zone TH** is controlled by means of the thermal inertia, and is neither very warm nor very humid. **Zone HD** is controlled by means of humidification, and **Zone EC** by means of evaporative cooling strategies, since they are warm, dry zones.



Zone CW and zone CS respectively represent the zones of wellbeing in winter and summer.



It is advisable to use permanent natural ventilation in **zone NV** because it is warm and humid. In **zone nV**, on the other hand, the temperature can be controlled by means of natural nocturnal ventilation because, in rooms with high levels of thermal inertia, the cooler night wind can help the comfort target to be reached. **Zone MV** represents the conditions of excessive heat which cannot be controlled by means of passive technologies and for which conventional cooling systems must be adopted.



The passive solutions identified are summarised in a table where, for each month, the potential strategies and recommendations are specified (identified by symbols), and their varying levels of feasibility are identified (marked green, yellow or red). The environmental and energy advantages and disadvantages of each passive solution proposed are then explained in greater detail.

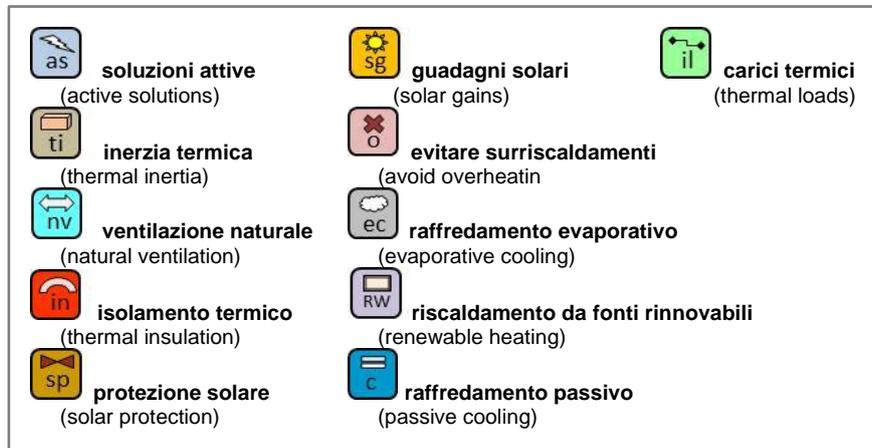
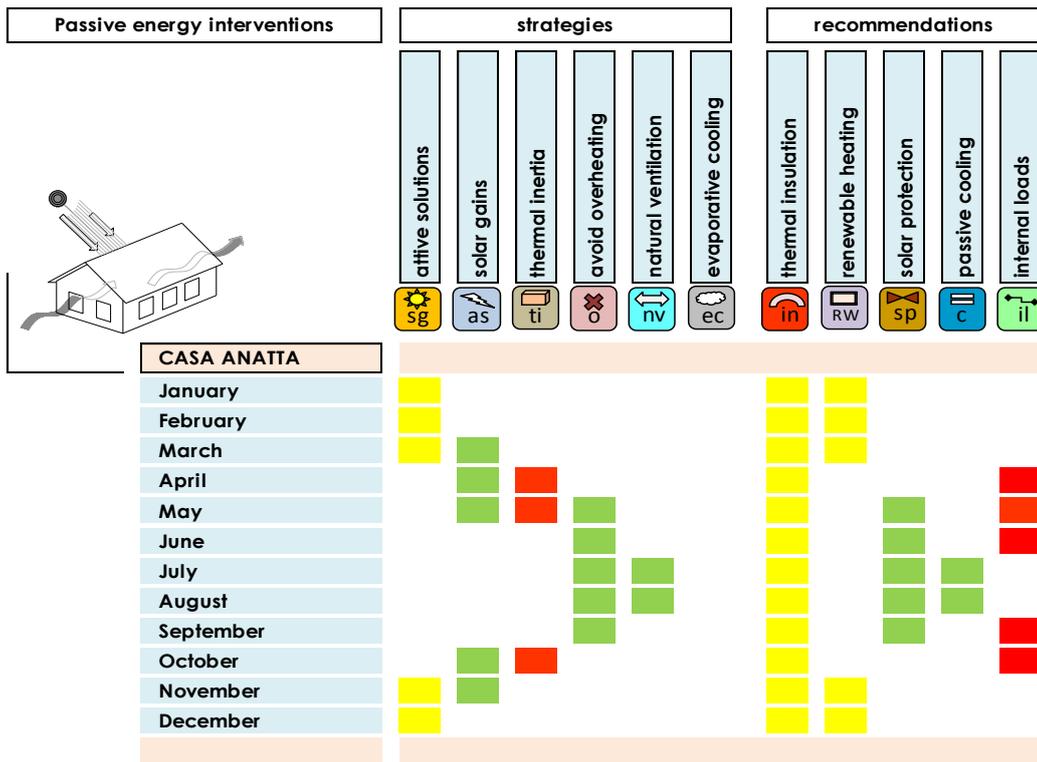


Fig. 20 – Symbols of the passive strategies.



- The criteria / recommendations can be easily exploited in the building. A good study of the particular building's conditions is always mandatory.
- The criteria / recommendations can be exploited in the building without difficulty. A thorough approach is also needed to verify certain aspects: constructive and design features of the building, architectural and aesthetic characteristics, use of the building and the surrounding environment, etc.
- The criteria / recommendations cannot be easily exploitable in the building. It is necessary to carefully consider some aspects and the real feasibility for the case study.

Fig. 21 – The matrix represents all the possible type of intervention to optimize the Energy efficiency of the building

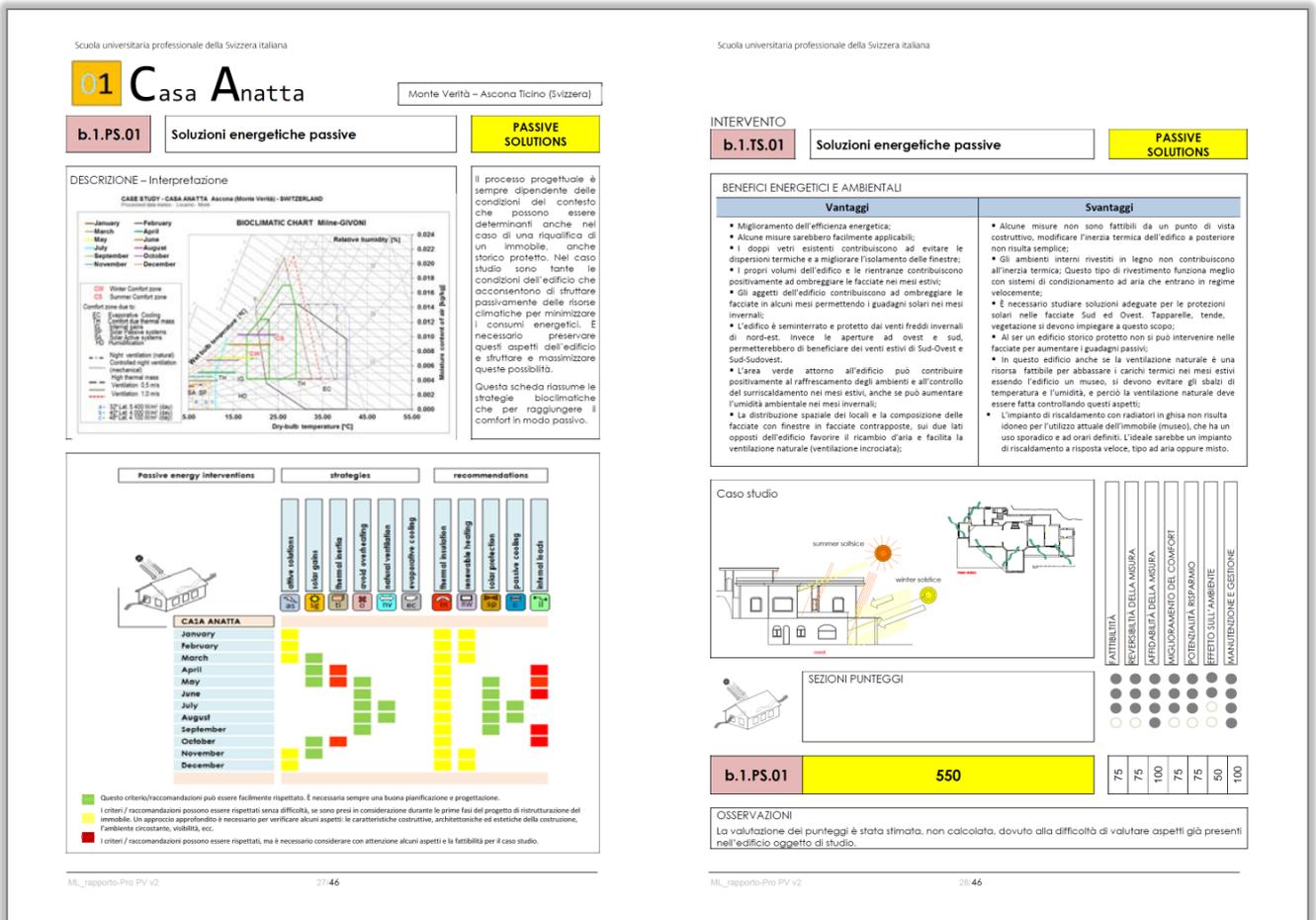


Fig. 22 – Example of the passive strategies chart (Section b.1.PS).

