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Energy Efficiency and Energy Management in Cultural Heritage

Case Studies Guidebook

. Energy Efficiency and Energy Management in Cultural Heritage



IMPRESSUM

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INTRODUCTION

Preservation of building heritage and improvement of energy efficiency are important aspects of sustainable development. Building heritage is part of the overall cultural heritage that bears cultural-historical significance and constitutes a component of human environment. Protection and preservation of building heritage is an obligation rooted in every community's sense of responsibility to cherish and safeguard its cultural goods.

Simultaneously, energy and environment issues as well as the fact that buildings comprise the largest single energy drain with the biggest energy savings potential oblige us to systematically reduce energy consumption in buildings. Along with thorough and necessary modernisation and adjustment to current building requirements and life standard, energy efficiency improvements made during renovation of heritage buildings extend the buildings' life expectancy. In the long run it also reduces expenses for the buildings' owners and users, increases the occupants' comfort and quality of life while positively affecting the environment and the buildings' value.

In the Republic of Croatia energy retrofitting of buildings will make up the largest part of construction activities in the next few years, due to clearly defined energy savings and environment protection goals. Therefore, it is necessary to develop guidelines for renovation of cultural heritage buildings for the purposes of their energy efficiency improvements while respecting conservation requirements and protecting building heritage. This Guidebook includes works and examples presented at the International Conference on Energy Management in Cultural Heritage (2011) held in Dubrovnik. It represents an excellent first step towards establishing national guidelines and recommendations for energy efficiency improvement during building heritage renovation. A multidisciplinary approach to energy renovation and synergies between building heritage and application of contemporary principles of energy efficiency is the only correct approach to systematic management of existing buildings.

In accordance with conclusions reached at the Conference, the Croatian legislation introduced mandatory regular energy audits and certifications of heritage buildings, thus providing the first and necessary step towards the implementation of energy efficiency measures in those valuable and important buildings.

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. Legislation

1. LEGISLATION

Energy efficiency and building conservation are two important aspects of sustainability. The key lies in balancing the historical value of buildings, implementing efficient energy consumption and satisfying the needs and comfort of their occupants. The implementation of energy efficiency measure within cultural heritage requires creative and advanced technological solutions, new tools, education and training, a change in behaviour of various building occupants, adequate building management, and a multidisciplinary approach.

Energy management in cultural heritage is a unique and innovative subject in the field of sustainable development. Until recently, renovation and adaptation of historical buildings for the purposes of preserving their cultural heritage have taken place with minimal attention to energy efficiency and environment protection. This manual aims to show that it is possible to achieve both. It helps to view heritage conservation and reduction in energy consumption as two faces of sustainable development.

Legislation on energy performance of buildings often completely excludes heritage buildings because it is believed that their cultural value should not be compromised or threatened by new regulations on energy performance of buildings. For example, European Union's Energy Performance of Buildings Directive (Directive 2010/31/EU) sets energy performance requirements for new and existing buildings. Still, it is left to Member States to implement the provisions of this Directive into their national legislation. This usually results in the exclusion of heritage buildings - which often comprise more than 25% of all public buildings - from national legislation making it difficult to achieve overall energy efficiency in buildings or to obtain sustainable preservation of heritage buildings.

This chapter gives an overview of legislative examples and measures presented at the Dubrovnik conference on Energy Management in Cultural Heritage (2011). These examples clearly show that legislation which include financing schemes can have a major influence on implementing energy efficiency measures in heritage buildings. It is very important to establish national guidelines for energy renovation of cultural heritage buildings.

1.1. CROATIAN EXPERIENCE

The fact that new strategic plans and directives are frequently being brought throughout the EU for the purposes of reducing energy consumption clearly indicates that a reaction in the field of building design and construction is urgent and inevitable. By year 2020 energy consumption is required to be reduced by 20%. On the other hand, concrete goals for energy building renovation and construction of buildings with almost no energy consumption are required to be set. Also, the fact that renewable and alternative energy systems in buildings are seldom used is being brought to attention and they are now required to be considered in both construction and reconstruction.

The Republic of Croatia has three basic laws regarding analysis of cultural heritage buildings:

1. Law on the Protection of Cultural Heritage (NG 69/99, 151/03; 157/03, 87/09, 88/10, 61/11, 25/12, 136/12)
2. Law on energy end-use efficiency (NG 152/08, 55/12)
3. Law on Physical Planning and Construction (NG 76/07, 38/09, 55/11, 90/11 i 50/12)

Added to these three basic laws are a number of regulations and technical provisions. Also, this February the Republic of Croatia adopted a National Energy Efficiency Action Plan which has been in the making for a long time and which puts emphasis of systematic energy renovation of existing buildings. In

order for Croatia to achieve energy saving goals set forth in strategic documents, the National Plan states that 3% of existing buildings will have to undergo energy renovation. This amounts to:

- Approximately 3.7 million m² of residential buildings per year,
- Approximately 285,000 m² of public buildings,
- Approximately 0.98 million m² of non-residential buildings in the commercial service sector per year.

If 3% (i.e. 5 million m²) of building surfaces are renovated annually, while specific annual consumption of thermal energy for heating is reduced from 200-250 kWh/m² to 25-50 kWh/m², and 10% of newly constructed buildings are net-zero energy buildings, together with stricter law regulations, the final energy savings in 2020 will amount to 20.69 PJ. This will bring us closer to the goal of 22.76 PJ required energy savings in 2020. These goals

. Legislation

are very ambitious and unattainable without systematic and continuous approach to implementation as well as significant financing mechanisms.

In this context the importance of establishing national guidelines for energy renovation of cultural heritage deserves special emphasis. An energy audit, determining of a building's energy condition and issuing of an energy certificate form the first step towards reduction of energy in heritage buildings. For this reason, the newest energy efficiency legislation amendments include the requirement for energy audits and certificates of heritage buildings. Quality implementation of suggested energy efficiency measures requires quality design of project documents with the approval by conservation services. Renovation should be based on an integral approach in order to achieve expected results in energy savings and to modernize and adjust existing buildings to contemporary construction conditions and living standards. This has to be taken into consideration while designing projects for energy renovation of heritage buildings.

1.2. ITALIAN EXPERIENCE

Italian experience on energy requalification of buildings is mainly based on tax incentives. In 2007 the government promoted a specific measure, introducing a 55% tax allowance, with a special VAT at 10%, an incentive higher than the one for traditional interventions of building renovation, which is at 36% tax allowance.

Italian state appointed ENEA to manage and monitor tax deductions for energy requalification.

At the end of 2008, it was clear that this policy yielded positive results, which provided a strong push forward for continuing such a scheme for the years 2009-2011.

Concerning technical contents of the 55% tax deduction requests, the main elements are:

1. prevalence of isolated interventions (in particular boiler and fixture substitution) compared to integral interventions;
2. a very limited number of interventions involving building envelopes.

The Financial bill of 2007 introduced incentives for interventions aimed at implementing energy efficiency measures in existing buildings in the form of tax deductions of 55% of the total amount spent for such interventions in 2007.

It is explained in detail which kinds of interventions are eligible to obtain a tax deduction:

- complete energy renovation of building;

- interventions on horizontal opaque structures, vertical opaque structures and windows with fixtures;
- solar panel installation for hot water;
- heating system substitution with condensation boilers.

The "building decree" clarifies that the deduction can be obtained by private companies or natural persons.

Monitoring of the requests and evaluation of the achieved results regarding energy, environment and economics, as well as providing of technical support to the requesters, were left to ENEA. A database of received requests provided knowledge of the number as well as the type of people taking advantage of the incentives. Furthermore, it allowed classification of the related investments and determination of the national revenue cost of the incentives as well as their results in terms of MWh of energy savings and tons of CO₂ reductions. The 2007 campaign recorded a considerable participation. From 26 February 2007 to the documentation submission deadline on 29 February 2008, approximately 106.000 requests were recorded. (1)

White certificates

"White certificates", also called "Energy efficiency credits", certify that energy savings requirements through the application of efficient technologies and systems are met. The Energy manager issues them on the basis of certifications of savings given by The Regulatory Authority for Electricity and Gas. A certificate equals savings in the amount of 1 Ton of Equivalent Petroleum (TEP), which is the standard unit used to express all the energy sources considering their calorific value. The projects aimed at obtaining the certificates are incentivized by the authority.

Italy is the first country to introduce white certificates (2001), followed by France and Poland, as a tool to meet goals of energy efficiency. In other European countries there are other models for quantifying savings from energy efficiency measures in industry (i.e. Denmark, Ireland, United Kingdom, Flanders region in Belgium).

The Directive 2006/32/EC explicitly lists the white certificates among tools that Member States can use to meet the energy savings goal introduced by the Directive itself and envisages that, based on the goals achieved in the first three years, the Committee shall consider the possibility to introduce a market approach based on white certificate trading to the European Community. The experience of Italy in developing quantification methods of energy savings with the white certificate scheme continues to be investigated by the technical committees created for implementing the Directive. (1)

1.3. GREEK EXPERIENCE

Renewable energy investments (REI) in historic environments in Greece are controlled by a strict legislative framework. Ownership, as well as protection, of monuments and sites within the territory of Greece recognized as national heritage is in the hands of the state. The responsibility for heritage protection lies in the Ministry of Culture and Tourism; even in cases in which other government bodies (such as the Ministry for the Environment, Spatial Planning and Public Works) are also involved, the Ministry of Culture and Tourism retains the final responsibility. Heritage protection is centrally administered: the Ministry sets the policy, while local offices implement this policy at the local level. Heritage protection has to be taken into account and incorporated within any REI (as with any type of urban, environmental and development project), in the context of sustainable social and economic development of local communities and in accordance with the principles of 'integrated' and 'holistic' conservation. On this basis, a REI presupposes the conduct and acceptance of an Environmental Impact Assessment (EIA). (2)

1.4. GERMAN EXPERIENCE

For years the European Union as well as national and federal (Länder) administrations in Germany are engaged to support energy efficiency measures by law, to realize the ambitious aims of the EU energy efficiency legislation and the energy policy concept of the German government.

In current plans of the Federal Government of Germany a "bonus for replacement buildings after demolition of old buildings" is being discussed, which will grant a scrap bonus for replacement buildings after the demolition of buildings, unsuitable for energetic modernisation to the standards requested. That in turn will create unacceptable difficulties for owners of built monuments. On the one hand, owners of built monuments are bound to preserve their property by the Monument Protection Law. On the other hand, a suitable support programme for energetic modernisation, in a monument friendly way, does not exist. For example, domestic promotion by the KfW Bank – the promotional bank of the Federal Republic and the federal states, which has a special responsibility for sustainable improvement of the economic, social and ecological living conditions – can only be obtained in case the requirements formulated by the German Energy Agency (DENA) are met. So these funds are out of reach for monument owners who are – according to the jurisdiction of the German Federal Constitutional Court (BVerfG) – sensitive to the concerns of monument preservation and behave in an exemplary fashion in close cooperation with the monument protection authorities.

The guidelines set up by the German Energy Agency (DENA) without involvement of the German Cultural Heritage

authorities, are in complete contradiction to the European and national legislative efforts, emphasizing the special legal status of built monuments and archaeological heritage particularly with regard to the field of energy efficiency. So in the DENA guidelines no exceptions are permitted, in case individual measures or package measures are supported by the federal aid programme "Energy Efficient Modernisation" or a building is not used for residential purposes.

In accord with this legislation, built monuments and archaeological artefacts are neither renewable, nor can they be translocated to other sites as a rule. Besides, built monuments represent a relatively small proportion of the building stock in Germany. From the constitutional and practical perspective climate protection goals have to be realized in those fields, in which a maximum of change can be achieved. This does not mean that built monuments should be excused in terms of energy performance.

The Code for Cultural Heritage and Landscape, states: "The protection and promotion of cultural heritage contributes to the preservation of memory of the national community and its territory, and promotes the development of culture." This opens a debate on the significance of energy efficiency and its value in the context of cultural heritage: efficiency interventions should not be understood in terms of mediating conflicting needs (conservation-innovation), but as an instrument for attaining protection objectives. (3)

The European Heritage Legal Forum (EHLF)

The EHLF was founded as a European consultation body in 2008 in Brussels. It is composed of representatives of several European countries who investigate the effect of EU legislation on European cultural heritage. Although cultural heritage is a major economic factor for Europe, especially from a touristic point of view, the European Union has no direct say on this. This field is reserved for the individual member states themselves. However, legislation in other areas, on which Europe has a say, such as the environment, working conditions or energy efficiency etc., increasingly affects the preservation of historical monuments and landscapes. Of course, European legislation never purposely harms historical monuments, but there may often be harmful side effects, resulting from a law or a measure, whose consequences could not be assessed sufficiently in advance.

Such harmful side effects to cultural heritage have to be countered in individual countries by implementing special or exception clauses if and where possible. Since some countries fail to do this at all, and others do this in their own ways, a highly differentiated, hard to oversee landscape of legislation on the protection of cultural heritage has come into being in Europe.

Some illustrative examples of confrontation of the new European legislative and cultural heritage are paintings of old masters, which have to be restored with the same lead-containing paint, originally used by the old masters, despite the European ban on the use of paints which contain metals. Similarly, the doors of our historic churches have to continue to open inwards as a sign of welcome, despite the European obligation that all doors of public buildings have to open outward for reasons of fire safety. And, of course, we must prevent that all windows of historic buildings be replaced by plastic windows because they fail to comply with European environmental requirements. In this respect, the EHLF aims to achieve that in the future all intended EU legislation is assessed in advance in order to detect harmful side effects legal measures may have for cultural heritage. Recommendations for exceptions or for developing alternatives can then be formulated at an early stage and may even be integrated into the intended legislation. (3)

. Energy efficiency measures

2.1. CONSTRUCTION MEASURES

2.1.1. INTRODUCTION

Energy efficiency construction measures usually contribute to major energy savings. Therefore, prior to renovation, adaptation or modernization of cultural heritage buildings, a person in charge should take into consideration possibilities for improvements of the building envelope following instructions from conservers. This chapter will give an overview of construction measures presented at the *International conference "Energy Management in Cultural Heritage"* (Dubrovnik, 2011.) and experience collected during eight years of energy audit management and evaluation for public buildings done by UNDP Croatia, through the "Removing barriers for energy efficiency" Project.

Thermal insulation reduces heat loss in winter, overheating of space in summer and protects supporting structure from external conditions and severe temperature stresses. A thermally insulated building is comfortable, longer-lasting and contributes to environmental protection. One of the requirements for designing energy efficient buildings is good knowledge of thermal properties. Heat losses through the construction depend on the composition of elements, orientation and thermal conductivity.

**Thermal insulation
of buildings reduces
energy costs for heating
by up to 70%.**

12 Potential savings can reach up to 70% for heating energy costs.

LOW COST MEASURES TO IMPROVE ENERGY EFFICIENCY IN BUILDINGS WITH FAST RETURN OF INVESTMENTS (up to 3 years and 700 EUR/100 m²) ARE:

- sealing of windows and outside doors
- replacing of glazing with double insulated low-emission glazing (recommended $U < 1.2 \text{ W/m}^2\text{K}$)
- checking and repairing of metal pieces on windows and doors to avoid thermal bridges
- insulating of niches for radiators and shutter boxes
- reducing heat loss through windows by installing curtains, shutters, etc. (4)

SLIGHTLY HIGHER COST MEASURES TO IMPROVE ENERGY EFFICIENCY IN BUILDINGS WITH LONGER RETURN OF INVESTMENTS (more than 3 years and 700 EUR/100 m²) ARE:

- replacing of windows and external doors (recommended $U_{\text{window}} = 1.1 - 1.8 \text{ W/m}^2\text{K}$)
- building envelope insulation (walls, floor, roof or sealing of unheated attic) (4)

2.1.2. WINDOWS AND EXTERNAL DOORS

Window is the most dynamic part of the building envelope. It acts as a receiver letting solar energy through as well as protecting building from external influences and heat loss. Heat losses through windows can reach up to 50% of heat loss in buildings and they are usually up to ten times higher than those through walls. Because of that, energy efficient windows can contribute significantly to the energy consumption decrease (see case study Music school in Varaždin, Croatia).

In older buildings the heat transfer coefficient U_w is around 3.00 - 3.50 W/m²K. European legislation limits the lower values and they are now mostly in the range of 1.40 to 1.80 W/m²K. In modern low energy and passive houses this coefficient ranges between 0.80 and 1.40 W/m²K.

Old window frames and doors have the reputation of being the “main gateway” for uncontrolled passing of air. Conservative reparation which demands that the materials and technology be as close as possible to the original ones will certainly, on a larger or smaller level, contribute to the improvement of the building's characteristics and longevity, even though the level of the up-to-date energy efficiency standards will not be reached. For example, research carried out for English Heritage has concluded that correct and functional historic windows have a U-factor of approximately $U_w=4.3$ W/m²K. Leaving the windows with a U-factor that high means bringing the building's energy efficiency, i.e. a renovation process into question.

In total, window profiles contribute to heat losses as well. Regardless of the material they are made, they must provide good sealing, absence of thermal bridge in profile, simple handling and low heat transfer coefficient. Window as a construction element has to provide sufficient soundproof and thermal insulation, as well as the function of natural ventilation, which can be achieved by using proper materials and structural profiles.

As presented by author Terer, the share of PVC windows used in the restoration of old buildings is increasing. Modern PVC systems by major producers with their manifold profile and equipment programme allow for a restoration in style in almost all historic and old buildings. All requirements can be met with various crossbar profile sections, pillars, vertical bars and crossbars as well as decorative profiles. When old buildings need to be adapted for modern use, using state of the art materials is imperative. Present day PVC profiles are very different from those manufactured twenty or more years ago. Furthermore, environment-friendly production has become a standard in most parts of this industry branch.

However, depending on the case, conservers decide whether keeping original materials for windows is necessary or not. In some cases it is possible to maintain the original shape, materials and single glazed windows on the outside while installing double glazed windows on the inside. (5)

Heat losses through windows can reach up to 50% and are usually up to ten times higher than those through walls.

Prior to replacing windows and external doors on a building which is a protected cultural monument, its user must contact authorised cultural heritage protection institutions to seek their expert opinion.
An approval from conservators must be obtained for such replacements. There are some rules that must be agreed upon when designing new windows, such as: division of windows, type of construction, material selection, profiling, surface treatment and assembly on site.

MUSIC SCHOOL IN VARAŽDIN, CROATIA



Building: Music school
Location: Varaždin, Croatia
Purpose: School
Built: mid 18th century

The Varaždin Music school (Croatia) built in mid 18th century; then completely rebuilt between 1999 and 2002 is a protected cultural heritage of Croatia. One of the energy efficiency measures identified by an energy audit was changing window glasses on the building. The auditors estimated that the adoption of this measure will result in a reduction of thermal energy consumption by 28%.

Table 2.1. Music school in Varaždin, Croatia

Surface:	3,253 m ²			
Number of floors:	3			
Height of ceilings:	4.20 m			
Total heated/cooled space:	95% heated		3% cooled	
Layer of thermal insulation	good	medium	bad	does not exist
			x	
Working (residential) area:	70%	Warehouses	5%	
Stairwells and corridors:	20%	Rest	5%	
Annually consumption of energy and water				
Heat consumption	kWh _t	468,325		
Electricity consumption	kWh _e	44,959		
Water consumption	m ³	1,877		
Total emission CO ₂	tCO ₂	95.17		
Indicators of consumption				
Specific annual consumption of heat energy	kWh _t /m ²	141.77		
Specific annual consumption of electrical energy	kWh _e /m ²	13.82		
Specific annual consumption of water	m ³ /person	6.68		
Energy efficiency measures				
SUGGESTION	Changing window glasses			
Short description of current situation	External joinery on building is mostly wooden, wing to wing and originally made. All exterior joinery was replaced in 2001, and replacement is not required. Since the joinery is made of ordinary glass, it is recommended to be replaced with insulating glass.			
Short description of measures/materials/ technologies to be applied	Replacing windows with glass heat transfer coefficient U _g = 1.1 W/m ² K, dismantling and erecting of box and installation of new glass.			
Results after applying measures	Annual thermal energy savings	28	%	
	Total estimated investment for implementation of measures	22,540	Euro	
	Simple payback time of investment	7.5	year	
UNDP Energy audit (6)				

UNDP, Energy audit (6)

THE BRAZILIAN REINSURANCE INSTITUTE BUILDING, BRAZIL



Building: Brazilian Reinsurance Institute

Location: Rio de Janeiro, Brazil

Purpose: Office building

Built: 1943

The Brazilian Reinsurance Institute building was built in 1943 and as an icon of modernist architecture in Brazil is legally protected by the municipality of Rio de Janeiro. Also, a legal protection process of their facades by IPHAN, a federal agency of heritage protection, is currently taking place.

The original design of its facade structure is composed of prefabricated concrete enclosed by wooden frames and glass, and locks in asbestos-cement boards, which certainly contained asbestos in its composition. During the latest facade project developed and performed in 2010, the 4 mm window glasses were replaced with the 6 mm ones, damages in casings were repaired and external marble coatings restored. The project also specified internal white PVC blinds. An additional study to improve energy efficiency of the building and its environmental comfort proposes the following:

- Replacement of glass from common 4 mm to 8 mm;
- Glass wool panels in the empty spaces between the plates of locks;
- Replacement of asbestos-cement panels with panels without asbestos;
- Application of internal solar blinds.

Prescriptive method of RTQ-C (Technical Quality Requirements for Energy Efficiency in Public, Commercial and Service Buildings) was used for determinating thermal efficiency of facade systems. The results are shown in Table 2.2.

To conclude, installation of window glasses with the optimum solar factor, inserting of glass wool between the plates and filling of the inner air chamber reduced thermal conductance and increased wall thermal capacity. This in turn reduced both the effects of thermal actions on the facade as well the internal thermal load and consequently the size and power consumption of the air conditioning system. (7)

Table 2.2. Comparison of different projects

Project	U [W/m ² K]	Absorptance α	Thermal Capacity [kJ/m ² K]	Solar factor FS	Envelope Consumption Index (IC)
Original	2.26	0.36	148	0.87	84.07
Current (After phase 1.)	2.16	0.36	132	0.83	83.97
Proposed (After phase 2.)	1.48	0.34	256	0.34	82.72

Since 2006 UNDP Energy Efficiency Project has been one of the key drivers in the development of the energy audit market while acting as an institution that monitors the quality of the audits at the same time. In the last eight years one thousand and two hundred energy audits on public buildings have been conducted. A conclusion derived from the proposed measures is that the building envelopes and windows are in bad conditions. Building envelopes of cultural heritage buildings usually have to undergo reconstruction of finishing layers as they often cannot be insulated with common materials. In such cases window replacement is one of the often proposed energy efficiency measures. A problem with the implementation of this measure is its investment cost as it exceeds costs of any other building that is not under protection. Namely, such buildings require tailor made windows, so even with the significant energy consumption savings arising from them,

there is no return of investment but is necessary measure to reduce heat losses and achieve thermal comfort in inner space. Measures such as sealing windows and replacement of glazing can have acceptable payback time.

From that experience and the examples of a majority of public buildings that underwent an energy audit, there are number of energy efficiency measures regarding improvements of windows. These are: sealing of windows, installation of blinds, glazing replacement and windows replacement. The tables (2.3., 2.4., 2.5.) below show approximate investments, energy savings and simple payback periods for each analyzed measure. It is evident that these measures are usually not very cost effective and that payback periods are longer than 10 years. Thus these measures should often be considered as regular maintenance rather than energy efficiency measures that can be paid off from energy savings.

Table 2.3. Sealing of windows

Type of building	City	Area [m ²]	Investment [Euro]	Financial savings [Euro/year]	Energy savings [kWh/year]	Simple payback period [year]
Office building	Samobor	675	990	292	5,500	3.38

Table 2.4. Installation of blinds

Type of building	City	Area [m ²]	Investment [Euro]	Financial savings [Euro/year]	Energy savings [kWh/year]	Simple payback period [year]
Office building	Zagreb	3,633	59,513	36,000	109,920	1.65

Table 2.5. Windows replacement

Type of building	City	Area [m ²]	Investment [Euro]	Financial savings [Euro/year]	Energy savings [kWh/year]	Simple payback period [year]
Office building	Zagreb	9,859	386,184	8,561	160,121	45.11
Office building	Zagreb	612.00	52,710	540	55,029	97.57
Office building	Zagreb	300	6,145	406	8,327	15.15
Dormitory	Zadar	991	8,395	787	7,525	10.66
Office building	Zagreb	14,004	70,276	6,342	130,274	11.08
Office building	Zagreb	8,460	96,526	8,440	173,379	11.44
Office building	Zagreb	5,641	53,882	4,420	90,795	12.19
Office building	Varaždin	6,487	127,526	8,287	196,747	15.39
Office building	Zagreb	16,923	30,913	2,196	40,398	14.08
Office building	Zagreb	13,383	117,368	11,506	284,426	10.20
Office building	Čakovec	2,386	56,447	2,656	40,916	21.3
Office building	Koprivnica	1,995	47,368	5,594	77,694	8.5
Office building	Varaždin	2,072	86,052	2,523	61,871	34.10
Office building	Zagreb	5,530	125,702	2,051	50,271	61.30

Type of building	City	Area [m ²]	Investment [Euro]	Financial savings [Euro/year]	Energy savings [kWh/year]	Simple payback period [year]
Office building	Velika Gorica	1,626	4,614	348.5	6,724	13.23
Office building	Sisak	710	12,647	540	6,501	23.42
Office building	Osijek	519	15,749	467.8	96,248	33.67
Office building	Osijek	253	5,122	727.4	144,604	7.04
Office building	Vukovar	4,756	94,853	5,300	74,737	17.9
Office building	Poreč	575	24,868	1,404	17,216	17.7
Office building	Pula	4,330	126,316	5,821	72,059	21.7
Office building	Rovinj	821	11,579	1,280	15,596	9.0
Office building	Krk	1,083	27,632	1,473	12,248	18.8
Office building	Mali Lošinj	976	19,737	647.4	4,749	30.5
Office building	Gospić	915	76,974	4,961	61,423	15.5
Office building	Opatija	1,989	55,263	2,847	29,808	19.4
Office building	Rijeka	3,808	126,316	10,115	105,896	12.5
Office building	Sinj	1,950	81,453	7,350	136,395	11.8

2.1.3. Roof insulation

Heat losses through roof cover approximately 10-30 % of the total building heat losses and they play a very important role in thermal comfort and inner space of the building. Inappropriate thermal insulation of the roof space causes big heat losses in winter and overheating in summer, which is an even bigger problem. The period of investment return for roof insulation (depending on the design of building and its condition) is one to five years.

When roof of cultural monuments is under reconstruction or reconstruction is planned, especially if attic is not used and visible it is highly recommended to consider use of rock wool insulation (thickness in accordance with the calculation). This measure is not destructive and will not influence value of cultural heritage building but it will significantly contribute to thermal comfort and energy savings in the building.

CITY PALACE DVERCE, ZAGREB, CROATIA



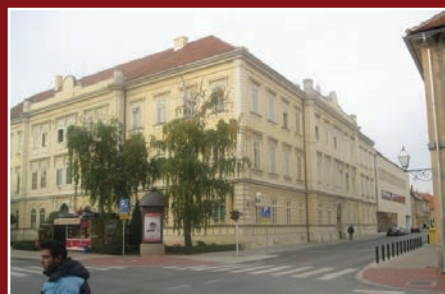
Building: City palace Dverce
Location: Zagreb, Croatia
Purpose: public administration
Built: 19th century

EE measure: Ceilings under unheated attic and external terraces (flat roofs) should be insulated with a 15 cm thick thermal insulation.

Table 2.6. City palace Dverce, Zagreb, Croatia

Surface:	1,068 m ²			
Number of floors:	4			
Layer of thermal insulation	Good	medium	Bad	does not exist
				x
Annually consumption of energy and water				
Heat consumption	kWh _t	258,469		
Electricity consumption	kWh _e	81,288		
Water consumption	m ³	331		
Total CO ₂ emission	tCO ₂	104.44		
Indicators of consumption				
Specific annual consumption of heat energy	kWh _t /m ²	284.05		
Specific annual consumption of electrical energy	kWh _e /m ²	77.41		
Specific annual consumption of water	m ³ /person	6.2		
Energy efficiency measures				
SUGGESTION	Thermal insulation of ceilings under unheated attics and flat roofs			
Short description of current situation	Ceilings were originally made of wooden beams on which boards, a layer of sand and bricks, and later a monolithic reinforced concrete structure were placed, without thermal insulation. Heat transfer coefficient is U = 1.76 W/m ² K.			
Short description of measures/ materials/ technologies to be applied	Ceilings under unheated attic and external terraces (flat roofs) should be insulated with a 15 cm thick thermal insulation.			
Results after applying measures	Thermal energy savings	22	%	
	Investment for implementation of measures	6,850	Euro	
	Return of investment	2.6	year	
UNDP, Energy audit (8)				

FIRST HIGH SCHOOL VARAŽDIN, CROATIA



Building: First high school Varaždin
 Location: Varaždin, Croatia
 Purpose: School
 Built: Old part built in 1870 (adapted in 2002), new part built in 2009

EE measure: Roof reconstruction and thermal insulation. Measures include substrate preparation, purchase and placement of vapor and permeable foil, 15 cm thick soft wool insulation, changes in the entire roofing (rafters, laths, tiles). Surface of the roof is 1,800 m².

Table 2.7. First high school Varaždin, Croatia

Surface:	3,164.15 m ² (Old part)			
	3,929.60 m ² (New part)			
Number of floors:	3			
Height of ceilings:	3.20 m			
Total heated/cooled space:	95% heated		10% cooled	
Layer of thermal insulation	good	medium	bad	does not exist
			x	x
Working (residential) area:	70%	Warehouse	5%	
Stairwells and corridors:	20%	Rest	5%	
Annually consumption of energy and water				
Heat consumption	kWh _t	286,785		
Electricity consumption	kWh _e	93,955		
Water consumption	m ³	1,519		
Total emission CO ₂	tCO ₂	108.97		
Indicators of consumption				
Specific annual consumption of heat energy	kWh _t /m ²	141.77		
Specific annual consumption of electrical energy	kWh _e /m ²	13.82		
Specific annual consumption of water	m ³ /person	6.68		
Energy efficiency measures				
SUGGESTION	Roof reconstruction and thermal insulation.			
Short description of current situation	Roof leaks in the old part of the building which will result in devastating damage on the construction of building. Ceiling under the roof is an arched vault made out of cane beams, plaster and rubble. Attic is classic, made out of beams, laths and roof tiles. Remediation is necessary because of the damage which could occur from the leaking roof. The current heat transfer coefficient U = 0.9 W/m ² K.			
Short description of measures/ materials/ technologies to be applied	Measures include substrate preparation, purchase and placement of vapor and permeable foil, 15 cm thick soft wool insulation, changes in the entire roofing (rafters, laths, tiles). Surface of the roof is 1,800 m ² .			
Results after applying measures	Thermal energy savings	10	%	
	Investment for implementation of measures	172,603	Euro	
	Return of investment	25	Year	
UNDP, Energy audit (9)				

2.1.4. FLOOR INSULATION

Ground floor, apart from requirements of mechanical resistance and stability, requirements related to space usage (durability, wear, resistance to chemical influences), sound insulation and sound transmission, must meet the requirements of thermal insulation to the ground, as well as insulation from moisture from the soil (or capillary pressure).

Heat losses through floor represent 10 % of the total heat loss in buildings. Experience has shown that installing a 10 cm thermal insulation on the floors reduces their heat losses by 60 %. Thermal insulation is unnecessary if the temperature difference between warm and moderately warm room is small or less than 4-5 °C. Only significantly colder rooms should be thermally insulated.

In older constructions the problem of waterproofing is usually solved by hoisting floors above the surrounding soil, installing layers with a higher proportion of voids (mound of large stones and gravel) as well as reduced capillary layers (dense mound of clay), and performing additional floor structures with cavities above these layers. Depending on the load, heat-insulating panels made of expanded polystyrene-foam whose thermal conductivity is $\lambda = 0.036 \text{ W/(mK)}$ (density 20-30 kg/m³), should be put on the waterproofing or on the concrete base. Thickness of the insulation should be calculated (but not less than 6 cm). PE – foil should be placed on boards before the application of reinforced concrete.

Thermal insulation of cold floors is an easy way to reduce heat losses and optimize living thermal comfort. Table 2.8. shows approximate investments, energy savings and simple payback periods for analyzed measures in about twenty office building from Energy audits conducted by UNDP.

Heat losses through floor can reach up to 10% of the total heat loss in buildings.

Ground floor repairment is often economically unjustified, due to its relatively small contribution to the reduction of total heat loss and the large investment it entails, but it certainly contributes to reducing heat loss as well as improving thermal comfort and indoor climate.

Table 2.8. Thermal insulation of ceiling and/or roof

Type of building	City	Area [m ²]	Investment [Euro]	Financial savings [Euro/year]	Energy savings [kWh/year]	Simple payback period [year]
Office building	Zagreb	3,633	13,297	6,816	139,850	1.95
Office building	Zagreb	1,077	14,604	4,274	87,712	3.42
Office building	Zagreb	612	9,520	4,970	101,971	1.92
Office building	Zagreb	290	3,992	1,491	30,597	2.68
Office building	Zadar	960	23,131	2,404	32,627	9.62
Dormitory	Zadar	991	12,013	4,251	40,637	2.83
Office building	Varaždin	6,487	275,163	7,846	185,941	11.25
University building	Zagreb	16,923	37,630	2,780	51,143	13.54
Office building	Krapina	1,424	16,447	1,786	25,186	9.2
Office building	Varaždin	2,072	34,079	5,402	132,449	6.31
Office building	Zagreb	5,530	77,013	7,633	32.50	10.09
Office building	Zagreb	3,500	12,541	2,084	29,732	6.02
Office building	Zagreb	4,005	30,222	2,806	91,136	10.8
Office building	Sisak	710	3,563	89	1,073	39.97
Office building	Glina	1,094	4,447	392	5,612	11.33
Office building	Hrvatska Kostajnica	1,284	9,021	2,162	31,369	4.17
Office building	Poreč	575	13,158	1,122	13,750	11.7
Office building	Pula	4,330	39,474	3,516	43,529	11.2
Office building	Gospić	915	13,158	1,176	14,550	11.2

2.1.5. THERMAL INSULATION OF EXTERNAL WALLS

Thermal insulation of external walls should be carried out by adding a new layer of thermal insulation on external walls from the outside. However, in most cases this is not applicable to protected buildings as it changes the building's visual identity.

