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D1.3 PRO-Heritage Best Practice Examples for Energy Efficient Historic Buildings

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Authors	Rory Cullen, EHT
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V	Date	Authors	Description
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1.0	2020-09-30	WP leader	Checked and released to the Coordinator for internal QA and subsequent submission to the EC.

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1. SUMMARY

This element of the PROtect Traditional Built Heritage Skills project sets out best practice energy efficiency approaches and documentation for historic buildings within the countries which form the PRO-Heritage project partner organisations - Austria, Portugal, Spain, the United Kingdom, and Slovakia.

All information provided is intended to relate to practical case studies for respective Craft trades. By showcasing the differences types of measures can make, the project is intended to influence wider Sector thinking and approaches through targeted and appropriate training for those who undertake the actual `improvements´.

It is worth noting that primary data relating to improvements in energy efficiency of traditional or historic buildings has proved extremely hard to find across Europe, with little 'hard' evidence behind thermal improvements, of any sort. The Welsh Government for example, where Cadw have jurisdiction for many public historic sites and publish research on many relevant heritage issues, purchased a typical 1850's stone timber cottage with its original windows that had hardly changed since its construction, and began investigating the differences that different thermal measures would cause, but this was never completed when funds ran out.

This is therefore an area which is currently very much in the research phase for Europe as a whole, with the sole exception in Scotland who are far more advanced in this field. Here Historic Environment Scotland, the public body responsible for maintaining many sites, setting policy/ legislation and publishing research, have undertaken a series of research case studies outlining the differences that potential energy saving measures have made to various types of traditionally constructed properties. These are all available in hard copy and on the Internet - with this extremely useful source of information to be used as part of the PRO-Heritage project, embedded within the training material being offered.

These case studies together with other potential sources of information which could be useful to the Practitioner are set out in the United Kingdom section below, whether in descriptive form or links. This format has been used as a template for the other partner organisations to set out the status of energy efficiency measures in relation to historic buildings in their respective countries, but as this does not seem to exist in most others they have also set out relevant Government policy, academic documentation and legislation.

This area is therefore very much work at an early stage, with potential examples even in progress during some of the site visits undertaken as part of the project. During the PRO-Heritage trip to the UK in January 2020 for example study visits were held at Warwick Bridge Mill, Hylton Castle and Belsay Hall, where thermal improvement works in progress were able to be seen. The intention is to monitor and publish the impact of the works over time - if the outcomes are available by the completion of the PRO-Heritage project, this document will be updated accordingly.

2. INTRODUCTION

2.1 Potential Project Impact

There is a common misperception within the Construction Sector that historic buildings not only perform poorly in terms of sustainability, but that few measures can be undertaken to improve their efficiency and these are prohibitively expensive. This stems from the training offered in Colleges which nearly always relates to new build, and thus historic buildings are being treated in wrong way.

This element of the project seeks to address this issue by highlighting examples of best practice across Europe, embedding such examples into the training material offered to Practitioners/Craftspeople in the various trades. This will give them a thorough knowledge of and understanding in how these buildings perform, and the difference that the various measures will make to their performance, so that they can be sure that they will be undertaking appropriate measures in the future.

2.1.1 Austria

About 327,000 buildings are erected before 1919, which means that traditional building technologies and approaches were used. This category of buildings represents 14.94% of the total number of buildings (2,191,280 buildings). The number of listed buildings, as provided by the Federal Office of Monument Protection, is much lower and contains also small monuments like field monuments and statues. In Austria, there are 38,519 listed monuments. This represents 1.76% of all buildings. Both figures are relatively low compared to other countries in Europe.

The structure of the cultural Heritage Sector in Austria is shaped by few large organisations, which own and manage the cultural heritage like Burghauptmannschaft Österreich, Bundesimmobiliengesellschaft, Österreichische Bundesforste, Esterhazy Stiftung, Salzburger Burgen und Schlösser. Others are owned by City Councils. Most of them just protect their buildings and monuments, but do not document publicly their work. Therefore, real energy data for historic buildings is rarely available. The available information is only a general one, based on single case studies.

For the Imperial Palace Vienna, the responsible owner Burghauptmannschaft Österreich implemented different measures to improve the energy efficiency and now have an energy consumption of approximately 80kW/h and m², which is now in energy Category C (in reference to the Energy Certificate in Austria, see following figure).

Figure 1: Energy Performance Category

HWB in kWh/($m^2 \cdot a$)	Kategorie	
≤ 10	A++	Passive house
≤ 15	A+	Low Energy House
≤ 25	A	
≤ 50	B	
≤ 100	C	Target value according to building regulations 2008
≤ 150	D	Old, not refurbished buildings
≤ 200	E	
≤ 250	F	
> 250	G	

In Austrian discussions about energy efficiency the main issue relates to measure consequences - which means that the main criteria to choose a measure is the potential harm it will cause to the structure. On that basis the Federal Office of Monument Protection published a guideline:

- The guideline is a guide for assessing those measures to be taken on a monument as part of the energetic renovation, to assess whether or not they are justifiable. It describes those ways that when weighing between the possibilities of an energetic Improvement on the one hand as well as preservation the substance, the traditional appearance and artistic effect of the monument on the other hand are to be treated.
- For some measures, the disadvantageous change of the monument would be so serious that after assessment the measure will be refused. However, the guideline is structured in such a way that numerous alternative measures for energetic renovation can be recognised.
- Only methods are shown where the structural changes will have a positive impact on the structure and appearance of a monument. In addition to these hard factors, criteria such as service life, location or ecology play an equally important role for the energy balance and sustainability of a building. These so-called "soft" and often difficult to measure variables are not included in this

context, but must not be overlooked when assessing whether energy-related renovation measures can be efficient and expedient.

- Finally, to a large extent the use and user-behaviour are responsible for the energy demand of a building. Currently, a large part of the energy savings due to a comprehensive energetic refurbishment of a building are equalised by the increase of user comfort (the ‘rebound’ effect). Personal behaviour can actually save energy in the fastest and cheapest way. In various competitions, it could be shown that consumption in public buildings could be reduced by between 10% and 40% within a very short time simply through conscious user-behaviour.

The last topic, personal behaviour was also the focus of the H2020 project “OrbEEt - ORganizational Behaviour improvement for Energy Efficient administrative public offices “, in which Burghauptmannschaft Österreich participated. As result, for the Imperial Palace Innsbruck (where measures were already implemented) a major reduction is still possible:

Table 1: Energy Savings by behaviour change/ Imperial Palace Innsbruck

Load Type	Energy Savings by behaviour change / Imperial Palace Innsbruck
Heating	21.44%
Lighting	17.41%
Other	7.12%
Total	**18.97%**

2.1.2 United Kingdom

There are many indicators which highlight the potential to have a positive influence on the Heritage Sector in relation to sustainability, a number of which were set out in the initial documentation for the PRO-Heritage project. For example, the Historic England database shows that there are currently just over 500,000 listed structures of all grades within the UK.

Most of these will retain windows, doors and other features which are significant but have the potential to be thermally upgraded by Craftspeople. A good example of this can be seen from Historic Scotland research (see link below), which demonstrates that a window in poor repair that will typically have a ‘u’ value of 3.5 can easily be thermally upgraded by over 50% to a figure of 1.7.

The UK has the largest percentage of traditional buildings (around 6 million or 24% - with this figure rising to 34% in Wales) in Europe - and again a significant amount of these will again have timber doors and windows which could be upgraded by Craftspeople with an understanding of the difference that this would make. Such measures could increase the energy performance of such buildings and make a significant contribution to a reduction in Carbon emissions. This is particularly important for rental market as recent legislation demands that residential dwellings now have to reach an EPC E level, and such simple repairs can easily make the difference to enable a building to be let.

The measures that different trades could undertake to assist with this issue, together with typical payback periods, will be covered in the training provided for this project, and will typically include:

- Draught proofing
- Insulation measures (all appropriate types)
- Carpentry repairs
- Secondary glazing
- Energy efficient technology (all appropriate types)
- Critical maintenance

Work undertaken by the National Trust on their residential let estate highlights the difference that this could make - prior to a project to upgrade their entire estate 50% of their properties (all of which are traditionally built) had an EPC rating below level E. Training was provided to in-house teams to understand the issues which subsequently had minimal works undertaken at little cost which raised the level to the requisite 'habitable' standard. It is estimated that this has resulted in an average energy saving of 20% for every property - when applied to the national picture the potential savings could be hugely significant over time.

2.1.3 Slovakia

The problem in integrating sustainability into the Historical Environment represents a set of complex issues also in Slovakia. The present values are greatly re-evaluated in the current global world. Ecological prosperity is being improved, there is effort to address global climate problems. Many countries aim to preserve stabilized archetypes in protected areas, this is why they try to lower often exaggerated requirements to increase monuments energy efficiency. Different countries approach the problem in different ways.

In 2017 in Slovakia there was a first national Conference on the topic. This Conference had the title "Applications of ecological principles in projecting renovation of monuments" and was organized within European Heritage Days by the Slovak Technical University, Faculty of Architecture, ICOMOS Slovakia and Trnava city. The main aim was to discuss the new challenges related to climate change and the quality of environment facing the monument preservation in our country. One of the main findings on which the participants agreed was that according the quality and quantity of the monument structures and the gas emissions it produces it is possible to choose the ecological interventions to the given structure.

Monument Board and Energy Efficiency

The specifics of ecological design in historically protected structures is the subject, which solutions are of great importance for the future of our cultural heritage. Even the historic buildings are not obliged to fulfil the requirements of EU Directive 2012; with the owners of historic buildings and structures interested in the possibilities of energy savings mainly owing to economic reasons.

Thus, one of the biggest challenges in the context of monument conservation and the new use of historic buildings is how to improve their energy efficiency. This is usually done by adding or replacing new materials and technologies.

Through its regional offices, the Monument Board issues decisions on the requirements of the owners for the insulation of national cultural monuments, as well as objects that are situated in protected areas.

Even decisions about the renovation of the monuments are taken on daily basis by the competent institutions and professionals working in the Monument Board in Slovakia and its regional offices with no guidelines or methodologies or training opportunities dealing with the basic principles of improving the energy efficiency of the building available.

There are still currently many listed buildings in poor condition. At present, 9,989 immovable national cultural monuments (15,168 buildings) are registered. Despite investment in recent years, their construction and technical condition is not improving in principle but is only kept at about the same level - with hundreds of them falling into disrepair, not being used, or not even maintained to a basic level.