b.2 Proposal charts for building envelope solutions (Building Envelope Solutions b.4.BE)

These charts propose the solutions required for the main elements of the building envelope to become operational again, and that aim to reduce the energy requirements of these buildings. The building envelope includes the opaque envelope (walls, covering materials, basements, internal cladding) and the transparent envelope (windows, window frames, shading elements).

A new energy balance of the building (using the same instrument as for the diagnosis and for the initial energy assessment) provides data that can be used to calculate the benefits obtained on completion of the work, and that can then be compared with the initial balance.

The advantages and disadvantages section gathers together all the considerations and solutions (in terms of thermal qualities, hygrometric qualities, waterproofing or draught-proofing of the windows, ventilation, dispersion, etc.) involved in the proposed measures (particularly in relation to the level of constraint imposed on the architectural element of the building in question). The solutions are visually localised in the building and their impact is evaluated in terms of the *reversibility* of the measure, the *improvement to the level of comfort*, the *savings potential and the environmental impact* in terms of reduced CO₂ emissions, also incorporating aspects such as the maintenance and administration requirements of the proposed measures.

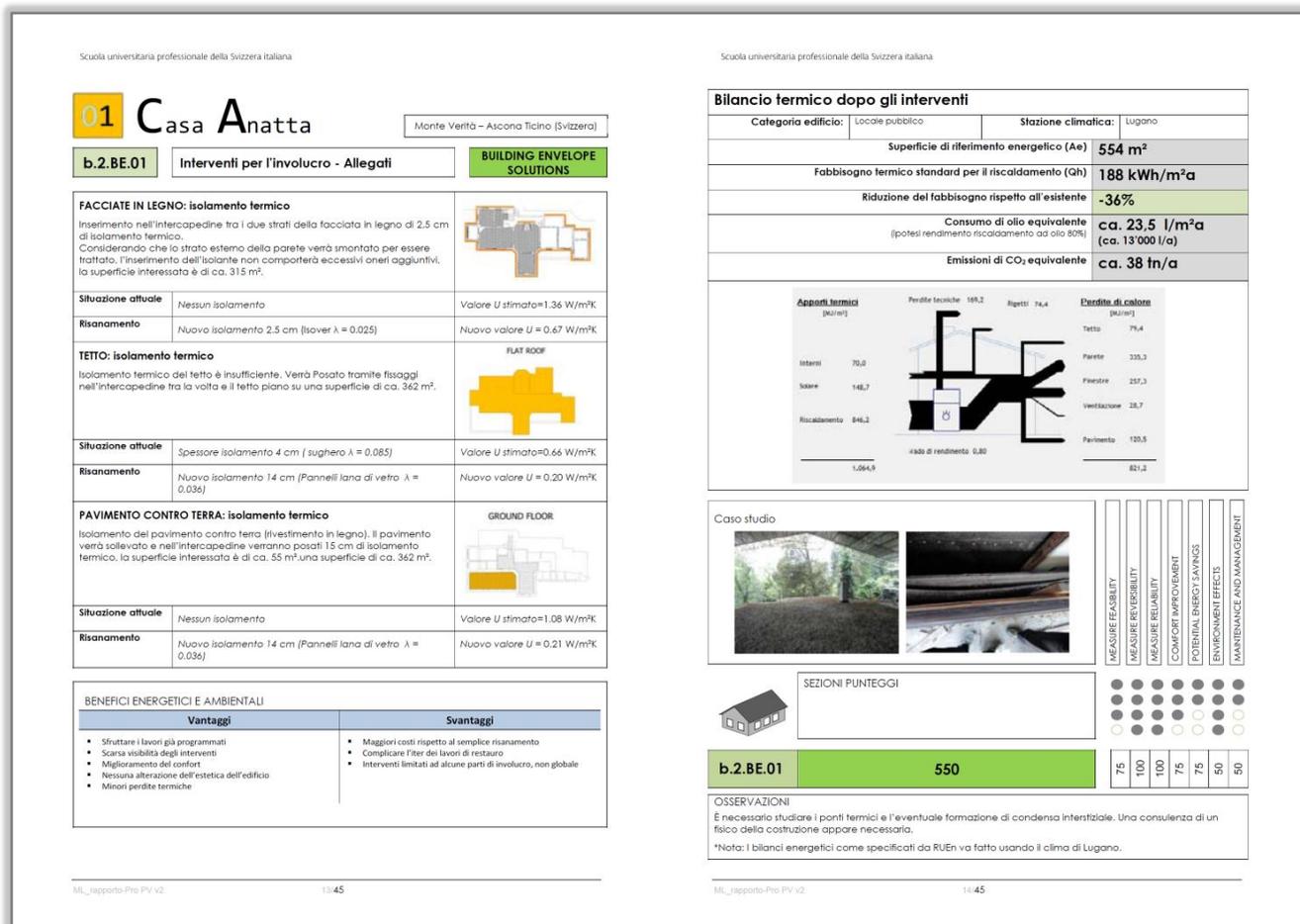


Fig. 23 – Some refurbishment proposal can be resume in this chart (Section b.2.BE).

b.3 Proposal charts for systems solutions (Technological Systems Solution, b.3.TS)

These charts summarise the solutions proposed for all the technological and installation systems of the building.

The development proposals are put into context with the local situation, also considering the potential conservation of the existing systems. Solutions can vary in accordance with the effective feasibility of the solutions, or with the impact: green represents minimum solutions, which have received technical approval from all the professional operators working on the project, and which can be executed without contravening the protection constraints. Other solutions, which would perhaps provide better energy performance, but which, due to the current condition of the building, or due to the regulatory and protection constraints, are perhaps not financially advantageous, are coloured yellow or red.

The methodology proposed, the eco-compatible development solutions and the energy savings considered for the buildings selected as case studies mean that the project results can be easily transferred to other protected buildings.

Each summary chart has attached documents related to the topic or that were fundamental to the entire proposal development process.