From the physical standpoint, performance of thermal insulation of external walls from inside is inappropriate and often more expensive because of the additional problems of diffusion of water vapour, the more stringent requirements in terms of security against fire, the lack of usable space, etc. Another reason why the installation of thermal insulation on the inside walls is not good in the physical sense is because even though insulating values are improved, heat flows in the walls change significantly causing the main load-bearing walls to become colder. Therefore, special attention should be given to the performance of a vapour barrier in order to prevent condensation and the appearance of mold. Also, heat should be insulated in partitions that are connected with the outside wall.

Heat losses through envelop can reach up to 60% of the total heat loss in buildings.

Tables 2.9. and 2.10. show approximate investments, energy savings and simple payback periods for analyzed measures in about thirty office building from Energy audits conducted by UNDP.

Thermal insulation of walls on buildings under monumental protection is usually done from the inside to avoid changes on the facade of the building because of its architectural value.

Table 2.9. Thermal insulation of external walls from the outside

Type of building	City	Area [m ²]	Investment [Euro]	Financial savings [Euro/year]	Energy savings [kWh/year]	Simple payback period [year]
Office building	Zagreb	1,077	16,452	4,400	90,268	3.74
Office building	Zagreb	612	1,974	341	7,003	5.78
Dormitory	Zadar	991	59,231	7,435	71,079	7.97
Office building	Zagreb	8,460	100,277	8,870	182,201	11.30
Office building	Zagreb	5,641	58,807	5,659	116,245	10.39
Office building	Varaždin	6,487	3,992	644	15,158	6.20
Office building	Križevci	1,278	26,315	2,588	30,176	10.2
Office building	Križevci	1,278	12,730	3,817	48,888	3.3
Office building	Varaždin	2,072	16,809	2,538	62,218	6.62
Office building	Zagreb	5,530	38,394	1,529	37,424	25.10
Office building	Zagreb	2,460	5,556	1,188	21,887	4.68
Office building	Zagreb	2,460	7,186	1,740	32,074	4.13
Office building	Zagreb	2,800	3,684	518	9,547	7.11
Office building	Zagreb	3,500	15,524	3,784	53,975	4.10
Office building	Zagreb	4,005	45,320	8,826	286,606	5.1
Office building	Zagreb	3,680	23,996	1,356	44,812	17.7
Office building	Sisak	710	20,010	1,244	1,073	16.08
Office building	Poreč	575	15,789	637	7,814	24.8
Office building	Pula	4,330	69,737	3,719	46,046	18.8
Office building	Buje	102	30,263	2,518	19,871	12.0
Office building	Krk	1,083	23,684	2,864	23,816	8.3
Office building	Mali Lošinj	976	23,684	1,416	10,389	16.7
Office building	Gospić	915	21,710	2,769	33,618	7.8
Office building	Opatija	1,989	50,000	2,847	29,808	17.6
Office building	Rijeka	3,808	113,158	5,700	60,512	19.8

Table 2.10. Thermal insulation of external walls from the inside

Type of building	City	Area [m ²]	Investment [Euro]	Financial savings [Euro/year]	Energy savings [kWh/year]	Simple payback period [year]
Office building	Zadar	6,630	77,887	3,328	31,619	23.4
Office building	Pag	370	6,039	134	1,619	45.0
Office building	Šibenik	4,710	59,947	4,310	27,528	13.9
Office building	Trogir	1,696	28,385	1,040	7,531	27.3

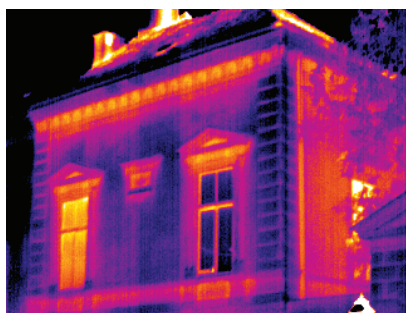
CITY PALACA DVERCE, ZAGREB, CROATIA



Building: City palace Dverce
Location: Zagreb, Croatia
Purpose: Public administration
Built: 19th century

EE measure: Thermal insulation of external walls should be carried out within dry walls in order to maintain the visual identity of the building. It is suggested to design a drywall system on 30% of the external walls surface and install a 10 cm thick thermal insulation.

Table 2.11. City palace Dverce, Croatia

Surface:	1,068 m ²			
Number of floors:	4			
Layer of thermal insulation	Good	medium	Bad	does not exist
				x
Annually consumption of energy and water				
Heat consumption	kWh _t	258,469		
Electricity consumption	kWh _e	81,288		
Water consumption	m ³	331		
Total CO ₂ emission	tCO ₂	104.44		
Indicators of consumption				
Specific annual consumption of heat energy	kWh _t /m ²	284.05		
Specific annual consumption of electrical energy	kWh _e /m ²	77.41		
Specific annual consumption of water	m ³ /person	6.2		
Energy efficiency measures				
SUGGESTION	Thermal insulation of ceilings under unheated attics and flat roofs			
Short description of current situation	External walls are made of full brick approximately 60 cm thick. The building is not thermally insulated. Heat transfer coefficient is U = 1.01 W/m²K.			
Short description of measures/ materials/ technologies to be applied	Thermal insulation of external walls should be carried out within dry walls in order to maintain the visual identity of the building. It is suggested to design a drywall system on 30% of the external walls surface and install a 10 cm thick thermal insulation.			
				
Envelope of Palaca „Dverce“		Thermographic image of the Palaca “Dverce” envelope		
Results after applying measures	Thermal energy savings	5	%	
	Investment for implementation of measures	7,123	Euro	
	Return of investment	11.75	year	
UNDP. Energy audit (8)				

2.2. ENERGY SYSTEMS

2.2.1. INTRODUCTION

Energy systems in heritage buildings usually provide great improvement in energy efficiency without or with minimal interference with cultural value of the building. This is because energy systems are often limited to interior of the building and seldom infringe visual identity of the building.

However, energy efficient energy systems alone cannot achieve significant energy savings (except lighting system) if outer envelope of building is in poor shape.

In the following chapters, best practice examples presented at the Dubrovnik conference Energy Management in Cultural Heritage are shown.

2.2.2. LIGHTING SYSTEM

Energy use for heating, ventilating, air-conditioning and lighting in buildings is responsible for more than 30% of carbon dioxide (CO₂) emissions, which contribute to climate change, while lighting solely can account for up to 40% of electricity use in buildings. Increased insulation levels (especially in new buildings) have drastically reduced the energy needed for heating. This means that electricity for lighting is a growing proportion of energy used in buildings. It is estimated that up to 75% of buildings have outdated lighting which is not only inefficient in its energy consumption but it also fails to provide the optimum visual environment which is especially true for cultural heritage buildings. The high cost of electricity makes lighting a prime candidate for action to improve energy efficiency.

Consumption of electrical energy for lighting can be reduced by:

- using energy efficient lamps and light fittings,
- directing light to where it is needed,
- controlling the use of lighting and user behaviour and
- using daylight as much as possible.

The first three of the listed measures bring immediate results whereas the last one can really only be satisfactorily applied during the initial lighting design or in the course of major reconstructions.

Refurbishment of the lighting system is a very cost-effective measure with the usual payback period of less than 12 months (in some cases even less than 6 months) and with energy savings that can reach up to 85% if new lighting systems and methods are implemented. For example, replacing old fittings with new T5 lamps in a building that uses outdated T12 fluorescent lighting achieves significant

energy reduction. Apart from improving lighting quality in the space this provides a 50% energy reduction even before the installation of lighting controls.

The following example shows a school building in Innsbruck where high quality visual environment is important for student performance. The focus was on using daylight to achieve good quality lighting and at the same time reduce electricity consumption for lighting.

One important goal of the planning process was to optimise the daylight access through classroom design. In order to accomplish this in the existing buildings it was necessary to install daylight redirecting elements in the box-type windows. They help to optimise daylight autonomy as well as visual comfort. The problem was that conventional lamellas cannot be hidden completely behind the window frame in ruffled condition. There is still improvement to be done regarding products applicable to historic buildings.

OPTIMISATION OF DAYLIGHT AND ARTIFICIAL LIGHT IN HAUPTSCHULE HÖTTING IN INNSBRUCK, AUSTRIA



Within the FP7 project “3ENCULT – Efficient Energy for EU Cultural Heritage”, the school building “Höttinger Hauptschule” in Innsbruck (Austria) is one of the 8 case studies for demonstration and verification of energy efficient solutions. Besides the reduction of thermal losses, a special focus will be on the optimisation of day lighting and energy efficient artificial lighting with high priority of conservation-compatibility for all of the interventions.

The secondary school Hötting (Fürstenweg, Innsbruck, Austria) is one of the 8 case studies for demonstration and verification of energy efficient solutions within the European research project 3ENCULT (Efficient Energy for EU Cultural Heritage). It is listed as one of the most important examples of early modern architecture in Tyrol.

High quality of visual environment is important for the performances of students in school buildings. In new school buildings, one important goal of the planning process is to optimise the daylight access through classroom design. On the other hand, energy use by electric lighting should be minimized. In principle, the same holds for refurbishing of historic school buildings, but with certain restrictions of conservation-compatibility for all of the interventions.

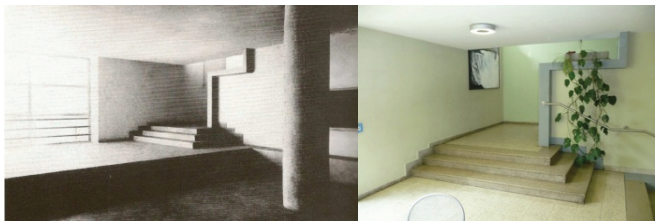


Figure 2.1. Entrance hall with large glazing area



Figure 2.2. Main Stairway and corridor oriented to day light

The geometry of the classrooms (depth of 6.6 m) and the different tasks which must be performed in it makes it a difficult task to light it with daylight.

The window area of 16 m² per classroom is large enough for good use of daylight for 67 m² of floor space. On the other hand, there is a risk of glare and overheating. The original drawings (pencil) of the windows and photos of the shading

(roller blinds) are shown in Figure 2.3.

The box-type window gives the chance to integrate shading and daylight deflection elements in the space between the glazings. The advantage to external shading is wind protection as well as protection against staining.



Figure 2.3. Photos and original drawings of the windows details (roller blind, tilt mechanism)

The roller blinds installed at the moment have the disadvantage of low transmittance. There is no option for daylight redirection at the moment. The best way to avoid glare and overheating in summer is by use of overhang. However, as this is not included in the architectural design of the historic building, new ways to solve the problem have to be found.

Box-type windows are a typical detail of many historic buildings, thus the development of window integrated shading and daylight elements with priority of conservation-compatibility has a high potential for transferability to similar projects.

In the first step, the luminance and illuminance in the classrooms and the lecture room for physics at daylight and artificial light were measured. From this, different possible design models of classrooms will be drawn up. These designs will be compared to each other by simulation of the light performances with light simulation programs (RELUX, DIALUX, RADIANCE) as well as the VIVALDI programme.

Moreover, the primary objective is to improve the light conditions in classrooms in respect to energy use and comfort. As a reference, the status quo is measured (light

quality, electricity consumption, hours of artificial lighting) as shown in this contribution.

Requirements for the illuminances in schools given in the European Norm EN 12464-1 depend on the tasks of both teachers and students. As the visual tasks and requirements are quite diverse, lighting concepts have to be flexible and adjustable to different activities throughout the day.

Example of luminance measurements

Figure 2.4. shows an example of a luminance false colour map calculated from a calibrated HDR. It shows the luminance in the classroom on a sunny day. The peak values of luminance above 12000 cd/m^2 illustrate the problem of physiological glare by direct sun. Consequently the roller blinds are closed in those cases. Unfortunately the resulting illuminance is too low for the visual tasks in the classroom without artificial light.

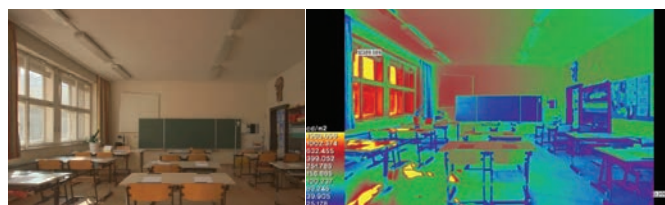


Figure 2.4. Luminance measurement in classroom with day light (direct radiation, 31.01.2011, 12:52 p.m.)

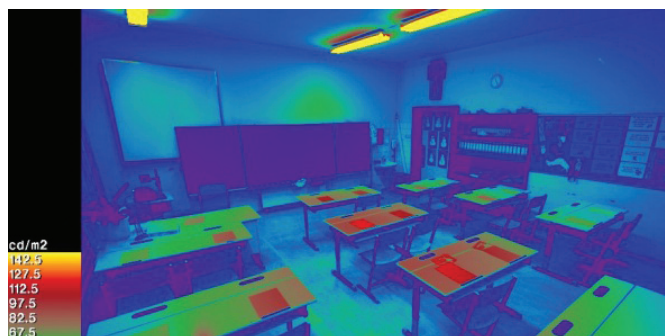


Figure 2.5. Luminance measurement in classroom with artificial light

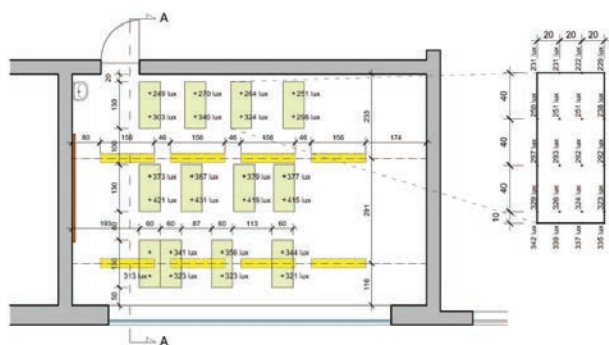


Figure 2.6. Luminance values measured at desktop level with sensor FLA603VL4

New visualisation software for planning of interventions in cultural heritage

Based on the evaluation of calibrated HDR photos (or simulation results), the software tool VIVALDI (Virtual & Variable Lighting Design tool for Intelligent ELI/LENI Management, ©2010 Zumtobel) can be used to compose particular situations of lighting from different sources.

With the application of schedules (timeline editor) for dimming of artificial light, the electricity consumption throughout the day (energy chart) can be calculated, if the dimming characteristics of the luminaires are known.

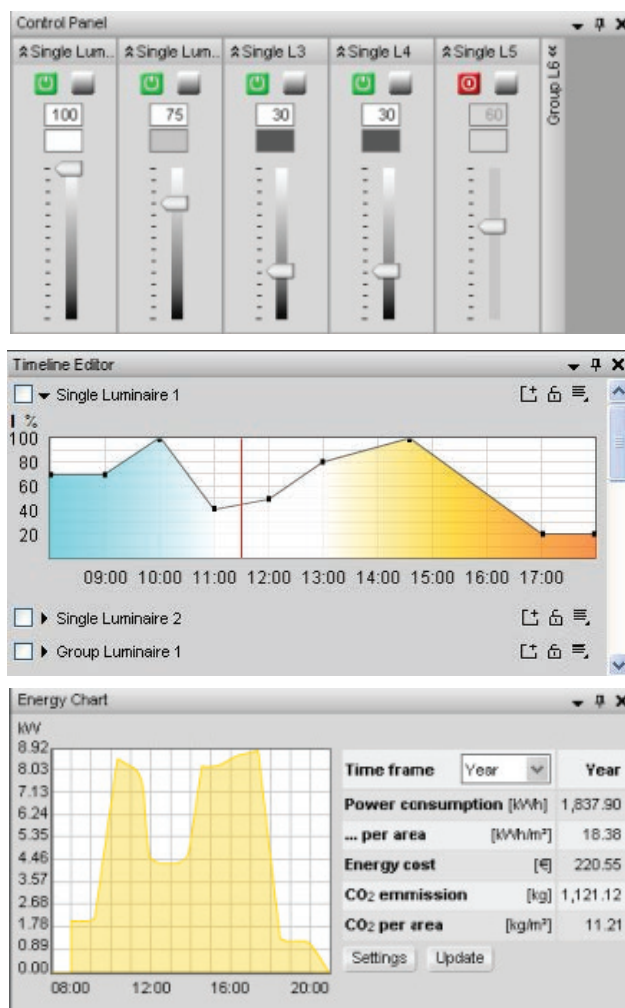


Figure 2.7. VIVALDI screenshots of control panel, timeline editor and energy chart

The advantage of this software for planning of interventions in cultural heritage is that a visualisation of the lighting situation is available for different alternative solutions in advance. It will be applied within the 3ENCULT project for comparison of different energy efficient solutions with priority of conservation-compatibility.

Technical solutions for shading and day light control

As learnt from measurement data, the performance of shading by roller blinds as installed at the moment is not suitable for good visual and thermal comfort in the classrooms. Daylight redirecting elements integrated in the box-type windows will help to optimise the daylight autonomy as well as the visual comfort. The problem is that conventional lamellas cannot be hidden completely behind the window frame in ruffled condition. There is still improvement to be done regarding products applicable to historic buildings. Application of surface coats of paint with high reflectance also helps to enhance the daylight redirection.

Energy efficient solutions for artificial light at high visual comfort

In case of a building renovation, a new lighting system will help to reduce future operating costs and electric energy demand. Most measures are highly economical.

Inventory of the artificial lighting system in the case study showed that most of the strip lighting fixtures in the classrooms can only be switched on simultaneously. When low daylight illuminance is compensated with artificial light it is more energy efficient for each individual strip lighting fixture to have its own electric circuit.

Newly developed light sources, like T5 fluorescent lamps, compact fluorescent and LED, improve the light output. Electronic ballasts reduce power loss to provide flicker-free light and a better starting of the lamps. Moreover, new reflector materials and designs help to increase the reflector efficiency and to reduce glare of the lamp.

When classrooms are not in use, presence control automatically switches off the light to save energy. The renovation does not affect the building aesthetics. There are lamps with matching designs and cutting-edge technologies for each architecture. Often, the latest technology can be mounted into existing lights. Since lamps and ballasts are getting increasingly smaller, more powerful and energy efficient, safe and bright lighting can be integrated in listed buildings without visually changing them.

Conclusion

The quality of daylight and artificial light can be measured with a digital lux meter, a shutter tube and a calibrated digital camera (via HDR-imaging) with high accuracy at low cost. New software tools help to optimise and visualize energy efficient lighting strategies. Especially for interventions in historic buildings, the visualisation of planned interventions is a valuable instrument for lighting designers and decision makers. (10)

Table 2.12. Standard illuminance values in schools according to EN 12464-1

Task	Teacher	Student	Standard Illuminance	
			In the class	In general
1	Writing on blackboard	Reading then blackboard	500 lux (vertical)	200 lux
2	Talking to students	Paying attention to the teacher	300 lux	300 lux
3	Showing a presentation (slides, powerpoint, television programme, etc.)	Looking at the screen	300/10 lux	10 lux
4	Paying attention to working students	Writing, reading, drawing, etc.	300 lux	300 lux
5	Coaching computer activities	Not present	50 lux	300 lux above the computer
6	Preparing a lesson	Not present	300 lux	50 lux

2.2.3. HEATING AND POWER SUPPLY

When refurbishing heating and power supply systems, Various applications can be used when refurbishing heating and power supply systems because these systems do not affect a building's outer appearance. In the following examples of Skokloster Palace, Castle of Viano and Venice Arsenal heat pump systems were installed. These interventions resulted in substantial reductions of energy consumption and increased thermal comfort, without negative visual impacts to the buildings. In the examples of the Pieve Modolena Church and St. Valentine Church new ideas were presented. In the Pieve Modolena Church floor heating was installed under terra cotta tiles whereas a hot air system in the shape and dimensions with reduced visual impact was installed in the St. Valentine Church. A centralized low temperature heating system with water heat pumps was presented in the Riverzana Village. An absorption cooling system fired with natural gas was installed to address the cooling needs of the Croatian National Theatre in the city of Rijeka. Antun Mihanović elementary school and Braće Seljan elementary school underwent thorough reconstructions during which old windows were replaced with new ones, and thermostatic valves were installed.

Just as historic cities have managed to adapt to new demands and functions the society requires of them, so should our historical buildings undergo measures to improve their performance so as to meet the modern standards of comfort (safety, energy efficiency, environmental quality) regarding use of heating facilities. Cultural heritage buildings were built when the comfort standards of its visitors and inhabitants were not as high as they are today. Now that standards have been raised generally, these buildings need to be equipped with installations that satisfy modern demands and that are capable of minimizing energy consumption, whilst raising the environment quality of its inside spaces. Building regulations are often oriented towards new development and the introduction of contemporary technology in buildings of historical value is thus to be entrusted to the individual sensibility of the architects, designers and professionals. Modern technological systems can be introduced, with the inclusion of various passages of the technological systems, with respect for the historic pre-existence and without causing any harm to the monument. 'Spontaneous' installations of technological systems in such monuments have caused damage not only to the cultural aspects of these buildings, but have often affected their stability as well.

Heating systems in heritage buildings have great potential in achieving significant energy savings without compromising their cultural value. Heating systems are usually not visually obtrusive and do not change visual identity of the buildings. Still, energy efficient heating systems should be accompanied with proper thermal insulation of outer

envelope of the buildings, which often presents a huge barrier when dealing with heritage buildings.

The following are case studies and examples of good practice in implementing energy efficient heating systems in heritage buildings.

SKOKLOSTER PALACE



Skokloster palace located in the south of Uppsala in Sweden is a complex of three buildings - palace, stone-house and church built in 1230. Today the palace is used as a museum.

Skokloster palace located in the south of Uppsala in Sweden is a complex of three buildings: a palace, a stone-house and a church built in 1230. At present the palace is used as a museum. Skokloster palace is still unheated with the exception of a few rooms in the ground floor which are heated with an oil-fired boiler. The Stone-house is heated with electric heaters with on-off thermostats. It was decided to install a heat pump with collectors in rock boreholes for the purpose of heating the old stone-house. Yearly savings are expected to be 23,800 EUR. The consumption for heating of the old stone house according to the certificate will be 94 kWh/m². In 2007 electricity consumption for heating of the stone-house was 213 MWh with 3,229 degree-days. In 2010 electricity consumption was 164 kWh with 4,193 degree-days. Recalculated to a standard year the electric energy consumption for the old stone-house has decreased by 41% from year 2007 to 2010. The museum staff report increased thermal comfort with the new heating system. All permissions were in this case obtained. (11)

PIEVE MOLENA CHURCH



A masterpiece of the architect Giovan Maria Ferraroni (1662-1755), this church belongs to the scenographic tradition of the Emilian region and shows a perfect synthesis between architecture, painting and sculpture. Some of the most important artists of the Este court, like Francesco Vellani e Antonio Schiassi, collaborated in the creation of this monument.

The restoration included structural consolidation, recovering of the original interior colours, replacing of the interior floors, changing of the technical installations and adapting the apse zone to modern liturgy. The modern heating facilities were placed under the new terracotta-tiled floor. (11)

CHURCH ST. VALENTINE



The restoration process of the St. Valentine church included replacement of the existing heating system, which caused damage to the monument's walls, with a hot air heating system that has a low intervention and visual impact.

The project for the new heating facilities started from the desire to modernize the church building, but without jeopardizing the already precarious structural conditions (masonry stone partially squared) or damaging its historical characteristics, such as the antique terracotta-tiled floor dating from the eighteenth century. After a careful analysis of documentary sources, combined with the reading of the monument, it was decided not to intervene with the more popular radiant panel system, but to introduce a hot air system located in the shapes and dimensions that might be of less impact. While the floor in the main part of the church is of high value, in the side chapels it was in need of restoration, after damage caused by structural failure. The side chapels thus could be used to allocate the dorsal parts of the heating system. The old heating system that had damaged the walls of the monument is replaced with steel laminas along the intercolumnio. (11)

CASTLE OF VIANO



The foundation of Castle of Viano dates back to 1596 and, after a long period of neglect, the castle and the village were restored for the first time in the seventies of the last century. Current refurbishment project focuses on renewable energy source heat pump system to provide heating, cooling and DHW.

RIVERZANA VILLAGE



Riverzana is a small village centre, located on a hill near Canossa with a panoramic view of the valley. It consists of a series of buildings to be renovated in order to create hospitality; in the village a restaurant with meeting rooms, residence accommodations for guests and a spacious wellness area are planned for building.

The Viano Castle occupies the top of a hill along the valley of the Tresinaro River. The fortress occupies a large area and encompasses the original village with sections of the defensive walls and buttresses. The fortified structure consists of a tall square tower, with battlements, and a residential building with a circular tower. The village is located between these two buildings and consists of a row of linear houses for the servants.

The current project takes into account thermal engineering, the procurement of hot water, heating and air-conditioning facilities with the use of a central heat pump, located in a place of low visual impact. (12)

A centralised heating system was applied using condensation to distribute its energy to the final users through electro pumps. The installations for heat emission use a medium of low temperature and, according to the different areas, the radiators can be skirting board type or radiant panel type with reduced thermal inertia. (12)



Figure 2.8. Layout of installations of Riverzana village

ENERGY EFFICIENT HVAC SYSTEM OF THE CROATIAN NATIONAL THEATRE BUILDING IN RIJEKA



The Croatian National Theatre Ivan Zajc in Rijeka was built in 1885 as the first of three European theatres designed by the renowned team of two Austrian architects, F. Fellner and H. G. Helmer. It was built in the neo renaissance style while the interior is in late baroque style decorated by G. Klimt. During the renovation period from 1970 to 1982 the new HVAC system was not completed. The newly constructed cube, with a cooling tower built on the place of an old oil reservoir is a simple architectonic solution, appropriate for a future urban area.

Project solution for the new heating, ventilating and air-conditioning (HVAC) system was reduced to minimal intervention or, rather, non-existent interventions on this registered heritage building.

Even at that period it was clear that the heating and cooling supply must be done outside the building and the provisional solution was to connect the building to the boiler-station of the nearby factory Istravino. The heat pipeline is long 250 m and it crosses the river's canal Mrtvi kanal. After analysing the potential locations it was decided that it should be on the space of the Delta and that it should be the permanent solution for the energy supply of the theatre building. The design was divided into four phases: reconstruction of the natural gas supply system on Delta area, reconstruction of boiler-station of the old Istravino factory, adjustments and reconstruction of the existing thermo technical - HVAC system in the theatre building and construction of the new cooling station next to the boiler station.

The design includes the cooling system by use of natural gas. ACU and natural gas absorption plant has been built which in summer period function as cooling devices. In winter time this devices are used as heating boiler-station. Thermo energetic connection with the theatre building is the existing pipeline system which is now a reversible energy connection in function all year around. The applied system of gas absorption devices represents a simple, modern, energy efficient technical solution. (13)

VENICE ARSENAL

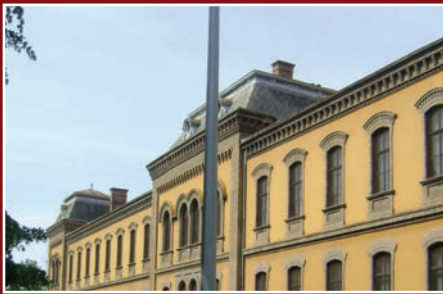


The Venice Arsenal is located on the eastern edge of Venice's historic centre and it covers an area of approximately 47 hectares. Open (unbuilt) area accounts for 218,000 m², while buildings cover a total surface of 150,000 m². The northern part of the Arsenal was constructed during expansion projects that began in the late fifteenth century and ended in the early decades of the 1900s. The newly designed heating and cooling system is based on water to water heat pump system with Venice lagoon sea water as an energy source.

High efficient HVAC systems are based on water heat pumps, geo exchange in lagoon that produces fluids for conditioning. In this case, low enthalpy district heating (closed loop) will connect all the buildings in the north Arsenal, transferring the geothermal energy to the heat pumps from the Venice Lagoon by means of a centralized heat exchange plant. The system operates on the principle of thermal exchange: the lagoon water is used to dissipate heat in the summer and provides a source of heat in the winter (in other words, a geothermal plant that uses lagoon water).

In addition to environmental sustainability, the geothermal plant designed for the Arsenal also offers benefits with respect to: energy recovery (the closed-loop system enables excess heat produced by equipment to be recovered by using heat pumps to transfer it to other buildings); flexibility (it may be preferable to produce energy on-site through cogeneration); losses on the line (costs relating to thermal insulation of the pipes are eliminated and losses of thermal energy on the line are avoided); environmental impact (the thermal exchange plant needed to balance thermal fluctuations in the water loop uses water from the lagoon as an energy source); modularity (it permits the building services to function in individual buildings even during transition periods when the general building services network has not been completed). (14)

RECONSTRUCTION AND CONVERSION OF "TVORNICA DUHANA ZAGREB" INTO CROATIAN HISTORY MUSEUM



"Tvornica duhana Zagreb" is the best preserved industrial heritage object in the Croatian capital. The building has the shape of a Neo-Renaissance palace with regular window distribution. The building is an individual protected cultural good and the Ministry of Culture and owner agreed to cooperate, i.e. open a Croatian History Museum in the old object and construct a new, mostly office building at the place of subsequent extensions. Invitation for tenders was published in early 2007 in the organization and execution of the Architects' Association of the City of Zagreb.

The space is divided across three floors: basement, ground floor, first floor and attic, with the total surface of almost 10,000 m². Walls are made from brick, the basement floor structure is brick arches, other floors' structures are systems of longitudinal and transversal beams (grids of beams), resting on cast-iron pillars and walls, the roof is wooden. All windows are classic wooden windows (double with inter-space). The average minimum temperature of heated rooms will be 20°C (depot and engine room have independent temperature regulation). The heating is central with hot water pipe distribution and fan coil devices or radiators serving as heating devices. The cooling of the building is envisaged by fan coil devices.

Heating and cooling of exhibition spaces, café, library, souvenir shop, conference hall, office spaces and documentation centre is envisaged through the four-pipe parapet fan coils attached to the supply system for the cold water at 6/12 °C and hot water at 60/50 °C. The office spaces will be the only rooms with windows that open, and they will be equipped with sensors for interruptions in fan coil convectors, when natural ventilation is used.

Every fan coil device is equipped with a three-speed fan for air circulation. Heating of large glass surfaces will be provided by floor-mounted fan coils.

Climatic chambers are intended for maintaining temperature and relative humidity within required limits, for internal depository spaces.

Auxiliary spaces will be heated by radiators at 75/55 °C, whereas the heating bodies will be compact radiators with the temperature regulation via the radiator valve with the thermo-head. (15)

ELEMENTARY SCHOOL ANTUN MIHANOVIĆ, KLANJEC, CROATIA



The oldest school building was built in 1888 with typical construction technique for that period. Due to bad shape of building construction and inadequate temperature regulation in classrooms energy efficiency measures that are implemented include increasing thermal comfort within the building and reduction of energy consumption for heating by automatic regulation of room air temperature and replacement of windows.

The Antun Mihanović elementary school in the city of Klanjec is an institution where children receive compulsory education from first to eight grade. The school building is situated in the city centre. Education is organized in one morning shift (8 a.m. till 2 p.m.) from Monday till Friday. 286 pupils attend the school. The school has 42 employees including teaching staff and maintenance personnel. A north-western and south-western part of the school building consists of teaching cabinets while the gym is located in the south-eastern part of the school.

The oldest school building was built in 1888 with typical construction technique for that period. The rest of the building was erected in 1960. From construction perspective the building as a whole is in bad shape. Plaster on building walls is damaged and at some places it is missing or detached. Damages caused by rain water on building envelope are clearly visible. Wooden window frames are damaged and in bad shape as well. Regardless of energy efficiency measures implementation, windows have to be changed due to their bad condition.

The building is heated by central heating system, with gas boiler and water radiators. Balance of heating distribution system and classroom temperature regulation is inadequate.

Installation of thermostatic valves on existing radiators included 66 pieces, 1/2", straight thermostatic valves and muffles and 4 pieces, 3/8", straight thermostatic valves and muffles that are installed on existing radiators. The implementation of this measure prevents uncontrolled overheating of classrooms and unnecessary operation of gas. This measure is implemented together with replacement of windows. It is estimated that the bad condition of windows

is responsible for significant heat losses through ventilation and transmission. Investment in installation of thermostatic valves is EUR 4,100 without VAT.

Wooden windows are completely worn-out, with destroyed seals, damaged shackles and peeled off protective primer colour. Particular parts of window frames are rotten and severely damaged so they present potential threat to users.

Single glazing metal doors and windows are made with metal profiles without broken thermal bridges, without seals.



Figure 2.9. Old (left) and new windows (right)

230 m² of new, double pane, five chamber PVC windows with broken thermal bridges and three seals, with thermo low E coated glazing are installed. Frame heat transfer coefficient is 1.3 W/m²K, of glazing 1.1 W/m²K and of complete window 1.2 W/m²K. Front entrance wall with doors embedded, back yard doors and doors at the end of corridors are made of aluminium profiles with broken thermal bridges with thermo low E coated glazing. Total heat transfer coefficient of entrance wall and doors is expected to be 1.6 W/m²K. Total area of applied aluminium doors and walls is 38 m².

The implementation of the proposed energy efficiency measures is expected to result in up to 22% savings for heating, in other words heating will be reduced by 48,025 kWh i.e. 5,742 m³ less gas will be spent per year. With the investment of 58,400 EUR and annual savings of 1,350 EUR, payback period is expected to be 44 years. (16)

ELEMENTARY SCHOOL BRAĆE SELJAN, KARLOVAC



Elementary school Braće Seljan in Karlovac, founded in 1893, is a two-story building with useful area of 2,000 m². The building is heated by a central water heating system connected to district heating system. The total investment for windows replacement was EUR 48,000, while annual heating energy savings are EUR 2,800.

Elementary school Braće Seljan in Karlovac, founded in 1893, is a two-story building with useful area of 2,000 m². Entrance hall, classrooms, cabinets, kitchen, headmaster and secretary offices and lavatories are located on the ground floor. On the first floor there are classrooms, cabinets, accountant office, library and lavatories.