Most of these have windows, doors and other features which are significant but have the potential to be thermally upgraded by Craftspeople. However, there are no officially certified and formal training opportunities in energy efficiency for these Craftspeople.

Requests for thermal insulation of buildings are usually rejected. The main reason is the fact that the solutions proposed by the owners represent in most cases only contact insulation with polystyrene from the exterior side. If more sophisticated solutions were applied (for example, thermal insulation from the interior with thin-walled insulation), they would mean an important compensation for monument owners, who bear most of the costs.

2.1.4 Portugal

There are currently 3,544,384 buildings in Portugal, with 206,343 built before 1919 in traditional construction systems (data: National Institute of Statistics, 2018). This list includes 4,107 listed assets, comprising 810 National Monuments, 2,701 listed as Public Interest and 569 listed as Regional Interest. Among National Monuments there are 17 World Heritage Sites listed by UNESCO.

Although building permits for new construction continued to be prevalent in 2016, representing 64.3% of total building permits, building pre-qualification works (alterations, enlargements and reconstructions) represented 27.6% of total permits in 2016 (28.4% in 2015), and 31,4% of all the concluded construction works. Works performed in existing buildings increased mostly in residential buildings (+ 17.0%, corresponding to EUR +151 million). Works performed in non-residential buildings decreased by 0.7% (corresponding to EUR -19 million). The highest decrease occurred in administrative buildings, financial institutions, post offices & similar services (-34.9%, corresponding to EUR -111 million), while the largest increase was in Industrial and warehouse buildings (+35.9 %, corresponding to EUR +112 million). These figures show the impact of rehabilitation of traditional buildings in the economy of the country, and give a perspective to the potential contribution these operations could have in the increase of energy efficiency and power consumption reduction, if appropriate models were followed and adequate solutions applied. The environmental impacts of this activity are recognized, but efforts to minimize them have not been successful so far.

In fact, the rehabilitation of traditional buildings built pre-1919 increased exponentially until 2019 in major cities, driven by tourism and a growing desire of heritage preservation. This focused upon modest urban construction - most of them with economic solutions, with low thermal performances, and therefore, with most potential of gaining higher improvements. These achievements however require knowledge and understanding in order to be effective and respectful to the historic fabric.

2.1.5 Spain

The large number of international initiatives that have the objective to improve the energy efficiency of historic buildings witness the importance of defining a common methodology towards innovative technological solutions and historical relevance. Most of the European-funded projects ended (or will be finalized) with the development of guidelines that help professionals in effective interventions and at the same time respectful of heritage.

At this moment there is a real problem affecting the European architectural and cultural heritage - the need to achieve a balance between the needs of reduction of energy consumption and CO2 emissions with the conservation and rehabilitation of cultural heritage. Traditional architecture was always undertaken as a direct response to needs and values of a time when energy was really expensive. Good practices should be promoted in the rehabilitation and conservation processes. These good practices should include the implementation of more sustainable improvement measures, but most of the procedures and resources currently used for energy consumption and uses of real estate are raised for contemporary building and new construction, so they are not valid for the historic environment. The energy efficiency of the buildings to be rehabilitated has to be improved.

In 2018, the European congress on energy rehabilitation of the Andalusian building heritage was held in Seville. This International Congress of Science and Technology for the Conservation of Cultural Heritage was developed in the context of the activity of the Technoheritage network. In this fourth edition, it also had the support of IAPH, (Andalusian Institute of Historical Heritage). This Congress was an international meeting for researchers and specialists in different areas who share an interest in the knowledge and preservation of Cultural Heritage, including sessions focused on architectural heritage and on digital strategies and tools for decision-making. This edition was organised in the framework of the Interreg European project Violet (preserVe tradItiOnal buiLdings through Energy reducTion). A number of good practices were presented, that showed new forms of interventions based on sustainability, energy efficiency and low carbon criteria.

In Spain, the number of professionals who are dedicating efforts to increase knowledge related to energy and historical building follows an upward progression from the creation of the Program for the Energy Rehabilitation of Existing Buildings (PAREER-GROW program) in 2013 and the approval of the Energy Efficiency National Action Plan 2017-2020, advancing in recent years in knowledge and solutions tailored to the specificities of protected buildings. Also, in this scope have to coexist new resources from the latest research with traditional formulas based on experience in real estate works: uniting both forms of knowledge are not easy and sometimes requires the presence of multidisciplinary teams to intervene correctly.

The Higher Technical School of Architecture of Barcelona with the help of the RecerCaixa 2011 call (a program promoted by La Caixa’s Social Project and the Catalan Association of Public Universities-ACUP) carried out a study of several catalogued buildings. The objective was to publish a guide of good practices for the restoration of buildings of the architectural heritage that also serves for the management and maintenance of the interventions that have been carried out.

In the Historic city of Santiago de Compostela in Galicia, an energy rehabilitation and maintenance project is being carried out. Energy efficiency is the key factor in determining the degree of habitability and sustainability of the Historic City. The objective of this proposal is to address the update energy of the Historic City through design of an Integral Energy Rehabilitation Program that articulates the generation of knowledge, the design of the tools of evaluation and intervention, and the performance management necessary for energy improvement.

The validation in the case of Santiago de Compostela has a clear vocation to generate exportable results that allow modelling intervention processes in other historical areas.

The city of Santiago de Compostela, Patrimony of the Humanity, is the best possible scenario for putting in place an Energy Rehabilitation Program, which will be a pioneer, due to all the previous work of urban renewal carried out during the last years.

The objectives of the project include:

- To promote the training of professionals and companies in the energy rehabilitation sector re-qualifying its human capital.
- To propose coherent solutions at the technological level and constructively compatible with the reality of the built heritage.

2.2 Training Issues

2.2.1 Austria

In Austria, all craftsperson will be trained for their profession in "Dual Education", which usually will be completed in the age of 15 to 18/19 years. "Dual Education" means that practice is thought at an apprentice's employer and - parallel - theory at a school providing vocational education. This kind of craftsperson's education is part of the regular Austrian education system and is one the reason for the low unemployment rate of young people in the age of 15 to 20 years in Austria.

However, there is no special education for craftsperson working for cultural heritage resp. historic buildings. Besides learning on the job, there are only courses available, which are organised by the Federal Office of Monument Protection - Information and Further Education Centre in the Charterhouse Mauerbach. The centre offering training courses to specialise craftsperson in historic buildings. In addition, as a follow up to the Erasmus+ project MODI-FY, led by Burghauptmannschaft Österreich, there are certified training offers for Maintenance Managers of Heritage Assets. These courses are organised in cooperation by Burghauptmannschaft Österreich and the Federal Office for Monument Protection since 2017. The core content of these courses is focussed on the requirements of Maintenance Managers, but are also helpful for Craftspeople.

2.2.2 United Kingdom

There are currently no recognised practical heritage training qualifications for Craftspeople within England, yet an estimated 50% of maintenance work is related to traditional (pre-1919 construction). This is despite the fact that this situation has been recognised for several years, with research documentation covering the whole of the UK available and updated since 2011. At present only Scotland has addressed this dire situation, with accredited courses now available in various trades, but only since December 2019.

If the training of Craftspeople within the Heritage Sector is very poor, then the provision of recognised courses for energy efficiency for Practitioners is practically non-existent - yet Craftspeople are in a potential position of great influence with regard to sustainability. It is worth noting here that the only officially recognised Level 3 qualification award is a three-day course (equating to 21 hours) entitled Energy Efficient Measures for Older and Traditional Buildings, which is accredited by the Scottish Qualification Authority (SQA). Details of this course can be found from https://www.sqa.org.uk/sqa/84013.html.

Although the actual provision of training is poor, there is however a significant amount of first-class practice documentation available within the UK, and in particular from Scotland. The PRO-Heritage project seeks to address this training issue by utilising links to relevant information available across Europe and incorporating relevant documentation and case studies into any training material provided and delivered.

This will be referenced and used as key tools for the training of Craftspeople to ensure they will have the requisite understanding of the issues and their approach to their respective type of work that they will be undertaking.

2.2.3 Slovakia

At present there are no training possibilities for people interested in energy efficiency of historic buildings.

Compared to other European countries Slovakia has a low proportion of historic buildings built before 1945, and so their contribution to climate change and gas emissions is perceived to be quite low. According Energy Efficiency Directive from 2012 these buildings do not need to fulfil the requirements of this Directive; thus, it seems that it is not necessary to apply energy interventions to historic structures!

In contrast to other countries there is also the problem that of renovation of cultural identity - retaining cultural continuity and authentic state of original structure. With the given requirement the need of permanent maintenance and knowledge about the traditional procedures in the area of monument maintenance is very important; in this context the following project is both important and interesting project for Slovakia.

Pro Monumenta - Prevention by Maintenance

Pro Monumenta is a new project of the Monuments Board of the Slovak Republic. The realization of the idea of preventive maintenance itself seems to be the most important benefit for ecology and effectiveness (compared with complex renovations of neglected buildings or complexes). This model has been used to a relatively large extent in the Netherlands since 1973 and to a lesser extent in some other countries.

Continuous use of buildings helps the environment because most of the originally built building material remains in buildings without the need to replace them. The second ecological aspect of the “Pro Monumenta” project is an effort to rehabilitate traditional building technologies and improvement of the interior micro-climate. Most historic buildings have technical problems with humidity. Solving these problems is often costly and requires specialists. In the framework of diagnostic reports and consultation the project offers advice on less demanding methods, whose gradual application greatly improves the condition of the masonry in combination with the correct ventilation mode and tempering also improves the conditions to healthy living conditions.

In the “Pro Monumenta” project, inspectors try to promote original technologies in the sense of repairs of historical constructions, by following the identical building method they used to be built. This is, for example the use of lime mortars, traditional carpentry, clay plasters and so on. An example of this may be the rehabilitation of wood coatings with natural linseed oil. This oil is an example of organic harmless application with sustainability features (restoration of paint only with clean oil without the need for additional colour pigments).

Another significant topic is the synergism of the buildings with the surrounding environment, drains, surface water, traditional ditches, a proper relation with surrounding greenery and the correct construction details with the terrain. The environmentally friendly processes are not just experimentally verified, but the project also has its scientific dimension in connection with other European academic and scientific centres, thanks to which there is a lot of exchange of experts and information.

The first years of the project implementation (the project has started in 2014) brought many field findings, statistical data, broad experience with working with the owners, application of information technologies and creation of a network of cooperating experts from Slovakia and other countries - but unfortunately primary research data from the project is not available.