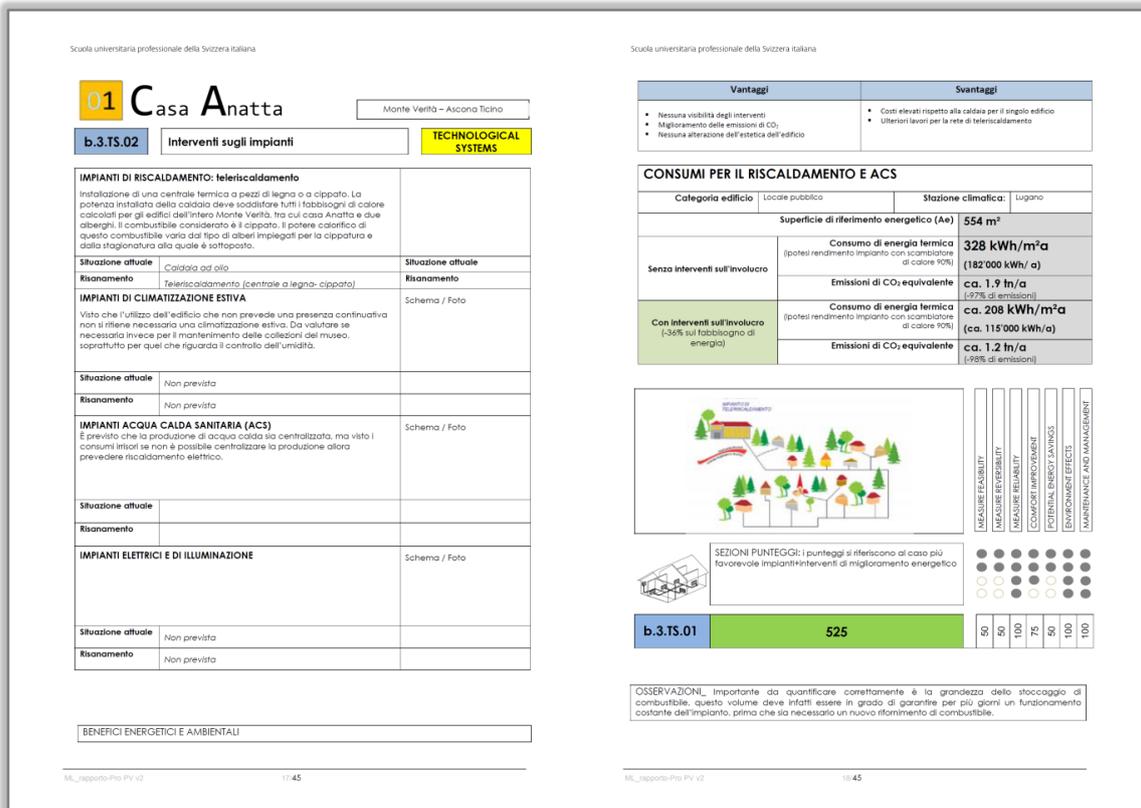
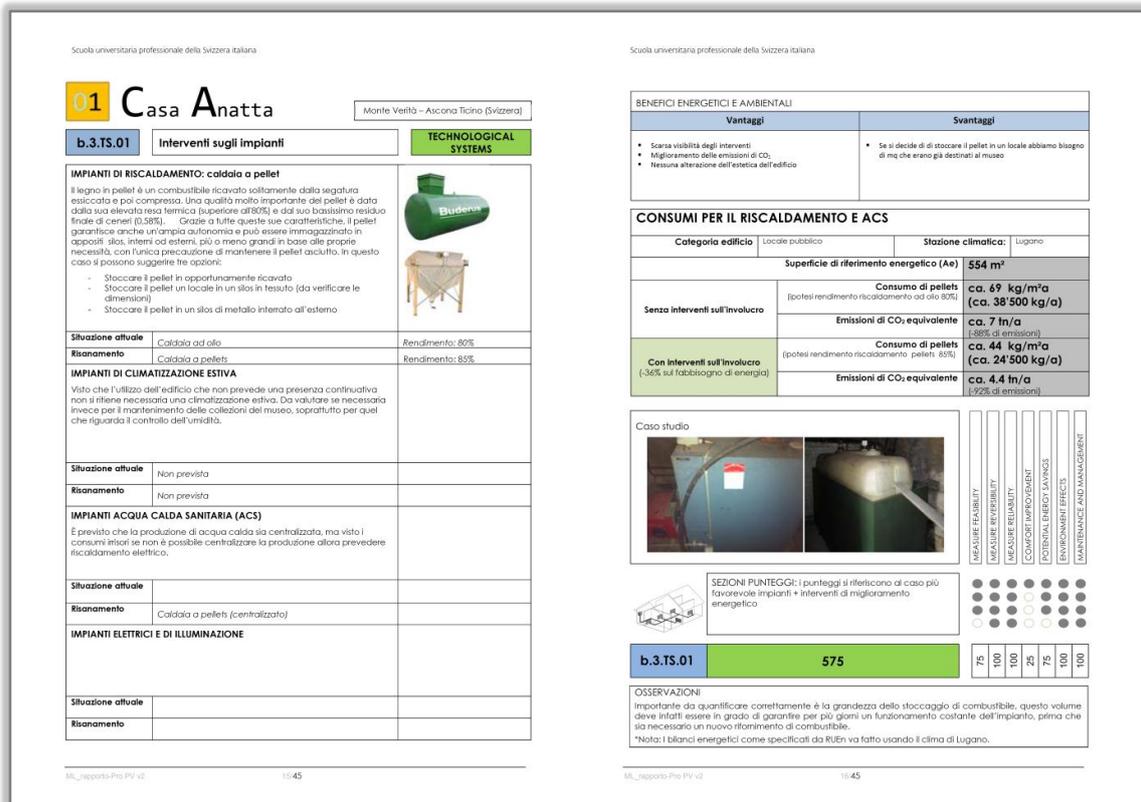


Fig. 24 – This chart shows the possible action in the equipment of the building (Section b.3.TS).

b.4 Charts for renewable technology integration (Solar Technologies Integration, b.4.RS)

Current Swiss legislation¹³ specifies that new buildings, and extensions to existing buildings, must be constructed in such a way that at least 20% of the energy required for heating and hot water purposes must come from renewable resources and/or energy efficiency measures. There has therefore been continuous growth in the number of solar energy systems in the country, and in the interest in renewable energy production systems. Increased consumer awareness of environmental measures such as energy saving, and the use of renewable energies, also play a role in this phenomenon.

Scenic parameters that perhaps currently prevent the use of these technologies in towns and in historical town centres mean that the owners of this category of property cannot exploit these benefits. One of the objectives of this project is to identify appropriate technical solutions in function with the diverse situations and in terms of reduced impact. Co-generation, geothermic energy production, the use of heat pumps, district heating as well as electrical energy production by means of photovoltaic solar systems, and water heating by means of thermal solar systems, are all solutions that can be appropriately integrated into historical buildings in an efficient and effective manner.

Nowadays it is not difficult to generate energy from renewable resources using a varied set of technologies, but integrating these renewable technologies to a greater and better extent (particularly in the photovoltaic and thermal solar field) into an urban context requires careful study, particularly in the case of historical buildings, whose architectural features must be given sensitive consideration. It is difficult to introduce modern, and foreign, technological elements to a historical context without in some way harming the cultural and architectural character of the building and of the surrounding countryside.

The technologies available on the market have devices that have been specifically designed and adapted for this type of integration, while also reducing the impact on the buildings. Devices currently offered include photovoltaic roof tiles, thermal apparatus for hot water production, lighting elements, transparent and coloured elements.

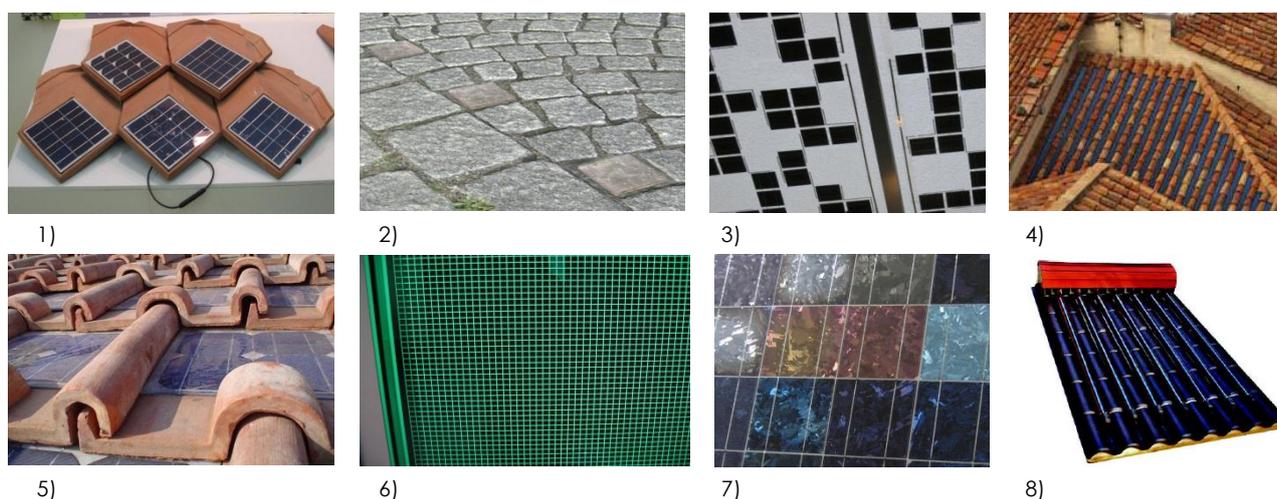


Fig. 25 – Some innovative PV or ST system for integration in buildings.