The building is heated by a central water heating system connected to district heating system. Heat between the district heat supply circuit and the school heating system is transferred by a shell and tube heat exchanger. The output heating power of the shell & tube heat exchanger is 400 kW.

Due to their poor condition windows and doors were replaced. Since the school falls under the cultural heritage category, the Directorate for the Protection of Cultural Heritage under the Ministry of culture of the Republic of Croatia has put several conditions on window material and appearance. The requested material for window frames was ivory coloured wood with the same window configuration as that of the existing windows. This meant that each individual window had to be tailored which is more costly than applying windows produced in a standard fashion.

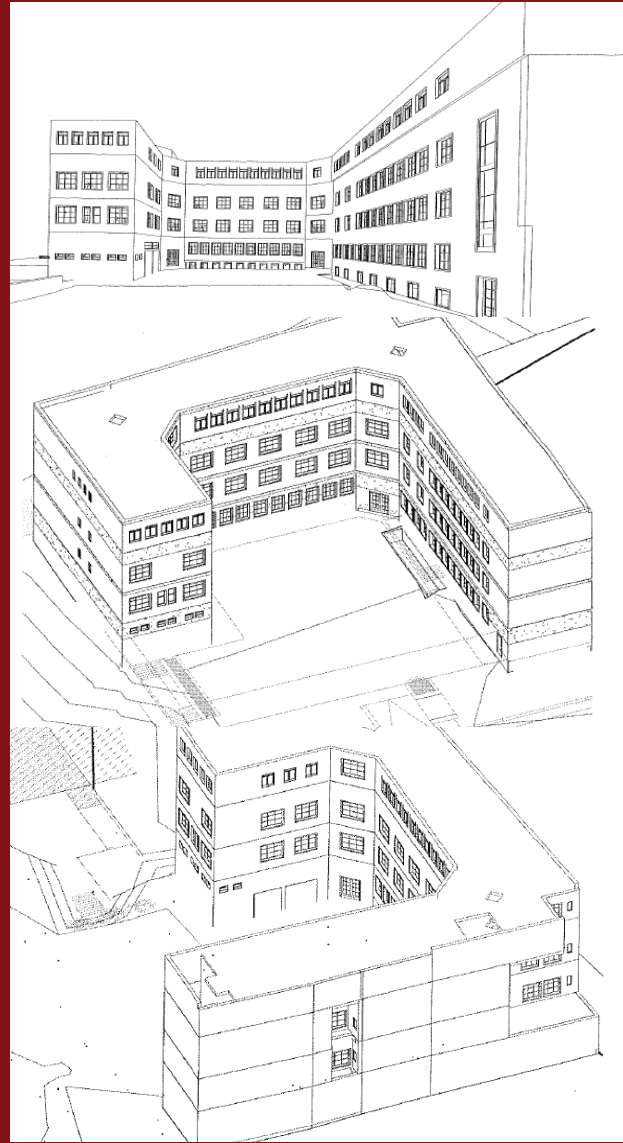
The total investment for windows replacement was EUR 48,000, while annual heating energy savings are EUR 2,800. (17)

2.2.4. VENTILATION AND AIR QUALITY

The implementation of energy efficiency measures into the existing building stock is essential to meet the 2020 targets set by the EU Energy Performance of Buildings Directive (EPBD) and reinforced with the “EPBD-recast”. Thus, energy refurbishment of existing buildings is fundamental to achieve these goals. However, energy issues should not be the only concerns since the indoor environmental quality (IEQ) is also as important. When planning a building retrofit it is necessary to consider the energy efficiency requirements as well as the IEQ.

The main objective of the study presented in this chapter was to characterize the actual situation of a building which represents a great number of Portuguese office buildings. This provided the basis for identifying the principal problems that occur in such buildings, as well as for supporting the development of the building refurbishment project aiming to optimize both energy efficiency and relevant parameters of the IEQ and therefore bring about solutions that may be applied in other buildings as well.

OPERATIVE CONDITIONS EVALUATION FOR EFFICIENT BUILDING RETROFIT, PORTO, PORTUGAL



From the energy performance perspective, tendencies of the most recent regulations are to increase insulation thickness and reduce air change rates.

Retrofit solutions that increase thermal insulation of the envelope (thermal insulation placed inside or thermal insulation placed outside the existing walls and roofs) must take into consideration their effect on the useful area available in the building.

Air change rate has to be planned carefully because its reduction can decrease fresh air intake and thus increase consequent build-up of internally generated pollutants including carbon dioxide, volatile organic compounds, fungi, etc.

Apart from the IEQ, thermal, acoustic and visual comfort, also have a significant effect, not only on health and well-being, but also on productivity. Studies show that increasing indoor temperatures in buildings may be associated with increased intensity of symptoms of fatigue, headache and difficulty in thinking clearly and on the prevalence of sick building syndrome (SBS) symptoms, even within the temperature comfort zone.

Lighting is also an important issue in minimizing overall energy consumption. Investment in energy-efficient lighting is considered as one of the most cost-effective ways of reducing CO₂ emissions and studies show that electricity use for lighting can be reduced by 50% using existing technology. A study of the combined effect of different comfort stressors in the overall comfort perceived by a building's occupants is thus very important for ensuring a suitable IEQ.

This work presents a study carried out in a large office building to identify the main pathologies with an aim to optimize the building's energy efficiency and the relevant parameters of the indoor environmental quality.

The building, located in the centre of Porto, in the north-west of Portugal, was chosen because it represents a great share of Portuguese office buildings built before the implementation of the first Portuguese Thermal Regulation, though without any thermal concerns.

The 5-story building (the ground floor is partially underground) built in the 1970 has a useful area of 2,713 m².



Figure 2.10. General view of the building (west, north and east wing)

The walls are concrete masonry units 27 cm thick with plaster finishing and the roof is a concrete slab. All the windows are single glazed with metallic frames. The ground floor windows do not have any shading devices and the first floor windows have venetian blinds placed inside. The windows on the second and third floors have roller shutters while the windows on the fourth floor have curtains. The building is naturally ventilated and has a central heating system with an oil boiler hot water distribution system and radiators in the offices and meeting rooms. There is no centralized cooling system and most offices do not have any active cooling systems.

In order to identify the building's main problems and to assess its operative conditions a series of measurements, in characteristic offices that represent different situations existing in the building, were performed, namely:

- comfort conditions:
 - thermal comfort: air temperature and relative humidity, operative temperature,
 - acoustic comfort: A-weighted sound pressure level, LA eq and
 - daylight conditions: illuminance level;
- indoor air quality conditions: measurement of the concentration of suspended particles, carbon dioxide (CO₂), carbon monoxide (CO), ozone (O₃), formaldehyde (HCHO) and total volatile organic compounds (VOCs);
- Characterization of the operative conditions of the buildings – building air tightness (air change rate, ACH), occupation patterns, equipment and appliances existing in the rooms and their pattern of use.

The “in situ” measurement of the parameters regarding the IEQ and energy efficiency followed the procedures defined in national and international standards,

- thermal comfort: EN ISO 7726, EEN ISO 7730 and ASHRAE 55;
- acoustic comfort: NP 1370 and EN 15251;
- visual comfort: EN 15251 and EN 12464-1;
- indoor air quality: according to the thermal regulations in Portugal, it is mandatory to carry out IAQ audits in office buildings;
- air tightness: blower door test was performed;
- occupants survey: a standard questionnaire (prepared in accordance with the methodology defined in EN 15251) was delivered to the occupants for the purposes of obtaining a subjective assessment of the IEQ and to assess the occupants' main complaints.

Moreover, the estimation of the building energy needs and energy consumption was done using the EnergyPlus simulation software.

Measurement results and survey assessments

According to the survey results the main deficiencies are associated with lack of thermal comfort due to inadequate indoor air temperatures, noise due to poor acoustic insulation of windows and office appliances. Air quality was rated just acceptable, while complaints regarding visual comfort were reported due to insufficient illumination even with the lights turned on.

From the results obtained in the measurement campaign, indoor air temperature and relative humidity (22°C to 27°C and 50% RH) exceed the comfort conditions defined in the EN 15251 standard for naturally ventilated buildings. It was also observed that the occupants do not leave the windows open during night time (when outdoor air temperature is approximately 20°C) and that the warmer air temperature could be used to cool the heavy thermal inertia of the building.

The thermal comfort conditions were also assessed through calculation of the PPD (percentage of people dissatisfied) and the PMV (predicted mean value) indicators. It was verified that in these circumstances, comfort conditions were not reached for the most part of the office rooms. According to the EN 7730 and EN 15251 standards, the desired thermal environment in a space of an existing building (category C or III buildings, respectively) are, PPD less than 15% and PMV from +/- 0.7. These conditions were only met in one tested office. In other assessed offices, PPD is over 30% and PMV varies from 0.9 to 1.1.

Regarding acoustic discomfort, the main source of noise is traffic, as the building is located near a heavy traffic road, while other sources are computers and printers. Due to that, the measured values ranging from 47 dB(A) to 58 dB(A) and 61 dB(A) outside are higher than the recommended ones (30 to 40 dB(A)).

Visual comfort conditions were satisfied only in one of the tested offices. Even when artificial light was used, the recommended illuminance level (500 lux) was not reached in most of the tested rooms. In one case due to poor regulation of blinds and shading devices the illuminance level was highly exceeded. Therefore it is necessary to intervene not only regarding daylight and shading devices but also regarding artificial lighting.

The Indoor Air Quality (IAQ) was assessed through measurement of the physical pollutants concentration (CO , CO_2 , HCHO , VOC , O_3 , PM_{10}). The measurements show that the concentrations of CO_2 and CO are considerably lower than the limits due to the fact that the occupants

open the windows and the outdoor concentration is low as well. Regarding volatile organic compounds (VOC) the measurements showed a high concentration (almost 5 times higher) only in the laboratory, where chemical reagents are used. A high concentration of formaldehyde (HCHO) (about 8 times higher than the maximum value allowed) was also measured in the laboratory and offices located above the laboratory.

Higher concentrations of other pollutants than allowed, i.e. ozone (O_3) were found in three tested offices, probably due to the outdoor concentration (intense traffic) and the presence of laser photocopiers. The recorded suspended particles concentration are lower than maximum allowed and are mainly present due to the outdoor concentration as the building is located near a heavy traffic circulation road.

Figure 2.11. shows the measured values of the air flow rate of one the tested rooms, depending on the building pressure. The minimum air change rate according to the Portuguese thermal code is $0,6 \text{ h}^{-1}$.

The difference between indoor and outdoor pressure was $P=0.45 \text{ Pa}$, the flow coefficient $C=74.5 \text{ m}^3/\text{h}/\text{Pa}^n$ and the flow exponent n was 0.588. The air change rate is calculated according to relation $Q = C \times P^n$ to be 1.03 h^{-1} .

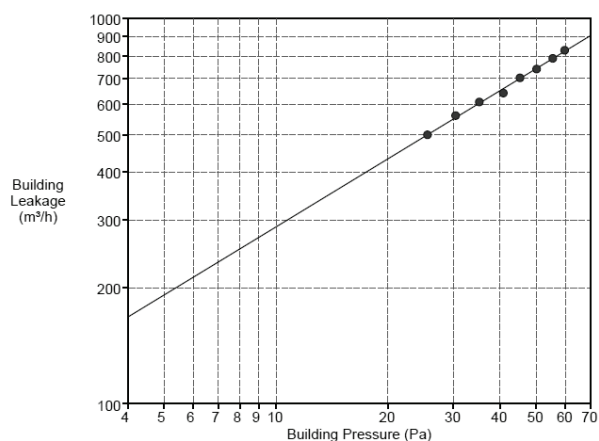


Figure 2.11. Blower door test results for one characteristic office

Taking into consideration the results of the IEQ and the air tightness assessment, an estimation of the building thermal behaviour was performed using Energy Plus simulation software. The building characteristics, envelope construction solutions, shading systems, lighting systems, appliances, air-conditioning systems were also assessed while the occupation and systems use schedules were defined in accordance with the Portuguese thermal legislation.

Table 2.13. presents characteristics of the main building envelope and the maximum U-value and shading factor according to the Portuguese regulation.

Table 2.13. Building envelope characteristics

	Walls	Roof		Windows
	U value [W/m ² K]	U value [W/m ² K]	U value [W/m ² K]	Shading factor (including glazing and shading device)
Building	1.90	1.40	6.2	0.45
Maximum allowed value	1.60	1.00	-	0.56

Simulation results on annual energy consumption are shown in Table 2.14.

Table 2.14. Summary of simulation results

	Heating	kWh/m ² year	68.5
Energy needs	Cooling	kWh/m ² year	11.2
	Total	kWh/m ² year	79.7
	Heating	kWh/m ² year	95.1
Final energy	Cooling	kWh/m ² year	11.2
	Appliances	kWh/m ² year	40.5
	Lighting	kWh/m ² year	16
	Heating	kW	168.6
Equipment rated capacity	Cooling	kW	32.4
	Total	kW	201.0

Measurements and simulation results confirmed the necessity of reducing the envelope U-values, using higher insulation levels and replacing the windows, since the original building values are higher than the recommended ones by the actual Portuguese legislation (0.6 and 0.45 W/m²K for walls and roofs, respectively), and in some cases even higher than the maximum allowed values (1.6 and 1.0 W/m²K for walls and roofs, respectively). The air change rate must also be controlled, replacing the windows.

On the basis of conducted measurements and operating condition assessments it is possible to identify critical problems and to propose refurbishment measures.

The assessment of the existing conditions showed an inadequate behaviour of the building at all IEQ levels.

The IEQ measurement campaign showed that the temperature in the offices was higher than the comfort zone leading to the thermal discomfort of the occupants. The offices were also noisy and uncomfortable at the acoustic level.

In what concerns the visual comfort, both with natural and artificial light the illuminance level did not meet the recommended values. If the occupants were not able to adjust the shading system to control the sunlight that enters the room, glare problem occurred.

Even with a high air change rate, the building also presented some problems related to the IAQ, namely high concentrations of VOCs, formaldehyde and ozone.

Thus, as the thermal and acoustic insulation of the façade is insufficient, the daylight and artificial light levels are inadequate, the ACH is high and the IAQ is inadequate, interventions at these levels are essential to increase the energy performance and IEQ.

It is then necessary to improve the thermal and acoustic qualities of the envelope, mainly through the replacement of windows, optimization of shading systems and improvement of thermal quality of the walls. As the windows should be more air tight, installation of a ventilation system is also necessary to ensure the IAQ.

The artificial light system should also be studied in order to effectively complement daylight levels, when necessary, and ensure an adequate illuminance level in the task area.

Refurbishment measures

Building envelope improvements for reduced energy use are typically measures that enhance thermal characteristics of the envelope and/or that increase solar gains through fenestrated parts of the envelope. The building envelope refurbishment options investigated in this case study primarily aim at improving the thermal characteristics of the envelope by reducing transmission, infiltration, and ventilation losses (as it is not possible to change the windows dimensions to increase the solar gains, and the existing glass has a high solar factor).

Maintaining the original wall construction, two retrofit options were studied to refurbish the building. These two solutions were selected as they are most widely used in

Portugal. The first option was to install a thermal insulation layer on the outside (8 cm of expanded polystyrene – ETICs system).

The second option was to apply thermal insulation inside (6 cm of cork and 1.3 cm plasterboard). When placing the insulation inside an existing wall it is necessary to consider the impact on the useful area of the room that will be reduced. Thus, a thinner layer of thermal insulation was used in this refurbishment option.

Due to local constraints that prevented the placement of insulation in the roof of the building, because the 4th floor was not subjected to rehabilitation, in both options, a suspended ceiling with a 10 cm thick layer of cork and 1.3 cm plasterboard was added to the ceiling of the 3rd floor. Cork was selected for these insulation solutions because it is an abundant material in Portugal with good thermal properties and sustainable characteristics.

It was also necessary to replace the windows as they were single glazed with metallic frame, leading to high heat losses in winter, and also to improve the thermal and acoustic quality of the envelope. Thus, the existing windows were replaced by aluminium framed windows with broken thermal bridges and double clear glazing with venetian blinds placed on the outside, in both refurbishment options.

Additionally an extractor must be installed in the laboratory to ensure the removal of polluted air. The polluted air should be released above the building in order to prevent it from entering the office rooms adjacent to the laboratory.

Table 2.15. presents the main building envelope characteristics of the original building and the two refurbishment options.

Additionally, it is necessary to select a HVAC system that fulfils the building's needs since the building has no cooling system whereas the existing heating system is not able to fulfil the heating needs.

Assessment of energy consumption for refurbishment measures

For the existing solution, the final energy consumption was calculated considering the reference system defined in the Portuguese thermal regulation (an electric resistance with 100% efficiency and a chiller with a COP of 3). Afterwards, a pellets boiler (efficiency of 60%) was selected to replace the existing diesel boiler (efficiency of 72%). The cooling needs will be ensured by a chiller (COP of 3).

According to results from simulation software the building envelope retrofit will result in a 45% reduction of heating needs and more than 25% reduction of cooling needs.

Table 2.15. Building envelope refurbishment characteristics

	Walls	Roof		Windows
	U value [W/m ² K]	U value [W/m ² K]	U value [W/m ² K]	Shading factor (including glazing and shading device)
Existing	1.90	1.40	6.2	0.45
Retrofitting – outside insulation	0.40	0.30	3.30	0.11
Retrofitting – inside insulation	0.48	0.30	3.30	0.11
Maximum allowed value	1.60	1.00	-	0.56
Recommended value	0.60	0.45	-	0.20

Also, for both retrofit options, more energy efficient appliances (the substitution of CRT computer monitors for TFT monitors) and light bulbs were applied.

The former heating system was replaced and a cooling system was installed. The heating system selected was a pellets boiler (efficiency of 60%) since it uses biomass as an energy source. Energy produced from pellets is cheaper than that one produced from oil (0.67 €/l for biomass and 1.15 €/l for oil). The radiators and heating control system were not changed.

The cooling system consisted of a water chiller with coefficient of performance (COP) of 3.

The annual energy needs will be reduced by more than 40%.

With the installation of the pellets boiler (efficiency of 60%) and the chiller (COP of 3) in addition to the improvement of the envelope, the required heating and cooling final energy consumption is reduced by more than 20%.

With the retrofit of the building envelope, the heating system, appliances, and light bulbs replacement and the installation of the cooling system, the final energy consumption can be reduced by about 47%.

Following the reduction in energy consumption the cost for energy will decrease as well. With the building envelope retrofit and the replacement of heating system, appliances and light bulbs as well as with the installation of chiller, the

annual cost for energy can be reduced by up to 37%.

Since the results obtained by applying exterior or interior insulation are similar (difference is less than 4%), both the use of insulation placed outside or inside the existing wall were an alternative.

The use of a mechanical ventilation system with heat recovery, would allow an even higher energy savings, ensuring the achievement of the optimum values for the air change rates, with minimum waste of energy during winter.

Discussion

The building was built before the introduction of the Portuguese thermal codes, thus the envelope, especially the windows, has a low thermal resistance, leading to high heat losses, during winter, and heat gains during summer. Additionally, the poor thermal quality of the envelope leads to low indoor temperatures in winter and high indoor temperatures in summer as well as high heat exchanges due to radiation from the surfaces. Therefore, even with the use of HVAC systems, the thermal comfort conditions are not met.

Inadequate airborne sound insulation of the facades failed to prevent outdoor noise, which also made the offices uncomfortable. The indoor noise, mainly due to occupancy but also printers and copiers contribute to uncomfortable noise levels as well.

To ensure the visual comfort it is necessary to select an adequate glass type and adjustable shading systems that balance and control daylight (preventing glare) and, consequently, the energy needs.

Artificial lights systems should be planned carefully because even with the lights on, the lighting levels failed to meet the requirements.

Thus, in general improving the thermal and acoustic quality of the envelope will have a positive effect on the thermal, acoustic and visual comfort indoors. Additionally, to ensure the thermal comfort conditions it is necessary to install an adequate heating and cooling system with high efficiency.

These measures would not have a direct impact in the IAQ, or will have a negative impact, as improving the thermal and acoustic quality of the windows will reduce the air change rate.

And, in this case study, even with a high ACH and the use of natural ventilation in the offices, the concentration of some pollutants was still high (mainly O₃, VOCs and HCHO).

As the printers and copiers are the potential cause of noise and high O₃ concentration the placement of these equipments in specific areas, with an adequate ACH and envelope, will be beneficial both for acoustic comfort and for IAQ.

Apart from the installation of more airtight window frames and doors it is necessary to install mechanical ventilation systems with heat recovery units to ensure an adequate air change rate of the building for the purposes of reducing the uncontrolled infiltrations through the envelope that lead to high energy losses through ventilation and to guarantee the indoor air quality.

To mitigate the VOCs and HCHO concentrations in the laboratory and, by extension, in the adjacent office rooms, additional measures are required. It is necessary to install an extractor in the laboratory to remove the polluted air and release it above the building in order to prevent the polluted air to enter in the office rooms adjacent to it.

The above referred measures are adequate for a vast set of buildings that might be represented by this case study building and can be adapted to their specific situation and would ensure the IEQ goals in an energy retrofit project.

The first measures to address must be the passive improvement of the thermal quality of the envelope, and when necessary, the HVAC systems must be selected carefully (type, efficiency and energy source).

Conclusions

This paper presents the “in situ” assessment of the operating conditions and of the Indoor Environmental Quality (IEQ) of a Portuguese office building located in the centre of a big city. The measurement campaign was divided into three major areas: characterization of the buildings operating conditions, comfort conditions (thermal, acoustic, visual) and Indoor Air Quality (IAQ).

With the operating conditions assessment carried out, it was possible to identify some of the most critical problems of the building, the ones that need particular attention during the rehabilitation interventions.

The study of the building’s actual situation revealed problems regarding both the indoor environmental quality and energy efficiency.

The IEQ assessment showed an inadequate behaviour of the building in what concerns the thermal, acoustic and visual comfort conditions.

The indoor temperature was above the comfort interval and the offices were uncomfortable due to both indoor and outdoor noise.

With the daylight availability analysis, it was possible to conclude that if the shading devices are not activated, the illuminance values are too high and glare problems occur, when direct sunlight enters the offices. The daylight conditions were also not adequate when the shading systems were partially activated to prevent the solar radiation to enter the building. The artificial lighting

system of the office rooms did not provide the necessary illuminance levels for the tasks that are usually performed in those spaces.

The study also showed some problems related to the indoor air quality as high concentrations of some pollutants, such as volatile organic compounds, formaldehyde and small concentrations of ozone, even in the presence of a high air change rate characteristic to this building, were detected.

The envelope had a poor thermal insulation. The envelope U-values were, in general, higher than the maximum values allowed by the Portuguese legislation and significantly higher than the recommended ones.

The poor thermal resistance of the envelope and high air change rate lead to high energy consumptions that the existing heating system was not able to deliver (electric radiators in some offices were a way to overcome this problem). Additionally, as there is no cooling system installed in the building, the occupants used fans to minimize their thermal discomfort.

The measurement campaign confirmed the necessity of reducing the envelope U-value, using higher thermal insulation levels.

It is also important to reduce the uncontrolled infiltrations through the envelope, using more airtight window frames and doors and using mechanical ventilation systems with heat recovery units to ensure an adequate air change rate of the building to reduce the energy losses through ventilation and to guarantee the indoor air quality.

Improving the quality of the window frames and doors and increasing the insulation level of the façades, will also have a favourable effect on the acoustic and thermal comfort. However, to achieve comfort conditions it is necessary to install heating and cooling systems, carefully selected to ensure energy efficiency.

The refurbishment options were defined to tackle the most relevant deficiencies presented by the building, at three levels: envelope quality, appliances and lighting and HVAC systems.

Two retrofit options were studied to refurbish the building: thermal insulation placed inside (6 cm of cork and 1.3 cm plasterboard) and thermal insulation placed outside (8 cm of expanded polystyrene). A suspended ceiling with a 10 cm thick layer of cork and a 1.3 cm plasterboard was added to the roof and the existing windows were replaced by aluminium frames with thermal break and double clear glazing with venetian blinds placed on the outside.

The dynamic energy simulation study of the existing office building and of the two retrofit options showed important reduction in the energy consumptions of the building.

Retrofitting the building envelope, replacing the systems, appliances and light bulbs with more efficient ones, will lead to a reduction of about 47% in the final energy consumption and to a reduction of the energy bill of about 37%.

The evaluation of the existing operative condition was essential to the definition of the refurbishment options for the building. Only with the analysis of the existing conditions and with the occupants' survey was it possible to identify the main problems of the building and thus to define the most adequate refurbishment options for the building. (18)

2.2.5. SOLAR SYSTEMS

When discussing solar energy, two typical systems need to be referenced:

- hot water production and
- electricity production.

In the following examples these systems and their introduction to the cultural heritage buildings are described in detail. In the example of Edinburgh's UNESCO world heritage site the most commonly recommended measures to improve the energy efficiency of residential buildings cannot be applied, such as: cavity wall insulation cannot be applied to solid stone walls; loft insulation is not an option unless the flat is on the top floor; double glazing is not permitted as it is a listed building; a gas boiler may not be permitted if the flue would go through the front wall, and the configuration of tenements can mean that some flats have no other external walls. With that in mind, solar water heating is installed with panels hidden in roof valleys, invisible for all intents and purposes.

Second example considers electricity production in the City of Rijeka, where photovoltaic power plant of 9.9 kWp was installed in 2009 with yearly electricity production of 12,000 kWh.

Elementary school Marin Getaldić, built in masonry limestone at the end of the 16th century, is located in the strict centre of the City of Dubrovnik. The school has electric heating with two 24 kW boilers. 89% of electricity consumption is for heating, 8% for lighting, 2% for office appliances and only 1% for DHW. Detailed plan for reconstruction was presented with building and HVAC system reconstruction. Due to a mild climate air to water heat pump system was suggested with installation of 5.5 kWp of photovoltaic panels placed on the roof of the gym located in the central courtyard.

EDINBURGH'S UNESCO WORLD HERITAGE SITE



Traditional Scottish tenement flat, built from stone in the 1800s and grade 'B' listed due to its quality and its location in central Edinburgh. Solar systems were provided to householders on all floors of the tenement buildings (even those at basement level), with the panels being hidden in roof valleys to satisfy conservation requirements.

Traditional Scottish tenement flat, built from stone in the 1800s and grade 'B' listed due to its quality and its location in central Edinburgh. It has solid walls; no loft, an expensive electric heating system, single glazing and its large rooms and high ceilings mean there is a lot of space to heat. Its location in the Old Town puts the householder at high risk of fuel poverty, one of the primary causes of which is poor energy efficiency.

Some of the most commonly recommended measures to improve energy efficiency in a home: cavity wall insulation cannot be applied to solid stone walls; loft insulation is not an option unless the flat is on the top floor; double glazing is not permitted as it is a listed building; a gas boiler may not be permitted if the flue would go through the front wall, and the configuration of tenements can mean that some flats have no other external walls.

Some of the more high-tech options to enable this flat to generate its own energy: solar panels and air source heat pumps may well not be permitted if they would be visible in this historic setting; wind turbines would not perform well in this built-up area; there is no water source for a hydro turbine; biomass systems are fraught with complications in urban settings due to concerns over particulate emissions; and a ground source heat pump would be hard to install due to limited ground space and legal complications due to the multi-ownership of the block.

As part of Changeworks' Renewable Heritage project, solar water heating systems were installed in 49 grade 'B' listed Georgian tenement flats in Edinburgh's Old Town, a conservation area and part of the UNESCO World Heritage Site. Solar systems were provided to householders on all

floors of the tenement buildings (even those at basement level), with the panels being hidden in roof valleys to satisfy conservation requirements. This has delivered an innovative microgeneration solution for both historic housing and tenements, and is now upheld as an example of best practice that can be replicated across Scotland.

In the first phase of the project, panels were installed in hidden roof valleys formed by the 'M'-shaped roofs of the Georgian tenements, making them invisible to all intents and purposes; pipework was then run down through the buildings to serve all flats in the stairs. In the next phase, panels will be installed on angled frames on the flat (mansard) roofs of Victorian and 1980s tenements (these installations are forthcoming, although permissions have already been granted).

All microgeneration systems were assessed, however it quickly became apparent that solar water heating systems would be the most viable option for these buildings.

The Georgian tenements are listed and so Listed Building Consent was needed; however Planning Permission was not necessary due to the proposed panel location in hidden roof valleys. The reverse was the case for the Victorian and 1980s tenements: they are not listed so no Listed Building Consent was necessary, but Planning Permission was needed as the panels would be visible on the flat roofs. Building Warrants were needed in all cases.

Each flat has a display monitor so the householders can see how much energy their system is generating. A more detailed data logger is fitted onto the pump station of each system, which it was decided to site in the roof space. These are secured to wooden back-boards, and flooring and lighting have also been fitted to satisfy health and safety requirements. The systems should generate at least half of the hot water needs of each property. The capital costs were around 4,673 EUR per system, which is slightly higher than average due to the complexity of the installations. (19)

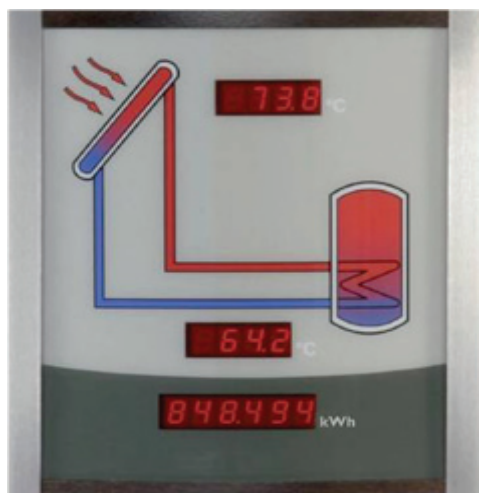


Figure 2.12. Solar water heating system data logger

EXAMPLE OF THE CITY OF RIJEKA, CROATIA



The Rijeka Municipality building was originally built in 1914. In 2009 photovoltaic power plant of 9.9 kWp was installed and put in service on the upper terrace of the building. That was technically and financially acceptable for the owner of the building, as well as for the investor. The City of Rijeka also accepted the Sustainable energy action plan (SEAP) and started with the implementation of smart metering in that same building.

The building was built in 1914, in the late historicism style, for the original owner Cassa Comunale di Risparmio - Ugarska banka, Fiume.



Figure 2.13. PV system on the Rijeka Municipality building

The first solar power plant was built in June 2009 on the Municipality building, in the centre of Rijeka. Total installation power is 9.9 kW and yearly predicted electricity production is around 12,000 kWh. Nowadays, the total electricity production is used for the building's electricity needs while the process of feed-in tariff registration is still ongoing.

Further research of PV investment feasibility demonstrates positive net present value and solid 9.17 percent of IRR. Calculations were made with the feed-in tariff selling price of 0.51 EUR per kWh electricity production and sale to the grid, for the next 12 years, according to Croatian regulations. (20)

ELEMENTARY SCHOOL MARIN GETALDIĆ, DUBROVNIK



Elementary school Marin Getaldić was built in masonry limestone at the end of the 16th century while first adaptations started in late 1817. Last renovation was done in 1986 when the roof was completely reconstructed. The school is located in the strict centre of the City of Dubrovnik and is therefore under protection as a cultural heritage building. Electricity is the only energy source present in the building. Instead of using pure electrical resistance heating, the utilization of air to water heat pump would cut electricity consumption for heating by factor 4. Moreover, installation of PV modules, with the total collector area of 36 m², would enable production of 5,133 kWh of electric energy annually with the total income of EUR 2,600 per year.

Next to the main building there is an archaeological garden and a gymnasium built in 2005 as an annex building. 21 employees, teaching and maintenance personnel and approximately 140 pupils occupy the school. School year starts in September and lasts till mid June with winter and spring breaks, i.e. 175 working days from 8 a.m. till 3 p.m. Classes are organized in one morning shift.

Total useful area of the main building is 1,030 m², and 250 m² of gym. Main building walls are built with 50 to 85 cm thick limestone blocks with 3 to 5 cm of lime-cement plaster on the inside. Floors and roof are wooden without thermal insulation applied. Double wing windows are of wooden frames with single 3 mm white glazing. Although construction elements of building envelope (walls, windows, roof, floors) are visually in good shape they do not satisfy conditions under Croatian Technical Regulation on Energy Economy and Heat Retention in Buildings (NN 110/09, 89/09) as shown in Table 2.16.

The main school building is heated with electric central heating system with output rated power of 48 kW. Heat is produced in two electric furnaces (2 x 24 kW) and is distributed via polyethylene pipes to floor heating registers. Heating temperature regime is 70/50°C. The gymnasium building is ventilated and heated by air prepared in a central air handling unit with a 18 kW electrical heater. There is no cooling system.

Energy and water consumption and its related costs are shown in the table 2.17.

According to calculations 89% of total electrical energy is consumed for heating, only 8% for lighting, 2% for office appliances and 1% for heating of domestic hot water.

Specific annual building energy consumption for heating, calculated from bills for energy, is 19 kWh/m³. According to the aforementioned regulation such energy consumption places the building in the energy class D.

96% of installed light bulbs are of classic type and only 2% are energy saving lamps (Figure 2.14.).

As a result of conducted energy audit of the building a list of measures to improve energy efficiency of the building is suggested (Table 2.18). Measures are divided according to height of investment cost, ranging from no-cost measures, low cost up to medium and high cost measures.