2.2.4 Portugal

The world’s first known secular Protection Law for Heritage was written in Portugal in 20th August 1721 (Jokilehto, 1986) by request of King John V. This defined that no piece of art could be destroyed or sold for outside the country without the King’s permission. This was followed by the first republican protection laws in 1911, the Heritage Protection Basic Law in 1932. The current legislation dates from 1970 and was ratified in 1985.

All of these laws were and are however merely well-intentioned, offering little in the way of ‘formal’ consequences; in reality heritage preservation/ conservation is taught in higher education contexts only, and therefore those Craftspeople responsible for undertaking the work largely do so with no understanding of the potential consequences of the inappropriate materials they use or their approach.

Today there are several higher educations in Conservation in different forms: Graduate Diplomas in Art and Heritage Sciences, in Conservation and Restoration and in Art, Conservation and Restoration in Lisbon and Oporto Universities. There are also Polytechnic Graduate Diplomas in Conservation and Restoration in Oporto and Tomar P1olytechnic Institutes, Higher Education Diplomas and Master diplomas in Cultural Heritage and Archaeology, in Contemporary Art production, Conservation and Restoration, in Heritage Studies in the Algarve, Lisbon and Oporto Universities.

At middle education level there are professional courses for Conservation and Restoration Assistant or courses for Heritage Recovery Technician in Tomar and Sintra professional schools. The former are traditional academic profiles, focused in theory, ethics and technics or conservation practice, and do not cover energy efficiency.

More recently, since 2015 in an attempt to address this issue new initiatives deliver Post Graduate education in Energy Rehabilitation and Buildings Conservation in Madeira University and Polytechnic of Guarda. The National Energy Agency also started a program of vocational training courses on Adaptive Reuse and Energy Efficiency - but unlike the first group, these courses focus clearly on energy efficiency issues and have very superficial approach to heritage conservation.

In conclusion, energy efficiency is the missing element of a holistic perspective for heritage conservation. Professional and vocational training for craftspeople - the people who will be doing the works on site - is unfortunately non-existent in Portugal.

2.2.5 Spain

In Spain there are good training programs at different levels, to preserve and restore Cultural Heritage, for example: Diplomas of Higher Conservation Schools Restoration of Cultural Property. Bachelor of Fine Arts with a specialty in conservation-restoration of cultural property. Bachelor of Fine Arts with curriculum itinerary in conservation-restoration of cultural property. Higher Degree in conservation-restoration of cultural property, taught at the Higher Schools of Conservation Restoration of Cultural Property. University degree in Conservation Restoration of Cultural Property. There is a great complexity of the map of official degrees in conservation-restoration but almost none of them adequately addresses the issue of energy efficiency.

The only master that addresses this issue is the master's degree in Sustainable Intervention in the Built Environment aims to produce graduates with advanced conceptual and technological knowledge of the urban environment to improve sustainability and manage projects involving intervention in the fields of architecture, building construction, urban design and infrastructure.

3. PRO-HERITAGE BEST PRACTICE REPORT EXAMPLES FOR ENERGY EFFICIENT HISTORIC BUILDINGS

3.1 Examples from Austria

3.1.1 Legal Situation in Austria

Monument protection law[1] is organised on a federal level, which means the competence is delegated to one office of the federal administration. Other legal areas are organised differently, like construction law, where the legislation competence is on regional level (regional government) and the operational competence is on municipality level. Therefore, there are nine different regional building regulations, which led to situations like the regulations for stairs in Upper Austria is different from those in Tyrol and the escape route regulations as well.

For monument protection, there are also different regional building regulations - for example, in Vorarlberg and Carinthia, in contrast to the other federal states, a decision from the Federal Monuments Office must be enclosed with the application for a building permit, which reduces the risk of conservation problems in the course of the refurbishment or conversion.

Also the OIB guidelines, which are intended as an instrument for harmonisation, turned out to be problematic in practice from the point of view of those affected due to different regulations in the counties and the strong focus on the state of the art. "Due to the different legal situations, there is always legal uncertainty as to whether one is subject to the state of the art or the regulations at the time of construction of the building."

Other quotes from the mentioned report:

- “The energy certificate is a wrong approach to monuments. Only 1.7 % of the building stock in Austria is under monument protection, of which only 0.8 percent is heated."
- “There is only one standardized calculation range for the energy certificate for old buildings; this is a comparative value. In Great Britain, heat management is calculated more precisely using complicated algorithms. But that could be made easier by developing calculation models for historical buildings that come closer to reality."

[1] Based on the report from Kovar & Partners „Better Legal Framework for Architectural Monuments”

3.1.2 Bundesdenkmalamt (BDA)

BDA (Austrian Federal Office for Monument Protection) is the specialised body that preserves, protects, maintains and researches Austria's cultural heritage in the public interest and on behalf of the law. Their approaches are not only based on physical quantities like u-values, but also taken into consideration other criteria like life-cycle and impact on the historic substance. Therefore, it as a rule-based approach. For energy efficiency measures there is a guideline published (https://bda.gv.at/de/richtlinie-energieeffizienz/; 2020-09-01; only available in German). It describes an assessment procedure for measures and the applied criteria for it:

For a successful energetic renovation, the following basic monument conservation rules apply:

1. ORIGINAL
The primary objective of monument protection and monument preservation is the preservation of the historically transmitted substance and appearance as unchanged as possible. In the case of necessary changes, the previous condition, the measures and the condition after the interventions are to be documented in accordance with monument conservation standards.

2. ANALYSIS
Many architectural monuments show an extremely heterogeneous substance that has grown over time. In the run-up to planning, it is therefore necessary to have as complete a knowledge of the existing structure as possible, both in terms of structural engineering and building physics.

3. OVERALL PROJECT
Projects should be characterized by a holistic Excellent planning and not focusing on individual measures. The achievement of individual area-related u-values or theoretical heating requirement information is not expedient, but a meaningful optimization of the overall energy balance of an object must be sought.

4. USER BEHAVIOUR
The objective of an energetic renovation cannot be based on given approaches as with the standardized energy certificate, but must specifically address the use and user behaviour in the property.

5. INDIVIDUAL
Architectural monuments require individual solutions instead of standard recipes. This requires those involved to be willing to under certain circumstances increased planning effort, improved quality assurance and increased communication with or between construction experts, the building owner and the preservation of monuments until the completion of the measures.

6. REPAIR
The first step is to identify sources of error in the monument, carry out repairs and reactivate original functional concepts in order to bring out the potential of the historical substance again. Only when the possibilities of a repair have been exhausted will a decision be made about possible additions or replacements.

7. MATERIAL COMPLIANCE
Necessary additions in the course of energetic improvements are to be implemented in the materiality as closely as possible to the existing stock.

8. ERROR TOLERANCE
Since experience has shown that no ideal conditions are found in either production or use, fault-tolerant, repairable or reversible constructions are to be preferred.

9. RISK-FREE
Long-term freedom from damage must be guaranteed. The participation of building physicists with relevant experience in dealing with the restoration of architectural monuments is often necessary for this. Innovations or attempts at the monument are only justifiable if they are accompanied by a scientific project. Otherwise, the following applies to all measures: better less and safely - than much and risky.

10. FAR VIEW
Measures on the monument are part of a gradual optimization over the past centuries. A maintenance requires a foresight that goes beyond the general liability or the amortisation period from all involved.

The guidelines categorised energy efficiency measures in the following colouring scheme:

GREEN -> monument compatible measure
The measure means little interference with the substance and appearance of the monument. It is compatible with historic monuments. This results in a simple eligibility for approval.

YELLOW -> Conditionally monument compatible measure
The measure means a certain disadvantageous interference with the substance and appearance of the monument. It is only partially compatible with listed buildings and requires increased planning effort. This results in a restricted eligibility for authorisation or an authorisation with conditions.

RED -> measure not compatible with listed buildings
The measure means a serious, disadvantageous intervention in the substance and appearance of the monument. It is not compatible with listed buildings. This results in a refusal of the permit.

3.1.3 Austrian Standards

There are no Austrian Standards for energy efficiency of traditional buildings. Additionally, the Federal Office of Monument Protection is working on the integration of following exemption in all standards:

“Exceptions may be required for buildings that are listed as well as for other historical buildings of architectural importance. If buildings are under monument protection, the results of the approval process according to the provisions of the Monument Protection Act are decisive. The "Standards of Monument Preservation" of the Federal Monuments Office apply."

(http://www.bda.at/documents/890637022.pdf, Bundesdenkmalamt (Hg.), Standards of Monument Preservation, Wolkersdorf 2014)

3.1.4 Österreichische Institut für Bautechnik (OIB)

The OIB was founded in 1993 on the basis of an "Agreement in accordance with Article 15a B-VG (Constitutional Law) on cooperation in the building industry" concluded by the Austrian federal states. It is a non-profit association based in Vienna, to which all Austrian federal states (Burgenland, Carinthia, Lower Austria, Upper Austria, Salzburg, Styria, Tyrol, Vorarlberg and Vienna) belong as members. The association's activities cover the entire territory of the Republic of Austria. In addition, the OIB serves as a common "mouthpiece" in European and international specialist bodies.

The Austrian Institute for Building Technology (OIB), as the coordination platform of the federal states for building products and building technology, fulfils the following tasks:

- The OIB issues the OIB guidelines in order to enable the federal states to standardize the structural requirements in the building regulations;
- The OIB issues the building material lists ÖA and ÖE as ordinances for the federal states;
- The OIB is the European technical assessment body and national approval body for construction products;
- As a product information point for the building industry, the OIB provides information on the technical requirements for building products applicable in Austria;
- As the market surveillance authority, the OIB ensures that construction products that are on the market in Austria meet all legal requirements and do not endanger health and safety.

The OIB guidelines are sometimes contrary to the BDA guidelines. Therefore, it is usually a negotiation required, as described in “3.1.1 Legal Situation in Austria”.

3.1.5 Vienna Zoo

The Vienna Zoo in the park of Schönbrunn Palace in Vienna's 13th district of Hietzing was founded by the Habsburgs in 1752 and is the world's oldest Zoo still in existence. The Zoo experienced several renewals and extensions. In Anthony Sheridan's Zoo ranking, the Zoo was named the best European Zoo five times in a row (2008, 2010, 2012, 2014 and 2018).

Special features:

- Oldest still existing Zoo in the world;
- Part of the UNESCO World Heritage Site Schönbrunn
- Area: 17 hectares
- Opening: 31st July 1752
- Animal species: 722 animal species
- Individuals: 8,409 animals
- Visitor numbers: 2.2 million (2017)

The first Giraffe came to Vienna in 1828 - the Giraffe House in Schönbrunn Zoo also dates from this time. Like most of the buildings in the Zoo, it is a listed building.