- 1) Tegola fotovoltaica Diamond dual. Elettro Sannio Ricerca Srl – ENEA – SUN Seconda Università degli Studi di Napoli - Fonte: Picture at MADE EXPO - Fiera Milano Rho 2010.

¹³ MUKEN (modello cantonale del fabbisogno energetico), l'articolo 9, comma 3, della legge sull'energia e l'articolo 1, comma 3.

- 2) LED-Light Fotovoltaico, for urban space. Special prize 2007, Solar City Copenhagen - Fonte: <http://www.solarcitycopenhagen.dk/>
- 3) Glass-Glass module with different transparency.
- 4) Photovoltaic roof, sistema Hemera (Thesan S.p.A.) www.thesan.com
- 5) Refurbishment of Castello di Acquabella (Toscana). Tegola Fotovoltaica ceramica DF2/DF3. Fornace Fonti s.r.l. Area industria ceramica. <http://www.lategolafotovoltaica.it/>
- 6) Thin film module, vetrina Schuco alla Fiera Made Expo 2010 (Milano). Fonte: ©Cristina Polo.
- 7) Multicristalline silicon module, Fiera Made Expo 2010 (Milano). Fonte: ©Cristina Polo.
- 8) Armadillo (Progeo Sas). CSolar Thermal collector. www.progeo11.it

Some technologies that are highly visible today, such as aerials, lightning rods and other technological equipment, which have been integrated into building coverings because they are considered as “necessary”, have now become generally accepted, although they often contravene the protection, conservation and preservation constraints of a historical building. In any case, materials are being developed and in the future there might be new forms and elements that can be integrated appropriately, and with reduced visual impact, even into buildings of architectural value. It is also very important that the designer understands the diverse qualities and the unique features of each photovoltaic element, in terms of both performance and aesthetics, in order to increase the number of potential choices and solutions.



Fig. 26 – Pictures mad at the Fiera SolarExpo, Mostra Convegno. Verona (Italia) 2012. Special modules for building integration.

PV systems designs should consider all the energy production aspects related to the location and orientation of the receiving surfaces, the inclination, the technology used, the shading effect, etc. In fact, the roofs and facades of these constructions are often already occupied by a series of protruding objects, such as chimneys, skylights, technical volumes or additional volumes that can cast shadows on the receiving surfaces. When drawing up the charts for this part of the project, all the case studies were considered individually

In order to define the criteria for correctly integrating renewable technologies (solar photovoltaic and thermal), the starting point was the methodology proposed by the work group of the SuRHIB project¹⁴ [46], which defined a series of architectural and scenic evaluation criteria related to the installation of solar and photovoltaic panels in historical town centres in Ticino. These criteria were applied to one particular case study (the old town centre of Bellinzona-TI).

Briefly, these criteria are:

- Consider the inclination and orientation of the pitch
- When possible, put together uniform shapes

¹⁴ CCEM SuRHIB Project: Development of Technical and Architectural Guidelines for Solar System Integration in Historical Buildings - Determination Of Solar Energy Opportunities. December 2012. ISAAC –DACD– SUPSI

- Respect the contours of the roof
- Integration methods for panels on built constructions
- When choosing the colour, consider the whole building
- Group the panels together

An example assessment chart, identifying the criteria and guidelines, is shown below.

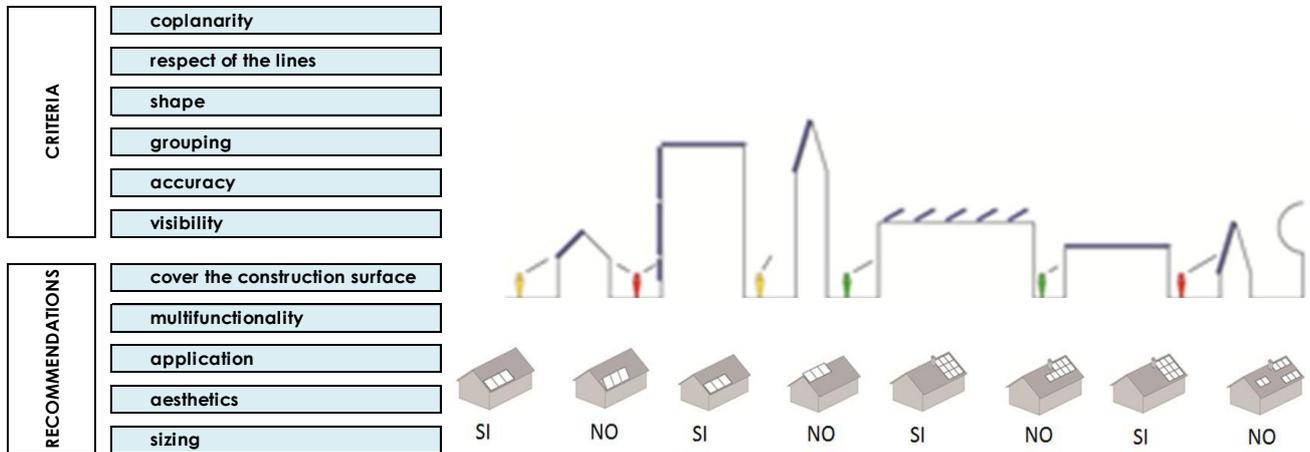
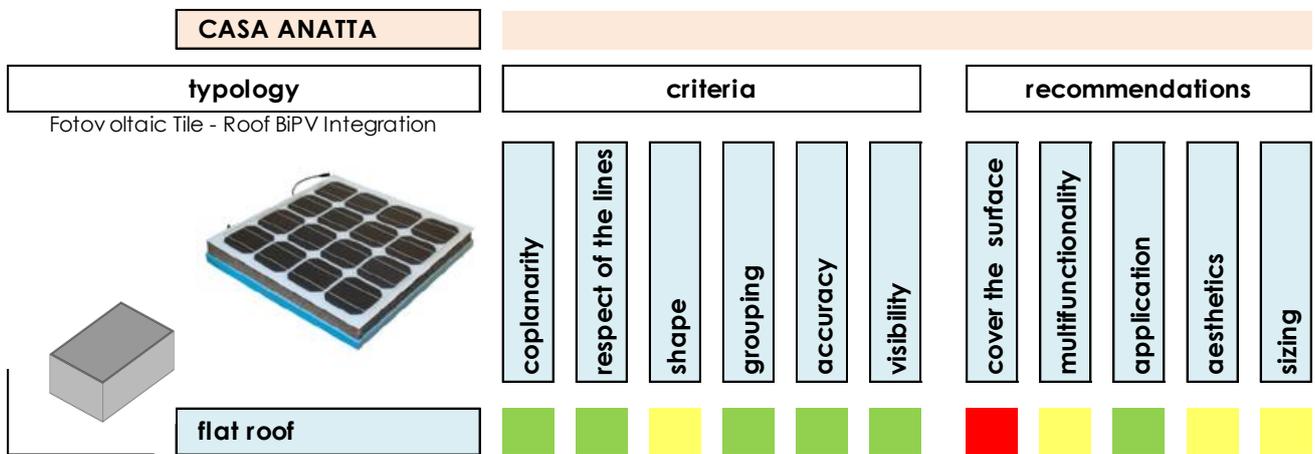


Fig. 27 – Criteria for solar system integration.

In function with the renewable technology utilised, and with the photovoltaic device considered, an analysis is made of the design solution integrated into the historical building in question. The criteria and recommendations are also classified in accordance with the feasibility of the proposed measure.



- The criteria / recommendations are easily respected. A good planning is always mandatory.
- The criteria / recommendations can be respected without difficulty if the installation is taken into account during the very first stages of the planning process. A thorough approach is also needed (check for: more suitable technology, constructive and technical features of the building, architectural and aesthetical characteristics, type and quality of the surrounding, visibility).
- The criteria / recommendations can be respected but it is necessary to carefully consider certain aspects (see the specific criteria / recommendation page for more information).

Fig. 28 –Example of possible solar system integration criteria.

In this approach aiming at the correct integration of solar technologies, it is first of all essential to consider a number of aspects: (CCEM SuRHiB Project) [47]:

- Define the constraints making a negative impact on a solar installation (Criteria) DIFFUSION OF THE TECHNOLOGY;
- Specify general rules that are re-interpreted for the case in question (Guide Lines) OBJECTIVITY;
- Importance of how solar integration is perceived (Evaluation) ACCEPTABILITY.