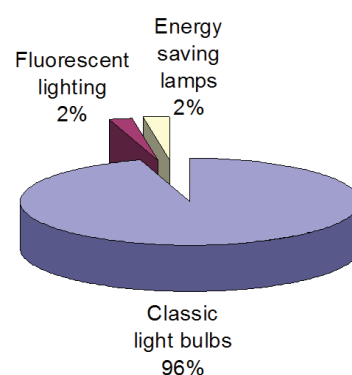


Figure 2.14. Lighting system

The first packet of suggested measures, i.e. no-cost measures includes organization of technical documentation on energy systems (heating system first and foremost), implementation of the Energy Management System, set up and adjustment of heating system regulation and control of ventilation losses. It is proven that installation of the Energy Management System can save between 10-15% of energy in average. Increasing the heating system set point temperature by only 1°C would result in an increase of energy consumption for heating by between 5-10%. Therefore, it is important to keep the set point temperature within reasonable limits, i.e. between 20 and 22°C depending on an ambient air temperature. Operation time of the heating system is another important parameter which, if not carefully monitored, can unnecessarily increase energy consumption. It is important to keep the heating system on only during school operating time (plus designated extra time period before commencement of school term needed for the heating system to reach operating temperatures). Leaving the heating system on after school hours increases the heating energy consumption by at least 15%. Since the school building does not have a mechanical ventilation system, ventilation of the premises is done by

Table 2.16. Building envelope construction elements

Construction element	U – value [W/(m²K)]	U – value allowed [W/(m²K)]	Comment
Door type 1	3.5	2.9	Outer door, wooden frame with double white 3 mm glazing
Door type 2	4.0	2.9	Full wooden door
Window type 1	3.0	1.8	Wooden frame, double wing window with one white 3 mm glazing for inner window and double pane 3 mm glazing for outer window
Window type 2	3.5	1.8	Wooden frame, single wing, double pane window, with 3 mm glazing
Floor	2.0	0.5	stone and concrete
Roof	0.6	0.4	Wooden roof construction with insulation elements
Walls	1.5 - 1.3	0.6	Lime stone 70 do 85 cm with plaster on the inside

Table 2.17. Energy and water consumption and its related costs in 2009

Energy source	Consumption [kWh/a] or [m³/a]	Specific consumption [kWh/(m²a)] or [m³/a]	Cost [kn/a]	Specific cost [kn/kWh] or [kn/m³]
Electricity	121,373	76.76	85,787.09	0.7068
Water	1,092	6.90	14,770.60	13.52

Table 2.18. Energy efficiency measures

EM	Energy measure	Investment cost	Savings		Return of investment	CO ₂ emission reduction
		[kn/a]	[kWh/a]	[kn/a]	[annum]	[tons/a]
1.	Organization of energy systems technical documentation	0	0	0	0	0
2.	Implementation of Energy Management System	0	0	0	0	0
3.	Adjustment of heating regulator (heating setpoints)	0	6,000	4,240.80	0	3.18
4.	Ventilation control	0	7,000	4,947.60	0	3.71
TOTAL (1-4)		0	13,000	9,188.40	0	6.89
5.	Heating system regulation	1,000.00	5,000	3,534.00	0.3	2.65
6.	Sealing of windows/doors	1,950.00	6,000	4,240.80	0.5	3.18
TOTAL (5-6)		2,950.00	11,000	7,774.80	0.4	5.83
7.	Adding roof insulation	80,680.00	5,540	3,915.67	20.6	2.94
8.	Windows/doors replacement	418,000.00	12,090	8,545.21	48.9	6.41
TOTAL (7-8)		498,680.00	17,630	12,460.88	34.8	9.34

EM	Energy measure description	Investment [kn/a]	Savings [kWh/a]	Savings [kn/a]	ROI [annum]	CO ₂ emission reduction [tons/a]
9.	Heating system refurbishment – Implementation of air-water heat pump	125,390.00	78,286*	55,332.54	2.3	41.49
10.	DHW heating with solar collectors	15,000.00	1,266	894.81	16.8	0.67
11a.	Heating system refurbishment– solar collectors with new electrical furnace	210,989.84	38,069*	26,907.17	7.8	20.18
11b.	Heating system refurbishment– solar collectors with air-water heat pump	329,129.27	87,568*	61,893.06	5.3	46.41
12.	Electricity production with PV panels	145,336.80	5,133**	19,360.65	7.5	2.72
13.	Water consumption reduction	2,955.50	164 m3	2,215.00	1.3	0
14.	Lighting systems refurbishment	7,500.00	8,152	8,604.63	0.9	4.32

* electric energy savings, not savings of heating energy distributed to consumer ;** produced and not consumed energy on site. Produced energy is to be fed to the national electro-energetic system; **Remarks:** adding particular measures savings and CO₂ emission reductions is not allowed due to interactions between particular measures; investment is expressed without VAT.

natural ventilation mainly by air infiltration through cracks in windows and doors as well as by opening of windows. Windows opening is a more effective way of natural ventilation than infiltration. In light of energy conservation during heating period, it is of highest importance to keep the windows opened only as long as is necessary for appropriate space ventilation in order to avoid increased ventilation energy losses. It is advised that all windows in a room should be opened periodically for a short period of time, e.g. for 5 minutes. This allows fast exchange of exhausted air with fresh air while preventing room walls and floor from cooling. Since air has a low specific heat capacity, fresh cold air is heated quickly without compromising comfort and energy efficiency.

School ventilation losses account for 30% of total heating losses. With careful windows opening ventilation losses can be reduced drastically. A decrease of air exchange rate by only 0,1 h⁻¹ would reduce annual energy consumption for heating for 7%.

The second package of measures, low cost measures, consists of modernization of the heating system regulation and reduction of infiltration ventilation losses by windows sealing. Since the heating system is operated manually and only the capacity regulation is done automatically through a temperature sensor, a replacement of the existing regulator with one that has a time function is suggested as it allows different modes of operation, e.g. night and weekend heating programme. This would enable a more precise system regulation with less manual interference. It would also allow a more flexible system start-up and shutdown, setting of setup temperature during off hours,

e.g. room temperature of 18°C after morning shift and 16°C on weekends. Retrofitting of the heating system regulation would decrease heating energy consumption by 5%. Air infiltration can be reduced with sealing of windows and doors. It is estimated that air exchange rate can be reduced by 0.05 to 0.15 h⁻¹. As a consequence the annual heating energy consumption would be reduced by 3 to 9%. Sealing can be done with EPDM rubber seal or polyurethane foam. Refurbishing of building construction elements demands high investments and yield long payback periods. Since the school building falls under cultural heritage category changing the building's visual identity is strictly forbidden. Therefore, in order to improve energy performance of the building (thermal insulation on exterior building walls is not allowed whereas its application on the inner walls would have a negative effect on the useful area available in the building) the retrofit options suggested consider increasing the roof insulation and replacement of old windows. However due to significantly long payback period it is suggested to initiate implementation of these measures when they become necessary. The existing roof insulation should be increased by adding a new 400 m² layer of 10 cm thick insulation. Recommended roof insulation thickness for Mediterranean climate region is 15 cm. The implementation of this measure would result in 6% savings for heating. Windows and doors replacement has to be conducted under supervision of the Directorate for the Protection of Cultural Heritage. The window material and appearance (window field arrangement and colour) have to be the same as existing. It is recommended to install new, double pane, five chamber wooden windows, with thermo low E coated glazing filled with inert gas, with total

heat transfer coefficient of $1.4 \text{ W/m}^2\text{K}$. 152 m^2 of windows has to be changed. The third packet of measures includes refurbishment of the heating and DHW systems and installation of PV panels for electricity production.

Since electric furnaces are old and barely functional it is highly recommended to replace them with a more energy sustainable solution such as an air to water heat pump, solar collectors and a new electric furnace as a backup or a combination of these systems, solar collectors in conjunction with the heat pump. The climate in the Mediterranean region is mild, average ambient temperatures are relatively high. Air, therefore presents an adequate, easy to harness and relatively cheap energy source. Moreover, because heat is transferred via low temperature floor heating all pre-requirements to exploit benefits of heat pump systems to the maximum extent are satisfied, so it is recommended to change the existing electric furnaces with an air to water heat pump system. Total annual heating energy that has to be produced and delivered to consumers is $105,515 \text{ kWh}$ and with average annual heat pump COP of 3.86, system would consume only $27,300 \text{ kWh}$ of electricity. This is almost 4 times less in comparison to the present heating system consumption. Moreover, the implementation of heat pump would result in a significantly decreased installed electric power demand, from 48 kW to 17 kW . Installation of a heat pump system would save electric energy by approximately EUR 7,300 annually. With investment of EUR 17,000 payback period is less than 3 years.

For the moment due to low hot water consumption the application of solar collectors for heating of domestic hot water is not a viable option. However, solar collectors can be used for heating of the building in conjunction with either electric furnaces or a heat pump. Installation of solar collectors on building roofs is not allowed in the city of Dubrovnik, but they can be easily mounted on the north and south side of the gymnasium building roof which is located next to the building in the back yard and it is hidden from view so that such installation would not harm visual identity of the building (Figure 2.15.).

The solar collector aided heating system consists of 30 solar collectors with the total area of 60 m^2 , two 2 m^3 water tanks, heat pump or electric heater, circulation pumps and regulation (Figure 2.16.). According to simulations 36% of the total heating needs can be produced by a solar collector field alone. The remaining 64% has to be added by heat pump system or electric furnace. Total system costs with electric furnace as a backup system is estimated at EUR 28,000 and with heat pump at EUR 44,000. However in comparison to the energy costs of the present system, payback period for the heat pump aided solar collector system is slightly over 5 years and approximately 8 years for the electric furnace.

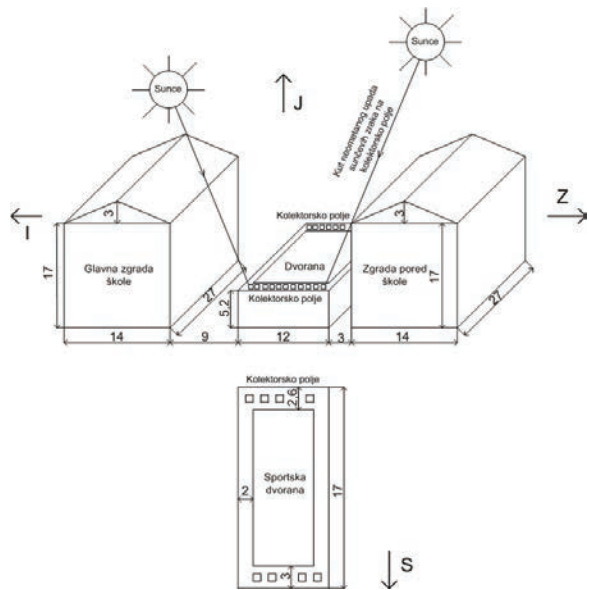


Figure 2.15. Sketch of collector field mounted on gymnasium roof

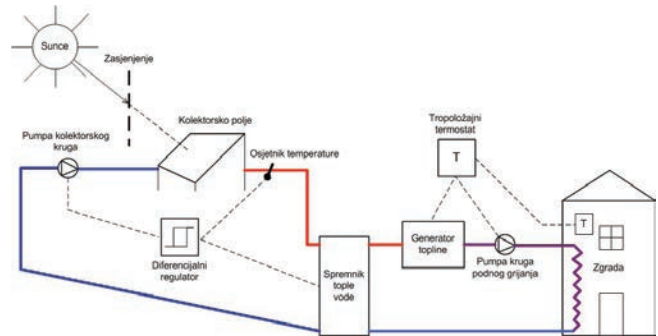


Figure 2.16. Solar water heating system in combination with heat pump or electric furnace

It has to be noted that the solar collector system annual efficiency of 36% could be significantly increased if the produced heat would be used also during summer which is presently not the case.

Electricity production with photo voltaic (PV) systems is stimulated in the Republic of Croatia. According to the Electricity Market Act (NN 177/04, 76/07, 125/08) the production of electricity in photovoltaic power plants is in the system of incentives. For electric power system of up to 10 kW nominal power for each kWh that is fed to the national electric grid the producer is paid HRK 3.7718.

With respect to the available space for installation of PV modules it is recommended to install a 5 kW solar power plant. Number of PV modules to be installed is 28 (configuration of 2 threads with 2×7 modules) with the total collector area of 36 m^2 . With this system it is possible to produce $5,133 \text{ kWh}$ of electric energy annually with a total income of EUR 2,600 per year. With investment cost of EUR 19,000 payback period is expected to be 8 years. (21)

COMPARISON OF CONVENTIONAL DIESEL SYSTEM AND RES SYSTEM FOR ELECTRICITY PRODUCTION ON LIGHTHOUSE, RT DONJI DUBROVAČKO-NERETVANSKA COUNTY, CROATIA



Usage: Tourist apartment

Period of use: April - September

Area: 40 m²

Number of persons: 4

Energy demand for domestic hot water for 4 persons in period from April till September is given. Also, solar PV system could cover 100% electric energy consumption in period from April till September, and only partially in the rest of the year, depending on the insolation. Lighting could be replaced with LED.

Table 2.19. Comparison of conventional diesel system and RES system for electricity production

Comparison	Conventional system	RES system
Annual electric energy consumption for appliances*	450 kWh	450 kWh
Annual electric energy consumptin for domestic hot water	1,440 kWh	0 kWh
Annual consumption of diesel fuel for electric energy production for appliances	225 l	0 l
	148 EUR**	0 EUR
	0.36 tCO ₂	0 tCO ₂
Annual consumptionof diesel fuel for electric energy production for domestic hot water	720 l	0 l
	473 EUR**	0 EUR**
	1.15 tCO ₂	0 tCO ₂
System lifetime	20 years	20 years
Investment cost	5,247 EUR	18,167 EUR
Consumption of diesel fuel during system lifetime	18,900 l	0 l
	12,395EUR**	0 EUR**
	30.2 tCO ₂	0 tCO ₂

*Lighting, water pump, computer, television and other small appliances

**price of diesel fuel 0,65 EUR/l (assumption is that price doesn't change during system lifetime)

Table 2.20. Economic analysis

Annual savings of diesel fuel for production of electric energy for house appliances	945 l
	620 EUR
	1.51 tCO ₂
Annual savings of diesel fuel for production of electric energy for house appliances during system lifetime	18,900 l
	12,395 EUR
	30.2 tCO ₂
Difference in investment cost	12,929 EUR
Simple rate of return	21 years

Simple return of return is calculated with the assumption that price of diesel fuel will not change during the system lifetime. It can be expected that price of diesel fuel will rise, which will make solar system more economical. Investing in RES system will ensure energy independent lighthouse which is also important. (22)

2.2.6. REGULATION

Heating can account for as much as 60% to 80% of total energy use. With inadequate and incorrect heating system control settings a large proportion of the energy consumed by heating is likely to be wasted. Implementation of simple energy saving measures for the purpose of avoiding overheating can cut heating costs by up to 30%.

When refurbishing and upgrading a heating system, time and temperature control need to be carefully considered. A well-controlled system will ensure that the heating system only provides heat when and where it is required in order to achieve desired temperatures. Therefore, the selection of appropriate controls plays a key part in the overall running costs of a heating or hot water system. Generally, upgrading controls on older heating systems, for example, can save over 15% on energy consumption when fitting a full set of controls to a system which previously had none. Controls can reduce energy use in two different ways:

- by reduction of heating requirements and/or
- increasing system efficiency.

Reducing heating requirements can be achieved by reducing the time when the heating is on and set temperature. Lowering heating temperatures by just 1°C can save between 5 and 10% of total energy consumption for heating.

Heating control can be divided into:

- heating system control – control of water temperature flowing from the boiler to consumers basically by firing control and sequence control with multiple boilers,
- temperature control – control of air temperature to maintain minimum required level of comfort usually by wall thermostats and thermostatic radiator valves and
- time control – control of time and period when the heating should be turned on usually by 24-hour dial time switch and seven-day programmable thermostats.

In all of the examples which are considering refurbishment of HVAC system in cultural heritage buildings shown in previous and following chapters certain upgrade of existing control system was envisaged.

The most relevant reports clearly presenting good practice of control system redesign are “Reconstruction and conversion of “Tvornica duhana Zagreb” in the Croatian history museum”, chapter 2.2.3. Heating and power supply and “Refurbishment of south complex of Faculty of Mechanical engineering and naval architecture in Zagreb” in chapter 2.3. Multidisciplinary approach.

Redesign of control system in “Tvornica duhana Zagreb” considers replacement of the high temperature heating system with a four-pipe low temperature heating and cooling system equipped with zone thermostats and three-way control valves; time control of the heating/cooling achieved by individual room thermostats and window sensors placed within offices with natural ventilation; heating and cooling capacity control by fan coils with air volume regulation and temperature control of spaces heated by radiators achieved with thermostatic valves.

Similar approach was taken in the case of HVAC system design of the building of Mechanical engineering and naval architecture in Zagreb, where the entire heating and lighting system were redesigned, passive cooling and central control and monitoring system introduced. With this proposed multidisciplinary approach more than 75% of energy consumed today is expected to be saved.

In examples where heating distribution systems were not subjected to reconstruction and only temperature and time controls were upgraded, as in the case of the Marin Getaldić Elementary School, in chapter 2.2.5. Solar systems and Antun Mihanović Elementary School, in chapter 2.2.3. Heating and power supply where individual measures of adjustment of heating regulator (heating setpoints), ventilation control, heating system regulation and implementation of a thermostatic radiator valves resulted with substantial energy savings and short payback period.

2.2.7. COOLING SYSTEMS

Many of the components of a historic building are significant because of the way in which they contributed to its original environmental performance. Among these are early heating and ventilation systems. Before considering any alteration to a historic building, it is essential to assess the elements that make up the special character and interest of the building. Since mechanical cooling and heat pump systems were not used traditionally and they came in focus just recently it is essential to fit them into such building without significant disturbance of internal and external historical values of the building. Therefore, barriers regarding implementation of air conditioning and heat pumps systems in heritage buildings will be mainly of aesthetic and practical aspects.

Generally it is advised to design cooling and heat pump systems in heritage buildings in a way to avoid placement of external elements (air condensers, evaporative units) and to exploit soil or ground water as a heat source or sink. If this is not possible and air is selected as heat source/sink the use of external elements cannot be avoided, before designing the system it is important to:

- contact heritage advisor who will assist in providing options and appropriate solutions, and
- contact a local planning authority as there may be requirements with respect to visibility, location from boundaries and noise impact on neighbouring properties.

Basically there are only few locations where external units (which reject heat in the cooling mode and absorb heat in the heating mode of heating) can be placed:

- at ground level which provides easy access for maintenance and it is easier to screen the unit from view or
- on the roof if it is possible to hide them from significant views. However, it is not advised to be positioned above awnings or in windows.

Regarding placement of internal elements again care should be given to ensure that they do not detract from significant historic elements of the building. Care should be taken to:

- avoid installing a dropped ceiling to hide equipment where this destroys the proportions of the room or conceals important historic features,
- position cabling appropriately, dependent on wall construction and
- place intake grilles in less visible spaces and use unobtrusive grilles for formal or significant spaces.

Therefore, it is suggested to design the system using the existing way of distribution and emission of cooling/heating effect as much as possible, e.g. central heating system with

radiators or fan coils, and to avoid further visual degradation of interior.

Only adequate selection and optimal design of air conditioning and heat pump systems will properly fit heritage building particularities and will contribute to energy efficiency, system lifetime and low impact of such systems on environment. In the following example, the Luka Sorkočević Art School in Dubrovnik, substitution of central electrical heating with other energy efficient solutions was analysed from energetic and economic perspective. The building with area of 1,730 m² is located in strict city centre and is under protection as a cultural heritage.

In the study two main direction of HVAC system reconstruction are presented:

1. substitution of electrical heating with energy efficient solutions,
2. introducing system for cooling and heating.

When thinking on substituting the pure electrical based heating system with alternatives capable for heating as well as for cooling, theoretically two options are worth paying attention for: air to water cascade heat pump coupled to electrical furnace and air to air heat pump with variable refrigerant flow. For this purpose 6 heating pumps connected in parallel with existing heating are needed. Annual electricity consumption of heat pump is 43,713 kWh and for electric heaters 5,402 kWh. In total energy consumption electric heaters consume only 10%. With total energy demand for heating the building (including losses) of 145,119 kWh, average system coefficient of performance is 2.93. Annual heating cost for this system is 9,330 Eur. In comparison to existing heating system, air to water heat pump system in bivalent mode of operation saves 9,317 Eur of running costs annually. With EUR 36,000 investment payback period is 3.9 years. Moreover, CO₂ emission is reduced for 52.72 tonnes per year.

System which can be used both for heating of building during winter and cooling during summer is air to air heat pump with variable refrigerant flow. This systems present good alternative to standard solutions when considering refurbishment of air-conditioning systems in buildings of cultural importance since construction works in this type of buildings are limited. Five VRF heat pump units are predicted, one for each floor level. System simulation considered operation under partial load. Annual consumption of electricity for heating is 28,858 kWh with seasonal coefficient of performance of 5.02 and cost of EUR 4,200. Analysed system is saving EUR 14,500 in comparison to existing pure electric heating system. With price for the system of EUR 94,000 return on investment is 6.5 years.

LUKA SORKOČEVIĆ ART SCHOOL IN DUBROVNIK



Luka Sorkočević Art School in Dubrovnik aims to substitute central electrical heating with other energy efficient solutions. The building with an area of 1,730 m² is located in the strict city centre and is under protection as a cultural heritage.

According to a preliminary energy audit, among various different options for retrofitting of the heating system and simultaneous introduction of a cooling system the most energy efficient and economically viable solution is to install air source heat pumps.

in bivalent mode of operation connected to existing electric furnaces is analysed. With the implementation of this kind of heating system in cultural heritage buildings it is possible to avoid changing of heating distribution and emission elements such as pipelines and radiators which can significantly reduce refurbishment costs. The analyzed heat pump is of medium temperature (leaving water temperature up to 80°C) cascade type. Dependence of the heat pump heating power on the ambient air temperature yields a bivalent point of 4°C and 96 kW output power of the heat pump (Figure 2.18.).

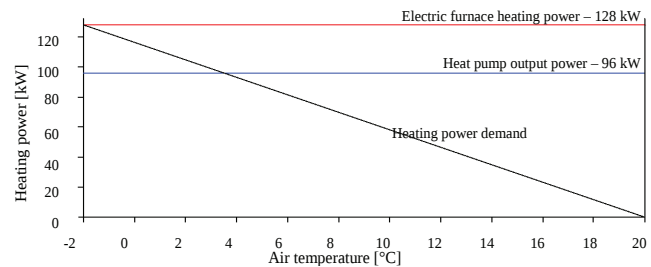


Figure 2.18. Dependence of heating demand and available heat pump heating power on ambient temperature

50

Energy consumption for heating

Power needed for keeping the school heated during the lowest ambient temperature (-2°C for region of Dubrovnik) is 128 kW. According to electricity bills, the average electricity consumption over three years is 211,973 kWh. Energy consumed for heating, for the same period, is calculated at 138,209 kWh. Distribution of year-round energy consumption is shown in the following diagram.

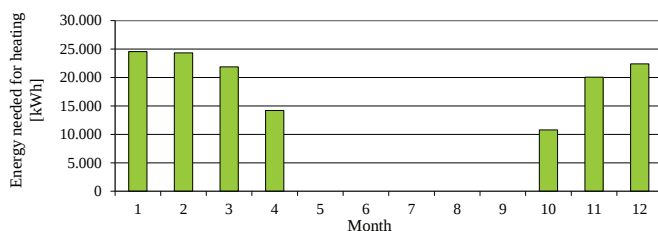


Figure 2.17. Monthly energy demand for heating

Energy efficient options

When considering substitution of electricity-based heating system with alternatives which can provide cooling as well as heating, there are two valuable options: an air to water cascade heat pump connected to an electric furnace and an air to air VFR heat pump.

The first energy efficient alternative to pure electric heating, i.e. medium temperature air-to-water cascade heat pumps

In order to provide 96 kW of heating it is necessary to couple 6 heat pumps connected in parallel with the existing electric heating system. Heat pumps operate when ambient temperatures are higher than the bivalent point whereas electric boilers provide adequately hot water when temperatures are lower. Therefore, water temperature dependence on the ambient air temperature should be controlled.

For this system it is not possible to arrange cooling of the building. In order to allow cooling, the distribution network (pipelines) would have to be adequately redesigned and existing radiators would have to be replaced with fan coils or a low temperature radiant panel system.

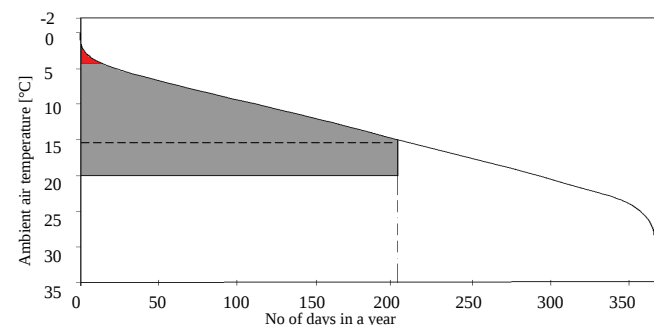


Figure 2.19. Degree day curve for given location with energy consumption for pure electric heating (red) and heat pump heating (gray)

Annual electricity consumption of heat pump is 43,713 kWh and of electric heaters 5,402 kWh. Electric heaters consume only 10% of the total energy consumption. With the total energy demand for heating of the building (including losses) in the amount of 145,119 kWh, the average system coefficient of performance is 2.93. Annual heating cost for this system is EUR 9,330. In comparison to the existing heating system, air to water heat pump system in bivalent mode of operation saves EUR 9,317 of annual running costs. With a EUR 36,000 investment, the payback period is 3.9 years. Moreover, CO₂ emissions are reduced by 52.72 tonnes per year. Although air to water heat pump system in bivalent mode of operation gives a short return of investment period, its application is not proposed as this system cannot be used for building cooling without substantial investment in refurbishment of radiators and the heat distribution system.

Heat pump with variable refrigerant flow (VRF)

System which can be used both for heating of building during winter and cooling during summer is air to air heat pump with variable refrigerant flow. Refrigerant pipelines between outer and indoor units are much smaller in diameter in comparison to water system with the same heating and cooling effect. Therefore, these systems present good alternative to standard solutions when considering refurbishment of air-conditioning systems in buildings of cultural importance since construction works in this type of buildings are limited.

Five VRF heat pump units are predicted, one for each floor level. System simulation considered operation under partial load. Annual consumption of electricity for heating is 28,858 kWh with the seasonal coefficient of performance of 5.02 and cost of EUR 4,200. The analysed system saves EUR 14,500 in comparison to the existing pure electric heating system. With the EUR 94,000 price for the system the investment return is 6.5 years. CO₂ emission reduction amounts to 61.6 tonnes per annum.

For the building cooling (68,444 kWh of cooling effect needed) VRF heat pump system would consume 9,426 kWh of electricity. European seasonal energy efficiency ratio (ESEER) of the system is 7.2 with total running costs of EUR 1,200.

Table 2.21. Energy consumption and CO₂ emission

Heating system	Annual consumption	Annual cost [Eur]	Annual CO ₂ emission [tonns per annum]
VRF heat pump system	Electrical energy 28,858 kWh	4,200	15.3
Gas condensing boiler	Gas 14,953 m ³	6,600	28.4
Oil boiler	Oil 14,818 lit	8,800	38.5
Electric furnaces	Electrical energy 145,119 kWh	18,700	76.9

Economic indicators

At first glance the heat pump system in bivalent mode of operation is economically more attractive since it requires lower investment which corresponds to short payback period. On the other hand the VRF heat pump system is much more economically demanding but it provides both heating and cooling of the building.

If the EUR 36,000 investment for the bivalent heat pumps system is divided with the expected system lifetime of 12 years and with annual savings in running cost of EUR 9,317 in comparison to existing pure electrical system, the total savings to be expected are EUR 6,317 per year and EUR 75,804 in the 12-year period.

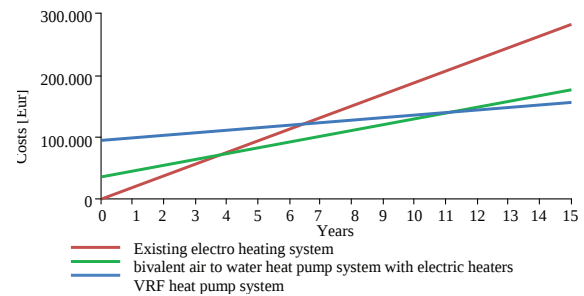


Figure 2.20. Heating costs depending on system in period of 15 years

VRF heat pump system is better in comparison to oil or condensing gas boilers as well.

The analysis results show that the application of heat pump systems is the most economically viable in case of HVAC system refurbishment in historical heritage buildings in regions of warm Mediterranean climate. (23)

2.3. MULTIDISCIPLINARY APPROACH

Historic buildings will only survive if maintained as living space – and energy-efficient retrofit can improve structural protection and “comfort”, both for users and heritage collections (Alexandra Troi, Roberto Lollini, Interdisciplinary research: FP7 project “3ENCULT – Efficient Energy for EU Cultural Heritage”). Energy efficient retrofit of cultural heritage buildings is useful for structural protection as well as for comfort reasons. Reducing the energy demand significantly is feasible, if a multidisciplinary approach guarantees high-quality energy-efficiency-solutions, targeted and adapted to the specific case.

Before starting a refurbishment it is fundamental to carry out an analysis of the actual existing building's performance and condition to understand which areas need to be improved. At first it is important to study the behaviour of the building without considering mechanical and electrical systems and try to implement the passive strategies to reduce the energy demand of the building. For instance, with regard to the envelope, in an existing building it is necessary, as often as not, to improve insulation and air-tightness but it is possible to use the thermal mass of the structures to reduce the peak loads and improve comfort; the use of natural ventilation or day lighting has also to be investigated before starting to design lighting or ventilation systems.

Passive strategies are referred to the behaviour of the building without considering mechanical and electrical systems:

- efficiency of the envelope (insulation, thermal mass, air-tightness),
- optimisation of solar gains (use of greenhouse and solar shading),
- utilisation of day lighting and natural ventilation.

During the design phase, these steps have to be followed:

- reduce demand (energy and water demand),
- maximise efficiency of the existing systems or replace them if it is necessary and
- install and integrate renewable energy systems.

The most common active energy efficiency solutions are:

- use of high efficiency systems such as condensing boiler, heat pumps, geothermal and heat recovery system, equipments like radiant panels or chilled beams that work with low water temperature and that are able to guarantee high comfort level,
- use of renewable energies (wind, sun),
- advanced automatic control systems; development of suitable control strategies and the retrofitting of the systems conditions.

In the fifteen following cases of energetic refurbishment of historic buildings multidisciplinary approach is demonstrated.

ENERGY REFURBISHMENT OF THE SOUTH BUILDING OF THE FACULTY OF MECHANICAL ENGINEERING AND NAVAL ARCHITECTURE (FSB), UNIVERSITY OF ZAGREB, CROATIA



Refurbishment of the FMENA south building complex consists of:

- building envelope reconstruction – application of thermal insulation on concrete elements and replacement of windows,
- heating system replacement – reallocation and reconstruction of central heating room, replacement of heating distribution system (pipelines and radiators), introduction of regulation system
- introduction of passive ground water cooling system
- reconstruction of lighting system – replacement of old lamp units and wiring and implementation of lighting regulation system
- installation of 30 kW photo voltaic power plant
- introduction of central monitoring and regulation system.

The existing building walls are solid concrete blocks without elements of thermal insulation. Windows are double pane wooden frames with venetian blinds between white glazings. Windows are generally in bad shape; wooden frames are distorted, rubber seals are missing, metal shackles are damaged and protective primer is partially colour peeled off. Venetian blind mechanism works only in few particular cases.

Present condition of building envelope construction elements are shown in Table 2.22.

Building envelope reconstruction considers application of 18 cm of thermal insulation on front building walls; 10 cm of polystyrene insulation sheets on the outside face of the walls and 8 cm of mineral wool on the inside of parapet (behind radiators). Side walls are to be covered with 15 cm of rock wool which is to be placed on the outer face of the walls. The reconstruction should not compromise the building's appearance, i.e. façade appearance and colour, window material and colour have to be preserved.

The existing north side windows are to be replaced with new double pane wooden windows, with thermo low E coated glazing filled with inert gas, with total heat transfer coefficient of $1.4 \text{ W/m}^2\text{K}$. Windows on the south side are to be replaced with triple pane wooden windows with thermo glazing (without low E coating) with venetian sun blinds inserted in between panes. The total heat transfer coefficient of the south windows should be $1.3 \text{ W/m}^2\text{K}$. Since windows dominate the building façade, in order to harvest solar heat in winter period to the maximum extent and at the same time to prevent incidence of solar irradiation during summer it is important to have windows without low emissivity glazing but with sun protection devices installed on the south building side.

Roofs which are not yet reconstructed are to be thermally insulated to achieve total heat transfer coefficient of $0.2 \text{ W/m}^2\text{K}$. Building is heated with energy provided from district heating system. One part of the building is heated directly by feeding the hot water from district heating system (110°C) to radiators. The skyscraper is heated by an indirect heating system where the heating energy is transferred from temperature level of 110°C in the primary circuit to a lower temperature level $90/70^\circ\text{C}$ in the secondary circuit. Transformation of heat temperature level is done in shell & tube heat exchanger with rated heating power of 900 kW. The heating system is more than 40 years old and is worn out. Many elements are not operating satisfactorily and have to be changed.

Temperature regulation is almost impossible since the existing hand valves installed on each radiator are old and in a bad shape (sedimentation of limestone) and practically cannot be fine regulated (closed or opened). Thermostatic valves or other automatic regulation elements do not exist. Central heating system pipelines are in bad shape as well and it is hydraulically not in balance.

Power needed and energy consumption is measured with remote measuring system which is installed in heating system, electrical system and fresh water system. Measuring system is connected to a monitoring system with wireless connection. Energy and instant power consumption are monitored while collected data are stored and analysed. Any unusual consumption or abnormality in operation is instantly discovered and alarmed.

In Table 2.24. building heating and cooling power needs and energy consumption before and after refurbishment are shown. Heating system refurbishment considers complete change of the secondary circuit, i.e.

- radiators are to be changed with two pipe fan coils which are oversized to allow implementation of passive cooling with ground water (temperature of 13-15°C),
- local and central temperature regulation will be possible,
- new pipelines (two pipe system) are to be installed with automatic elements for hydraulic balance,
- variable volume flow distribution system with frequency controlled pumps is to be applied,
- plate heat exchanger for heating will be installed to decouple district heating system from consumers,
- plate heat exchanger for cooling is designed to allow heat transfer with close temperature of primary and secondary circuit; temperature difference across heat exchanger is 1°C,
- two ground water wells will be drilled with total capacity of 118 m³/h.

Today, only 12% of building area is cooled mostly with unitary split cooling systems. Electricity consumption of existing cooling system amounts to approximately EUR 4,000.00 per year. Future annual power consumption of the passive cooling system for 69% of the building area (corridors and communication areas will not be cooled) will amount to approximately EUR 1,650.00.