In order to keep Giraffes welfare facilities up to date, the existing building needs to be renovated and the facility enlarged. The specifications for this project were set in consultation with the Federal Office of Monument Protection. Additions from the 1980s to the historic house will be removed, but an extension similar to a Winter Garden may be built at the rear. The indoor enclosure for the animals with an area of 440 square metres will thus be more than three times the size of the existing one. A large, bright Winter Garden, which offers the Giraffes more room to move around even in the cold season, will be the core of the new Giraffe facility. The surrounding buildings - pheasantry and marsh bird house - are also included in the renovation, and the outdoor area for the Giraffes is also being enlarged.

The specifications of monument protection and animal husbandry often leave little scope for energy-saving measures. In all new and renovations in the Zoo, however, special emphasis is placed on energy-efficient execution. Good thermal insulation and the use of LED lamps for lighting, to name just two examples, has become standard and is also being implemented in this project. The Winter Garden for the Giraffes (a glass house) enables two innovative measures to be taken for the Zoo. The use of renewable energy through glass-integrated photovoltaics and the intermediate storage of thermal energy in a gravel storage facility. In addition, conventional photovoltaic panels and collectors for hot water preparation will be installed on the flat roof of the visitor corridor.

Figure 2: Energy Performance Category

Table 2: Range of ***roof insulation*** *types and performance improvements*

Name of Object	**Vienna Zoo**
Address of Object	1130 Wien, Maxingstrasse 13b, 1130 Wien
Project Nb	AT01
Project title	**Innovative Green Technologies for the New Giraffe Park at Schönbrunn Zoo (Vienna, Austria)**
Start date	January 2015
End date	April 2017
Implemented measure 1	**Winter Garden with Photovoltaic glazing - light and shadow**
Description of measure 1	Power generation, shading and design, all combined into one solution: the combined use of photovoltaic technology with laminated safety glass results in a unique, multifunctional energy saving symbiosis. The Winter Garden is made of steel and glass and rests on a supporting structure imitating an acacia tree – the common tree of the giraffes' natural habitat. The trunk branches upwards into the glass areas and their photovoltaic cells.
Data before intervention 1	New construction
Data after intervention 1	The maximum performance of the glazed photovoltaic installation (16kWp) and the flat panels (4kWp) equals to 20 kWp. Together, the two installations may generate between 18,000 - 22,000 kWh of electricity per year. Estimated electricity consumption of the building Lighting - exclusive use of LED light bulbs Animal enclosures: 6,300 kWh Visitor areas: 1,079 kWh Animal keepers: 411 kWh Heating pumps: 1,440 kWh Ventilation system: 7,796 kWh Total: 17,026 kWh + 10% for other items (elevators, door operators, cleaning etc.) This amounts to a total of 18,700 kWh of energy consumed per year. The photovoltaic system is able to cover the facility's entire demand on electricity.
u-Value before intervention 1	Not known
u-Value after intervention 1	Not known
Implemented measure 2	**Thermal Energy Storage Based on Gravel - Hot Air**

Name of Object	**Vienna Zoo**
Description of measure 2	A thermal energy storage system is situated underneath the Giraffes' Winter Garden. Relying on gravel and air circulation, it stores heat during the day and releases it at night. This helps mitigate the problem of thermal peak loads in a greenhouse and saves much energy during transition periods. The giraffes' new winter garden works just like a greenhouse, which uses solar energy for heating; this effect is produced in spite of partial shading provided by the glazed PV elements. During the cold season, and even more so in the transition periods, there is a heat surplus during the day, while additional heating is required at night. The heat captured during the day will be stored in a storage medium in order to be released for heating at night: An air-flooded gravel pit underneath will be used for that purpose. Only one-day storage media has been found to be economically viable for this project: They store the heat of the day until the upcoming night.
Data before intervention 2	New construction
Data after intervention 2	According to calculations and simulations, a storage entity of $60m^3$ is needed for this project. The pit underneath the foundation respects these dimensions, measuring 8.6 x 3.6 x 2m, which equals to $62m^3$ in total. It was backfilled with approximately 122t of gravel (marble quarry, grain size 63/150). The gravel pit has a storage capacity between 17,190 and 20,500 kWh depending on the calculation method used. Consequently, around 30% of the Winter Garden's demand for heating can be covered. Once the operating period had started, surveillance monitoring was carried out in order to determine optimum use and real-time figures.
u-Value before intervention 2	Not known
u-Value after intervention 2	Not known
Implemented measure 3	**Photovoltaic panels on the flat roof**
Description of measure 3	Tilted photovoltaic modules were installed on the flat roof above the visitor corridor. Monocristalline PV module Producer: AXITEC Module area: $24.4m^2$ Peak output: 4.05 kWp
Summary	**Savings potential:** **18,000 kWh of electricity equal to 5,040 kg of CO2 emissions** **17,000 kWh of long-distance heating equal to 3,247 kg of CO2 emissions** **8,287 kg of CO2 emissions** **Thanks to innovative technological measures the operation of the New Giraffe Park saves at least 8,287 kg of CO2 emissions per year.**

3.1.6 Upper Belvedere

The Belvedere Palace (from Italian “beautiful view”) in Vienna was constructed by Johann Lucas von Hildebrandt (1668–1745) between 1714 and 1723 for Prince Eugene of Savoy (1663 -1736). The Upper Belvedere and the Lower Belvedere (named because of their location on a slope south of the town at that time) form a baroque ensemble with the connecting gardens. The two palace buildings now house the collections of the Austrian Gallery Belvedere (Österreichische Galerie Belvedere) and rooms for temporary exhibitions.

The Upper Belvedere was originally designed as a small building that was supposed to visually complete the garden. After further land purchases by the prince, Hildebrandt expanded the planning and built the Upper Belvedere 1720–1723 in the size it is today; The construction work was completed in 1725/1726. The Prince continued to live in the Lower Belvedere, while the Upper Belvedere was used for representation. To the east of the Upper Belvedere, the Prince's menagerie was also housed in a semi-circular area (the floor plan can still be seen today), which ended up in the imperial Schönbrunn Zoo after Eugen's death.

Based on the existing situation, the energy balance can be maintained with the help of an inner level of the box window that uses today's possibilities of the building can be significantly improved while maintaining the architectural/ visual specifications.

Table 3: Project description Upper Belvedere

Name of Object	**Upper Belvedere**
Address of Object	1030 Wien, Prinz Eugen Straße 27
Project Nb	AT02
Project Title	**Upper Belvedere - Refurbishment measures on box-type window in historical buildings**
Report	**Research report "Upper Belvedere - Development of a box-type window - interior Layer for historical buildings" ACOM Research 2019**
	"On behalf of the Burghauptmannschaft Österreich Ing. Ursula JÖRG Austrian Gallery Belvedere Scientific Institution under public law Thomas RATH "
Start Date	2019
End Date	2020
Implemented Measure 1	**2.1 Exterior Layer**
Description of Measure 1	2.1.1 Remaining of the wings: The existing wings will continue to be used and carpentry-like renovation will be carried out and made common. 2.1.2 "Glazing rebate" instead of "Ledging" the existing glass. The temporary wooden ledge is removed and the glazing rebate stop bar turned outwards. This allows the glazing rebate stop bar and the wooden sash bars to be carried out correctly and the glazing to be sealed. 2.1.3 Receiving the fittings: The substance remains unchanged 2.1.4 Width of the rebate clearance: To improve ventilation of the box, the wing rebates are expanded 2.1.5 Installation of sash bars: In order to align the ensemble picture with the historical substance, sash bars are placed on the exterior layer.
Implemented Measure 2	**2.2 Box and Fabric clearance**
Description of Measure 2	2.2.1 Remaining the box: The box remains 2.2.2 Establishing a driving rain, wind and airtight layer: renew joint to stone walls. Partially existing seal with tarred horsehair is crumbled and ineffective. When assembling the boxes, UV-resistant and driving rain-proof joint tape are inserted.
Implemented Measure 3	**2.3 Interior Layer**

Name of Object	**Upper Belvedere**
Description of Measure 3	"2.3.1 New production of the entire interior layer: type of wood --> solid oak or layer glued (cover laminations end-to-end) 2.3.2 View profiling is retained: When designing the prototypes, the view profiling was assumed and retained. 2.3.3 Fittings 2.3.3.1 Espagnolettes adjustable: In order to compensate for the tolerances of the locking hooks and to be able to regulate the contact pressure, a grub screw is worked into the striking plates. 2.3.3.2 Replacing hinges: The existing brass hinges are exchanged for stainless steel hinges, the existing sleeves and washers will continue to be used. 2.3.4 Use of insulating glass with special properties 2.3.4.1 Glass structure 6Sun - 16Ar -: 5TVG1 This glass used on the interior layer in combination with the existing glass on the exterior layer results in the following pane properties: Ug: 0.8W / m²K; Light transmission: 65%; g-value: 38%; UV transmission: 11% 2.3.4.2 Edge bond: Edge spacers are installed with a Psi value for double insulating glass and wooden windows of ≤0.030 W / mK. These are available in the colors "white", "light brown" and "dark brown". 2.3.5 Installation of two sealing levels: A stick seal (special round profile) and a common profile are used as wing seals. Both profiles are made of silicone and available in the colors "white", "light brown" and "dark brown" "
Implemented Measure 4	**2.4 Surface**
Description of Measure 4	2.4.1 Exterior Layer and box: The surface of the oak windows is painted with a glaze: Primer: 1x Sikkens Cetol HLS Extra; Top coating: 2x Sikkens Cetol Filter 7 plus 2.4.2 Interior layer with glazing coating: according to the exterior layer With opaque coating: Opaque white closed porous Primer: 1x Aquawood TIG HighRes; Intermediate coating: 1 x Aquawood Intermedio HighResISO; if necessary Filling necessary; Top coating: 1x Aquawood DSL Q10 M
	Results

Name of Object	**Upper Belvedere**
Data before Interventions:	Glass structure 4 - 200 - 4 Ug value 2.9 Light transmission 82% UV transmission 55% g-value 79% Uw value 2.34
Data after Interventions:	Glass structure 4 - 200 - 6Sun-16Ar-: 5TVG Ug value 0.8; -72% Light transmission 59% or 65%; -28% - -21% UV transmission 8% or 11%; -85% - -80% g-value 36% or 38%; -54% - -52% Uw value: 1.17; -50%
u-Value before Interventions	**Ug value: 2.9 W / m2K**
u-Value after interventions	**Ug value: 0.8 W / m2K**

3.1.7 Vienna Technical Museum

The Vienna Technical Museum (TMW for short) shows exhibits and models from the history of technology, paying particular attention to the Austrian contribution to technological development. It has numerous historical demonstration models, some of them quite large, from the fields of railways, shipbuilding, aviation and industry. The functional steam engines are outstanding. TMW also houses one of the largest collections of historical musical instruments in Austria. The Austrian Media Library is attached to the museum.