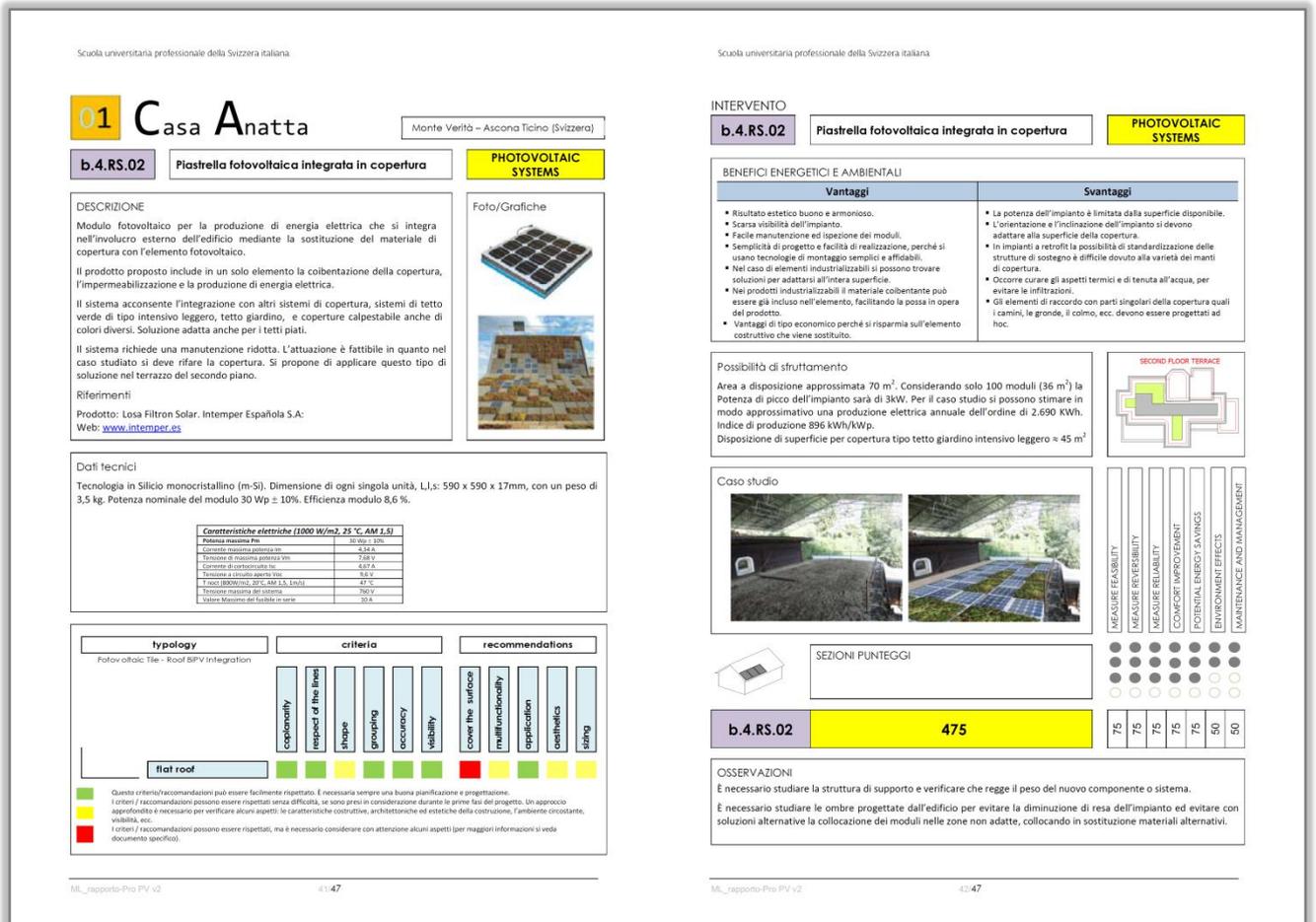


Fig. 29 –Renewable energy system are also considered in the work (Section b.4.RS).

A specific product has been proposed for each solution (as an example, and therefore not binding), and described in the chart, which provides the technical features of the product, shows where the element is integrated into the building, lists the potential advantages and disadvantages of the system and gives an approximate calculation of the energy produced.

C. Global energy assessment charts (PHASE C)

These charts summarise the final results in order to obtain a global, tangible and clear overview of the benefits brought to the building by the proposed solutions.

c.1 Global energy summary assessment chart (c.1.FR Final Energetic Results Analysis)

This chart summarises all the proposed solutions in terms of envelope and installations, and considering the possibility of integrating renewable energy into the project. The solutions viewed as minimum target, and that are feasible without being invasive, are coded green. Those that in terms of finances or of current feasibility (incompatibility with the existing building) are viewed with greater uncertainty are coded yellow or red, even if they could potentially generate greater energy-environmental benefits. These solutions currently require further technical study before being implemented but could be potential alternative solutions in the future.

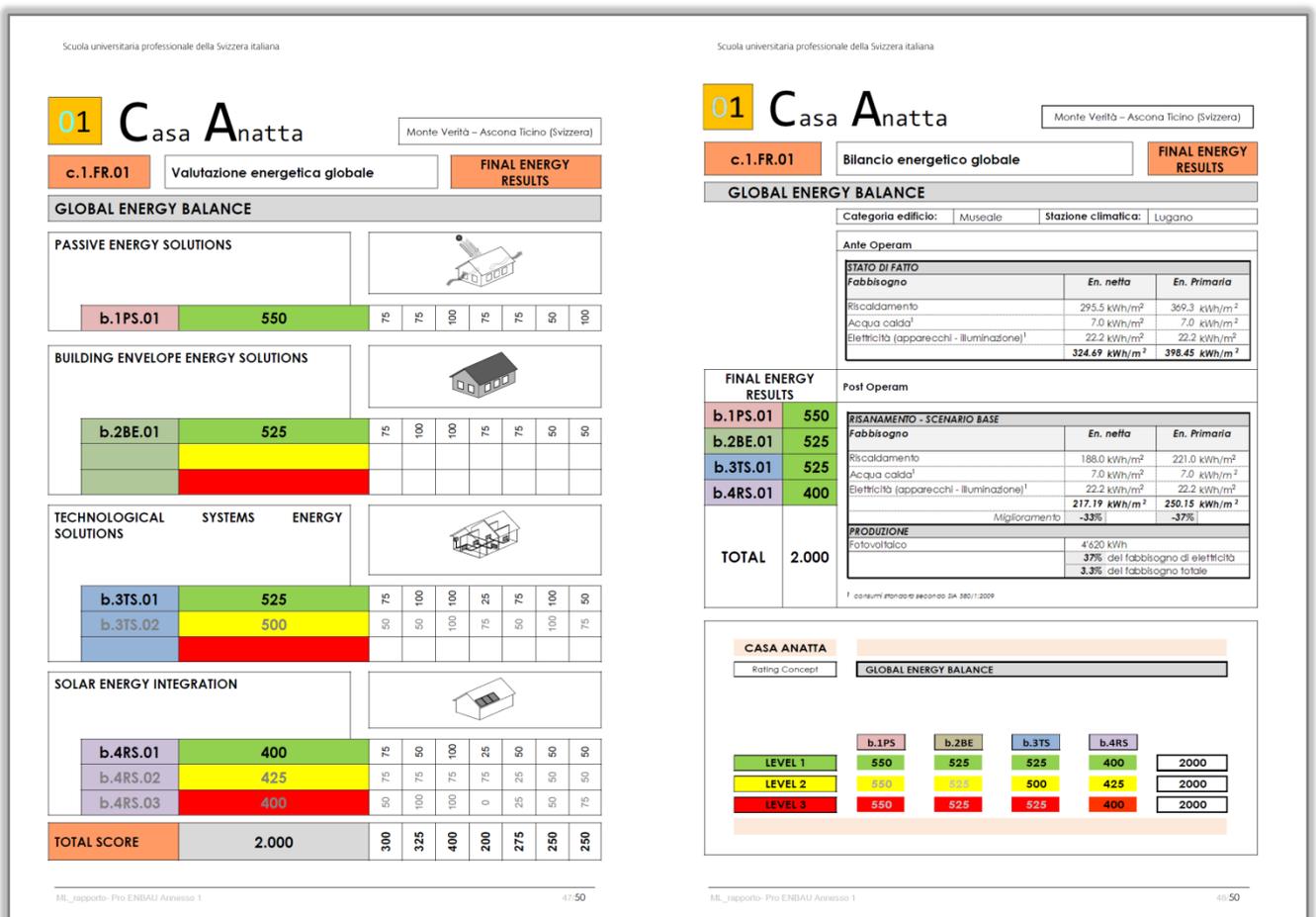


Fig. 30 – Last part of the charts is dedicated to the resume of the results, here is presented an example (Section c.1.RS).