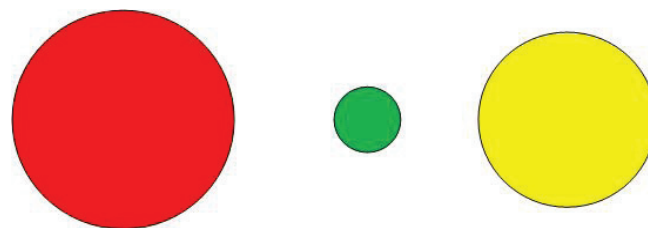


Figure 2.21. Consumption before reconstruction (left); Consumption after reconstruction (middle); Savings (right)

With the total refurbishment investment of EUR 2,500,000 and future energy price trends the return of investment period is expected to be between 10 and 14 years. (24)

54 For the moment the ground water will be used only for passive cooling. However, since the heating/cooling distribution and emission system is designed to accommodate heat transfer at low temperature levels for heating (55/40°C) and high temperature levels for cooling (14/18°C) (fan coils are fairly oversized), they will be able to operate properly in connection with water to water heat pump system or other low temperature energy source as well, when the ground water could also be used as a heat source.

Refurbishment of electrical installations include reconstruction of lighting system, i.e. replacement of old lamp units and wiring and implementation of lighting regulation system (motion sensors, light intensity regulators), installation of 30 kW photo voltaic power plant and introduction of central monitoring and regulation system. In order to gain full financial benefits the electric energy produced in a photo voltaic power plant has to be sold on market. According to calculations and conducted analysis year of return on investment period is 11 years.

After the refurbishment process heating energy consumption will be reduced by 72%. Energy savings for heating relative to the current energy prices are calculated at EUR 127,000 per annum (Table 2.25).

As a result of the reconstruction the consumption of electrical energy will be reduced by 15% which amounts to annual savings of EUR 23,500 (Table 2.26).

Table 2.22. Characteristics of existing building envelope construction elements

Construction element		Comment	U [W/m²]	Maximum allowed U value [W/m²]
Walls	Parapets	Without thermal insulation	1.30	0.45
	Side walls			
Windows	North	High air infiltration index	4.50	1.80
	South			
Roofs		Refurbished	0.20	0.40
		Not refurbished	0.90	

Table 2.23. Characteristics of refurbished building envelope construction elements

Construction element		Description	U [W/m²god]	Maximum allowed U value [W/m²]
Walls	Parapets	outside – polystyrene 10 cm, inside – mineral wool 8 cm	0.19	0.45
	Side walls	Outside wall face – rock wool 15 cm	0.24	
Windows	North	Double pane wooden window with low E coated glazing	1.40	1.80
	South	Triple pane wooden window with venetian blinds in between	1.30	
Roof		To apply thermal insulation	0.20	0.40

Table 2.24. Heating and cooling power and energy consumption

		Needed power [kW]	Power contracted [kW]	Energy consumption [kWh/m²year]
Before refurbishment	Heating	1,250	2,587.90	192.50
	Cooling	1,110	-	37.40
After refurbishment	Heating	503	600	48
	Cooling	547		47

Table 2.25. Energy savings for heating

		Current consumption	Consumption after refurbishment	Savings
Heating energy	[kWh/year]	2,515,000	653,250	1,861,750
	[Eur/year]	95,000	25,000.00	70,000.00
Contracted power	[kW/month]	2,588	600	1,988
	[Eur/year]	74,000.00	17.000,00	57,000.00
TOTAL SAVINGS	[Eur/year]			127,000.00

Table 2.26. Electrical energy savings

		Current consumption	Consumption after refurbishment	Savings
Electrical energy	[kWh/year]	866,070	678,414	187,656
	[Eur/year]	88,000	69,000	19,000
Contracted power	[kW/month]	451	423	28
	[Eur/year]	73,000	68,500	4,500
TOTAL SAVINGS	[Eur/year]			23,500

VITIĆ'S SKYSCRAPER, ZAGREB, CROATIA



The building has undergone an energy audit for the purposes of establishing possibilities for energy efficiency improvements. It is a protected cultural monument planned for restoration due to deterioration. The Laganjina 9 ("Vitić's skyscraper") residential building is located in Zagreb city centre. It was built during the period between 1957 and 1960 based on architect Ivan Vitić's design.

Total useful heated area of the building is 3,753.72 m². According to the calculated energy consumption for heating the building is rated **energy class E** with the reference value of necessary thermal energy of **182.13 kWh/m²a** which is significantly more than maximum allowed value of 58.63 kWh/m²a. **Electric energy and natural gas** are used for energy requirements of the building.

Calculated energy consumption for heating for actual climate data $Q_{h,nd} = 709,371$ kWh.

Calculated energy consumption for heating for reference climatic data $Q_{h,nd,ref} = 683,668$ kWh.

Actual consumption of natural gas for heating and domestic hot water = 1,034,894.66 kWh.

The energy audit suggests energy renovation measures for: building envelope; heating, cooling and ventilation system; domestic hot water preparation as well as electric installations and lighting. The investment includes all works in accordance with conservation guidelines, so the relatively long return period is a consequence of bad condition, lack of maintenance as well as the fact that the building is a protected cultural good.

Implementation of building energy renovation which represents an optimal combination of suggested energy efficiency measures will result in achieving savings in required thermal energy for heating by 60% compared to the current state of the building, thus upgrading it to energy class C.

If the suggested energy efficiency measures are implemented, the required thermal energy for heating

will be $Q_{h,nd} = 284,005$ kWh/year for actual climate data, i.e. $Q_{h,nd,ref} = 277,854$ kWh/year for reference climate data with the specific required thermal energy for heating in the amount of 74.00 kWh/m². This will upgrade the building to energy class C.

Assuming that 50% of the costs for energy renovation will be financed from a heritage rent, the remaining costs can be co-financed by various mechanisms of incentives, for example Environment Protection and Energy Efficiency Fund. If favourable financing conditions, i.e. acquiring 10 or 12-year loans, are achieved then a loan instalment amounts to less than the achieved energy savings.

In order to determine the optimal level of energy renovation of building envelope, a full-scale reconstruction which partially ignores conservation requirements and limitations for building renovation has been analyzed. At the same time the cultural heritage status hasn't been ignored, but the intention was to apply the biggest scale of envelope reconstruction in order to determine the ultimate technical possibilities of the renovation. Criteria in the evaluation of necessary coefficients of envelope heat transfer was applied so that the building achieves as high an energy class as possible, i.e. reaches the aimed $Q_{h,nd} < 50$ kWh/m²a, upon the renovation. The cost of renovation of such scale is 87,000 EUR higher than the cost of works on the reconstruction of building envelope planned in the budget. It, however, allows for the building to be upgraded to energy class B, i.e. lowers its required thermal energy for heating to under 47.50 kWh/m²a. For such an intervention it is necessary to request an opinion from the City Institute for Protection of Cultural Monuments and Nature.

Energy renovation of protected cultural heritage buildings as valuable as this can increase the value of their apartments that are in energy class B or C.

Calculated energy consumption for heating for reference climate data

$Q_{h,nd,ref} = 709,371$ kWh/a, 182.13 kWh/m²a, energy class E

If suggested measures are implemented, the required thermal energy for heating will amount to:

$Q_{h,nd,ref} = 365,314$ kWh/a, 92.68 kWh/m², energy class C

or 284,005 kWh/a, 74.00 kWh/m²,

If additional energy efficiency measures are implemented, the required thermal energy for heating will be:

$Q_{h,nd,ref} = 181,306$ kWh/a, 47.50 kWh/m², energy class B

Savings in energy consumption: minimally 48%, realistically 60%, possibly 75%. (25)

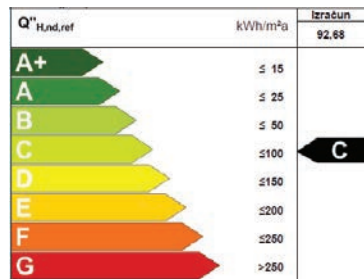
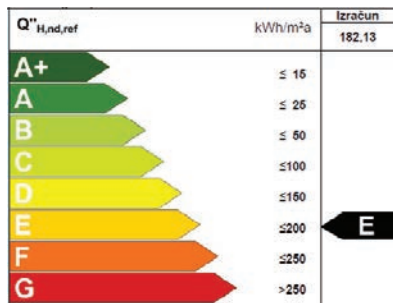


Figure 2.22. Energy certificate values before and possible energy certificate values after reconstruction

MERCADO FERREIRA BORGES, PORTO, PORTUGAL



The Mercado (market) Ferreira Borges was built in 1885 and is a relevant example of the iron architecture in Porto.

The design solution was tailored to the intended use for the building, namely the installation of a live music performance hall, the Hard Club. Accordingly, two large containers were installed inside the building with no connection with its envelope thereby housing two fully insulated concert rooms.

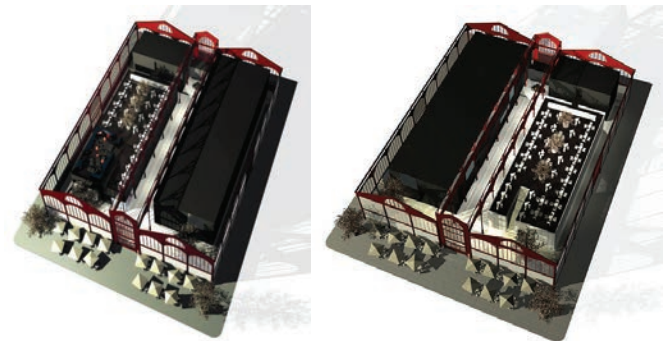


Figure 2.23. Container halls in Mercado Ferreira Borges

All the remaining space, including on the containers' top is usable but not thermally treated as the external building envelope has not been insulated. Indeed, the rehabilitation solution adopted for this building provides a mixed internal/external space inside thereby sheltering users from the elements but not providing them comfort conditions for extensive use (Figure 2.23). The containers however conform to high thermal and acoustic standards, permitting two events to take place at the same time while preventing substantial impacts on the neighbour residence areas.

The thermal efficiency of the external building envelope was improved by installing thermal insulating material on the inner faces of external walls and over the original pavement, treating thermal bridges, replacing single by double glazing on external windows and providing external window protection. The thermal improvement of the external building envelope enabled a great reduction of the air heating and cooling requirements of the internal warehouse spaces. (26)

INDUSTRIAL WAREHOUSE IN PORTO, PORTUGAL

Recent changes in the European industry left large old industrial buildings and warehouses vacant and with apparent little use. Reusing these buildings is quite a challenge nowadays as the focus of the economic activity shifted, and old buildings no longer respond to the new needs. The feasibility of refurbishment projects for those old buildings is often very hard to prove and it may become even harder if thermal insulation requirements are imposed. However, those requirements are common in many refurbishment projects whenever the installation of office spaces in all or part of an old building are considered. Actually, the cost of thermal refurbishment of such buildings is very high and may conduct to infeasible solutions, therefore leaving behind refurbishment opportunities. However, space availability is not a problem for those buildings therefore allowing for alternative refurbishment solutions to be envisaged.

This case-study addresses the refurbishment project of an old warehouse for the installation of an office facility and other complementary areas in Porto. The project mainly comprises the rehabilitation of the internal building spaces as depicted in Figure 2.24. Dark shaded volumes in the figure correspond to the office facilities and clear shaded volumes to complementary building functions with lighter air treatment requirements (showroom, stocking areas, car park, etc.)

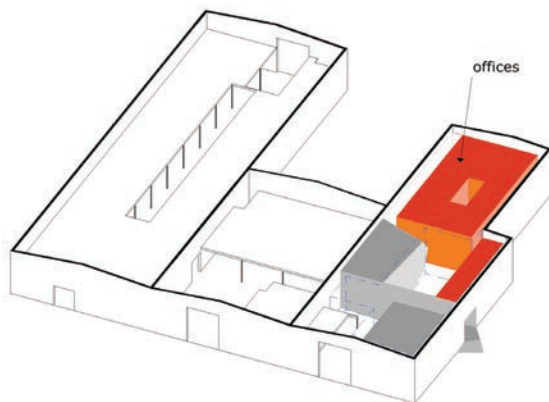


Figure 2.24. New office facilities inside an old warehouse in Porto

The design solution adopted was erecting a container inside the external building envelope for housing the office facilities and locating complementary functions required on the surrounding inner areas. The thermal efficiency of the external building envelope was improved by installing thermal insulating material on the inner faces of external walls and over the original pavement, treating thermal bridges, replacing single by double glazing on external windows and providing external window protection.

Figure 2.25. below shows some design details for the implementation of these measures.

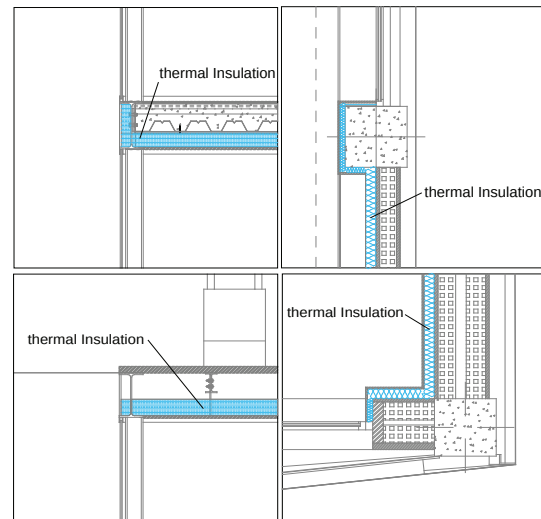


Figure 2.25. Thermal correction details for the external warehouse walls and floors

The thermal improvement of the external building envelope allowed for a significant reduction of the air heating and cooling requirements of the internal warehouse spaces. This enabled the installation of the light air treatment requirement areas inside the building with very low heating demands and no cooling demands. As for the office container, very attractive transparent solutions could be adopted with substantially decreased thermal energy consumption. All in all, keeping the external building skin allowed for sheltering the new project requirements with decreased initial investment and lower energy consumption in the life cycle although using more space at virtual no cost increase. (26)

THE MUSEUM OF HERZEGOVINA IN TREBINJE, BOSNIA AND HERZEGOVINA



The Museum of Herzegovina is located in the Old Town of Trebinje, which is a listed cultural and historical complex. It is a three-storey stone building (ground level + two storeys) and it was constructed at the very beginning of the 20th century. The Museum complex comprises a few more stone structures - a building for storing bequests, an accessory building housing the museum depot, a clock tower, and a building used as a station or dove cote for carrier pigeons, one of a kind in this region. Energy needed for heating and cooling is 250 kWh/m²a.

Exterior walls are impossible to insulate on the outside. Therefore, the plan proposes to install thermal insulation on the inside. Given the fact that the plaster is already in a fairly bad condition, it is planned to remove the current interior layer of plaster, install mineral wool as thermal insulation, including a vapour control layer, and cover the walls with plasterboards. Also, it is necessary to rewire the building and install ventilation ducts. The minimum 10-cm thermal insulation planned for installation will help secure the required heat transfer coefficient $U = 0.273 \text{ W/m}^2\text{K}$, while 15 cm of thermal insulation would help have as much as $U = 0.197 \text{ W/m}^2\text{K}$. Since the attic will be used as exhibition space, it needs to be insulated additionally. A total layer of 22 cm of thermal insulation needs to be installed between and under the rafters, which would ensure the heat transfer coefficient of $U = 0.154 \text{ W/m}^2\text{K}$. As the ground level floor is not insulated, it is planned to lay additional

thermal insulation on top of the existing flooring, which should not be removed (in case interior windows and doors are replaced) for the purpose of easier installation. This would help ensure a floor heat transfer coefficient of $U = 0.577 \text{ W/m}^2\text{K}$, whereas the installation of a 10-cm layer would achieve as much as $0.316 \text{ W/m}^2\text{K}$. It is planned to replace all exterior windows and doors with new ones with better insulation properties. As the building is listed, it is not possible to install super windows, as triple glazing would change their appearance. The most acceptable solution would be to replace them with double-pane insulated glazing, which would considerably upgrade their performance. In case this solution is impossible, the exterior panes should be single glazed and the interior ones double glazed; outdoor blinds should also be installed as protection against overheating. U-values of the building envelope are given in Table 2.27.

Table 2.27. U-values before and after reconstruction

Building element	Existing U-value [W/m ² K]	Insulation thickness [cm]	New U-value [W/m ² K]
Outside and inside stone walls	1.395	10	0.273
		15	0.197
Roof	-	22	0.154
Ground floor	3.3	-	0.557
		10	0.316

The amount of energy needed to provide a sufficient level of comfort prior to and following the completion of the proposed works would be reduced a lot, from **235** to **64 KWh/m²a**. (27)

BUILDING IN KARMEN NEIGHBORHOOD, DUBROVNIK, CROATIA



An 18th century building located in the Karmen neighborhood. Originally built as a hospice, and remodeled in the 19th century as a prison, the building has not been in use since the early 1980s. Three decades of neglect have left this heritage property in a state of decay, and the city's allocation of the building for a public program, makes it an exemplary candidate for renovation. In addition, the building is located next to an archeological site Pustjerna, which has been designated for a new, mix-use construction. The heritage property chosen is a 3 story (ground floor, first floor, second floor, attic) building with an attached garden and an underground water cistern. Similar to other historic stone buildings in Dubrovnik, both the interior and exterior walls of the former prison are 50cm - 80cm thick, consisting of massive stone layers coated in stucco on the outside, and an intermediate fill layer consisting of smaller rough pieces of stone and cement. The ceilings are wooden, and the roof consists of a wooden frame covered in clay tiles.

Strategies for better energy performance were tested in energy modeling software. The calculated energy demand for the baseline model is **94.8 kWh/m²**, which is relatively high compared to contemporary standards. After simulating the baseline model, four sets of strategies were separately tested: thermal insulation, glazing, HVAC and lighting. The results suggest that incorporation of this set of improvements will decrease electrical demand by **40%**.

The improvements would include: primary renovation material will be steel. In order to acquire more flexibility on the two lower, public levels, segments of some interior walls will be removed. The structural reinforcement of new openings will be achieved with steel beams, which

are left exposed, and designed as a part of the steel door construction. The existing single-glazed wooden windows will be replaced with the slim stainless-steel double glazed windows. Incorporation of stainless steel shutters which are designed to take advantage of the successful functionality and aesthetic of the traditional shutters, are less costly to maintain. To achieve better natural lighting of the interior spaces, and thus create a more comfortable indoor environment and decreased need for artificial illumination, some of the existing openings will be enlarged and new windows will be added. Heating, cooling and ventilating requirements will be met with a small-diameter-high-velocity heat-pump system, consisting of two indoor units - one for the two lower public levels, one for the two upper residential levels - and one outdoor unit. The indoor units will be placed in the unused areas next to the main staircase, and the outside unit will be placed within the unused chimney on the east façade. The main 250 mm plenum ducts will run along the main longitudinal corridor to avoid disruption of historic construction elements, with the much smaller supply-air and return-air ducts, running through the ceiling to supply the individual rooms. Plenum ducts will be masked with a steel channel, which also holds the LED lighting fixtures. (28)

The approximate calculation of thermal losses of the building showed that the specific transmission heat loss is

THE SCHOOL BUILDING IN THE KRIŽANIĆEVA STREET, ZAGREB, CROATIA



92.5% higher than the quotas set for specific transmission thermal losses. Annual thermal heat demand needed for heating is **92%** higher than the quotas set for annual heat demand needed for heating (Table 2.28).

This project suggested thermal improvements to the building envelope divided into three steps: 1. improving thermal performance of basements, floors and roofs, 2. Improving walls insulation and 3. Improving window insulation. The heat requirement can be reduced by insulating the unheated attic ceiling (by adding the insulation layer i.e. expanded polystyrene EPS or mineral wool MW: 12 cm). If the basement is used, the thermal performance of floors (EPS: 10 cm) and walls (XPS: 10 cm), contribute reducing heat loss. In order to attain a satisfactory heat loss limitation level thermal insulation should be applied in the unheated basement ceiling (MW: 12 cm) as well as in the roof construction (by adding the insulation layer in flat roofs - EPS: 12 cm and in pitched roofs (MW: 10 cm). Thermal insulation of walls is integrated inside with the mineral wool (MW: 8 cm) with vapour barrier in order to prevent condensation. Wooden double windows (single-glazed) and outer sun protection (shutters) should be kept and repaired. This project suggests specific windows advanced with double glazed low E (3+8+3 mm) secondary glazing (**U-value = 1.1 W/m²K**) but will need a planning permission from the Municipal Institute for Protection of Cultural and Natural Monuments. If all three measures are implemented in the building the annual thermal heat demand will be reduced from **38.5** to **16.41 kWh/m³a**. (29)

Table 2.28. Energy consumption and the ratio (%) between allowed and current parameters

allowed Ht' [W/m²K]	current Ht' - [W/m²K]	Ratio [%]	allowed Qh' [kWh/m³a]	current Qh' [kWh/m³a]	ratio [%]
0,66	1.27	92.5	20.07	38.5	92

Table 2.29. Improvments with suggested measures

allowed Ht' [W/m²K]	steps of improvements Ht' - specific transmission heat loss [W/m²K]			allowed Qh' [kWh/m³a]	steps of improvements Qh' - annual thermal heat demand [kWh/m³a]		
	1.	1.+2.	1.+2.+3		1.	1.+2.	1.+2.+3
0.66	1.10	0.65	0.52	20.07	33.33	19.94	16.41

THE REAL ALBERGO DEI POVERI



The Real Albergo dei Poveri is one of the hugest XVIII century hospices in Europe and it is being restored as an "Eco-building". The worksite for the construction of the Real Albergo dei Poveri, in Naples (Italy) started in 1752, under design by architect Ferdinando Fuga.

A transition from the concept of "monument" to the concept of "cultural heritage" leads to a methodology of investigation, design and work which binds the observation and study of environmental characters determined by monuments and their context. The project team aimed at applying an integrated design for an eco-building - innovation in planning and architecture to reach sustainability, at adopting natural and local components and materials, as well as integrating renewable energy systems in the restoration of the ancient building. Considered a *demonstration site*, the project includes integrated project planning, active and passive solar design, low energy construction, including sustainable materials and components as well as renewable energy technology and building energy management systems. Thermal mass has been taken into account, because the building is a massive structure made of brick and volcanic tuff and its walls have very good thermal insulation properties. This is used in the restoration project within the energy strategy.

A large underground storage was created for storing and reusing of rainwater collected by the building, in order to reduce the building's water needs. This will be used for toilet flushing and for watering of plants in the gardens. The upper floors were designed to take maximum advantage of the natural light (passive solar design) in order to reduce the energy demand for lighting. Another benefit of a passive solar design is good control of overheating in summer. To be in accordance with the original building pattern, custom designed semitransparent PV modules will be installed to produce around **88,125 kWh/a** of electricity. Photovoltaic has been chosen for its multi-functionality as it is a roof material that can allow natural lightning and generates energy. (30)

ST. CLAIRE'S FORMER CONVENT IN GORIZIA, ITALY



The work included restoration, reconstruction and completion of the former St. Claire's Convent, with an overall budget of 5 million Euro within the Program for the Thousand-year-celebration of the city of Gorizia. The main activities were the restoration of the whole convent building, the reconstruction of the electrical and mechanical systems and the seismic and functional adaptations.

The aim of the restoration and renovation project was to make the building suitable for housing of educational and research activities related to university courses for "Operators in the Cultural Heritage Sector" of the Faculty of Letters and Philosophy of the University of Udine, as well as Paper Material Restoration Workshop activities and "Translation and Interpreting" courses. The project envisaged the complete reconstruction of internal and external building finishing, the re-definition of the new internal layouts in compliance with the structural constraints, the restoration of the most valuable architectural elements, the reinforcement of the existing vertical and horizontal structures as well as the seismic codes adaptations.

The climate and energy strategy adopted in the project has taken into consideration the environment where the building is placed, both for the climatic constraints and for the architectural issues. The design aims at the maximum energy efficiency, the best "value for money" goal, and the reduction of the carbon footprint of the Project.

The project entailed the development and installation of the following systems: central heating system, refrigeration unit, air treatment system, heating/air conditioning systems, primary air distribution system, sanitary and waste water system and fire-protection system. The service systems of the new structure are incorporated in the building and are of primary importance for achieving environmental comfort which is expressed in terms of hygiene and climate well-being.

During the restoration walls were consolidated using reinforced injections instead of lime-based inorganic hydraulic binders; structural reinforcements were set in place using carbon fibre bars and mesh followed by rendering with lime-based mortar (without cement) with high structural resistance. The consolidated walls were then

internally and externally coated with two layers of natural lime-based plaster: base and finishing coat of suitable granulometry. The walls were then painted internally and externally using lime-based paint.

Regarding new doors and windows, the project included larch-wood doors and windows with triple-glazed glass panels made of 4+4 mm external safety glass – 10 mm chambers filled with argon gas - of 4+4 mm internal safety glass panes.

The wooden roof was restored by recovering almost all of the existing trusses and replacing only a few elements. The wood purlins that connected the trusses were replaced; these represent the secondary structure of the covering. Waterproofing and insulation was achieved through the supply and installation of AIREX panel mod. 5 composed of a 12.5 mm thick upper layer of plywood made of glued OSB type wood flakes, treated with phenolic resins coupled to form a rigid structure with UNI IIP certified shaped expanded polystyrene (EPS), self-extinguishing and Euroclass E according to UNI EN 13163/2003 standards.

The profiled polystyrene insulation panel is 10 cm thick in the lower part and 14 cm thick in the upper part of the fret surmounted by the above mentioned OSB panel. The panels are fitted with side battens that overlap according to the direction of the roof pitch to avoid thermal bridges, seals and joints. The shaping of the panels allows the formation of 4 cm deep ventilation channels.

The panel was waterproofed in the production phase using a 3 mm thick bituminous polyester sheath self-protected with slate chippings. (31)



Figure 2.26. Claire's former Convent in Gorizia, Italy

ENERGY MODELLING OF THE GARDEN BOTHY, UNITED KINGDOM



The Garden Bothy is an unoccupied 19th-century stone building in Ayrshire, South-West Scotland. It is a two storey cottage with two rooms on the ground floor and three rooms (including a small bathroom) on the upper floor.

Windows of the cottage are timber-framed, single-glazed and they will be removed, re-glazed, fitted with draught strips and re-fitted. With windows and door improvements a calculated improvement of **5%** in the energy running costs, equating to **0.8 tons of CO₂ per annum** is achieved with this intervention.

In order to retain original and historic linings, the current focus by Historic Scotland on internal wall insulation is intervention in the void behind the lath and plaster (the traditional internal lining technique used since the 17th C). Site trials over the winter of 2010/2011 involved the insertion of various form of blown materials into the cavity space in a range of structures. This will reduce volume advection of air, but not compromise the ability of water vapour to disperse through the structure – which ideally remains vapour permeable both inside and out. Insulation material has now been blown into cavities in a range of properties, including the test cottage. Long-term in situ monitoring will assess the humidity levels at the internal masonry and in the now partially filled void. These blown insulation techniques have also been used in the upstairs rooms of the test cottage. In the down stairs rooms, where no original plaster remained, hemp board, finished with a lime plaster, was installed. This internal insulation is a modelled energy improvement of **25%** or **3.9 tons of CO₂**.

Sheep's wool insulation has been laid on roof between and above the joists to a thickness of 250mm.

As is well know, roof and loft insulation is by far the most cost effective intervention on any building, and in this case there is a modelled saving of **15%** in energy consumption or

2.3 tons of CO₂. A new lime concrete floor was laid. Upgrade of the floors at the cottage gave a reduction of **4%** in energy costs or **0.6 tons of CO₂**. (32)

Table 2.30. U- values before and after reconstruction

Building element	Existing U-value [W/m ² K]	New U-value [W/m ² K]
External walls (ground floor)	1.25	0.86
External walls (first floor)	1.15	0.86
Roof	2.30	0.16
Shaft to rooflight	2.30	0.16
Suspended floor	3.60	0.20
Solid floor	3.60	0.32
Windows	5.50	1.80
Door	2.75	1.85
Rooflight	5.90	1.75

LEŠIĆ DIMITRI PALACE, KORČULA, CROATIA



The building of the Lešić-Dimitri Palace complex consists of two parts historically and structurally different: a four storey Palace and a line of five monacellular ruins. They were built between 15th and 16th century and are protected cultural monuments registered at the Register of immovable cultural assets of the Republic of Croatia – the List of protected cultural assets.

The total complex amounts to some 1,300 m² and contains a host of original features, mainly in stone, which reflect the long history of the site. The owners decided to create six luxury apartments, one on each floor, in order to preserve the existing floor plan as much as possible, as well as other common facilities. The whole complex would be supplied with luxury five star hotel services.

It was decided very early on that a full restoration of the complex would be carried out in such a way as to restore the structural integrity of the buildings to the highest standard, preserve all existing features, maintain the existing floor plan as far as possible, and present the intrinsic qualities of the buildings. The main issue was how to provide comfortable space with all the facilities needed for residential functions while preserving the existing spatial concept. The stone walls, traditionally not plastered from the outside, were impossible to insulate in the contemporary manner. The walls consist of two layers of stone, exterior and interior, and had loose material in between which has, with time, turned into dust. The majority of stone joints were cracked, transparent and leaking. The first stage was cleaning the old joints and removing old plaster. Once the walls had been consolidated and the space in between cleaned with compressed air, they were injected with limestone grout, ground brick, white plaster and some additives. Following this, the joints were sealed in a traditional way. From the inside, the walls were laid with plaster with good thermal conditions.

The openings in the walls were closed with new windows. The new windows are made of oak-wood, with IZO glass. The roof and floors on the grounds were treated as in any modern

building. The existing horizontal constructions (wooden beams and wooden boards) didn't offer any sound insulation, and the new content demanded high sound insulation. The problem was that it was almost impossible to expand the height of horizontal constructions. The solution was found in the implementation of two very thin layers of lead sheets, with some additives. The biggest problem with the design was how to provide facilities needed for residential functions while preserving the existing spatial concept. For example, the building previously had two sanitary systems and its repurposing demanded a fully equipped kitchen for each residence and a bathroom for each room. Therefore, now the complex has 13 toilets, 7 bathtubs, 13 showers, 20 bathroom sinks, 6 kitchen sinks and 6 washing machines. Bathrooms were organised in accordance with different conditions found on each floor mainly within the area belonging to the medieval division canal which served as a sewage system while a bathtub and sink were placed inside each room, evoking traditional ambience with a basin and a sink. This little architectural trick solution worked around the existing design to provide the necessary functionality. The biggest technical problems concerned the new standard utility functions such as hot running water in all parts of the building as well as heating and cooling. Previously, of course, cooling and heating systems did not exist and there were no water supply lines (limited amounts of water were preserved in underground tanks). The heating and cooling VRV system was chosen. Outer units were placed on one roof terrace but also hidden from the fifth facade view which is very important for Korčula, and inner units mostly found their places in some piece of furniture, without disturbing the beauty of the interior as a whole. (33)

VILA BOŽIĆ IN BANJA LUKA, BOSNIA AND HERZEGOVINA



Vila Božić in Banja Luka was built in 1912. by the prominent Croatian architect Rudolf Lubynski. It was heavily damaged by an earthquake in 1969. and completely demolished in 2002. The heat loss of the original house, according to the design of the house as described in the above-mentioned blueprints, equaled 48,940 W, or approximately 111.2 W/m² of the heated area. The annual energy consumption used for heating was estimated at approx. 123.5 kWh/m². According to the new preliminary design, the envelope, ceilings and floors will be insulated, and windows with improved energy performance will be installed. This will help reduce the heat loss, which will amount to approx. 19,880 W, or around 45.2 W/m² of the heated area, on the condition the house is continuously heated. The calculation results show that by using multi-layer insulated walls and changing the mode of

operation of the central heating system the heat loss of the building may be reduced by about 29,000 W. In addition, the capacity of the heat source to be exploited for its heating can be almost 60% lower than what will be needed if the proposed measures are not implemented. The proposal to reconstruct the entire villa in its original form takes into account its historical value, the possibility to change its use and use modern materials to reduce its energy consumption. The results obtained taking into account the proposed energy efficiency measures are compared with those obtained without their application. (34)



Figure 2.28. A photograph of Villa Božić in the 1980's, showing traces of time and neglect that gradually led to its demolition

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Figure 2.27. Villa Božić, a cross section showing layers of the walls that can be used to make the reconstructed house more energy efficient

HAMPTON COURT PALACE, THE TOWER OF LONDON AND KENSINGTON PALACE, UNITED KINGDOM

Rockwool and British Gas install insulation in Hampton Court Palace, the Tower of London and Kensington Palace. The project was broken down into five phases.

Due to the nature of the buildings involved in this project and the scope of works, there were some fundamental constraints which had to be considered such as some of the ornate ceilings below the lofts were priceless so other factors had to be included in the decision making process in order to minimise the risk and to enable sensible decisions to be made on how to proceed. Below are just some of the steps taken:

- The Palaces were declared as Scheduled which means that they are protected from any interference and as the programme of insulation required that the fabric of the building would need to be interfered with, a Scheduled Monument Consent had to be applied for before any work could begin on the Palaces.
- English Heritage, (a non-profit, government funded organisation, who champion the UK's historic palaces and advise the government on how to get the best from their cultural heritage), had to be consulted to ensure that all elements of the installation and the products used would comply with building regulations and those that are applicable to historic buildings.

- The Trustee and curators for each Palace has to authorise every programme of works at each step; without their buy-in and authority works could not progress
- Detailed health and safety risk assessment had to be undertaken of each element of the programme to take account of:
 - Voids in the attic areas of the palaces
 - Manual lifting and carrying of the rolls of insulation to the area of installation – historic buildings don't always have elevators
- Very detailed thermal (U value) calculations and dew-point calculations were undertaken. In conjunction with these reports, condensation risk analysis was carried out and reported upon. Both reports influenced the approach to take with depth of insulation and what products to use.