The main building was built from 1909 according to plans by the building councilor Hans Schneider and opened on May 6, 1918 as the "Technical Museum for Industry and Commerce", which is now a listed building. The bright inner courtyards covered with glass domes are a special feature of the building.

In the TMW there are excessive temperatures in the entire exhibition hall as well as in the administration offices and the library on the top floor, especially in summer. There is currently no active cooling system installed in these areas and no mechanical ventilation is active.

The increased temperatures are mainly caused by the high solar entry via the three glass domes over the east, middle and west wings, under which the exhibition hall extends over three levels. Even though the double-shell domes in the side wings have been shaded in the space in between and the central dome since 2013 both in the space and outside by tarpaulin (Soltis Perform 92), the heat input, especially through the side domes, remains considerable.

The glass roof of the entrance hall also creates solar inputs, albeit reduced, as it was provided with a sun protection film (Helios RHE 20) in 2011.

Additional heat input is caused by waste heat from devices, lighting and visitors, as well as the numerous windows, even if some of these have internal roller blinds. In addition, the building has a high storage mass that does not cool down sufficiently overnight, especially in the summer months.

Due to the large air space, the possibilities for temperature control of individual areas and targeted cross ventilation are limited, furthermore, opening the windows is for reasons of air quality (entry of dust, pollen, etc.), visitor safety and the positioning of exhibits (sometimes the windows are not accessible) not practicable in the long run.

Table 4: Project description Vienna Technical Museum

Name of Object	**Vienna Technical Museum**
Address of Object	1140 Vienna, Mariahilfer Straße 212
Project Nb	AT03
Project Title	Climate Project
Report	**Preliminary study on the feasibility of passive measures to improve the indoor climate in the Vienna Technical Museum**
	Obkircher Plus Engineering Office for Technical Building Equipment and Technical Physics on behalf of the Burghauptmannschaft Österreich - department 304 Vienna Technical Museum - Directorate General Ms. Karin Skarek MBA
Start Date	2019
End Date	2021
Implemented Measure 1	Increase the albedo of the roof
Description of Measure 1	Reduction of heat input through the roof covering consisting of gray titanium zinc sheet with a surface of approx. 4,950 m² by increasing the retro reflectivity and reducing the surface temperature by means of a cooling coating Lifespan: >25 years, coating practically maintenance-free Implementation: 2020 planned
Data before Intervention 1	SR value (Solar Reflection) & TE value (Thermal Emittance) of the substance are not yet known - measurements with applied sample coatings are currently underway
Data after Intervention 1	Target values: SR value of 0.8 and TE value of 0.8 - 0.9 Values depend on the chosen color of the Cooling Coating (the lighter the better), coordination with the Federal Monument Office is still in progress
u-Value before Intervention 1	Not known to date
u-Value after Intervention 1	Not known to date
Implemented Measure 2	Permanent sun protection system for the two lateral glass domes on the roof

Name of Object	**Vienna Technical Museum**
Description of Measure 2	Reduction of heat input by external shading of the two glass domes with approx. 400 m² by installing a ventilated textile shading - shading practically maintenance-free Lifespan: 10 years; Implementation: 2020 planned
Data before Intervention 2	Temperature in the dome space: 37 ° C (outside temperature: approx. 30 ° C) but with the unclosed smoke extraction dampers
Data after intervention 2	Not known to date
u-Value before Intervention 2	Not known to date
u-Value after Intervention 2	Not known to date

3.2 Examples from the United Kingdom

The United Kingdom is fortunate to have a significant amount of information from various organisations which will be used in the different types of training material for developing awareness in energy efficiency relating to historic buildings for all Craftspeople involved in their care.

There is however no central database available, so in its absence the following list of organisations and references has been prepared which should provide a comprehensive bank of knowledge for training purposes. This will be updated as and when further documentation is published or is brought to the project team's awareness.

3.2.1 Historic Environment Scotland (HES) Documents

Historic Environment Scotland (HES) provide an equivalent research and legislative service to for the Historic Environment to Historic England, and their highly respected website provides a wealth of relevant information which will be embedded into the training material for the project.

Their website can be found from the link
https://www.historicenvironment.scot/archives-and-research

whilst the link to the suite of case studies can be seen from

https://www.historicenvironment.scot/archives-and-research/publications/?searchPubText=refurbishment+case+studies

All of the following documents contain highly relevant information which will be used for training material in this project, with Technical paper 24 (highlighted in blue and discussed below) as a primary focus:

- *Refurbishment Case Studies*
- Technical Paper 1: *Thermal Performance of Traditional Windows*
- Technical Paper 2: *In-situ U-Value Measurements in Traditional Buildings - Preliminary Results*
- Technical Paper 3: *Energy Modelling Analysis of a Traditionally Built Scottish Tenement Flat*
- Technical Paper 4: *Energy Modelling in Traditional Scottish Houses*
- Technical Paper 5: *Energy Modelling of a Mid-19th Century Villa - Baseline performance and improvement options*
- Technical Paper 6: *Indoor Air Quality & Energy Efficiency in Traditional Buildings*
- Technical Paper 7: *Embodied Carbon in Natural Building Stone in Scotland*
- Technical Paper 8: *Energy Modelling of the Garden Bothy, Dumfries House*

- Technical Paper 9: *Slim Profile Double Glazing*
- Technical Paper 10: *U-Values & Traditional Buildings*
- Technical Paper 13: *Embodied Energy Considerations*
- Technical Paper 14: *Keeping Warm in a Cooler House*
- Technical Paper 15: *Assessing risks in insulation retrofits using hygrothermal software tools: Heat and moisture transport in internally insulated stone walls*
- Technical Paper 16: *Green Deal Financial Modelling of a Traditional Cottage & Tenement Flat*
- Technical Paper 17: *Green Deal, Energy Company Obligation & Traditional Buildings*
- Technical Paper 18: *Evaluating Energy Modelling in Traditionally Constructed Dwellings*
- Technical Paper 19: *Monitoring Thermal Upgrades to Ten Traditional Properties*
- Technical Paper 20: *Slim Profile Double Glazing in Listed Buildings: Re-measuring the Thermal Performance*
- Technical Paper 21: *Data Sources for Energy Performance Assessments of Historic Buildings in the United Kingdom*
- Technical Paper 22: *Scotstarvit Tower Cottage*
- Technical Paper 23: *Thermal assessment of internal shutters and window film applied to traditional single glazed sash and case windows*
- Technical Paper 24: *Historic Environment Scotland Refurbishment Case Studies: Review of Energy Efficiency Projects*

Technical Paper 24, published in 2018, provides invaluable primary research examples of training material for the PRO-Heritage project, as it contains an independent review of a number of types of energy efficiency projects undertaken by HES to 18 domestic and non-domestic traditional properties over the last ten or so years. These describe how traditional buildings have been improved, and what lessons can be learnt about how best to upgrade Scotland's traditional building stock.

During this time HES developed and implemented energy efficiency upgrades to a range of domestic and non-domestic traditional building to demonstrate and test how traditional buildings can be adapted to deliver improved thermal performance, reduce carbon emissions and create buildings which are more comfortable and easier to heat. Each case study comprised the refurbishment of a building to improve its energy efficiency and thermal comfort. The refurbishments were carried out on a range of domestic building types including traditional cottages and tenements, and public buildings such as libraries or schools. All the buildings studied were of traditional solid wall construction, and some were listed.

The proposals were not limited to energy-efficiency measures, but considered issues of sustainability, indoor environmental quality, life cycle assessment and available skills. Each case study focused on one building, or a collection of buildings, upgraded with support from Historic Environment Scotland. The refurbishments typically incorporated innovative, adapted or non-standard materials - although most are readily available on the market. The impact of the interventions on the buildings' performance and Occupants' comfort forms much of this Technical Paper.

One of the aims of these case studies was to demonstrate a variety of upgrade options which, although not always directly transferable to other projects, could provide inspiration for developing creative upgrade measures suitable for the refurbishment of the existing building stock. The measures were designed above all to be minimally invasive and physically compatible with existing building fabric in terms of maintaining ventilation and vapour permeability and conversing historic finishes. The measures aimed to retain as much of the existing fabric, finishes and fittings as possible for reasons of both building conservation and waste reduction. This contrasts with some conventional approaches which involve the removal of existing finishes and the use of vapour-impermeable components and finishes.

Various types of interventions are examined: insulation upgrades to roofs, walls and floors; thermal performance improvement of windows and doors; and the installation of new heating. The Paper reports on the success of the inventions in terms of their current condition and performance, and the impact on the building occupants in terms of their thermal comfort and energy bills.