Each solution is coded in accordance with a pre-established scoring system. The final energy balance is compared with the initial situation so the benefits obtained can be checked immediately. This methodology produces, contemporaneously, solutions that can be compared in function with their level (high, medium or low).

When, for some of the categories, some level of intervention is missing (mainly yellow or red) and basic quality standard solutions are the only ones possible (code green, level 1), the total number of points considers those of the level immediately below considering a minimum level to reach. The red

boxes, representing solutions with greater impact on the building and therefore on its artistic value (as explained above), do not always turn out to be the best solutions according to the various criteria analysed and so may score even lower than the previous levels (yellow or green boxes).

The system is therefore scalar, modular and expandable in function with the quantity of solutions that are possible and considered for each case study.

The ratings of the individual criteria make it possible to consider each aspect separately for each solution. It is therefore possible to discover the impact of each assessment criterion in terms of improving the energy efficiency of the building. These criteria are shown in Fig. 31:

- FEASIBILITY MEASURE
- REVERSIBILITY MEASURE
- RELIABILITY MEASURE
- COMFORT IMPROVEMENT
- POTENTIAL SAVINGS
- ENVIRONMENT EFFECTS
- MAINTENANCE AND MANAGEMENT

The decision-making process can therefore be executed in function not only with the final rating of the solution, but also in function with each criterion analysed.

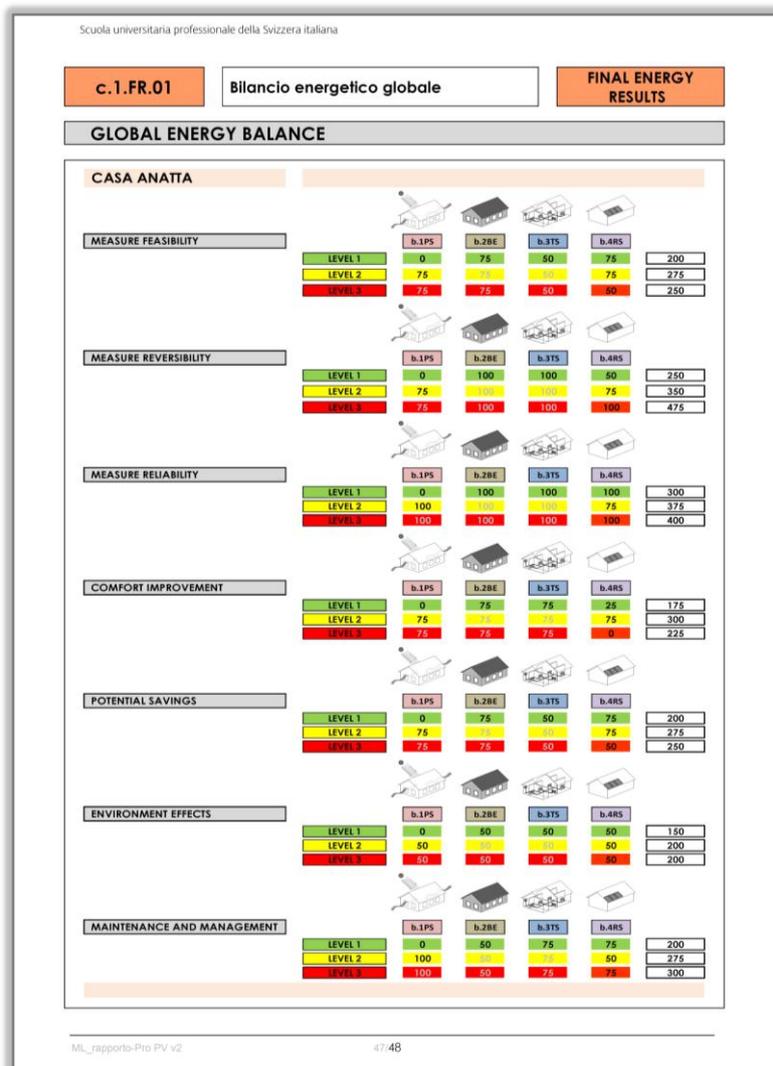


Fig. 31 – Global energy balance chart, divided in different points (Section c.1.RS).

7. Results

During the analysis of the critical aspects (Building Diagnosis) was evinced that the historical value of the building can change a lot from building to building and it depends strongly from the degree of conservation and of maintenance. The different restoration or changes during the building life can also influences the architectural value of the building.

7.1. Identification of different building typologies

The three case studies analysed within the ENBAU project provided the opportunity to apply the proposed methodology to examples with different features and problems, and, in particular, with varying levels of freedom in terms of permissible solutions.

In particular the three building, casa Anatta, casa Manetti and Hotel la Sage, diverges mainly in the degree of conservation and presents three different history: while casa Manetti was maintained as it was built with only minimum changes on the installation levels, casa Anatta and Hotel la Sage, in a different way, undergone many transformation both in term of uses (residential to museum on one hand and residential to hotel on the other hand). This affects the degree of possible intervention and of preservation. The investigation of the transformation of casa Anatta took a lot of time and many references had to be reviewed in order to understand where is the original value of the building and what are the main element and characteristics to be preserved. For casa Manetti this process was easier and more straightforward. For Hotel la Sage, differently, the different transformation occurred during the buildings life are well obscured by the earlier modification and by the creation of new volumes and services.

Preserved and only slightly modified during the time	Partially preserved and modifies in present day	Not preserved and with many transformations
		
<p>Building remains a residential house. It was continuous used during the time. Not modified but maintained where needed. The proportion of elements of low historical value is greater, most of them are in good condition or slightly damaged. Almost all elements (opaque wall, transparent element and equipment) contribute to the high energy demand of the building. In general there is a great potential for improvement, especially in the building. Comfort is a problem due to the large volumes of the spaces.</p>	<p>Building changed its use. It was continuous used during the time. Was modified in order to change the use. The proportion of elements of low historical value is greater, most of them are in good condition or slightly damaged. Almost all elements (opaque wall, transparent element and equipment) have been renovated during the time. Further improvement can be done to achieve a lower energy demand of the building. In general there is a great potential for improvement, especially in the building services (HVAC).</p>	<p>Building serves as a museum use not continued, the proportion of elements of high historical value is considerable, most are in poor condition or slightly damaged. Almost all the elements (opaque wall, transparent element and equipment) are degraded and contribute to the high energy demand of the building.</p>

With regard to the implementation phase and the proposal charts, thanks to the implemented design methodology, general conclusions on the possible amelioration (both for the envelope and for the system) can be extrapolated.

A list of recommendations and design advice can be draw up to increase the energy efficiency of historic protected buildings.

These issues are as follows:

Strategies and passive energy solutions contribute significantly to improve the energy efficiency of the building without invasive and intrusive intervention. They are however not always possible. These considerations are always related to the specific building (affected by the shape, volume, orientation) and by the climate where it lies.

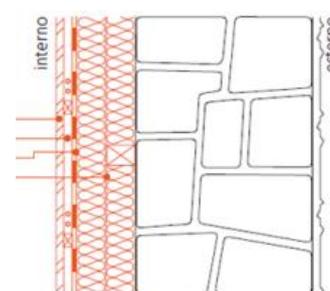
7.2. Identification of possible technical interventions

With regard to the improvement measures applicable to the building envelop to increase the energy savings and comfort, the analysis carried out reveals that by applying carefully modern technologies and materials, you can get substantial energy savings in buildings. You can achieve this also without having a destructive impact or without causing an unacceptable change in the structural elements of the building that are of particular historical/architectural importance and worthy of protection. This emphasizes the fact that, if the interventions are performed according to the state of the art, the indoor comfort could be comparable to that of a contemporary building.