After these historic buildings, Hampton Court Palace, Kensington Palace's Orangery and the Tower of London's Queen's House, have been properly insulated they will cut a combined **150,325 Euro** from their gas bills and reduce their CO₂ emissions by **850 tonnes** over the lifetime of the insulation. In total, nearly **4,500 square meters** of the three palaces were covered by insulation – the equivalent of 100 average semi-detached houses. Altogether **11,000 rolls** of insulation were required for the project which took around **1,000 hours** to complete (Table 2.31). (35)

Table 2.31. Data of the Project

	Hampton Court Palace	Tower of London	Kensington Palace	Total
Areas to be covered by insulation (m ²)	3,624	241,9	614	4,479.9
Total size of Palace (m ²)	16,902	8,304	2,926	28,132
CO ₂ Savings per year (tonne CO ₂)	29.9	1.82	2.61	34.33
CO ₂ Savings lifetime (tonne CO ₂)	747.5	45.5	65.25	858.25
Savings on Fuel Bills per year - gas (Euro)	5,296.42	350	540	6,186.42
Savings on Fuel Bills lifetime – gas (Euro)	132,410.4	8,751	13,494	154,655.4
Packs of Insulation (roll)	851	72	214	1,137
Packs of Insulation (blown)	238	-	-	238
Hrs to Insulate (hrs)	782	52	149	983



Phase 1

Tower of London, Queens House and Butler's Pantry - Built around 1530 and situated within the walls of the Tower on Tower Green. The insulation task - a building which is divided into two main areas; the first only accessible with scaffolding and the second made of six compartments or voids, accessed by a stone spiral staircase.



Phase 2

Hampton Court Palace, Barrack Blocks and Apartments - Hampton Court Palace was originally built for Cardinal Wolsey circa 1514. The Barrack Block provided the earliest purpose built barracks still standing in Britain dating back to 1689. The insulation task - the Barrack Block contains 15 lofts, and there were 15 apartments all covered by a single void with various access points.



Phase 3

Hampton Court Palace, Base Court - The Base Court is the first court one comes to when entering the palace, leading straight to the Anne Boleyn gate and the clock Court where one enters the palace itself. The insulation task - the Base Court comprises 16 apartments, 2 offices, an IT area, 2 plant rooms and 3 living apartments. There were also 4 apartments in a state of disrepair.



Phase 4

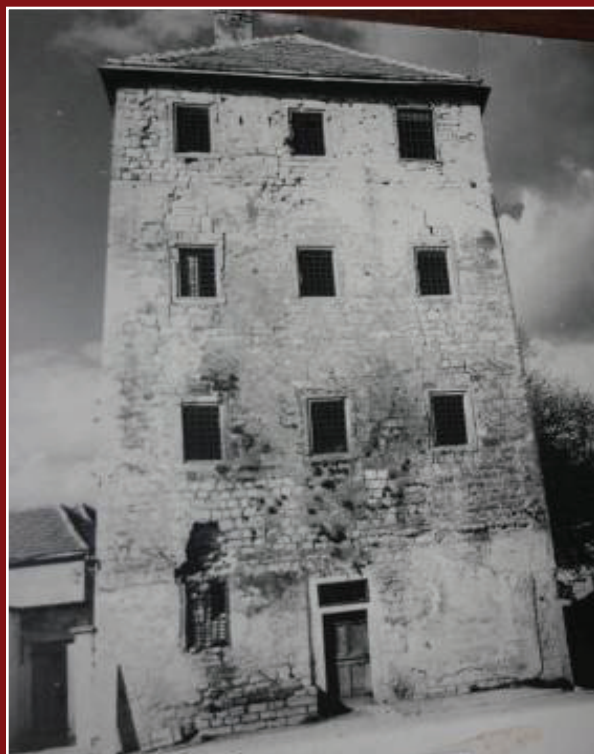
Hampton Court Palace, Fountain Court - Fountain Court was designed by Sir Christopher Wren for William III to replace Henry VIII's courtyard which stood on the same site. The insulation task - this comprised 11 voids (the unused space between the ceiling of the highest storey and the roof).



Phase 5

Kensington Palace, The Orangery - Kensington Palace has been a royal residence since the 17th century and today it is the official residence of the Duke and Duchess of Gloucester, The Duke and Duchess of Kent and the Prince and Princess Michael of Kent. The Orangery was built in 1761 for Queen Anne and is situated in the gardens of the Palace. The insulation task - This was a single building which included a restaurant and tea room all of which had a single void.

THE CAPTAIN'S TOWER IN BIHAĆ, BOSNIA AND HERZEGOVINA



Captain tower is situated in the Old city core of Bihać, and is proclaimed as a National monument under governmental protection. Today's condition of the monument is poor due to serious destruction of the façade by the atmospheric waters. The project covers repairment of its walls, both interior and exterior, substitution of openings, amendement of roof covering, major changes in the ground floor (pavement and partition). This monument is now a museum.

Captain's Tower in Bihać requires a serious reconstruction of stone walls. Current condition shows that damage is the result of aggressive atmospheric water causing vegetation. After the consolidation of the walls from both sides and injection works, it will be possible to prevent leaks into the structure.

Considering the fact that financial sides of all reconstruction projects in Bosnia and Herzegovina are poor, the project is divided into four phases of the reconstruction (depending on grants received) (Table 2.32.).

Table 2.32. Steps through phases

Phase 1	Phase 2	Phase 3	Phase 4
1.1. Scaffolding (The scaffolding would be mounted around the entire Tower and will be used for works on the roof, repair of the walls)	2.1. Repair of the ground floor (lower layers and pavement)	3.1. Protection layer smear for the interior walls	Ventilation system (including previous construction works on the attic for the air-conditioning unit, openings for 24 air throttles under the roof)
1.2. Roof reconstruction (shingle and roof window)	2.2. Toilette	3.2. Sandpapering and painting of the floor constructions	
1.3. Façade repair (cleaning, joints repair, protection layer)	2.3. Electric installation	3.3. Assemblage of the wooden ceiling on the first three floors	
1.4. Injection works	2.4. Repair of the interior walls	3.5. Carpets on floors 1 to 4	
1.5. Window replacement (3 layer glass), repairment of the stone frames, missing caging	2.5. Glass partitions in the ground floor		
1.6. Repairment of the plateau ascent in front of the Tower	2.6. Entrance door and windshield		

Roof exchange (Phase 1.2.)

Current roof covering is inappropriate and damaged. The roof construction is in good condition and needs no intervention except possible cleaning and protection coating. The roof will have no thermal insulation. On the roof construction it is necessary to mount wooden flooring, hydro-insulation, vertical battens, longitudinal battens and wooden shingle made of chestnut three.

Also, air throttles for the air-conditioning unit should be made under the crown of the wall, as should some strengthening of the structure for the a-c unit weight. **Thermal insulation will be added in the floor construction.**

Façade repair (Phase 1.3.)

This activity is key to the longevity of the Captain's tower. It will be performed in the following phases:

cleaning of the façade with metal and plastic brushes (joints and stone surface), removal of the cement mortar, removal of the damaged lime mortar, replacement of the damaged and missing stone blocks, repointing of the joints, injection works (lime hydraulic mortar Rofix 993) and covering of stone protection coating.

Windows replacement (Phase 1.5.)

As this reconstruction is meant not only to preserve the monument, but also to improve the conditions in the entire facility and save energy, windows are a very important part of the assignment. Although an average reconstruction does not include triple-glazed glass with insulation gas and Low-e coating – this one is an exception.

Ventilation (Phase 4.)

In order to ensure longevity and good conditions within the Tower, it is important to provide perfect ventilation. As the flooring structure is not historical – it will be possible to place the pipes in the corners of the tower. The main source of energy would be water - water heat pump. The air-conditioning unit will require air throttles made under the crown of the wall, as well as some strengthening of the structure for the main unit weight.

Ventilation is very important in this building – not only for its longevity but also for the safekeeping of its valuable artefacts. Placing the unit under the roof will provide necessary air exchange in the entire building. The main source of energy will be water-water heat pump situated in the ground floor. (36)

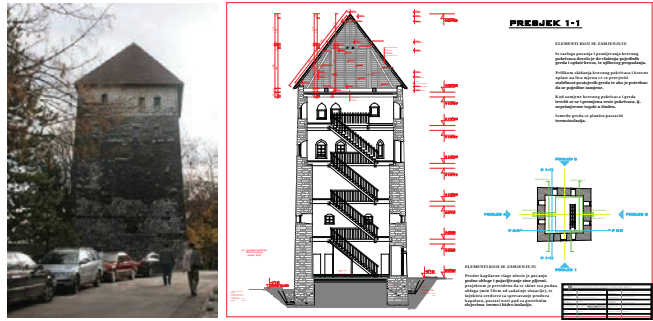


Figure 2.29. Captain's tower today and cross section

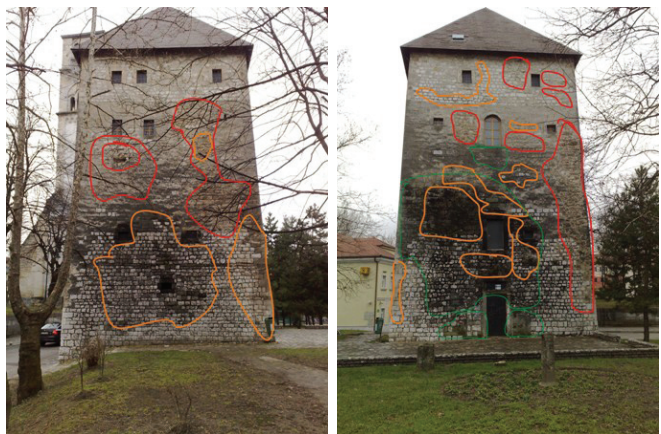


Figure 2.30. Captain's tower Façade damage



Figure 2.31. Ground floor today



Figure 2.32. 4th floor today

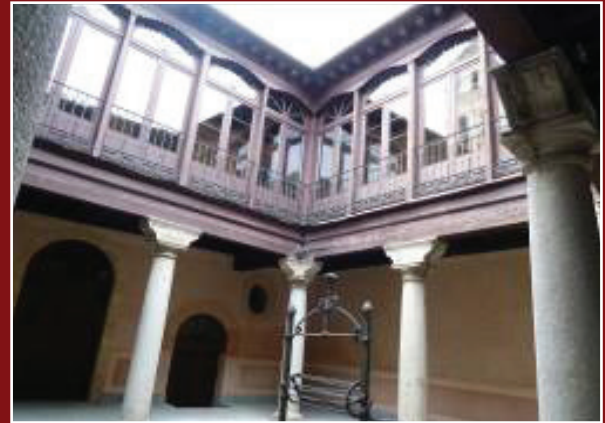


Figure 2.33. 2nd floor today



Figure 2.34. 1th floor today

MODIFICATION OF BUILDINGS IN SEGOVIA, SPAIN



When talking about bioclimatic strategies, technicians usually present two possible priority objectives: the use of these strategies to have the largest solar uptake or, on the contrary, to avoid (if possible) the production of such an uptake. However, there are a lot of weathers where it is advisable to search for solar heat uptake in determined seasons, while in others such capitation turns out to be undesirable.

Example of building modification and hygrothermal behaviour of three patios located in three different palaces is shown in Segovia, Spain. These are: the palace of Quintanar, the palace of the Lozoya Marquis and the palace of the Castro family. They are all historic-artistic monuments. Segovia (Spain) was declared by UNESCO a World Heritage Site in 1985. The urban palaces built in Segovia, between the 15th and 18th centuries, are functionally distributed around interior patios with galleries on three or four sides. In view of the purpose of the buildings, some modifications can be done in three different ways: partial enclosure of the gallery with windows, new structures covering the whole patio or no modification at all (open patio).

Option A.- Open patio, no modification.

This intervention is merely for the purposes of conservation of the building typology, with no further transformation, keeping both levels of the patio opened and allowing the natural air flow, as well as direct solar incidence all year long. Foreexample, the Quintanar Palace Patio that has undergone a restoration project, with the objective to adapt the Palace for cultural use, readjusting rooms to create space for exhibitions, a studio, an archive and offices. By not altering the disposition of the patio, its hygrothermal behaviour is the same as before, that is to say, the one it was designed for. Figure 2.35. shows, in blue, the cross ventilation that is produced in the first and second floor from the garden, and, in green, the entrance of fresh air produced in the patio, from the garden, through the basement.

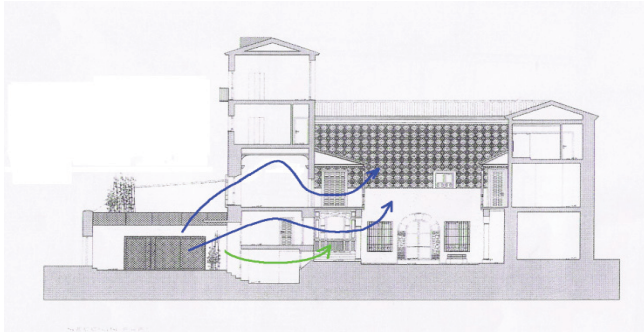


Figure 2.35. Section of the Quintanar Palace, where the functioning of the whole patio + garden during summer is observed.

Option B.-Enclosing the open gallery, usually with wood carpentry and glazing. This intervention closes the gallery's upper level with wood carpentry and glazing, adapting it to the pre-existing cavities of the patio. The ground level is kept opened, allowing the natural air flow. An example of the modification is shown in the Patio of the Marquis of Lozoya Palace by closing the gallery on the upper floor with glass walls with wood carpentry in the 19th century. The closing of the gallery gaps caused a huge change in its hygrothermal behaviour, because the phenomenon known as "greenhouse" started to occur, more especially as the glass closings were installed in the exterior edge of the facade, immediately behind the pre-existing metal railing (Figure 2.60). Therefore, the protecting shadow the lintel offers over the glazing is low.

It is observed that the closing was practically installed to external bundles (graded with the exterior face of the facade, as much as the wrought iron railing permitted).



Figure 2.36. Second floor of the Marquis of Lozoya Palace, in which the possibility to generate cross ventilation through the rooms on the upper floor during summer is observed, from the north facade towards the patio.

Likewise, we see that the glass surface is about 4/5 of the total, that is to say, when they decided to glass the gallery they tried, as far as possible, to guarantee the maximum solar uptake in the enclosure created in the other upper gallery of the patio. On the contrary, the incorporation of this glazing prevents the cross ventilation that, coming from the building facade –oriented to the north, and therefore, permanently in the shadow- could previously refresh the main rooms of the building on the second floor (Figure 2.36). Therefore, it is evident that the modification efficiently improves the behaviour during winter, while it makes it worse during summer.

Option C.- Total cover of the patio.

This intervention completely covers the patio with an independent structure and with complete glazing. With this action the space of the patio is modified, transforming it in an interior space and intercepting the natural renovation of the air. Example of this is shown in the Castro family Palace. This is the patio whose functioning was most altered from all the analyzed patios, because it was completely covered by a glass closing. The new closing, even increasing the habitable surface, has turned the patio into a greenhouse with costless solar heating during winter, so in sunny days there is no need to heat it, but it causes very harmful heating during summer making it hardly habitable without artificial air conditioning. However, a simple opening mechanism in the highest part of the enclosing could quite efficiently improve its functioning during summer, because it would act as a solar chimney (Figure 2.37), taking advantage of the convective effect provoked by the great solar uptake to generate air flow refreshing the rooms attached to the patio.

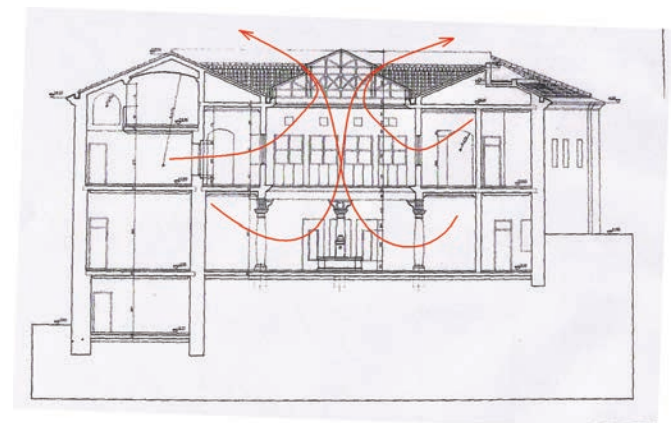


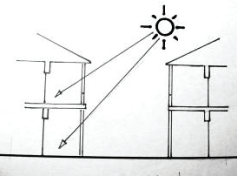
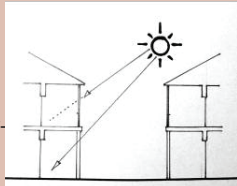
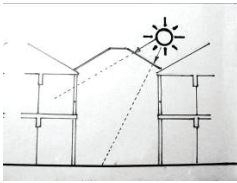
Figure 2.37. Convective flow that could be generated in the patio of the Castro family Palace with adequate automatic opening of the glass cover

For this purpose it would have been better if the cover had been built with a higher slope to gain height and improve air flow, but this would have made it more visible, which would cause a greater alteration from the aesthetic-heritagepoint of view. The fountain located in its centre which produced evaporative refrigeration during summer time has ceased its functioning due to condensation problems that have occurred on the new glass cover, but it could start working again if the convective ventilation is generated, cooling the moving air and allowing the patio to work reasonably good, at least during spring and autumn.

Option A proposes a continued air flow and a temperature interchange, between the patio and the adjacent rooms all year long, it proposes an advantage when the mean exterior temperature is similar to the interior temperature, but it involves a high loss of energy during the coldest months of the year. From the cultural heritage protection point of view, this intervention does not include any alteration of the protected building, assimilating it as a conservation and maintenance intervention. Option B proposes an advantage during the coldest months of the year because an interchange of air between the patio and the gallery is

not produced, allowing its alternative use. From the point of view of its functioning during summer, it gets worse if the installed carpentries are not detachable, or at least, permeable in great part of their surface. However, given the climate of Segovia –with a higher need of heating than cooling–, the annual energetic balance is usually favourable in this type of interventions, given that they provide solar energy to the heating, lessening the strongest needs. From the patrimonial point of view, the impact is acceptable, as far as the materials are respected and the rhythm of the gaps, designing an integrated intervention with the architectural values of the building. Option C turns the patio into a close space allowing a higher diversity of its uses. From the cultural heritage point of view the typology of use is transformed and it creates an exterior view impact by incorporating a new element to the cover. From the energetic point of view, this type of intervention is quite deficient if shielding elements that control the excess of solar uptake when it is not necessary are not contemplated and a correct ventilation of the covered space. However, making practicable the highest part of the glazing –always without compromising the water tightness of the cover, it can even improve the original ventilation regime of the patio. (37)

Table 2.33. Comparison of the proposals

	ADVANTAGES		INCONVENIENTS	
	Energetic	Heritage	Energetic	Heritage
PROPOSAL A - open patio- 	Undisturbed flow of air. Generally better behaviour during summer.	The original architectural aspect is preserved.	During cold months the loss of heat is high and the possible uses are limited.	Unacceptable.
PROPOSAL B - Carpentry in the upper gallery- 	During cold months sunshine is used.	The intervention does not modify the typology.	Possibilities of cross ventilation for passive cooling of the adjacent rooms get worse.	Acceptable, as far as materials and gap rhythm are maintained.
PROPOSAL C -covered patio- 	During cold months there are few losses. Possibility for new uses.		During intermediate months forced ventilation is needed and during summer, air conditioning.	The image of the cover is transformed.

. Lighting in cultural heritage

3. LIGHTING IN CULTURAL HERITAGE

When illuminating cultural heritage, besides taking into account the usual aspects of lighting such as: energy efficiency, quality of lighting and lighting pollution, one should consider and understand why that space or building has been declared a cultural heritage. Lighting brings new perspective to it – a new atmosphere and a new dimension. But, it should not underestimate or degrade its relevance. This is a responsibility which lighting designers and installers should bear in mind.

In professional terms, there are two fundamental categories of lighting: indoor and outdoor. Why? Design and implementation of their installation are different for several reasons: the weather impact, the purpose and users of the illuminated space, possible lighting control methods (switching on/off, dimming ...), maintenance ability etc. This division is applicable also when we speak about lighting in cultural heritage.

There are numerous different lighting technologies applicable in indoor lighting. Technically, comparing it to outdoor conditions, the task standing before designers and installers - creating energy efficient lighting of cultural heritage, is not too difficult.

In chapter 2.2.2. lighting system is presented a very valuable experience of application of energy efficient indoor lighting. The case study shows how the building, which is declared a cultural heritage and at the same time used as a secondary school, can be efficiently illuminated. Very demanding conditions typical for schools have been met using a sophisticated lighting management system and carefully selected luminaries. The solution enables savings not only during night time, but also during daylight.

When located outdoors, cultural heritage is usually situated in city centres. In those cases, criteria which designers should follow are: improvement of city center's visual identity, emphasis of historical amenities, temperature of light, appearance of light source, reduced maintenance possibilities, lighting pollution and above all energy efficiency.

Energy efficiency presents a limiting factor when some of those criteria are attempted to be achieved, but new technologies available on the market enable designers to produce lighting of historic city centres which meet all mentioned criteria while lowering energy consumption.

That is well presented in examples described in chapters 3.1. Lighting of buildings (3 buildings in Sarajevo using LED lighting), 3.2. Lighting of historical city cores (massive project of illuminating the Old City in Dubrovnik, Croatia and 3 other similar examples in Rijeka, Croatia, Liverpool, UK and Lyon, France). In chapter 3.3. Public lighting systems there are four examples which describe how ESCO projects in places containing cultural heritage can be financially feasible and energy efficient.

. Lighting in cultural heritage

3.1. LIGHTING OF BUILDINGS – ENERGY EFFICIENCY MEASURES AND SAVINGS

CITY HALL IN SARAJEVO



The City Hall in Sarajevo is one of the most remarkable architectural examples built at the end of 19th century. It was made in the Neo-Moorish style, inspired by the Islamic architecture of North Africa and Spain. The building is located at the forefront of the historical part of the city and represents a significant element of its landscape. It has a triangular form with corner towers, its sides having south, north-east and north-west orientation. Hexahedral central hall with a glass dome dominates in the interior space of the building. Total useful area of the building of 7,716.10 m² is distributed on five levels.

In terms of energy efficiency of lighting installations, the City Hall building presents an extraordinary example on several aspects. On one hand, the original appearance of the building should be preserved and its cultural and historical significance should be highlighted, and here illumination of both internal and external side of the building is very significant. On the other hand, new disposition of interior useful space of the building – featuring a range of uses, from classical office and educational spaces to public and museum spaces – requires the lighting system to ensure comfortable working conditions.

Table 3.1. shows some of the most significant economic indicators of the two lighting solutions. It is evident that, at the expense of slightly larger investment costs, a substantial savings can be achieved in terms of energy and maintenance costs over lifetime of the system. Simultaneously, as Table 3.2. indicates, annual energy consumption and specific energy consumption of the lighting system per useful area of the building are significantly reduced.

We can say that with a proper choice of energy efficient light sources and installation of lighting control systems, energy efficiency can be increased by around 40%, with total initial investment cost for lighting installation increased by not more than 20% in comparison to the current estimated costs. Also, these measures enable use of a smaller number of lighting fixtures, keeping lighting quality within the functional and decorative requirements of the building. Results of the proposed measures will be visible in savings of energy used for illumination, energy used for air-conditioning systems and maintenance costs of the installation. (38)

Table 3.1. Comparative summary of economic parameters

Overall results	Currently available lighting system (P1)	Newly proposed lighting system (P2)
Average total costs per year (EUR/a)	10,521.92	8,253.04
Total absolute cost of solution over lifetime (EUR)	157,828.81	123,795.57
Return on investment – ROI	17.12	Base
Amortisation of solution (a)	0.88	Base
Absolute investment costs vs. running costs (EUR)	61,194:96,634	63,306:60,490
Ratio of investment costs vs. running costs (%)	39:61	51:49
Numerical ratio of investment vs. running costs	1:1.6	1:1

Table 3.2. Comparative summary of economic parameters

Lighting of City Hall in Sarajevo	Currently available light- ing system (P1)	Newly proposed lighting system (P2)
Average energy consumption per year (kWh/a)	45,854.59	29,59.47
Average energy consumption per area per year (kWh/m ² /a)	62.75	40.63
Total energy consumption over lifetime (kWh)	687,818.48	445,402.11
Total installed capacity (kW)	13,383.40	8,802.80

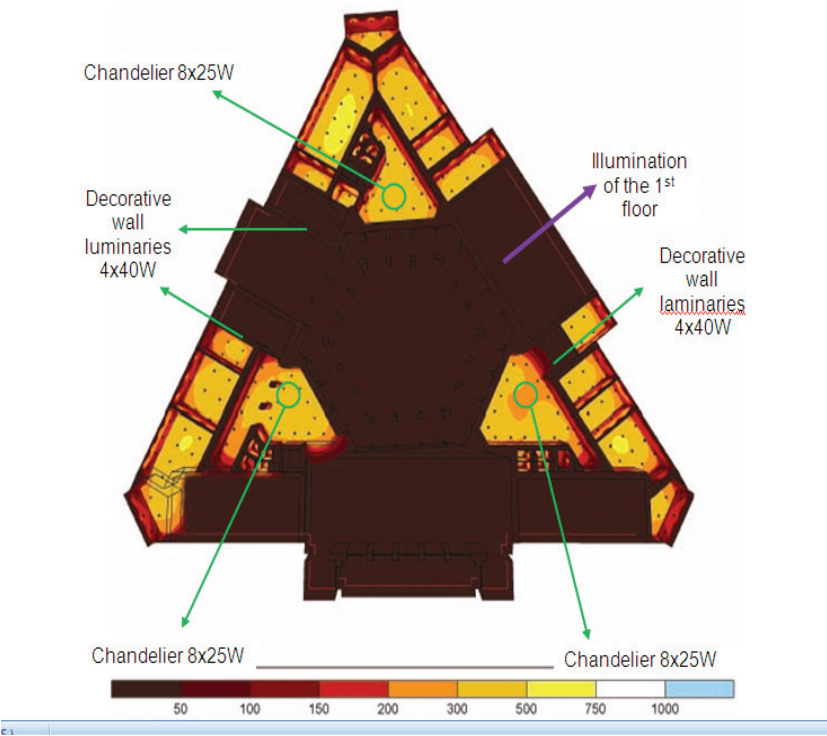


Figure 3.1. Illuminance of the 2nd floor of the City Hall building using energy efficient light sources

ILLUMINATION OF THE OLD TOWN BAŠČARŠIJA SARAJEVO, BOSNIA AND HERZEGOVINA



The City of Sarajevo and the Municipality of Stari Grad are jointly implementing the project of illumination of the street Kazazi within the illumination project of the Old Town of Sarajevo - Baščaršija. The total value of the works is EUR 121,119.

Visually, the arrangement of this site will contribute to the rehabilitation of office space in Kazaz, which included a reconstruction of roofs, eaves, gutters and building facades in the street Kazazi. The Kazazi street lighting is also based on the use of decorative LED lighting that is unobtrusive, environmentally friendly and cost-effective in the long-term.

The Mayor believes that the implementation of the lighting project in Kazaz is a continuation of the renovation process in the most representative part of the Old Town – Baščaršija, with an aim to make it more attractive and appealing to citizens, visitors and tourists. (39)

ILLUMINATION OF THE ŠEHER-ĆEHAJINA BRIDGE IN THE OLD TOWN OF SARAJEVO, BOSNIA AND HERZEGOVINA



This project was supported by the City of Sarajevo who recognized that promotion of our cultural heritage treasure is very important for the city's economic development. LED lighting is used in this project as well (39).

ILLUMINATION OF ACADEMY OF FINE ARTS IN SARAJEVO, BOSNIA AND HERZEGOVINA



The City Hall in Sarajevo is one of the most remarkable architectural examples built at the end of 19th century. It was made in the Neo-Moorish style, inspired by the Islamic architecture of North Africa and Spain. The building is located at the forefront of the historical part of the city and represents a significant element of its landscape. It has a triangular form with corner towers, its sides having south, north-east and north-west orientation. Hexahedral central hall with a glass dome dominates in the interior space of the building. Total useful area of the building of 7,716.10 m² is distributed on five levels.

Table 3.3. Comparison of budget cost of external illumination during the night

Academy of Fine Arts in Sarajevo	Mixed use of incandescent and LED lighting lamps (20% LED)	Use of LED lighting lamps only (100%)
Annual demand for electricity	27,953 kWh _{year}	5,600 kWh _{year}
Annual costs*	2,292 EUR _{year}	459 EUR _{year}
*1 kWh in Bosnia and Herzegovina is 0,16 KM, converted in euro the price for 1 kWh is 0,082 EUR (1 EUR =1,96 KM)		

The modelling from Table 3.3. above shows that illuminating the building exterior with LED lamps only spends five time less energy than with 20% of LED lamps. (39)

3.2. LIGHTING OF HISTORICAL CITY CORES

ILLUMINATION OF THE OLD CITY IN DUBROVNIK, CROATIA



Historical city core of Dubrovnik is under the protection of UNESCO since 1979, therefore good illumination as well as energy efficient solutions are necessary.

Reconstruction of public lighting in Dubrovnik was carried out in three phases. The first phase included illuminating of the external line of city walls so that the entire city could be visible from the open sea. The first phase of the lighting project of the city walls (apart from the external line) as well as squares, streets and parking areas around the whole

city, was implemented in 2009. The second phase included lighting of the interior of the Old City while illuminating of the southern Wall was the third phase, all scheduled to be finished in 2012. This lighting project is considered as one of the most complex and technically demanding projects of architectural lighting in Europe. It consists of around 600 light fixtures for the lighting of the city walls, 500 new luminaires whose design was based on the appearance of the old lanterns for the lighting of main squares and streets, 120 luminaires for public street lighting, parking spaces and green areas, 1,000 light fixtures for illuminating historical buildings within the Old City core and more than 8,000 LEDs for lighting of walking paths above the city walls (4).

Reflector housings have a high level of protection due to the proximity of the sea. Colour temperature was adjusted according to the colour of the stones.

Before reconstruction, Stradun was illuminated with tungsten bulbs (200 – 300 W) so the decrease of power consumption sums up to 80% as shown in Table 3.4.

The lighting is managed from the municipality office which allows energy consumption analysis, easier and planned maintenance etc. All architectural and decorative lighting has to be turned off at 11 p.m. by this system.

Table 3.5. shows a comparison between the old and the new lighting of the whole project including savings of total annual consumption of electric energy and total annual price of electric energy. (40)

Table 3.4. Annual savings through phases

Lighting of Dubrovnik Old City	Annual savings (kWh _{year})*	Annual savings (EUR _{year})	Annual savings %
New lighting of City walls	89,000	10,647	38
New lighting solution around Old City	53,802	6,436	57
New lighting of main street Stradun	132,720	12,908	83
Total savings (whole project)	397,320	47,351	34

*1 kWh in Croatia is 0,71 KN, converted in euro the price for 1 kWh is 0,097 EUR (1 KN = 7,3 EUR)

Table 3.5. Comparison between old and new lighting of whole project (savings)

Public and decorative lighting (including walking paths above the city walls)	Number of luminaires	Working hours per year (h)	Total annual consumption of electric energy [kWh]	Total annual price of electric energy with tax [EUR]
Old condition	873	4,200	1,170,540	140,031.9
New condition	10,520	4,200	773,220	92,500.42
TOTAL SAVINGS AFTER THE RECONSTRUCTION	-	-	397,320	47,531.51

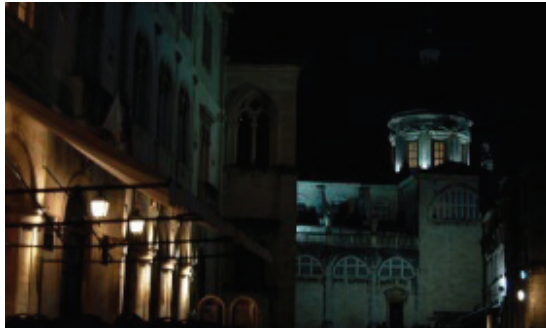


Figure 3.2. Old lighting situation



Figure 3.3. Realization of lighting of Dubrovnik City walls

ILLUMINATION OF KORZO IN RIJEKA, CROATIA



Illumination of Korzo before reconstruction



Illumination of Korzo after the reconstruction and transition to "white light"

Illumination of the urban centre of Rijeka has been done with decorative lightning custom made for that purpose. Lighting installed on the main pedestrian zone in the City of Rijeka - Korzo, includes decorative bronze poles and Philips lighting equipment installed inside decorative light fittings. Classic high pressure sodium lamps which have been used in the light fittings until 2007 had the colour temperature of 2,000 K and colour rendering index of 20. In 2007 Philips MasterCity White lamps with the colour temperature of 2,800 K and CRI of 83 replaced the existing installation of yellow sodium lights. The dimensions and the caps of the new lamps matched the old ones which made the transition much easier. The technology used in the new lamps is A ceramic halide technology, so far mainly used in shopping malls, is applied in the new lamps.

The difference in colour temperature and in increased colour rendering index can be seen on the above photos of Korzo and its illumination before and after reconstruction. The installed light-fittings are not shaded and have a spherical form, placed along both sides of the pedestrian zone. This ensures high quality illumination of the pedestrian zone as well as the historical buildings and their facades. (41)

ILLUMINATION OF THE CITY OF LIVERPOOL



Liverpool city centre has a rich architectural heritage which includes the world famous Waterfront, Cultural quarter and two iconic cathedrals. The city owes its wealth of civic buildings and historical architecture to its development throughout the 18th and 19th centuries as one of the world's most prominent commercial ports. Today, Liverpool is enjoying a new period of revival, inscribed onto the UNESCO World Heritage List in 2004 and selected as European capital of culture for 2008. Following the above, Liverpool has delivered a 5 year programme of architectural and feature lighting for the city centre.