Key data from the Paper relates to the typical increased thermal performance in terms of 'u' values (thermal efficiency) as a result of each of these measures, which can be seen in the tables below:

*Table 5: Range of **wall insulation** types and performance improvements*

Property	Wall Insulation	Pre intervention U-values (W/m2K)	Post intervention U-values (W/m2k)	% Improvement
Five Tenement Flats, Edinburgh	Polystyrene beads, 40mm blown into cavity between internal plaster linings and external masonry walls	1.6	0.8	50%
	Polystyrene beads, 45mm blown into cavity between internal plaster linings and external masonry walls	1.4	0.7	50%
	Polystyrene beads 100mm blown into cavity between internal lining and external masonry walls	0.5	0.4	20%
	Aerogel, 100mm, plastered on hard	-	0.8	-
Well o'Wearie	Cellulose insulation blown behind lath and plaster (average post intervention U-values)	1.3	0.7	46%
	Aerogel 10mm behind plaster	1.4	1.0	29%
Wee Causeway	Calcium Silicate board, 15mm thick, applied to inner face of external walls and plastered	1.5	0.7	53%
	Polystyrene beads blown into cavity between internal plaster linings and external masonry walls	1.5	0.5	67%
	Aerogel 10mm applied to inner face of external and plaster	1.6	0.9	44%

Sword Street	Blown polystyrene beads 50mm	1.1	0.32	71%
	Blown Cellulose 100mm	1.1	0.29	74%
	Hemp insulation 100mm	1.1	0.22	80%
	Wood fibre board 80mm	1.1	0.19	83%
	Aerogel 40mm	1.1	0.37	66%
	Aerogel	1.1	0.32	71%
Kildonan	Wood fibre board 100mm	2.1	1	52%
	Calcium silicate board, 50mm thick, applied to inner face of external wall and plastered	2.1	0.4	81%
Rothesay	Aerogel 10mm applied to inner face of external wall and plastered	1.3	0.6	54%
Kirkton of Coull Farmhouse	Cellulose insulation blown behind existing plaster linings (average U-values)	1.4	0.15	89%
Annat Road	Icynene	1.1	0.41	63%
Downie's Cottage	Insulated lime plaster to inner face of external masonry applied on the hard	1.8	1.1	35%
Lauriston Terrace	Polystyrene beads blown behind lath and plaster	0.57	0.3	47%
	Average	**1.32**	**0.55**	**58.3%**

*Table 6: Range of **roof insulation** types and performance improvements*

Property	Roof Insulation	Pre intervention U-values (W/M2K)	Post intervention U-values (W/m2K)	% Improvement
Wells o'Wearie	Sheep's Wool insulation 280mm	1.4	0.2	86%
Wee Causeway	Hemp insulation 250mm	1.5	0.2	87%
The Pleasance	Polystyrene beads blown into cavity behind coom	1.5	0.4	73%
Kildonan	Wood fibre board 50mm	1.6	0.8	50%
	Wood fibre board 100mm to ceiling	1.9	0.4	79%
	Aerogel, 10mm, to dormers	1.7	1.2	29%
Leighton Library	Wood fibre insulation	1.3	0.2	85%
Newtongrange	Sheep's wool insulation 240mm	1.6	0.4	75%
	Bonded polystyrene beads, blown into cavity behind coom	1.9	0.4	79%
Kirkton Coull	Wood fibre board insulation 80mm to dormers	0.45	0.37	18%
	Aerogel, 11mm, applied to inner face of existing plaster finishes (average U-values)	0.49	0.32	35%

Annat Road	Wood fibre board insulation 100mm (average U-values)	1.0	0.14	86%
Downie's Cottage	Wood fibre board insulation laid over attic floor	4.0	1.1	73%
	Average	**1.56**	**0.47**	**66%**

*Table 7: Range of **floor insulation** types and performance improvements*

Property	Floor Insulation	Pre intervention U-values (W/m2K)	Post intervention U-values (W/m2K)	% Improvement
Wells o'Wearie	Wood fibre insulation, 80mm	2.4	0.7	71%
Kildonan	Aerogel, 30mm, to existing solid wood floor	3.9	0.8	79%
Kirkton of Coull Farmhouse	Wood fibre board insulation 80mm	4.0	1.0	75%
Downie's Cottage	Insulation lime concrete 100mm, laid over underfloor heating pipes	4.0	0.5	87%
	Average	**3.58**	**0.75**	**78%**

*Table 8: Range of **window intervention** types and performance improvements*

Property	Windows	Pre intervention U-values (W/m2K)	Post intervention U-values (W/m2K)	% Improvement
Five Tenement Flats, Edinburgh	Secondary glazing, double glazed with aluminium frame to existing single glazed timber sash and case	5.4	0.8	85%
	Secondary glazing, double glazed with timber frame to existing single glazed timber sash and case	5.2	0.6	88%
	Secondary glazing, single glazed with timber frame to existing single glazed timber sash and case	5.2	1.5	71%
	Aerogel, 10mm, blanket fitted to timber window shutters	2.2	0.4	82%
Wells o'Wearie	Polycarbonate secondary glazing held with magnetic strips	5.4	2.4	56%
Archibald Place, Edinburgh	Sashworks argon filled double glazing	4.4	2.5	43%
	Histoglass (D11, krypton filled)	4.4	2.8	36%
	Histoglass (D10, krypton filled, hand drawn outer pane)	4.4	2.6	41%
	Pilkington energiKare Legacy	4.4	1.9	57%
	Slimlite (air filled)	4.4	2.9	34%
	Slimlite (xenon and krypton fill, crown outer effect)	4.4	2.6	41%

	Slenderglaze (xenon and krypton fill)	4.4	2.3	48%
	Slimlite (xenon and krypton)	4.4	2.7	39%
	Average	**4.5**	**2.2**	**55%**

*Table 9: Range of **door interventions** and performance improvements*

Property	Door	Pre intervention U-values (W/m2K)	Post intervention U-values (W/m2K	% Improvement
Five Tenement Flats, Edinburgh	Aerogel blanket, 10mm, fitted within recessed panels covered with plywood	3.0	0.7	77%
Rothesay	Aerogel blanket, 10mm, fitted to recessed panels	3.9	0.8	79%
	Average	**3.5**	**0.8**	**78%**

The importance of the data in these tables cannot be over-estimated, as the green highlighted sections at the bottom of each table demonstrate that these measures resulted in average energy saving efficiencies of between 55% - 78%. When multiplied across the number of traditional/ listed buildings in Europe the potential of the PRO-Heritage project becomes clear.

All HES documentation has been published with the stated aim ‘to invite discussion and support decision-making in the drive to make heritage more energy efficient and sustainable’. These invaluable case studies and technical documents will also be used as key training material to provide the requisite knowledge and understanding for Practitioners to support their learning in energy efficiency of historic buildings.

3.2.2 Sustainable Traditional Building Alliance (STBA) Guidance Wheel & Other Documentation

The STBA was initially set up to provide guidance for those involved with retrofit work on historic buildings, and has morphed into a lobbying body to try to prevent destruction of the Historic Built Environment.

The Guidance Wheel will undoubtedly be a principle tool throughout the training as it is user-friendly and was developed particularly with Craftspeople in mind. In essence, the wheel is a visual tool which depicts more than fifty measures that might be possible to incorporate in refurbishments or retrofitting of traditional buildings. It provides an assessment of the impact that each measure will have on technically, in terms of energy efficiency and in terms of heritage.

The wheel is a very useful interactive tool that can be accessed via the STBA Responsible Retrofit website, directly from www.responsible-retrofit.org/wheel

The STBA website is also very useful source of information for the Heritage Sector, which can be accessed through its 'Knowledge Centre' found within www.stbauk.org.

The following documents will therefore also be utilised as training tools for the PRO-Heritage project:

- Planning Responsible Retrofit
- What is Whole House Retrofit
- Responsible Retrofit Toolkit
- Bristolian Guide to Solid Wall Insulation
- EPC's & Whole-House Approach - a Scoping Study
- Moisture in Buildings - an Integrated Approach to Risk Assessment & Guidance
- STBA's Responsible Retrofit of Traditional Buildings Report

3.2.3 Historic England Documents

Historic England and the legislative guardians of the Historic Environment within England, and as such their website which can be found from https://historicengland.org.uk.

Historic England were the first to commission research into the state of traditional skills within the UK, and the following documentation as well as their research into energy efficiency into historic buildings which was published in 2010 will provide valuable insight into the project:

- Planning Responsible Retrofit
- Skills Needs Analysis 2013
- Mapping Heritage Craft: Focus Group Briefing Paper August 2013
- Mapping Heritage Craft Full Report October 2012
- NHTG Skills Research England 2008 Summary
- NHTG Skills Research England Summary 2005
- NHTG Skills Research Ireland 2009 Summary
- NHTG Skills Research Scotland 2007 Summary
- NHTG Skills Research Wales Report 2007
- Energy Efficiency & Historic Buildings November 2010

3.2.4 National Trust Environmental & Retrofit Case Studies

From 2002, Rory Cullen, then Head of Buildings for the National Trust, devised a series of case studies (originally referred to as 'Design Guides') for all projects undertaken. These were divided into different types of project, with a key theme being environmental examples, with another area covering retrofit. To date, over 450 examples have been produced, with at least a quarter of these focussing on sustainability. Access to these case studies will therefore be highly relevant to the PRO-Heritage project as Craftspeople will be able to gain an insight into what materials and technologies will work in their field, and how this will for into overall conservation philosophy.

The case studies are intended to highlight the whole process from conception to completion, and in this guise include a post-project review at the end of the document from users which highlights the pros and cons of the whole project. This section is also updated on a regular basis.

Typical environmental case studies available include detail on technologies and other forms of sustainability suitable for all types of historic buildings such as:

- Air Source Heat Pumps
- Draught-proofing
- Ground Source Heat Pumps
- Heating Controls
- Limecrete floors
- Solar PV
- Solar roof slates
- Types of insulation

These have proved an invaluable aid for managers of other similar projects who can access the user-friendly material, gaining valuable insight into performance, pitfalls and cost, and preventing reinvention of the wheel.

Originally intended for internal use, they have proved to be of such value that it was agreed that they should be made available to the wider Heritage Sector, and thus they can now be accessed under https://www.nationaltrust.org.uk/features/building-design-guides on the National Trust website.

Table 10: Case Studies Examples – National Trust

NATIONAL TRUST DESIGN GUIDE CASE STUDY EXAMPLES					
Case Study	**Theme / topic**	**Aim of project**	**Actions**	**Review data**	**Trades**
Dolmelynllyn, Dolobran Farm, Wales (2009)	Sustainable technology: Natural insulation & heating system review	Aim of the project to reduce energy wasted through unnecessary heating of the property & the domestic hot water, & to provide more user-friendly means of heating provision offered by a more management system	- Replacement of storage heaters - New heated towel rail - Anti-tamper timer controller - External thermostat to ensure low level frost & damp protection - Timed controller for the hot water immersion tank	Baseline 12-month monitoring gave an annual consumption reading of 32,231 kWh. Measured at a cost of 8 pence per kWh meant an energy efficiency saving of £1,123 per annum, plus a carbon reduction of 6,036kg.	Carpenter Building Surveyor Mason Electrician
Claydon House, England (2017)	Conservation Maintenance: Re-glazing the staircase lantern	Aim of the project to focus on the preventative conservation & stabilisation of the environment around the lantern	- Repair the structural integrity of the lantern - Remove harmful asbestos - Reduce visible light & UV levels	Condition of the glazed roof lantern over the main staircase had begun to deteriorate leading to raised levels of UV (higher than the National Trust upper limit 75 µw/lumen) & water ingress during heavy rain. Decision to re-glaze the lantern & add mesh blinds proved to be an excellent option. The light levels reduced by half immediately after the mesh blinds were fitted, without any negative effect on the visitor experience. The new glazing system also prevented further water ingress.	Carpenter Building Surveyor Mason Electrician
Pontbrenmydyr Cottage, Wales (2009)	Renovation to create holiday cottage: Re-use of existing materials / biomass & solar thermal energy	Aim of the project to sensitively restore building, conserving as much of the original structure, fixtures & fittings as possible. Undertake a sustainable approach to renovation. Install a number of modern technologies – including a biomass pellet boiler & solar thermal panels & rainwater harvesting	- Insulation was added to the upper side of the ceilings. All doors & windows were made as draught proof as possible. - re-using materials, reducing future energy consumption & installing plant to reduce the building's dependence on fossil fuels. - Insulation was added to the upper side of the ceilings - A biomass pellet boiler provides the primary source of heating & hot water - Timberwork renewed	The solar panels are predicted to produce around 1,770 kWh of heat a year, making a saving of around 566.4 kg of wood pellets per annum. The total expected heat energy consumption of the cottage is predicted at 2,308 kWh per year. The solar thermal system has been reviewed & rated as 'very good' for system design, installation, day-to-day running & maintenance. Biomass boiler expected to use around three to four tonnes of pellets per year (£450 - £600 at 2009 prices). There have been no problems with the installation or use of the combined biomass-solar heating system, & all plant has performed correctly.	Carpenter Building Surveyor Mason Electrician
Terenichol House, Northern Ireland (2016)	Remodelling & refurbishment: External detailing of	Aim of the project to restore a derelict vernacular building & bring it	- Full re-roof & part re-construction of chimneys / dry-lining throughout structure	The project successfully restored a derelict vernacular building. The new windows received bespoke, puttied-in double glazed units, with the aim of achieving a non-double-glazed aesthetic. Standard double glazing has a depth of approx. 18mm (4mm glass, 10mm gap) which	Carpenter Building Surveyor Mason Electrician