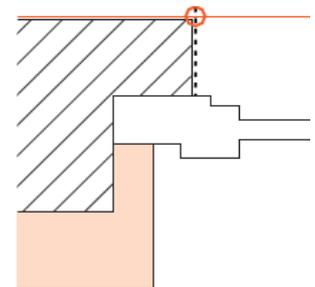
The evaluated case studies suggest this elements:

- adopt when possible the use of highly performing thermal insulating materials, in order to reduce the thicknesses of the new layer;
- assess the possibility of placing the insulation layers inside the walls instead of outside when it is not possible or acceptable to change the architectural design of the exterior facade (if the historical importance of the external walls and the design of the façade is not greatly influenced, you may want to consider an external thermal insulation);
- pay particular attention to the design of the construction details and the placement of vapour barriers in order to avoid thermal bridges and condensation interstitial and surface that can lead to staining or mold;
- if there are any windows of historical importance, it is possible to evaluate the extreme possibility of installing new windows inside and keep the old ones at same place. It should be evaluate carefully the installation of the new windows (with probably a greater air tightness than the previous ones) without isolating the walls because it could lead to the formation of mold and stains (thermal bridge). It is advisable in this case to ask the advice of a physical construction.

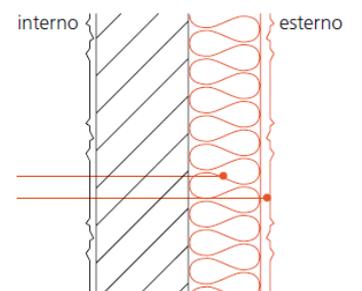
Internal insulation



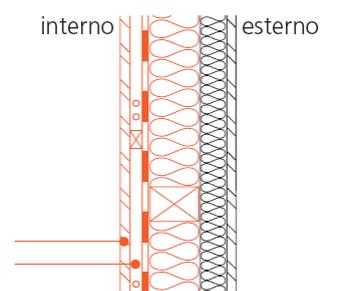
Internal insulation: solution thermal bridge of window



External insulation



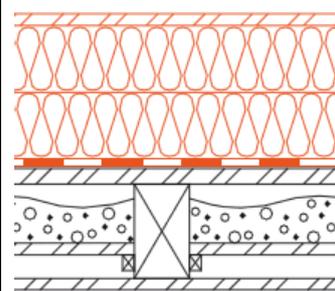
Layers inside the wall insulation



Triple glazing window



Slab insulation



Roof insulation



Floor insulation



As regards to the building services, the analysis carried out shows that the application of a modern plant concept, that allows to obtain good internal comfort in every room, is often difficult. Typically, the buildings are not equipped with a hydraulic distribution system for the heat and also thermal losses, due to the poor isolation, are considerable. In some cases, even if it would be feasible to install a new hydraulic distribution, if the building (mainly the heated zones/rooms) is not well thermal insulated, the considerable thermal losses causes that the required thermal power for heating is too high, making difficult, if not impossible, the use of renewable energy sources (for example heat pumps).

In the case of buildings where the existing system is recent, or update, we can only advise future restructuring actions to be taken when the heat source (such us the boiler) reaches the end of its life. This situation is important to plan a maintenance program over time: at the beginning thermal insulate the house and then replace the boiler with a service unite with lower power and using renewable energy (wood chips, pellets or heat pump).

The following indication can be resumed:

- If possible, plan the interventions in different stages which include: as first insulation of the envelop, then p update the building services so that it is correctly sized (with consequent energy and cost savings);
- Keep in mind the principle that the more the flow temperature of the heating system is low, the more the efficiency of the heat pump is high. If the building is poorly or incompletely isolated it is advisable to consult a heating engineer designer that will assess the feasibility of an installation of an efficient heat pump. With the use of other renewable energy sources, such as wood chips and pellets, you can get high flow temperatures. It is recommended, however, to isolate the building because otherwise, although the boiler is able to reach high temperatures, it will be necessary to provide substantial volumes of fuel (wood).

Nowadays the installation of direct electrical heating is no longer permitted (for cantonal regulations) and in case you want to opt for this solution you will need to apply for a derogation to the competent authorities. However, this solution may be viable in case of buildings which is not possible to realize

a hydraulic distribution system due to the historical protection of the house. In this case at least plan to insulate the building to decrease the energy demand. Identification of different building typologies

7.3. Installation and integration of solar systems

The existing housing stock is a repertory of very heterogeneous constructions which not only have to fulfil different needs but which can also be identified according to building techniques, the year of construction, the materials used, the representative status and, of course, by the architecture. Consequently, it is necessary to define a dynamic approach that can be used and adapted depending on the specific situation.

Different building parts can be considered:

- Roof
- Façade/Envelop
- Decentralized plant

While the first two installation typologies focus on the building itself, the last typology allows the preservation of buildings where historical or cultural reasons have to be preserved.

Respect for historical heritage, protection of the landscape and the employment of renewable energy can and must be conciliated, especially in specific contexts like historical protected buildings.

In order to prevent an indiscriminate and uncontrolled use of solar technologies and, at the same time, to invest economic and space resources in the most effective possible way, it is necessary to find a proper balance, or compromise, between technical and aesthetic requirements. The existing housing stock is very heterogeneous. Constructions have to fulfil not only different needs but can be categorized also according to building techniques, year of construction, materials, components, representative status and, of course, architectural quality.

While there exists clearly a technical possibility for the integration of PV and solar thermal on a building façade, most of the potential is intrinsically related to intervention in the roof, especially in sensitive urban environment. The roof typologies identified are listed in the following table. Additionally, in order to enhance the overall architectural design quality and durability of solar installations, it is necessary to define, first of all, the formal constraints which can negatively affect the project, and then to identify appropriate solutions. Six criteria, focusing on shape and emplacement of the solar panels are considered and described in the following table.

Table 1: Roof typologies identified.

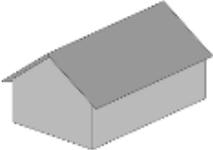
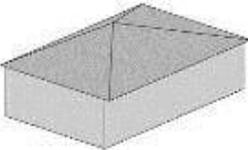
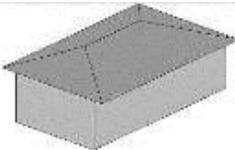
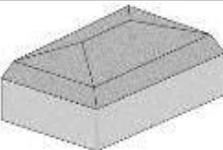
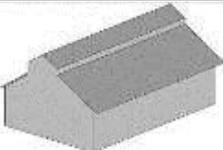
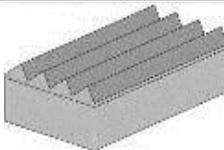
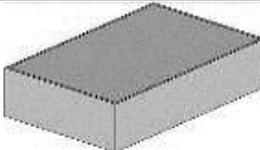
Skillion roof	Gable roof	Pyramidal hip roof	Simple hip roof
			
Mansard roof	Monitor roof	Saw-tooth roof	Flat roof
			

Table 2: Criteria for the overall design quality and durability of solar installations.

Criteria	Description
<i>Co-planarity</i>	Solar system has to be installed on the same plane of the building surface.
<i>Respect of the lines</i>	System has to respect the lines which provide the outline of the construction, particularly in the upper part
<i>Shape and grouping</i>	Random solar installation has to be avoided
<i>Grouping</i>	Modules have to be grouped together in an ordered way
<i>Accuracy</i>	Solar panels added to or integrated into a building must be perfectly connected or inserted into the construction element
<i>Visibility</i>	The decision to install a solar system on a (protected or not) building must consider the environment in which it is located

This criteria are the basis for a high quality solar installation, but high architectural design quality for BIPV or Solar thermal is a necessity.

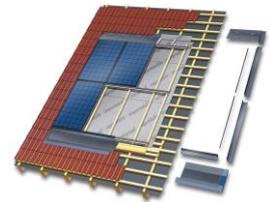
Today a number of innovative and advanced products for building integration that can be used in sensitive built environment are present on the market. These products can be used, for example, in historical centers and can be acceptable also in naturalistic contexts where buildings need energy supply. They are characterized by different technology, performance, morphology and can constitute high quality assembled building envelope components. We can consider as BIPV the products that effectively replace building envelope components (an exhaustive BIPV product database can be found at www.bipv.ch).

Some examples of these products are reported and proposed for the case studies and are resumed here.

Solutions for Flat roofs



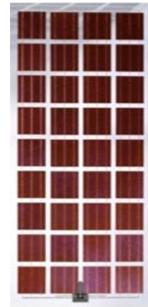
Solution for tilted roofs



Solutions for windows



Solutions for windows, balcony or terrace



Solution for annexes or pergola



The use of solar thermal systems in historic protected buildings, requires always deep analysis of the pre-existing building service, not only from the point of view of technical integration into the building and from aesthetic factors. The use of this type of installations for domestic hot water or as a contribution to the heating system often implies the correct integration with the existing system, that is not always possible.