Programme targeted landmark buildings and key beacons, defining the city identity & aiding orientation. Later phases focused on building up a critical mass of lighting within priority areas, giving consideration to key vistas and pedestrian routes. During the period 2002 to 2007 the city centre feature lighting programme has seen more than 60 buildings and monuments lit in the heart of Liverpool. The impetus of this programme has also encouraged additional lighting schemes by building owners and developers outside of the programme. (41)

FESTIVAL OF LIGHTS IN LYON



Many cities have developed a special culture of decorative lighting, for example, the City of Lyon in France annually hires the world's best lighting designers to light the gorgeous creations in the city. "Festival of Lights" ("Fête des Lumières") starts each year in early December and lasts for four days. While it lasts, famous monuments of Lyon such as: Saint Nizier church, Town Hall Theatre (Theatre des Celestins), Cathedral (Cathedrale St Jean), hotels (L'Ville Hotelde, Jacobin square) are illuminated. Each year those buildings have to be illuminated differently than the previous year. All artists from around the world participate in the illumination of Lyon. They usually apply the latest technological innovations in lighting installations. New ideas in the approach to illuminating the buildings are presented every year. From the very beginning of the festival "Fete des Lumières" has been a major tourist attraction. (41)



Figure 3.4. Fête des Lumières example

3.3. PUBLIC LIGHTING SYSTEMS

PUBLIC LIGHTING IN SAN VITO DEI NORMANNI

San Vito dei Normanni is an historical town of about 20,000 inhabitants, in the Brindisi district of Puglia, southern Italian Region.

The Municipality of San Vito dei Normanni made a tender for a 15-year energy and maintenance service and complete energy and safety requalification of public lighting systems of the whole town.

The public lighting systems have 2,710 light points. The expected energy saving is 58.7% and the maintenance saving is 33% as shown in Table 3.6. The total cost of the initial requalification works, to be charged on the ESCo, is 2,152,425.68 EUR. (42)

Table 3.6. San Vito dei Normanni – Power and Energy reduction

	Before	After	diff.	diff. %
Power (kW)	556	336	-220	-39.7%
Energy (MWh/year)	2,031	839	-1,192	-58.7%
TOE (tonne of oil equivalent)	508	210	-298	-58.7%

PUBLIC LIGHTING IN GEOVEST

Geovest is an association of several towns, in Emilia Romagna, central Italian Region.

Geovest, together with the Municipalities of Sant'Agata Bolognese, Sala Bolognese, Nonantola, Crevalcore, Calderara di Reno, made a tender for a 15-year energy and maintenance service and complete energy and safety requalification of public lighting systems of each of the five towns.

The 5 towns' public lighting systems have about 9,000 light points. The expected energy saving is 33.3% (as shown in Table 3.7.) and the maintenance saving is 27%. The total cost of the initial requalification works, to be charged on the ESCo, is 2,222,175.67 EUR. (42)

Table 3.7. Geovest (n.5 Cities in Emilia Romagna) – Power and Energy reduction

	Before	After	diff.	diff. %
Power (kW)	1,028	892	-136	-13.2%
Energy (MWh/year)	4,427	2,951	-1,476	-33.3%
TOE (tonne of oil equivalent)	828	552	-276	-33.3%

PUBLIC LIGHTING IN SAN DONATO MILANESE

San Donato Milanese is an industrial town of about 33,000 inhabitants, in the Milan district of Lombardia, northern Italian Region.

The Municipality of San Donato Milanese made a tender for a 20-year energy and maintenance service and complete energy and safety requalification for the public lighting systems of the whole town.

The public lighting systems have 5,176 light points. The expected energy saving is 48.4% (as shown in Table 3.8.) and the maintenance saving is 30 %. The total cost of the initial requalification works, to be charged on the ESCo, is 3,429,658.39 EUR. (42)

Table 3.8. San Donato Milanese (Milan) – Power and Energy reduction

	Before	After	diff.	diff. %
Power (kW)	661	546	-115	-17.4%
Energy (MWh/year)	3,109	1,604	-1,504	-48.4%
TOE (tonne of oil equivalent)	581	300	-281	-48.4%

PUBLIC LIGHTING IN COSENZA

Cosenza is a town of about 70,000 inhabitants, in Calabria, southern Italian Region.

The Municipality of Cosenza made a tender for a 20-year energy and maintenance service and complete energy and safety requalification for the public lighting systems of the whole town. on the whole town public lighting systems, for a 20 years energy and maintenance service, and for the complete energy and safety requalification.

The public lighting systems have about 11,000 light points. The expected energy saving is 63.8% (as shown in Table 3.9.) and the maintenance saving is 35%. The total cost of the initial requalification works, to be charged on the ESCo, is 6,945,723.75 EUR. (42)

Table 3.9. Constanza (Calabria)– Power and Energy reduction

	Before	After	diff.	diff. %
Power (kW)	2,555	1,766	-789	-30.9%
Energy (MWh/year)	10,220	3,696	-6,524	-63.8%
TOE (tonne of oil equivalent)	1,911	691	-1,220	-63.8%

. Historic city centres and energy management plans

4. HISTORIC CITY CENTRES AND ENERGY MANAGEMENT PLANS

“Sustainability” is the central political concept for the 21st century. In ratifying the World Heritage Convention in 1972, all Parties accepted the concept of sustainability. The protection and conservation of natural and cultural heritage constitute important contributions to sustainable development as explained in A Practical guide for Management Plans for World Heritage sites published by the German commission for UNESCO. When a site is nominated to be inscribed on the World Heritage List, this is accompanied by a basic responsibility to develop strategies for sustainable use of thereof. The Operational Guidelines specify that World Heritage properties may be used in a multitude of ways, as long as they are environmentally and culturally sustainable. It is emphasized that the State Party and all other partners involved must ensure that such sustainable use does not entail any negative effects on the outstanding universal value, the integrity or the authenticity of the property. In the management plan, key measures and local initiatives within the framework of the Agenda 21 worldwide action program should be summarized. (43)

A “Cultural heritage integrated management plan” (CHIMP) is an innovative instrument to effectively manage the sustainable safeguarding and development of historic urban areas and their cultural heritage to attractive, competitive and multifunctional places. It balances and coordinates cultural heritage needs with the needs of the (manifold) “users” of the historic urban area and the responsible governmental bodies (demands of and towards the historic urban area and its cultural heritage). Thus, a Cultural heritage integrated management plan determines and establishes the appropriate strategy, objectives, actions and management structures to safeguard cultural heritage, to balance the different needs and to use historic urban areas and its cultural heritage as a developmental asset. (44)

UNESCO and the International Organization for Conservation of Cultural Heritage (ICCROM) recognized the importance of management plans, especially for UNESCO protected areas. Consequently, they established a course whose aim is to equip participants with practical knowledge that would allow them to initiate and develop management plans in their own countries.

However, energy management in historic city centres is not recognized as a specific category. Instead, it is incorporated under sustainability and other environmental issues. Since the world community has decided to tackle global warming by passing the Kyoto protocol, and other environmental and energy efficiency EU directives, and has set ambitious plans known as 3 x 20% by 2020, cultural heritage city centres should without a doubt introduce energy efficiency and energy management practices as well. Over 4,200 European

cities supported and signed the Covenant of Mayors, a mainstream European movement involving local and regional authorities that voluntarily obligate themselves to improving energy efficiency and using renewable energy sources in their cities. By obligating themselves, Covenant signatories aim to meet and exceed the European Union’s objective to reduce CO₂ emissions by 20% by 2020. Since the majority of these cities have a historical city center, their Sustainable Energy Actions Plans should take into account how to improve energy management in protected areas as well. Local authorities in charge of SEAPs and the local cultural heritage administration should collaborate in supporting sustainability in these areas, which would contribute to the overall success and energy savings in these cities.

In conclusion, the recommendation for future projects is to foster collaboration between cultural heritage management plans experts and experts in energy management, by including energy management and renewable energy sources in each Cultural heritage integrated management plan.

This chapter gives an overview of a proposed approach to energy management in heritage city centres as incorporated in cultural heritage integrated management plan for the city of Split. During the Dubrovnik conference on Energy Management in Cultural Heritage (2011), management plans for the city of Ravenna and the island of Corfu were presented, but lacked examples of specific energy management or energy efficiency plans.

The methodology used for the implementation of sustainable energy management in heritage city centres gives an overview of the various factors which should be taken into account during the planning phase. A methodology structured in three subparts was created in order to address an increasing need for sustainable energy management in heritage city centres:

1. Generation of knowledge – data survey
2. Design of the strategy, and finally
3. Management, which encompasses:
4. Implementation
5. Monitoring

First of all, in order to gain more insight into the energy performance of a historic centre, a survey that will examine the efficiency and adaptability of traditional buildings to the environment, and which will include the various energy scales that define energy efficiency and energy conservation - urban scale, building scale and specific energy systems scale - must first take place.

Urban renewal strategies must be based on a continuous decision-making process which focuses on identifying what is important in order to protect the cultural heritage, and what allows for a controlled evolution of the historic environment. In order to achieve this goal, the relationship between heritage preservation and livability in historic cities must be deepened.

In this sense, the historical heritage of the city, as well as its material form, can be understood as a process, in which authenticity is also prioritized in the management model. The historical processes of adaptation and evolution of the historic city must be understood in order to design strategies and actions that will facilitate the reconciliation of conservation and improvement of quality of life of the inhabitants, thus allowing for sustainable management during the entire process.

In order to incorporate effectively the idea of improving energy efficiency in historic cities with sustainability and preservation, the following three main criteria have been identified during the decision making process:

- Compatibility with the system
- Energy Efficiency
- Feasibility

Compatibility with the system

The continuous building of technical knowledge and skills in traditional architecture are key aspects of cultural and socio-economic development of a city. They are also the criteria that ensure compatibility of the chosen solutions with the energy system in the traditional building. The following are the sub-criteria that should be kept in mind during this process:

- Respect for authenticity
- Respect for integrity
- Respect for the original typology
- Compatibility with traditional construction techniques in the historical city
- Readability of modern inputs
- Adaptation to the lifestyle of the inhabitants
- Use of historical conditioning strategies
- Use of traditional materials

Energy Efficiency criteria

The improvement in quality of life is marked by a continuation of traditional housing but with concrete standards. In this context energy efficiency means improving liveability with minimal energy expenditure. This sub-criteria is structured

as follows:

- The sub-criteria for energy consumption optimization
 - Performance of the systems
 - U-value of the materials used
 - Improvement in energy performance
 - Use of renewable energy systems
- Sub-criteria for improved liveability:
 - Humidity
 - Noise
 - Thermal comfort
 - Air quality (and ventilation)
 - Lighting
 - Security

Feasibility criteria

It is necessary to ensure that the solutions and measures proposed are viable from economic, technical and legislative points of view:

- Economic viability
 - Initial cost of the investment
 - Return of the investment
 - Maintenance Cost
 - Cost-benefit analysis
- Technical feasibility
 - Compatibility with the energy performance of traditional buildings
 - Easy installation
 - Minimal discomfort for the user
- Feasibility standards
 - Compliance with heritage legislation
 - Compliance with energy legislation (45)

CULTURAL HERITAGE MANAGEMENT PLAN FOR THE CITY OF SPLIT

The Diocletian's Palace, the Historic Core of Split, represents a vibrant urban area of exceptional historical and cultural importance. It was listed on UNESCO's World Heritage list in 1979.

The Historic Core is located seaside on the northern (central) part of the city's port. The Core is surrounded by a border, and it encompasses 17th c. baroque fortifications, with an area of approximately 212.613 m² (21,26 hectares), divided into five characteristic urban zones as shown in the figure below:

In order to improve planning, a systematic and continuous approach towards developing and updating strategic planning documentation must be taken.

Recently, the Historic Core Management Plan was developed and presented to the general public following a requirement by UNESCO. According to UNESCO standards, every cultural site enlisted on the World Heritage List must develop a Management Plan. The Historic Core Management Plan, as a fundamental strategic planning document, is supplemented by two additional strategic documents: the

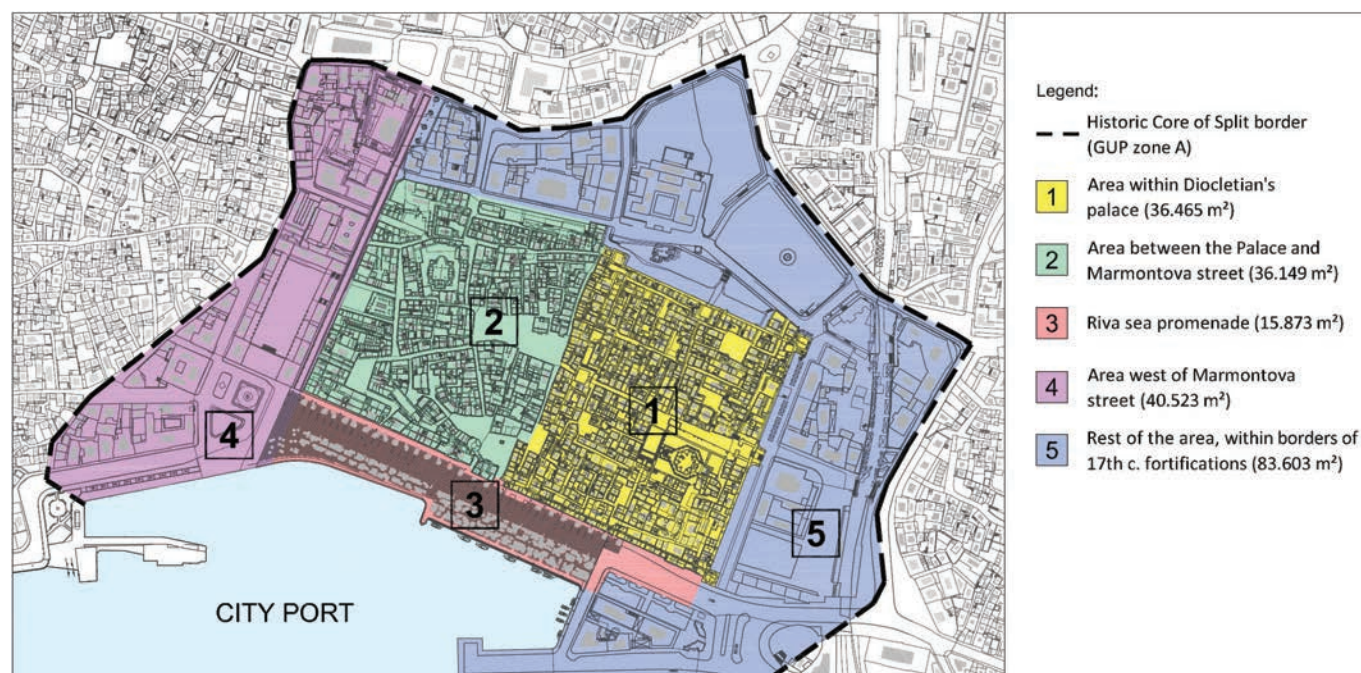


Figure 4.1. The Historic Core of Split with its characteristic urban zones

The revitalization of urban historic centres entails very complex multidisciplinary projects. In order to implement them successfully, a complete management system must be utilized, including systematic planning, organizing, leading, controlling and financing. Moreover, in order to ensure long-term sustainability of these projects, both modern theoretical principles and international examples of best practice, where sustainable development and integrated conservation are implemented through professional and multidisciplinary management systems (while utilizing a wide array of available financial instruments), must be taken into consideration. These are indeed the building blocks of long-term sustainable restoration and revitalization.

Organising and Financing Plan and the Revitalization Plan. Neither one of these plans is currently existent in the case of Split. Therefore, the goal is to have the Revitalization Plan incorporate measures that would improve energy efficiency which are aligned with conservation requirements (these measures would be established by the Ministry of Culture / the Split Conservation Department) in order to simply streamline further practical implementation of these measures.

These three interconnected plans should form a strong foundation for the strategic management of the Historic Core of Split. After the completion of these Plans, the operational-execution documentation should be developed, and finally,

the actual realisation of planned project activities should take place.

The objective of the Management Plan is to preserve the Spirit of the Place (Genius Loci) by minimizing conflicts between cultural values and stakeholders' values, and still fulfilling the need to further develop and amend 5. The Plan proposes a new model of management in order to improve the planning and coordination of activities that aim for better quality of life of the inhabitants and of the economy, while also securing long-term, sustainable protection of cultural values of the Historic Core. (46)

Infrastructure

Infrastructure is an important facet of the Management Plan. The historic core of Split, which has been inhabited for more than 17 centuries, is comprised of all kinds of infrastructure from different periods, starting with an extensive sewage system of vaulted channels built during the Roman period, which is blocked by a thick layer of organic deposit, and has only partly been explored and surveyed.

The most recent infrastructure being used today can be divided into:

- Macro infrastructure – includes sewage, drainage, water supply, electricity, telephone, cable TV.
- Micro infrastructure – has been installed by the inhabitants to fulfil their immediate needs (antennas, air conditioning, etc.).

Planning, implementing and maintaining infrastructure (above or underground) can have a big impact on the built heritage. Uncertainty regarding the management, maintenance and liability might also damage the built heritage and affect life in the historic core. (46)

Energy efficiency

The study of improving energy efficiency in a historic core takes into account the use of renewable energy sources through efficient and ecologically acceptable systems. Although solar panels are officially not allowed in the historic core of Split, the Management Plan proposes to reconsider such a decision. However, it is probably unrealistic to expect a broader use of solar energy in the historic surrounding. On the other hand, the utilization of energy potential of ground and seawater should be taken into more consideration. Due to its specific geological conditions, the city of Split, and especially its historic central area, abounds in fresh water sources. On a grand scale, an air conditioning system could be devised using drainage channels in and around the old city core. An example of a more localized use of such a system is the fish market which is in plan to be revitalized and renovated. The neighbouring area is rich in ground

water, and both the building and the merchandise require air conditioning.

The split system air conditioning is the most often used system because of its low cost and ease of installation. The widespread use of such a system has resulted in disfigurement of many facades in the historic core. In the near future conservation regulations will become stricter and as a result the owners will be asked to remove the exterior units from the facades facing public streets. In order to prepare for this, the City will undertake a study on the possible solutions for installing air conditioning systems in historic buildings. An increase in energy efficiency will be achieved by exterior restoration of historic buildings without deteriorating their historic and aesthetic value.

Public lighting is another area with great potential for energy savings. Good examples are the new lighting solutions in the Peristyle and the Cathedral in Split, where a large number of strong floodlights have been replaced by a much smaller number of low intensity spotlights, resulting in a much more appropriate atmospheric setting. (46)

On the level of individual buildings, energy efficiency improvement can be achieved not only through the use of appropriate insulation materials, but also through a well-coordinated system of management, revitalization and maintenance of buildings. The new management model should ensure continuous restoration and maintenance of historic buildings by using technically proven procedures that increase energy savings, and that have been approved by conservation authorities. Maintenance is the key to good housekeeping. Ensuring regular maintenance prevents an unnecessary waste of time, money and energy. The implementation of systematic management is of critical importance: maintenance should be the basis for the financial framework which should be created following previous experiences in other cities, but still adapted to the local conditions. (47)

In order to improve the existing organisational system, the "Historic Core Agency" should be established as the main institution responsible for planning, organizing, leading, controlling and financing of a full spectrum of revitalization and maintenance activities (within the Historic Core) by building its service on a project basis. The recommendation is to have the Agency legally become a public institution, with the City of Split as its founder. (46)

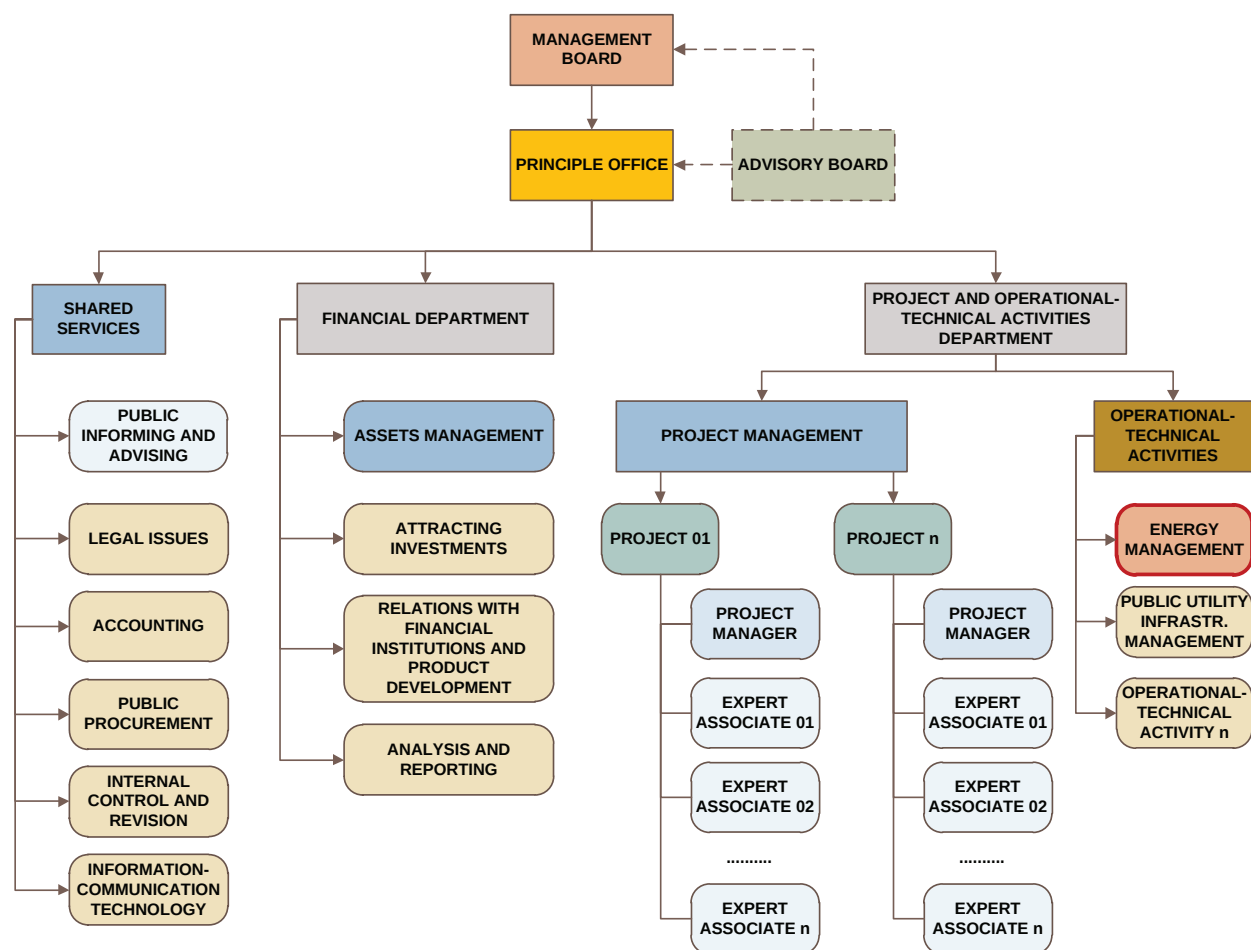


Figure 4.2. The Organisational chart of the Historic Core Agency [4]

The utilization of energy infrastructure and the application of energy management measures cannot evolve separately but rather as part of an integrated approach to the reconstruction of spatial and built structures.

An analysis of the current condition of built heritage and the public utility infrastructure identified the measures necessary for improving energy efficiency. In the domain of built heritage, energy efficiency measures are applied primarily for the revitalization of the respective building blocks (or individual buildings), by applying physical and thermal improvements (the installation of adequate roof, facade and window thermal insulation, as well as the installation of energy efficient heating and cooling systems).

Energy efficiency measures which could be implemented as part of the restoration/reconstruction of public utility infrastructure apply to:

- Public lighting – usage of energy efficient lighting systems and automatic regulation systems,
- Water network – restoration and reconstruction to reduce uncontrolled water wasting,

- Drainage system – its implementation would significantly reduce moisture on many ground floors,
- Utilize the energy potential of underground water present on a larger area of the Historic Core –by building an adequate technological water network for the heating and cooling requirements of respective buildings.

By implementing the aforementioned measures, energy consumption could be reduced by 30-40%, while at the same time creating preconditions for the implementation of aesthetically acceptable cooling and heating solutions (eliminating split system air conditioning units from cultural heritage buildings' facades).

To ensure successful implementation of recommended energy efficiency measures as well as generation of satisfactory results, their integration in future built heritage and public utility infrastructure revitalization projects is an absolute imperative. (46)

. Energy management

5. ENERGY MANAGEMENT

Almost a quarter of all buildings may soon bear the cultural heritage status. This presents a challenge to the building sector in accomplishing the EU 3x20% target by 2020. It also raises the question of what can be done to ensure energy savings across all building stock. There are a number of energy efficiency measures that cannot be implemented in the buildings due to a high level of heritage protection. However, there is no doubt that energy management and "soft" saving measures can and must be implemented to result in savings up to at least 10%. These measures include rising awareness of energy consumption and global warming through education that encourages occupants' behaviour change. Furthermore they include monitoring and analysis of energy consumption by an energy manager or a person in charge for operation and maintenance of technical systems resulting in optimal utilization of energy systems. (48)

5.1. EDUCATION AND GREEN OFFICE

Energy consumption is heavily influenced by users in the building. Even the most advanced and energy efficient technology and equipment cannot achieve significant savings if users of the building are not aware of energy consumption. Significant amount of heritage buildings, especially public ones, are used as office buildings. Since users in the building are responsible for energy consumption, education and awareness is one of the most important aspects of the Green office concept.

Green office is a name signifying a series of activities aiming to decrease energy consumption in office environment.

5.1.1. Office equipment

Office equipment includes various appliances (computers, printers, scanners, hand dryers, coffee machines, refrigerators...). Sometimes more than 20% of total energy consumption in office buildings goes for office equipment. Additionally, it is important to know that operational costs of the equipment are usually bigger than investment costs. Thus, it is important to take into account all running costs when procuring new equipment, where equipment with energy label A is recommended. But, it is also important to think about proper use of equipment where general advice is:

- Turn off or put on *sleep* mode devices not being used at given moment (especially overnight and during weekends).
- Don't use *screen savers*, turn the monitors off instead.
- Use multifunctional devices (printers, scanners,...).

- Use the two-sided printing feature wherever possible.
- Recycle electronic equipment.

5.1.2. Office paper

Energy concerns with regard to office paper are linked with resource consumption such as wood, water, transport fuel, electrical energy etc. as well as environment pollution such as waste paper generation, water pollution and emissions of greenhouse gases. Collecting used paper is a good way for later recycling or even incineration for energy production. General advice regarding the use of office paper:

- Print only when necessary, and always use two-sided printing when possible.
- Reduce the size of physically archived documents
- Organize personal archive on computer rather than in print.
- Use recycled paper.
- Use easily removable document bindings.

5.1.3. Lighting

Office building lighting system accounts for 15-20% of total energy consumption in buildings. Therefore, the most energy efficient lighting system uses as much daylight as possible. Advanced lighting systems can achieve significant savings by using automated light switches which are recommended in bigger offices.

General advice regarding lighting in offices:

- Replace standard light bulbs with CFL or LED bulbs.
- Whenever possible, use daylight as a light source
- Turn off the lights when no one is in the room.
- Install automated sensors where possible (especially in hallways, toilets, stairways,...).
- Install timer to turn lights off automatically.
- Properly dispose of old light bulbs.

5.1.4. Heating, ventilation and cooling

Adequate regulation of heating, ventilation and cooling systems (HVAC) and adequate information about system operation allows thermal comfort and increases energy efficiency. Recommended temperature in office rooms during heating season is 20-22 °C. For every degree Celsius higher than 20 °C, energy consumption rises by approximately 5%.

Thermostatic valves should be set at recommended room temperature, which can be lower in hallways, storage rooms, server rooms etc. Thermostats with programmable timing should be set to retain room temperature of 15°C after working hours (afternoon, during night, weekends, holidays, etc.).

During summer months, recommended room temperature is 25-26 °C. With every degree Celsius lower, 3-5% more energy is consumed.

General advice regarding HVAC in offices:

- Use natural insolation. In winter months, open curtains and blinds on windows during day time, but close them at night to reduce thermal loss.
- In summer months, close curtains and blinds on windows during the day.
- Do not block radiators or fan coils with curtains, furniture or decorative masks.
- Adjust thermostat to lower temperature during non-working hours.
- Use products in energy class A (A+ or A++).

5.1.5. Water

Water is not considered as energy source, but it can be treated in a similar way due to its importance as a resource and because conservation of potable water is an essential step in reducing negative impact on environment. Moreover, as much as 50% of the total cost of potable water is due to electricity consumption in pumping system.

General advice regarding water savings in offices:

- Water savings can be as high as 50% if faucet sensors are installed.
- Install aerators on faucets.
- Install toilet cistern with 2 compartments (smaller and larger).
- Replace old seals on faucets.
- Use rainwater for watering the garden in front of the office building.

5.2. MONITORING ENERGY AND WATER CONSUMPTION

Monitoring energy consumption is a cornerstone of every energy efficient facility. If energy efficiency measures are to be implemented in the most productive way, questions as to where, how much and which energy sources are consumed in a particular facility should be answered. All those questions can be easily answered if systematic tracking of energy and water consumption is established.

Monitoring energy consumption can also be seen as a standalone energy efficiency measure. Persons faced with actual consumption and costs are more aware of consumption and more likely to behave in an energy efficient manner. In this way, monitoring energy consumption is a cost-free energy efficiency measure which is essential for any further planning. Moreover, monitoring gives us a possibility for benchmark with similar buildings and evidence of areas of improvements.

Energy Management Information System

For the purposes of effective monitoring of energy consumption, software applications and databases can be developed. UNDP experts in Croatia have developed an Energy Management Information System as part of the "Systematic energy management in cities and counties" national project and "Bringing your own house in order" government programme. This system is being used in the public sector buildings, i.e. buildings owned by cities, counties, and the Croatian Government (such as administrative buildings, hospitals, schools, kindergartens, etc.). In six years of extensive collection of data from public buildings, more than 9.000 buildings have been imported with required properties in the database.

Subsequent to the first energy audit performed by UNDP assistants, experts responsible for energy management are obliged to enter relevant information about buildings and facilities in their jurisdiction.

After entering static data on each facility (these include general, construction and energy system properties), users enter dynamic data on energy and water consumption. Data provided in energy bills are entered on a monthly basis, whereas data from smart metering devices are entered on a weekly or daily basis.

Also, the way EMIS was designed will in future enable it to collect consumption data from buildings with remote reading devices (smart metering). Currently the system is in the test phase with 45 buildings (including stand-alone buildings and building complexes) connected with remote reading of energy consumption. 70% of these are cultural heritage buildings or they are part of the heritage conservation area.



Figure 5.1. User interface

Data entered into EMIS are used for various calculations, analysis and controls that enable understanding of how energy and water in a particular building are consumed. They are also used for comparison of similar buildings, as well as for identifying unwanted, excessive and irrational energy and water consumption. A part of the necessary analysis and consumption control EMIS implements automatically and informs the person in charge of the critical results (e.g., a drastic increase in energy or water consumption), which then reduces unwanted and unnecessary costs. Also, based on information obtained through the analysis, the experts responsible for energy management identify and implement necessary measures to increase energy efficiency, which ultimately result both in energy and financial savings.

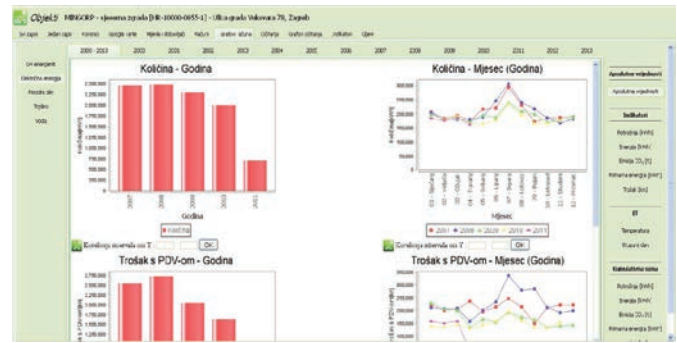


Figure 5.3. Graphs module

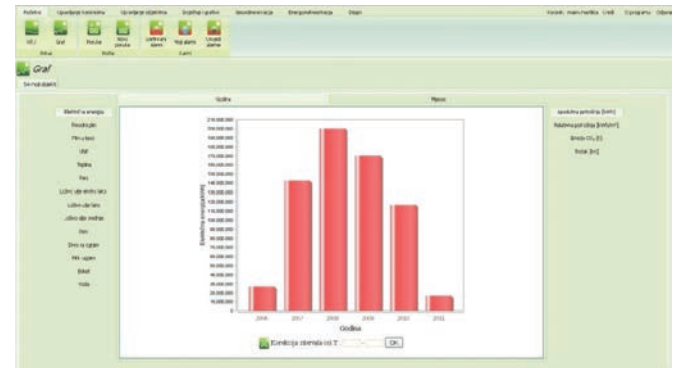


Figure 5.4. Administrative interface (home page)

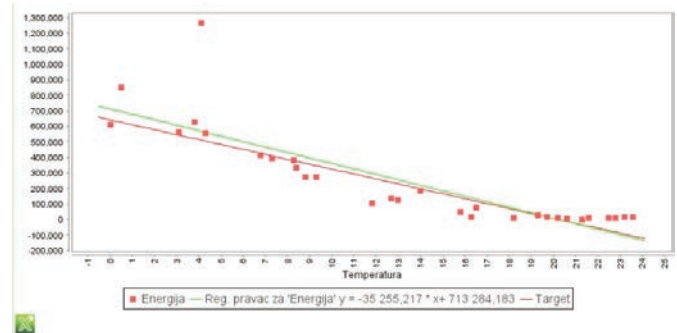


Figure 5.5. Setting targets (ET curve)



Figure 5.2. Data entry

EMIS greatly simplifies the process of sustainable energy management in public buildings because it allows easy access to data on consumption and energy costs, an easy graphical and tabular display, export of data and the results of the analysis, and easy preparation of data required to create local plans for improving energy efficiency and related reports. Using EMIS provides a transparent view and control on energy consumption with energy-related costs in all public sector buildings.

5.3. SMART METERING

Smart metering is a system which automatically tracks energy and water consumption in a facility. Smart metering consists of measuring and IT equipment which enables automatic and remote connection with information system for energy management.

It makes tracking energy consumption more comfortable and more precise. Also, smart metering allows remote tracking and analysis of energy consumption. It is best used in combination with display panels placed in halls or waiting rooms, which shows energy consumption in real time to the end users. These displays can also display various educational materials about energy efficiency, which is a good way to maximize the smart metering system.

Because of the quality and frequent (hourly) update of energy consumption to end users, conservative assumption is that with smart metering system energy managers can achieve savings from 5% to 10%. With that conservative assumption, simple payback time for smart metering system is usually less than three years. However there are examples of accomplished savings where payback period was less than 6 months.