NATIONAL TRUST DESIGN GUIDE CASE STUDY EXAMPLES					
Case Study	**Theme / topic**	**Aim of project**	**Actions**	**Review data**	**Trades**
	structure / biomass heating system	back into use, fully refurbish the property to a high standard, generate additional rental income	- New low-pressure wet heating system & fuel source / install secondary heating in living room - Demolition of rear extension & construction of additional storeys, cavity walled extension within same footprint - Overhaul of Victorian sash windows / bespoke ultra-thin, double-glazed windows in extension	renders it visibly double glazed. On this project, the main contractor was asked to create bespoke, extra-thin units using thinner glass (2mm) & a smaller gap (4mm), total 8mm, with the glass held in place with putty. The result is an aesthetic appropriate to the historic environment, delivering a significantly better thermal performance than single-glazing. The depth of solid floor insulation installed in the extension in Terenichol House achieved a design U-value of 0.13W/m2K (in comparison with the Building Regulations requirement of 0.22W/m2K).	
Carleon House, England (2014)	Sustainable renovation of an historic building: Conservation work using traditional materials / Application of environmentally sustainable technologies	Aim of the project to renovate the building low-impact conservation works including repairing joinery, replacement of roof covering, lime pointing & installation of natural sheep's wool insulation. Building also fitted with a series of new environmentally sustainable mechanical & electrical services including a mechanical ventilation/extraction system, a ground source heat pump, a solar thermal hot water collector & a rainwater recycling system.	- Installation of new, environmentally sustainable mechanical & electrical services & building technologies	The heat pump was designed for a coefficient of performance in the region of 1:3-4. It provided the majority of comfort heating for approx. 30% of the energy input of a conventional heating system. A solar thermal water heater was mounted on the roof to provide hot water & should met approx. 50% of demand. All pipes & tanks were insulated against heat loss & frost damage. A very small 6kW electric boiler was installed to top-up this system as required. A rainwater collection system was installed taking water from the roof to be stored in a 2000 litre underground tank & used for flushing toilets & supplying an outside tap. The size of gutters & downpipes was also upgraded throughout the building in order to prevent overflow & consequent damp problems.	Carpenter Building Surveyor Mason Electrician

3.2.5 Institute of Historic Buildings (IHBC) Technical Guidance

The IHBC is effectively the institute for conservation professionals involved in decision-making. Their full members largely come from a technical background and they tend to publish scholarly documentation suitable for this level.

A recent guidance document however entitled '*Retrofitting of Traditional Buildings'* can be found on their website www.ihbc.org.uk. This demonstrates a holistic approach to making buildings more energy efficient, and covers maintenance and repairs, significance and Heritage Impact Assessments - and as such will be referenced within the training material provided for the project.

3.2.6 British Standards

BS 7913 *Guide to the Conservation of Historic Buildings* is the authoritative document used by Conservation Officers, Consultants and others within the Heritage Sector for reference on guidance and best practice.

It is also currently the only legislation which refers to sustainability in relation to conservation, where it is states under *Section 5.3.1 Other influences on the management of heritage assets (Sustainability):*

> *"Sustainable use of heritage assets is influenced by national and local economies, community interest and involvement, opportunities to benefit educational uses, health and well-being activities and facilities. When a historic building becomes disused, under-utilized or where a change of use is considered for other reasons, a viable economic use might be required to allow for the conservation of the building. Any changes should be based on research to ensure a thorough understanding of significance. Economic sustainability should be balanced with other issues such as impact on significance. The sustainability of historic buildings is likely to be improved if they have a use that provides an income, (e.g. occupancy that provides an income, tourism etc.). Retaining and re-using existing buildings generally has a lower environment impact than replacing buildings in terms of embodied energy. The most effective way of ensuring energy efficiency and sustainability is to keep historic buildings in good repair so that they last as long as possible, do not need replacement and do not suffer from avoidable decay that would require energy and carbon to rectify. They should provide occupancy in an efficient manner, involving minimal production of carbon and use of energy without harming significance or the physical performance of the historic fabric. Using natural ventilation and light, and proper temperature and humidity control for individual rooms are ways of minimizing energy usage that respect the building's material characteristics. Keeping appropriate records of energy use can enable the comparative performance of the building and any changes to be evaluated. Elements such as walls can be over a third less energy efficient*

if damp. Some energy efficient measures can have an adverse effect on sustainability. The actual energy efficiency of historic buildings and their potential energy efficiency with the addition of energy efficient measures should be taken in account at the outset (see 6.3). The need for energy efficiency and low carbon might also influence the selection of materials and work methods as they can impact on thermal performance and weather resistance. Building materials and products should be sourced and procured in a sustainable manner.

The historic building should be regularly inspected (see 6.2) and maintained (see 6.7 and Clause 7). This is important to avoid damage from blocked drainage and ventilation. Works identified from inspections should be managed in a sustainable manner in a reasonable time frame. Sustainable management of historic buildings includes ongoing risk analysis for the hazards of fire and flood and to monitor measures put in place (e.g. warning or active systems) for the provision, checking and use of equipment and services. Many historic buildings with potentially vulnerable elements and contents that are highly significant require frequent environmental control and monitoring systems in order to provide optimum environmental conditions and aid the management and conservation of the historic building. The data from any monitoring systems should be regularly collected and analysed. Where the data analysis indicates further conservation works or a change in environmental conditions is required, these should be implemented in a timely fashion. When the use of a historic building is changed it can result in changes to internal environmental conditions that have an adverse effect. An analysis on this should be carried out. This could include comparing current environmental with predicted environmental conditions. New uses that involve an increased use of energy should be avoided where possible. The heritage bodies of the United Kingdom provide guidance on energy efficiency. This guidance has a holistic incremental approach that promotes repair and alteration rather than replacement of elements such as windows. Change of use can also affect the sustainability of the structure and floor loading and this should be taken into account. Research commissioned by the government and undertaken by the NHTG has shown that there are declining skills in the heritage sector and the age of the workforce is increasing. This could lead to an inadequate level of labour and skill in traditional craft trades."

This key piece of guidance will be instrumental in the training to Craftspeople in any of their respective trades, and will thus be referenced throughout the different forms provided.

3.2.7 Chartered Institute of Building (CIOB) Retrofit & Refurbishment Guidance

The CIOB is traditionally the Institute of choice for Site Managers and many Craftspeople, and now has over 45,000 members in the UK and internationally. It is expanding its core membership base and is the only organisation offering potential Heritage Certification to the Crafts.

In recent years they have also developed their range of documents which could be useful references for retrofit projects, including the following suitable information:

- *Low Carbon Retrofit Toolkit*
- *Re-use of Buildings March 2013*
- *Buildings under Refurbishment & Retrofit March 2011*

These can be accessed from the CIOB website link https://www.ciob.org/carbon-action-2050/retrofit-and-re-use.

3.2.8 British Standards Institute (BSI) Materials

PAS 2035, the specification and guidance for *retrofitting dwellings for improved energy efficiency* - was published in June 2019, and can be found via the BSI website.

The document includes a simplified Significance analysis written by the STBA, but this is not robust as it does not follow BS 7913 guidance. It is being updated for non-designated buildings, and recognises that there is a need for proportionality in decisions taken for traditional buildings.

This document represents a major step forward for the industry, especially as the aims of the retrofit process as set out in PAS 2035 include the avoidance of unintended consequences, improved comfort, health & wellbeing plus the protection and enhancement of architectural heritage.

While the standard will initially apply only to publicly funded works (mainly ECO3), it is hoped that this will establish best practice across all retrofit activity. In conjunction with this document BSI also publish PAS 2030, the over-arching standard for actual installations, with PAS 2037, which will set out standard specifications for commercial & public buildings due to follow shortly.

The European Standard is BS EN 16883: 2017 *Consultation of Cultural Heritage - Guidelines for Improving Energy Performance of Historic Buildings.* This document will also be widely referenced within the training material provided.

3.2.9 Building Research Establishment (BRE)

The BRE is a centre of building science in the United Kingdom, owned by charitable organisation the BRE Trust. It is a former UK government national laboratory that was privatised in 1997. BRE provides research, advice, training, testing, certification and standards for both public and private sector organisations in the UK and abroad.
The BRE is another potentially useful source of information for training material - their website can be found from https://www.bregroup.com.

3.2.10 The Society for the Protection of Ancient Buildings (SPAB)

SPAB's report, written by Dr Caroline Rye, formerly MSc student at the University of Portsmouth, compared the in-situ U-values (U-value is the universally known unit to describe the rate of heat transmittance or loss through a wall / roof / floor etc) of various traditional vernacular walls against the theoretical U-value for these walls using the class-leading BuildDesk U 3.4 software. Importantly, the theoretical value obtained from the U-value calculations is used by professionals as the base-line for assessing thermal performance of different types of constructions. However, SPAB's on-the-spot research suggests that 77% of the traditionally built walls sampled (including walls of timber, cob, limestone, slate, and granite) actually perform better than expected.