Factors such as the shadows of neighboring elements (parts of the building, roof elements such as chimneys, antennas, projections and the like) or far away such as trees, nearby buildings or mountains must be considered carefully to determine the correct size of the system to avoid losses in energy production.

When the preservation of the existing surfaces, either rood or façade, is mandatory, it is envisaged to add, if possible, the solar system on the building with a removable substructure or to evaluate the possibility to use annexes construction (garage, deposit,...) as existing structure for solar installation.

When dealing with the use and the installation of PV in the built environment there are preservation problems, which very often are ignored by installers and enterprises that look at the cheapest and most effective solution. This condition, together with a maze of administrative problems, is a serious obstacle to the use of PV in cities (and buildings) as well as in landscapes. We know this result is not new, but the innovative aspect that emerged from the discussion within the project is that we have now appropriate methodological tools and suitable PV products to take up the challenge of using PV in a good relation with the pre-existing. What is still missing is a culture that sees PV as a design issue. On one side, in fact, technicians cannot know the points of preservation; on the other hand officials who are responsible for preservation ignore the possibilities that solar energy and solar products offer. As a consequence they are not able to give advice to improve the quality of the projects, and they cannot but reject what seems to threaten the preservation of our cities and landscapes. This culture is the common effort that all of us should take up in the next years.

8. Conclusion

This research project was fundamental for identifying the factors and processes that lead to energy efficiency improvements when redeveloping existing historical buildings. The final result, both architecturally and in terms of cultural heritage protection and energy efficiency, was due to the willingness to compromise and to the technical know-how demonstrated by all the players involved in the project.

When implementing solutions aiming to improve the energy performance of a building belonging to a country's historical and cultural heritage, it is necessary to evaluate how to reduce consumption in function with conserving the historical identity of the structure. These energy improvements are desirable but cannot always be implemented in such a way as to reach the highest standards.

If artefacts are to be conserved and maintained correctly, buildings of this type must be provided with appropriate environmental conditions and optimal energy performances. However, prior to the redevelopment work, it is important to conduct a careful study considering simultaneously all the causes – not only environmental - of degradation and malfunctioning, while also focussing on the aspects associated with building management, comfort, current use and conservation of the collections housed in the structure.

The task of drawing up the action strategy requires multidisciplinary expertise in order to identify needs and priorities, and to find the resources for the solution. The starting point consists of analysing the current status, which is conducted by inspecting the premises, gathering data and examining the management procedures.

Owners - both public and private - of historical monuments are chiefly responsible for their protection, although various private organisations give notification regarding the requirements associated with the protection of cultural heritage assets and of the countryside, at the national, regional and local levels. Cantonal offices appointed to this area are responsible for all cultural heritage protection measures¹⁵, but may delegate these responsibilities to municipal offices. The Federal Commission for the Protection of Cultural Heritage has expertise in this area, and answers basic questions related to the protection of cultural heritage items. These official bodies, together with the designers and specialists in all areas, make it possible to achieve the project objectives. The project has clearly demonstrated the importance of close collaboration between the public and private bodies that, right from the start, must participate in a renovation and energy redevelopment project for a building that is part of the cultural heritage of a town or of a country. An interdisciplinary work team, where the bodies in charge of protecting the building, the architects who have to implement the solution, the engineers and the installation experts, the renewable and solar energy experts, together with the clients and owners of the property reach a consensus and decide on the measures appropriate to the specific case.

The methodology developed in this project considers a global energy concept that examines the aspects linked closely to the climate and the site, as well as those tied to the building itself and to its unique features, and that proportions a useful instrument for the decision-making process, based on different multi-criteria analysis that will help identify the potential strategies for the renovation/reconstruction or energy redevelopment of historical buildings belonging to our cultural heritage. This methodology considers three different decision-making levels: understanding the critical aspects and the environmental and social / cultural requirements; the aspects closely related to concrete and effective solutions; the aspects closely related to administrative procedures.

The summary charts propose an objective comparison of the solutions in terms of the current condition of the building, and constitute a useful and immediately accessible guide to consult when

¹⁵ Article 78 of the Federal Constitution of the Swiss Confederation specifies that the Cantons are responsible for protecting nature and the countryside, and that this also involves cultural heritage protection.

selecting or checking projects that have been executed or that will be executed. The charts, which are the main part of the work, provide important information regarding the energy improvement techniques for each building on which the solution will be implemented. Of course, these charts do not replace the necessary, specific studies that must be conducted in order to work on a historical building, but they provide valid assistance in both the preceding, decision-making phases, and also once the solutions have been implemented, when they act as a tracing and recording control tool that enriches the database of this type of building. This methodology, and the utilization of the charts, are helpful to various users: the designers, the owners and the officials from organisations delegated to approve and control alterations to historical buildings.

The redevelopment solutions considered, and divided into pre-established colour-coded categories, also make it possible to prefer certain solutions in relation to the objectives and needs of individual projects: according to the features of each historical artefact, preference will be given to the feasibility of the solution, compatibility with and respect for historical features, reversibility, energy benefits, the environmental impact and the future administration/maintenance and conservation aspects. The final scoring system makes it possible to evaluate the parameters considered as fundamental for work executed on historical structures; parameters that can be used to evaluate subsequent solutions.

The proposed methodology and charts can be used to achieve quality standards: at times the expectation is for minimum compulsory requirements to be met, while on other occasions quality objectives are to be pursued by means of a pathway dedicated to growth and improvement. In fact, charts with 3 levels (the minimum standard is coded green) have been established for all areas in function with the impact on the building, but subsequent work can be scheduled for potential improvements (coded yellow or red). The validity of this method lies in the fact that it is a flexible, scalable system that grows in function with the number of solutions proposed, and with the capacity to take on different but effective forms for individual or global solutions, while considering all the aspects related to the building.

The system developed has highlighted the fact that even minor alterations can generate significant results in improving the level of comfort and reducing the energy consumption in buildings of this type. It is interesting to note that, in accordance with the pre-established criteria, the scoring system both evaluates the performances of the redevelopment solutions proposed as examples of the methodology developed in the project and that meet the initial objectives of reducing the energy requirements of these buildings, while also making it possible to highlight the most important aspects related to respecting the building and implementing the solution, with the aim of preserving and conserving the historical building and at the same time considering improvements to its energy performance.

The models for forecasting the effective energy and environmental benefits of the various scenarios considered for each case study will then be checked once the work has been completed and the measures implemented. Correspondence between the design phase and the definition of the implementation methods and the execution phase will show the extent to which these alterations affect the real situation and if it will be possible to evaluate the validity of the methodology proposed in this paper.

Renovation work conducted on historical buildings situated in city centres, and on cultural heritage buildings, together with the installation of new technologies (e.g.: thermal solar and photovoltaic) must be compatible with the surrounding countryside, with respect for the environment and for the cultural values represented. In order to cope with the challenges set by today's society, and to meet local and international legal / regulatory requirements, there must be more in-depth discussion between all the technical fields and all the parties involved in any work to be executed on buildings of historical and cultural heritage.

The new political scenario is expected to promote a growing use of renewable energies, particularly in the electrical energy sector. In view of the criteria and recommendations developed in the previous chapters, and of the issues discussed, it is also possible to consider the question of

integrating renewable technologies into the built environment (even technologies that may make a greater impact on the aesthetic value of the historical heritage: solar, thermal and photovoltaic), with an appropriate level of understanding regarding the problems, resources and existing technologies. Numerous solar systems currently available on the market can also be integrated into historical structures and in an urban context, without compromising the asset, but rather in the awareness that any change alters the nature of the building, and with the constant aim of responding to the global necessity for a more sustainable and less energy-devouring world.

The first step to overcoming barriers successfully is to better understand the processes for both historic preservation and solar PV project implementation and to work with professionals in each sector to receive appropriate buy-in and guidance. Establishing criteria for each sector assists in achieving a successful project. Solar PV projects can be assessed based on performance, cost, and economic payback of the system. Historic preservation can be assessed based on impacts to the historic character of the site, economics, and energy savings.

Ultimately, historic preservation and solar PV work toward achieving a shared objective: resource conservation. Educating key stakeholders and tracking project implementation is imperative to achieving success.

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