Smart metering system is suitable for larger facilities or complexes with large energy consumption, due to its relative high cost for installation and equipment, and is economically feasible to install in buildings with energy and water costs higher than 40,000 EUR/year. It is also important to emphasize that smart metering system can be used to identify critical failures of water pipes, which can lead to huge financial savings.

Smart metering system can be upgraded from passive tracking into active energy management tool for achieving significant savings of 10%.

Croatian example:

In 2011, a smart metering system was installed in the Lepoglava penitentiary, Croatia. The Lepoglava penitentiary is a protected cultural heritage building which means that, due to its historic significance, the number of possible interventions is limited. Still, the smart metering system proved to be non-intrusive but very efficient in establishing sustainable energy management. Upon installation, the system identified a huge water leakage – around 90,000 EUR/year. The cost of the leakage repair was 7,500 EUR. Therefore the smart metering system already saved around 8 times more than it cost in less than a year from being put in production.

5.3.1. Display Panel

Information about energy consumption tracked with a smart metering system can be shown on a display panel. The display panel enables end users to see energy consumption in real time as well as information about daily, weekly, monthly or annual energy consumption, annual CO₂ emissions and annual energy costs.

Apart from the real time data, the display panel can show practical advice on energy savings which employees can utilize at home or at workplace. Positioning of the panel on a location with high visibility raises awareness about energy consumption in offices and emphasises the importance of energy efficiency and energy management.

With the aim to collect data about hourly and daily energy and water consumption in order to be able to analyze and monitor energy performance of buildings, the implementation of smart metering system of energy and water consumption was implemented within the HIO Program. There are 140 facilities covered by this smart metering system at 20 locations throughout the Republic of Croatia, with the annual expenditure on energy and water in the range of 8.13 million EUR. Expected annual savings on the basis of the establishment of remote reading of energy consumption are estimated at 10% of the total annual consumption, or 808.220 EUR per year. In the first months of system operation it was observed extreme water consumption in complex of buildings (including some protected buildings). It is expected that after water pipes repairmen financial saving will be 90.000 EUR per year while payback time of this investment will be less than four months. (49)



Figure 5.6. EE display panel

5.4. ENERGY AUDIT AND ENERGY CERTIFICATION

Energy audit is a good way to identify and analyse potential energy inefficiency in a particular building. It is also non-intrusive and does not compromise historic value of the facility. In addition to monitoring energy consumption, energy audits and energy certifications are fundamental in any sustainable energy management process. Heritage buildings can particularly benefit from a good quality energy audit as it can identify potential improvements in energy systems which do not compromise historic values of the facility. Since heritage buildings are usually exempted from energy efficiency laws, energy audits are rarely conducted in heritage buildings, but in Croatia they are mandatory.

Energy certification shows an overall state of a building's energy systems as well as specific annual consumption of energy. This is a good indicator which can be used for comparison of energy performance to buildings of similar type. Cultural heritage buildings are excluded from EPBD directive and are not forced to issue energy certificates, however energy audits and energy certificates can provide an important step towards implementation of energy efficiency measures. (50)



Figure 5.7. Example of energy certificate for non-residential buildings, Croatia

Example:

The Palace of Justice in Pula, Croatia, is a heritage building built in the second half of the 19th century. It is used as a court house with the total floor area of about 4,300 m² and has 1,250 users a day (250 employees). An energy audit revealed that certain cost-effective measures can be implemented without compromising the building's

heritage value. Reconstruction of the system was proposed on the building's attic which now uses electric radiator heating system and is separated from the central heating system of the building. This reconstruction will not achieve energy savings, but it will achieve financial savings which are significant and have a simple payback time of 7.5 years. Installation of thermostatic valves on radiators, with approximated savings of 10% on fuel oil used for heating will achieve payback in less than 2 years. Water saving measures are also cost-effective with a payback time of 1.3 years.

Table 5.1. EE measures in Palace of Justice in Pula, Croatia

Measure	Capital investment [EUR]	Savings [EUR/a]	Simple payback time [years]
Reconstruction of heating system	7,027	932.43	7.5
Installation of thermostatic valves	3,210	1,840.41	1.74
Installation of water saving equipment	648	501.35	1.3



Figure 5.8. Palace of Justice in Pula, Croatia

This example, as many others presented in this publication, shows how energy audits can identify critical points in energy management of a building otherwise exempt from the energy efficiency law in Croatia. Energy audits proved to be very useful when dealing with heritage buildings because those buildings are rarely included in reconstruction and energy management improvement.

. Financing

6. FINANCING

Financing energy efficiency measures in heritage buildings may not seem sensible and cost-effective at first glance. Energy efficiency measures are usually not a priority during maintenance of cultural heritage buildings. Any reconstruction in these types of buildings requires special attention, which results in higher costs. This chapter gives an overview of financial models for implementing energy efficiency measures in heritage buildings that have already been applied in various countries, and which were also presented at the conference.

Financial models in cultural heritage buildings vary considerably among countries depending on the purpose for which they are required: museums, offices, and even residential sectors. Adequate usage of heritage buildings can secure sustainable financial means for preservation and maintenance of the property.

Financing of heritage buildings is always established by a national legislative framework since the vast majority of heritage property is financed from the national state budgets. Consequently, it is of great importance that national legislation and various strategies for sustainable development of cultural heritage incorporate provisions that define energy management and energy efficiency as a crucial aspect of renovating and reconstructing cultural heritage.

In addition to financing from the state budget, funds can also be obtained through direct financing from commercial entities that have an economic interest in energy efficient heritage buildings. Funding energy efficiency measures in heritage buildings through commercial activities is a viable option whenever possible.

In addition, projects that tackle preservation and protection of heritage buildings at a national or international level often have a budget for concrete measures in respect to energy efficiency. Even if projects do not have a financial contribution for concrete measures in cultural heritage, such as EU funded research projects, they are nevertheless very important for developing capacity, exchanging know-how and promoting examples of best practice.

It is also important to mention that adequate utilization of heritage buildings is often the key for the sustainable preservation of thereof.

6.1. MONUMENT ANNUITY

The Croatian Law on the Protection and Preservation of Cultural Property is the basic regulatory law that identifies the types of cultural property as well as the protection of

thereof, and it also establishes the financing of cultural property protection and preservation. (51)

The funds necessary for cultural property preservation in Croatia can be drawn from the following:

- Monument annuity
- The state budget
- The county budget, or the City of Zagreb (as a separate entity)
- The city or municipality budget
- Donations, deeds, concession allowances, and trust funds
- Other sources which are viable according to rules and regulations

Monument annuity is one of the most important methods for providing the necessary funds in Croatia. Monument annuity represents an economic form of collecting assets for the usage of a monument and its monument properties. As such, it represents the following:

- Equivalent for direct and/or indirect monument consumption
- A regulator of monument usage
- A factor that stimulates the owner to manage the monument by keeping in mind its preservation

Monument annuity is payment for using a monument as a fixed resource, and its collection prevents the free-of-charge use of the monument in the economic process. Monument annuities are paid by legal or physical persons, including all those who pay income or corporate income taxes, and by those who are involved in economic activities in immovable cultural property or in the area of cultural and historic areas.

As a rule, the annuity collected from direct usage of the monument is quite clear and evident as it is collected during direct contact of the consumer with the monument either in the form of a ticket purchase in order to see the monument or as a component of services or products available when sightseeing. On the other hand, indirect collection of monument annuity is often disguised in the market price for various products or services. In this case, in order to establish the amount collected, both an analysis of the price structure as well as an analysis of the connection of the specific service or product to the protected built heritage must take place.

In order to assess the benefits to individuals from monument consumption, economists have developed methodologies that determine the economic value of the monument, and

then evaluate the effects of the preservation policy which is applied and implemented.

The minimum level of monument consumption, therefore, implies the existence of a minimum level of preservation and consumption, including the development of necessary facilities for the provision of appropriate services.

The consumption of the monument, both direct and indirect, potentially generates benefits to the consumer. These benefits can be defined as the value of its use for the consumer and as an authentic (implicit) value manifested through the existence of the monument, which in the future could result in the possibility of consumption by every individual in society.

The very existence of an economic value of a monument should theoretically motivate the owner to invest in the preservation of the monument. The economic assessment of a monument can be carried out by applying appropriate methods in order to find the difference between the overall incomes generated or potentially generated by the monument in a given period, and the overall costs of managing and maintaining the monument during the same period.

Monument annuity is, therefore, an important component of the overall income generated by the monument since it represents the value of the direct and indirect consumption of the monument. (52)

The Croatian experience with monument annuity

The potential for the application of monument annuity in Croatia is evident from previous monument preservation projects that have been transformed into business projects whose revenues exceeded the total amount invested in the preservation of the monument.

Thus, monument annuity should motivate the owner to preserve the monument either for its own purpose or for others to use it. In other words, while pursuing his or her own interests, the owner contributes to the preservation of the monument which is a socially valuable object.

The Law on the Protection and Preservation of Cultural Goods has a special section that explains collecting budget income on the basis of usage of the cultural good. These provisions regulate monument annuity collection from indirect consumption of a monument in two ways: in cases when the monument or a recognizable portion of thereof, is used for commercial purposes in photographs, badges, stickers and souvenirs; and in cases when the monument or a portion of thereof is used for promotional activities.

All economic subjects that take part in one of the aforementioned activities are legally bound to deposit

0,05% of their realized annual income from the previous year for monument annuities into the National Budget. Most of the activities which fall under this category are related to the following sectors: tourism, banking, telecommunication and passenger transportation.

The connection between tourism and heritage is quite evident, as are the reasons for making monument annuities for the indirect consumption of a monument obligatory (2).

Although monument annuity's main purpose is the preservation of cultural heritage buildings and the improvement in the level of comfort of thereof, this source of financing should also incorporate energy efficiency measures. The authorities that approve the use of these funds should incorporate energy efficiency requirements in the criteria for receiving the funds in question.

It is important to stress the necessity for establishing national guidelines for energy restoration of heritage buildings. These buildings are jeopardized by inappropriate construction interventions that fail to respect conservation requirements and are often implemented without professionally verified conservation and technical documentation. At the same time, residents and users of such buildings, particularly residential ones, have exceptionally large energy costs which is why improving energy efficiency while meeting conservation requirements is necessary for those buildings. For this same reason, clear guidelines on energy efficiency improvements in restoration of heritage buildings is essential.

Given that in the next 20 years energy restoration of buildings will comprise the majority of construction activities in the Republic of Croatia, it is necessary to develop guidelines for restoration of heritage buildings for the purposes of increasing energy efficiency and essential modernization. Apart from energy efficiency improvement, a method of restoration must integrate natural potentials, innovative principles and contemporary energy concepts. (52)

6.2. EU FUNDING

Despite the fact that energy efficiency and the use of renewable energy sources are top themes discussed in the EU, there are no specific EU funding schemes aimed strictly at improving energy efficiency in cultural heritage buildings. There are, however, a number of general funding schemes whose main goal is building renovation. Here are also a number of EU funding schemes whose aim is to improve energy efficiency and reduce CO₂ emissions by raising awareness among different target groups, promoting various activities involving energy efficiency measures and energy management, such as developing the methodology for energy audits, detailed energy investment studies, project design, activities aimed at educating various target groups, as well as preparing different publications

and educational materials. The funds can also be used to establish guidelines on how to use renewable energy sources. Most of these activities can be applied to different specific groups of buildings, one of them being cultural heritage buildings. The funds can also be used for research and the application of new materials and technologies for reconstructing and improving energy performance within old buildings. Research and analysis in cultural heritage can lead to better understanding of the energy performance of a building, as well as contribute to reaching more practical and useful legislation in this area.

6.3. PROJECT 3ENCULT

3ENCULT, one of the projects presented at the conference, is a FP7 funded project. The project was launched in 2010 and will last for 42 months.

3ENCULT bridges the gap between requirements for conservation and climate protection. These two requirements are not contradictory: historic buildings will endure only if maintained as living spaces. The project will demonstrate that reducing energy demand from Factor 4 to Factor 10 is feasible if a multidisciplinary approach that guarantees high-quality energy efficiency solutions is applied and adapted to a specific case.

The research activities are accompanied and supported by different case studies. The latter will help with assessing the developed solutions. From there on, an analysis will be conducted to generalize the proposed solutions, to identify the replicable factors and the context in which replication is plausible.

3ENCULT could contribute to the diagnosis, support the design and the planning phase, and produce feedback derived from monitoring. The project could not, however, contribute financially to the intervention itself. It was, therefore, important to select various case studies whose authors were committed to implementing creative solutions, and whose planned intervention time schedule matches the project's time schedule.

The work packages that were developed aimed to identify EE measures on real buildings, and ensure replicability and knowledge transfer guidelines.

Case studies reflect typical uses in urban areas, which are applied anywhere from residential, commercial, office and educational sector in schools and universities. In addition, so as to cover the special case of preservation of cultural heritage collections in historic buildings, museums are also included. (53)

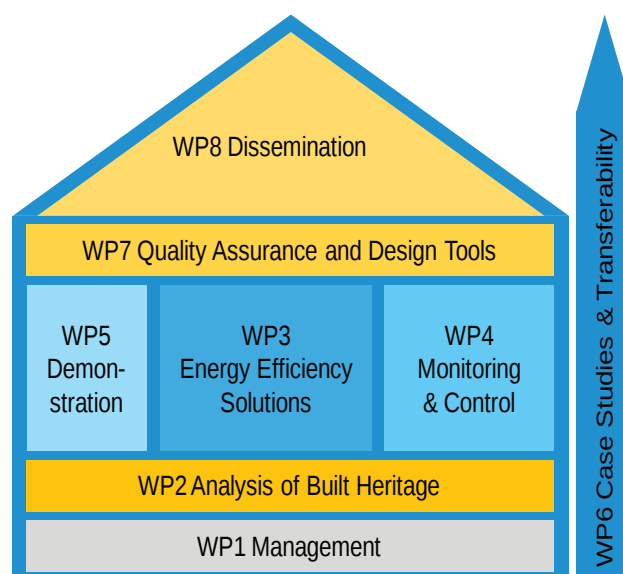


Figure 6.1. 3Encult project structure

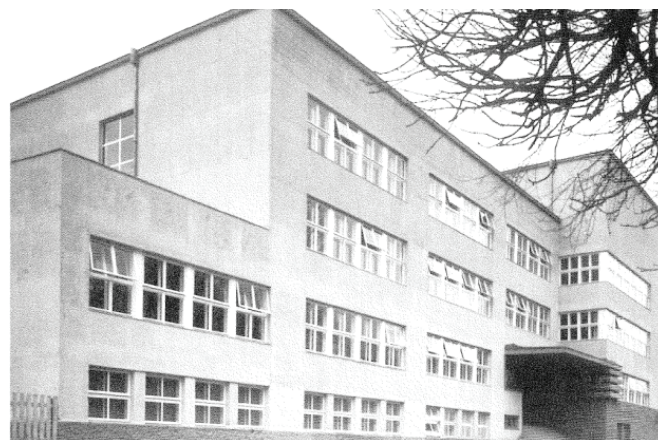


Figure 6.2. Case studies from the 3ENCULT project



Figure 6.2. Case studies from the 3ENCULT project

6.4. PROJECT E2CH

Another EU project presented at the conference is the E2CH project, which intended to define criteria, methodological approach and tools necessary to perform energy rehabilitation within historic cities. The project aimed to develop a framework for a “second generation” rehabilitation of the historic urban context, which links improvements in energy performance with preservation of authenticity.

The following were the project’s main goals:

- To attain greater knowledge on energy performance in a historical center by viewing it as an “environmental system”, by analyzing the efficiency and adaptability of traditional buildings to the environment.
- To develop coherent and technologically compatible solutions for built heritage, and pre-industrial building techniques by viewing historic buildings in terms of not only their special cultural value but also by taking into account the technical and constructional systems of the building.

- To preserve and reuse unique bioclimatic solutions characteristic to built heritage within historic centers.
- To define the criteria, the methodological approach and the tools necessary to tackle energy rehabilitation in historic cities by taking an integrated approach when evaluating, decision-making and managing energy at the urban level.
- To improve the users’ energy saving habits by actively involving them, and by learning from historical energy management strategies.
- To provide stakeholders with the management tools necessary to establish an action program in order to improve quality of life as well as energy efficiency. (45)

Although communities, municipalities and regions are, according to EU directives, required to apply renewable energy resources and energy efficiency measures more broadly, this is not always an easy task to accomplish, especially in the case of historical cities.

A renewable energy investment (REI) should keep in mind the historic environment in its entirety. A historic environment, as a combination of both culture and nature, can be seen in terms of: a) the specific monument/site; b) the surrounding environment of the monument; and c) the broader landscape. Oftentimes, REIs are concerned with a specific monument rather than the surrounding environment, let alone the landscape, as shown in the case of the Hosios Meletios Monastery and the Gyaros Island in Greece.

A REI should consider and treat a historic environment as inextricably linked to its local community, which means that every heritage environment is unique and should be treated differently. The local community should take this into account from the onset of the planning process.

In order to understand a historic environment, and to approach and engage the local community, a series of practical steps should be taken in case of a REI. First, during a REI mapping of the historic environment in question should be conducted, and its impact on the local community over time and presently should be established. Second, a REI should take into account the local community’s needs, including those concerning life in general (exp. unemployment, human conflict) and those concerning specifically the historic environment, and then examine all the ways in which the investment could serve those needs. It is important that the local community understand the benefits of the investment, while and at the same time discussing with the local community possible concerns regarding the investment. Third, the key figures, leaders,

(legal) representatives and the decision-making process of the local community should all be taken into account. It is important to make the cooperation with the local community legally binding. Fourth, the resources of the local community (exp. human and material resources) should be mobilized and utilized. This could help in creating a stronger link between the local community and the investment – it could create a sense of ‘belonging’.

In order to better understand a historic environment, a REI should engage a heritage consultant. The heritage consultant should serve as a member of the investment planning and implementing committee. The local community may be approached and motivated by a third person that is not necessarily a member of the local community – but is aware of the context and the concerns of the local community, and is respected and approved by the community. This person would act as a ‘mediator’ between the REI committee, and specifically between the heritage consultant and the local community. (2)

UN organizations funding

At the conference specific financial models for financing projects for cultural heritage buildings energy efficiency renovation were not presented. However, some of the known energy efficiency funds, financial models such as ESCO models or funds for implementation of energy efficiency measures in buildings or building renovation are suitable for financing these projects.

For example as presented at the conference, UNESCO as an agency that primarily deals with cultural heritage buildings and their preservation, has included energy efficiency criteria for cultural heritage buildings renovation and adaptation.

UNDP Croatia through its Energy Efficiency Project has assisted in promotion and development of pipelines of energy efficiency projects financing energy studies, introducing smart metering and implementing low cost energy efficiency measures in some Croatian cultural heritage state owned buildings. These activities may lead to implementation of building renovation projects financing by owners or by some specific Funds.

Croatian Environmental protection and Energy Efficiency Fund

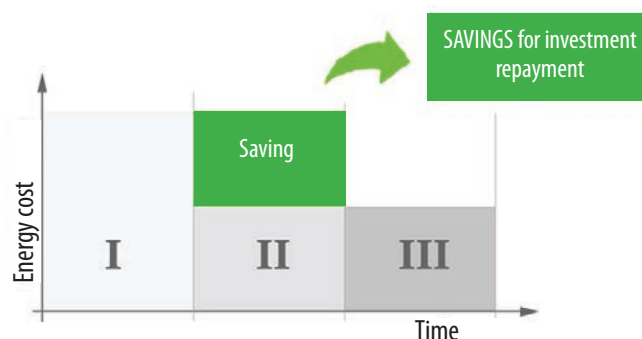
The Croatian Environmental Protection and Energy Efficiency Fund (CEPEEF) is founded in order to secure additional funding for development of environmental protection, sustainable development and energy efficiency projects. CEPEEF operates as extra budgetary fund and is regulated by law. CEPEEF does not have a specific funding

scheme for cultural heritage buildings, however all public buildings are eligible to apply for a financial grant for co-financing energy efficiency measures (40% co-financing). Various grants are available for different measures, such as heating system, lighting, cooling and ventilation etc.

ESCO model

According to the Energy efficiency Directive (2012/27/EU), amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, Energy Services is defined as: the physical benefit, utility or good derived from a combination of energy with energy-efficient technology or with action, which may include the operations, maintenance and control necessary to deliver the service, which is delivered on the basis of a contract and in normal circumstances has proven to result in verifiable and measurable or estimable energy efficiency improvement or primary energy savings. An ESCO company provides energy services and thus develops, executes and finances energy efficiency projects on a commercial basis. It provides a broad range of comprehensive energy solutions including designs and implementation of energy savings projects, retrofitting, energy conservation, energy infrastructure outsourcing, power generation and energy supply, and risk management.

ESCO financing model could be suitable for any type of building including cultural heritage buildings in which ESCO companies provide energy services including development, execution and financing energy efficiency projects on a commercial basis. The aim of the ESCO project is to reduce energy and maintenance cost by installing energy efficient equipment and optimizing energy systems, which ensures investment repayment through savings in the preferable period of 5 or 8 years (up to 14 years), depending on client and energy efficient measures to be implemented. The risk of savings being achieved can be assumed by an ESCO though giving guarantees to the client in accordance with the International Protocol for Verification and Measurement (IPMVP). After the investment is repaid, the ESCO withdraws from the project and passes all achieved benefits to the client. All projects are tailored specifically to each client so that it is possible to extend the project to include reconstruction, additions, more comfort and the like by splitting the investment. Accordingly, the client is able to modernize equipment without an investment risk because the risk of savings being achieved can be assumed by an ESCO company. Thus, a positive cash flow is achieved over the period of repayment and long-term savings. There is a possibility to share savings within client and ESCO company.



- Legend:
- phase I – before ESCO project execution
- phase II – during investment payback
- SAVINGS for investment repayment
- phase III – after investment payback

Figure 6.3. Esco model timeline

During the repayment for the investment in energy efficiency, the client pays an even amount which is divided into energy cost and investment repayment cost.

The client or end user of ESCO services is the direct beneficiary of all benefits deriving from the execution of an ESCO project. The benefits of a ESCO project are:

- Best practice in energy efficiency and energy management measures
- New equipment and systems installation
- Investment repayment from savings
- Technical and financial risks in all phases are assumed by ESCO company
- Client has an extensive insight into the project
- Client contributes to pollution reduction
- ESCO's fast withdrawal from the project

**. Conclusions of the
Conference Energy Management in
Cultural Heritage
Dubrovnik, Croatia, April 2011**

CULTURAL HERITAGE

Architectural cultural heritage is an important segment of the overall cultural fund, and its cultural and historical importance makes it an integral part of the environment. The protection and preservation of architectural heritage is a commitment based on legislature, as well as on a communal sense of responsibility to cherish and preserve our cultural goods.

Architectural heritage with determined/designated cultural goods consists of individual buildings, various architectural compounds, as well as cultural and historical entities. The latter can be fully or partially preserved.

Architectural cultural heritage is permanently exposed to various outside pressures to modernize, and because of its material structure it is particularly sensitive and prone to decay. Architectural heritage is also threatened by some inadequate construction practices that do not honor all of the conservation requirements, and which are often performed without first consulting a verified conservation professional and the pertinent technical documentation.

ENERGY MANAGEMENT

Currently, the government of the Republic of Croatia is implementing the program Bringing your own House in Order (HiO) whose aim is to improve energy efficiency and energy management in government-owned facilities, whose many buildings are considered to be cultural heritage. More than 15% are considered to be protected cultural goods, and an additional 23% are located within protected cores. Therefore, it can be concluded that 38% of buildings are in one form or another protected by conservators. Although the concepts of “energy management” and “cultural heritage” are rarely linked together, energy management in such objects is possible and necessary by carefully applying the principles of cultural heritage protection.

CONFERENCE „ENERGY MANAGEMENT IN CULTURAL HERITAGE“

The aforementioned issues were the main reason for organizing the international conference “Energy management in Cultural Heritage”, which took place in Dubrovnik, Croatia, from 6th to 8th April 2011. The importance and relevance of this topic in regards to implementing EE in the building sector, was recognized by a number of international and Croatian partners, who helped organize the conference.

The conference was attended by 10 invited speakers, some 80 authors and lecturers with an overall number of over 280 participants from 22 countries worldwide. UNDP Croatia was the main organizer of the conference, while a number of well established international and Croatian partners, institutions and governments including UNESCO

Venice Office, UNDP Bosnia and Herzegovina, GIZ Open Regional Fund (ORF-E) with German Federal Ministry for Economic Cooperation and Development, ICE-Italian Trade Commission, the Ministry of Economic Development of the Republic of Italy, OICE- the Italian Association in the field of engineering, architectural and technical economic consulting, the City of Dubrovnik with the City of Dubrovnik Development Agency, the City of Venice, the Ministry of Economy, Labor and Entrepreneurship, the Environmental Protection, Ministry of Culture and Energy Efficiency Fund, various professional association such as the Croatian Architects' Association, the Croatian Chamber of Architects, the Zagreb Architects' Society, the German Croatian Chamber of Industry and Commerce, as well as companies that distribute energy efficient products and systems, were the official co-organizers and sponsors of the conference.

The working part of the conference consisted of 4 units that dealt with the following: energy efficiency in buildings, energy management in old city centres, legislature, guidelines to improving energy efficiency in protected buildings, and various financing models. During the conference, numerous examples of good practice showed improvements in energy efficiency while reconstructing and renovating buildings within protected city cores. Foreign cases showed how modern technologies and innovative solutions can achieve significant savings while fully preserving the buildings' cultural value.





EXAMPLE 1

Solar collectors that provide hot water for all the building tenants were installed in 49 residential buildings within the UNESCO-protected city of Edinburgh.

The collectors were placed between roofs shaped in the form of the letter “M” and as such were not visible from the road, thus satisfying the conservationists’ requirements. This solution deemed plausible to be replicated in Scotland and beyond.



EXAMPLE 2

In addition to examples and simulations carried out on actual buildings, the legislative framework and the various possibilities of financing similar projects were also tackled during the conference. Emphasis was placed on the 3ENCULT project, which began in October of 2010 in scope of the program FP7 that united 22 partners from Europe. The project entailed 9 examples of energy efficient buildings in cultural heritage as well as other activities that aim to adapt the legislative framework in order to improve energy management in cultural heritage. One example that stood out is the renovation of the Ansitz Kofler house into a low-energy home with an annual heat energy consumption of less than 30 kWh/m² (in comparison to the previously 450 kWh/m² spent before).



EXAMPLE 3

The project encompassing the renovation of the French Pavilion in Zagreb was also presented. The project was based on the principles of conservation of cultural heritage and energy efficiency, thus accomplishing a reduction in the annual energy use for heating by more than 320,000 kWh.



EXAMPLE 4

Besides examples of specific building renovations, various examples of significant energy savings in protected urban cores were also presented. After completing the reconstruction of public lighting in Dubrovnik, the city's annual costs for lighting will be reduced by more than 400,000 EUR.



CONCLUSIONS:

The politics of sustainability:

WE APPLAUDE the established dialogue during the conference between all the relevant stakeholders and professionals, such as conservers, architects, engineers in the building and energy sectors, investors and decision makers, legislators and all others involved in reconstruction and sustainable development of cultural heritage.

WE INVITE all relevant institutions to coordinate and implement all activities involving the national goal that aims to improve energy efficiency and reduce greenhouse gas emissions in protected buildings as well as old city centres.

WE INVITE conservers to recognize the importance and benefits of implementing energy efficient measures while renovating, reconstructing and managing cultural heritage buildings and old city centres and settlements.

WE INVITE energy experts and engineers to apply new technological solutions so as to incorporate the need for lowering energy consumption and the cost of using the building while also ensuring sustainability of cultural heritage.

Legislation and guidelines:

WE ADVISE that, following the fulfilment of the various commitments of the Kyoto protocol and our contribution to reduce greenhouse gas emissions, the adequate implementing regulations and the all so-far accumulated experiences and practices be incorporated into the law.

WE WELCOME the application of guidelines or standards that could help cities, counties, the state and other owners of buildings of cultural heritage, find applicable solutions in their own cultural heritage buildings and old city centres.

Technologies, solutions, education:

WE RECOMMEND conducting energy audits in protected buildings in order to identify the measures necessary to improve their energy efficiency, and in case that the buildings are exempted by the law, that they still get CERTIFIED.

WE RECOMMEND, in identifying the energy efficient measures necessary in cultural heritage, we take an interdisciplinary approach that would involve all relevant professions in order to reach a solution that would satisfy the principles of conservation and promote energy efficiency at the same time.

WE POINT to the need to apply advanced software solutions, which could contribute to a better analysis and to finding the best solutions and technologies for a specific building, while also taking into account the building's location and its climate conditions.

WE POINT to the need to apply energy efficient equipment, technologies and renewable energy sources whenever possible, all in accordance with the conservers' instructions.

WE POINT to the need to further research and apply new materials when reconstructing and isolating cultural heritage buildings.

WE POINT out that it is possible to reduce energy consumption without decreasing thermal comfort and indoor climate by amending the occupants' behavior, by improving the facilities and energy management, and by implementing systematic energy management and a continuous monitoring of energy consumption (i.e., smart metering), including the implementation of low cost or no cost energy efficiency measures.

WE POINT to the need to raise awareness and **educate** the buildings' occupants, owners, managers and experts in restoration, in order for all to contribute to reducing energy consumption and improving the sustainability of cultural heritage objects.

Financing:

WE HAVE ESTIMATED that the potential for energy efficiency and renewable energy projects is great, and in constant rise. However, not one of the involved institutions specializes in funds specifically allocated for energy efficiency in cultural heritage.

WE RECOMMEND to all financial institutions, banks, funds and others to work on developing specialized ways to finance energy efficiency projects in buildings considered cultural heritage.

WE RECOMMEND that all specialized funds allocated for the restoration of cultural heritage introduce, as one of the main criteria, the need to improve energy efficiency.

PROPOSED NEXT STEPS

The conference proceedings published during the conference will present a valuable source of case studies. The latter will be featured in the Guidebook for energy management in cultural heritage. Once published by the end of August, 2011, the guidebook will be distributed to all of the conference participants. It will also be available in electronic form on the official UNDP website.

UNDP Croatia will continue to work on energy audits and pilot projects that aim to improve energy efficiency in public buildings considered cultural heritage, while at the same time closely cooperating with conservers. In addition, UNDP Croatia is involved in developing a strategy for sustainable development of cultural heritage buildings that will include recommendations on energy efficiency and energy management.

FINAL WORD

Energy efficiency in the building sector has recently become a priority topic relating to the fulfilment of the EU 3x20% targets by 2020, due to the share of buildings in total energy consumption as well as the complexity of this matter. However, the fact that a number of buildings are protected by cultural heritage regulations presents an empirical obstacle for deep energy renovation of the building stock. Percentage of buildings listed as cultural heritage is significant, by some estimates as high as 25%. UNDP's research of the Croatian data has shown that the percentage of cultural heritage buildings in the public sector is in fact 38%. This has created an unnecessary gap between energy managers and conservers which, at first glance, may seem to present an insoluble problem. Still, although seemingly oppositional, bringing the disciplines of conservation and energy management together can result in creative and advanced technological solutions. This is demonstrated in a number of excellent cases that ensure sustainability of cultural heritage while contributing to sustainable use of resources.

The energy efficiency project, which UNDP implemented in Croatia for many years, placed its main focus on public buildings. Recognizing the significance of energy efficiency and energy management in cultural heritage buildings and protected city areas, UNDP Croatia researched and evaluated many related projects on both national and international level.

UNDP Croatia brought together a long list of relevant international partners, including the German Agency for International Cooperation (GIZ) / Open Regional Fund for Energy (ORF-E); the German Ministry of Economic Development and Cooperation; the Ministry of Economic Development of the Republic of Italy, the Italian Institute for Foreign Trade (ICE); the Italian Association of Engineering, Architectural and Technical-Economical Consulting Organizations (OICE); the German-Croatian Chamber of Industry and Commerce. In addition, the list of co-organizers also included the representatives of UN agencies – UNESCO Venice Office and UNDP Bosnia and Herzegovina. Domestic institutions and ministries have also provided their support – including the Ministry of Economy, Labour and Entrepreneurship; the Ministry of Culture; the Environmental Protection and Energy Efficiency Fund, joined by the local government of the cities of Split and Dubrovnik, the Dubrovnik Regional Agency, and the City of Venice, as well as professional associations: Croatian Chamber of Architects (HKA), Association of Croatian Architects (UHA), and Zagreb Croatian Architects' Society (DAZ). This comprehensive partnership resulted in organization of the International Conference on Energy Management in Cultural Heritage held in Dubrovnik in 2011. The event gathered more than

300 architects, civil, mechanical and electrical engineers, conservers and other professionals from 22 countries worldwide.

The interest shown by conservators and other professionals during and after the Conference was the inspiration behind publishing a special edition of conference proceedings combined with UNDP's research, findings and analysis in the form of this guidebook. The scarcity of material dealing with multiple subjects was another reason UNDP decided to make this publication user friendly and available to various experts in the future.

Although the number of collected papers prior to the Conference amounted to 80, this guidebook presents a compilation of best practice. It focuses on real case studies as well as calculated and demonstrated energy savings potentials through specific measures for energy efficiency, energy management and renewable energy sources. In addition to the chapters which deal with energy efficient construction, HVAC and lighting in buildings, there are specific chapters on energy management in protected city centres and public lighting as well as a presentation of utilization possibilities of renewable energy sources. There is another specific chapter dealing with no cost energy management measures easy to implement in any building. The guidebook also addresses topics of relevant legislation and financing that can either be the main drivers or obstacles for such demanding projects.

This guidebook contains excellent examples demonstrating that a multidisciplinary approach can result in inventive solutions which reconcile two important principles, that of preservation of man-made heritage and that of preservation of natural environment. The book is intended for professionals in the field of energy and engineering and conservators of cultural heritage as well as building owners both in private and public sectors. It is our hope that the readers will find ideas and inspiration for the projects they wish to implement in their buildings.

The publishing of this guidebook has been made possible by UNESCO and UNDP.

Finally, I would like to render special thanks to UNDP Croatia EE team who contributed to the success of the Conference in Dubrovnik, particularly to Vanja Hartman, Mislav Kirac and Iva Nekić who have given a huge contribution to this edition.

Vlasta Zanki, PhD

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