For more information read the SPAB Briefing on energy efficiency. Below is an extract from this report:

Table 11: Estimates of whole window u-values – Historic England vs. Historic Environment Scotland

Estimates of the whole window U-values and reduction in total heat loss through the windows with various options

	HISTORIC ENGLAND WINDOW		HISTORIC ENVIRONMENT SCOTLAND WINDOW	
	Whole window U-value W/m²K	Reduction in total heat loss through window	Whole window U-value W/m²K	Reduction in total heat loss through window
Window with single glazing only	4.3	-	4.5	-
Heavy curtains	2.5	41%	2.1	55%
Modern roller blind	2.7	38%	2.3	49%
Modern blind with DIY low-emissivity plastic film fixed to the window facing side of the blind	1.9	57%	1.9	58%
Honeycomb blind	2.1	51%	2.2	51%
Shutters	1.8	58%	1.9	58%
Insulated shutters	-	-	1.3	72%
Low-emissivity secondary glazing	1.8	58%	1.7	62%
Low-emissivity secondary glazing & shutters	1.6	62%	-	-
Slimline double glazing replacement panes	-	-	2.2	51%

An article by Caroline Rye and Cameron Scott for IHBC's magazine, Context which discusses their research into the energy performance (heat loss, moisture content) of traditional construction in historic buildings. Their findings showed that walls insulated with vapour-open, wood-fibre insulation had much more satisfactory levels of relative humidity (below 80% RH, on average) than those insulated with commonly used materials such as PIR (90% RH, on average, and rising year on year). Relatively humidity levels of over 80% is deemed the point where mould growth can flourish.

Table 12: Interim Findings "The Performance of Traditional Buildings"

EXAMPLES TAKEN FROM REPORT by Caroline Rye & Diane Hubbard: 'The Performance of Traditional Buildings – the SPAB Building Performance Survey 2011 Interim Findings			
INSULATION			
Type of wall	**Levels of relative humidity**		**Comments**
Walls insulated with vapour-open, wood-fibre insulation	Below 80% RH		80% is deemed the point where mould growth can flourish
Walls insulated with materials such as PIR	Average 90% RH (and rising year on year)		
DAMP-PROOFING			
Property	**Below 1200mm**	**Above 1200mm**	**Comments**
Lower Brailes: 19th Century, mid-terrace house with 20th Century extension	1.49 W/m²K	1.39 W/m²K	Variations & increases in moisture content beneath this level probably indicated the effect of groundwater rising into solid walls built of porous materials without damp-proofing courses (rising damp)
Riddlecombe: 19th Century, semi-detached house with 20th Century extensions	1.05 W/m²K	0.76 W/m²K	
Drewsteighnton: 19th Century, detached barn conversion with 1970's extension	1.50 W/m²K	1.24 W/m²K	

3.3 Examples from Slovakia

Even with the importance of energy efficiency of historic buildings it is evident there are not so many project examples at the moment in Slovakia. There is no data available relating to improvements in energy efficiency of traditional or historic buildings; there are no organisations primarily dealing with this issue and also documentation in this area is not available in Slovak language. There is also only one book entitled "Energy Efficiency of Renovation of Historic Buildings" by Milan Smutný and co.

The published or documented best practice examples in this area are very rare. Most implementations of improving the energy balance are happening at a practical level and the results are not published. Unfortunately, improving the energy balance has not even been the subject of university research.

One of the few best practical examples in the area of energy efficiency in historic structures is the renovation of the power plant - an industrial heritage site Power Plant in Piešťany.

3.3.1 Power Plant in Piešťany

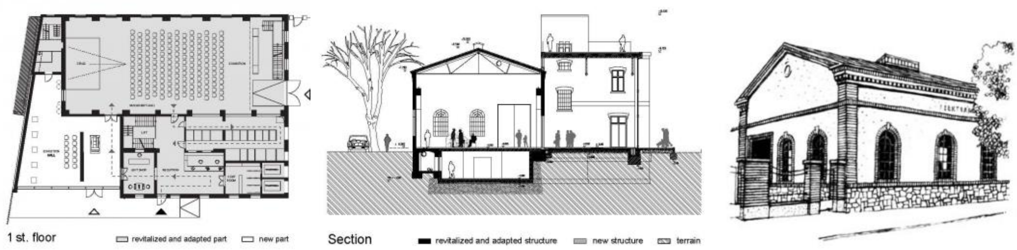
The Power Plant in the City of Piešťany in Slovakia is a National Cultural Monument of industrial heritage. Important issues during the process of its renovation were the original design of the building, the building technical condition and the future operating regime.

Hands-on science centre and power generation museum in the city of Pieštany (80 km NW from the capital of Bratislava) has centred on a landmark building of a municipal power station built in 1906 from the Registry of the Slovak National Monuments. The main and most important principle of the project are minimal changes to the original construction, retaining all the original features, structure and interior technical elements with sensitive adaptation to the new facility. The Elektrarna Pieštany project has expanded its original mission by preservation of a remarkable piece of industrial heritage and interactive education in field of electricity.

The Power plant of Pieštany was built in 1906. The object is heritage listed. Added new structures are non-invasive and reversible. Preservation effort started in 2008 with the announcement of a public competition of architecture students for reconstruction of former power plant in Pieštany, organized in Bratislava in 2008. EON Foundation and Design Factory has continued working with the two-member winning team (architecture students Michal Ganobjak and Vladimir Hain), in cooperation with architects Zuzana Zacharova, Martin Pasko from ADOM. M Studio under the consultancy with of Associate Professor Eva Kralova from Faculty of Architecture SUT in Bratislava.

From historical sources it is known that for the construction of municipal Power plant took place public money collection. Rumours that every citizen of Pieštany had his/her own brick. This idea was transformed into project. From the beginning there was an ambition of reuse of abandoned and unused building - not only by accessibility for wide public, but also enable to active use and participation of public. Here, where once was the site of energy production and transformation, the idea of the electricity sector continues. New cultural and educational centre offers interactive education to visitors - what is the energy, how it can be used, saved and in which type it can be converted. Reversible extension of power plant, new minimalistic reversible glazed roof-extension, barrier-free rooftop with terrace and new underground level were continuously consulted and the resulting solution was approved by the Regional Monument Board. The Elektrarna Pieštany project has expanded its original mission by preservation and active re-use of a remarkable piece of industrial heritage.

Figure 3: Power plant of Pieštany



Project reduces energy demands while maintaining historical appearance of this national cultural monument of power plant. Sustainable aspects: large atrium for heat gains (winter) and buffering zone between interior and exterior as natural exchanger of large volume of air; new flooring with energy efficient heating cable.

Table 13: Power plant of Pieštany - Areas

Areas	
Original Condition:	643 m²
Restoration Value:	795 m²
Total Project Area:	1,438 m²
Site Area:	1,550 m²

The enclosure wall of the monuments according to the recent norm on Thermal protection of the buildings STN 730540 very often belongs to the very heavy kinds of constructions build from the burnt bricks with high thermal capacity. As the enclosure wall of the given monument (Elektrárňa Piešťany) was thicker than 500 mm and also in respect of its high thermo-accumulative capacity the external cladding from the point of energy saving would be problematic and questionable. This wouldn´t be problematic only because of the preservation values but the second important argument was that high thermal capacity of enclosure walls after its cladding would cause heat leakage to construction from the inner side and this way it would cause the energy inefficiency of continual heating (according the authors of one of the few publications dealing with the energy efficiency of historic buildings which was mentioned above the high thermal inertia of the enclosure wall is possible to use in a way of flexible discontinuous heating).

The proposal for the renovation of the monument in Piešťany had also to fulfil the requirements of the law number 555/2005 Z.z. on energy efficiency of buildings. Because the structure in Piešťany is the declared National Cultural Monument, the exemption clause was used which says that if in the buildings which were given to use before the 1st of January 1947 is not appropriate to use the external or internal cladding it is possible to use for the purposes of energy efficiency some other technologies. However, the improved energy efficiency of historical building improves the sustainability and viability of the historic building. In this case in the first stage according the results of the research as the optimum solution was chosen the air conditioning in the combination of the use of the properties of natural circulation and solar gains through glass facade. A big atrium was proposed using the principles of buffering zone thanks to which the big generator hall can be open anytime without big heat losses.
Technological solution: Thanks to the common steps taken by architects, engineers and conservators which were involved in the project and also because the use of the

results of the research about the object history and using the natural properties of the air ascent it was possible to reduce by more than 50 percent the amount of the pipelines. It was possible to use an effective and good solution – for the purposes of the new pipelines use the original underground technological canal, which was given an old-new function. This fact was very positively appreciated by the Regional Monument Board in Trnava. Also due to this fact the technological canal could become the integral part of educational exposition for the professional and - also – for the general public. The hidden heating by drag cable was possible to integrate to new constructions of the cast decks and thanks to this it was possible to eliminate the new visual technological feature. The natural ventilation was retained.

New reconstruction of historical monument respects all preserved historical stages and values. Architectural solution sensitively adds the necessary facilities and presents authentic spaces with new function of interactive hands-on science centre about electricity.

3.4 Examples from Portugal

There are 3,544,384 buildings in Portugal, 206,343 of which built before 1919 in traditional construction systems (data: National Institute of Statistics, 2018). Mainly in this group of buildings, are 4,107 listed assets, comprising 810 National Monuments, 2,701 listed has Public Interest and 569 listed Regional Interest. Among National Monuments are 17 World Heritage Sites listed by UNESCO.

Although building permits for new construction continued to be prevalent in 2016, representing 64.3% of total building permits, building requalification works (alterations, enlargements and reconstructions) represented 27.6% of total permits in 2016 (28.4% in 2015), and 31.4% of all the concluded construction works. Works performed in existing buildings increased mostly in residential buildings (+ 17.0%, corresponding to EUR +151 million). Works performed in non-residential buildings decreased by 0.7% (corresponding to EUR -19 million). The highest decrease occurred in administrative buildings, financial institutions, post offices & similar services (-34.9%, corresponding to EUR -111 million), while the largest increase was in Industrial and warehouse buildings (+35.9 %, corresponding to EUR +112 million).

These figures show the impact of rehabilitation of traditional buildings in the economy of the country, and give a perspective to the potential contribution these operations could have in the increase of energy efficiency and power consumption reduction, if good models were followed and adequate solutions were applied. The environmental impacts of this activity are recognizably high but efforts to minimize them have not been successful so far.

Following the sustainable energy policy of the European Commission and the legislation for increase of energy efficiency in EU member states, Portugal is committed in developing a series of energy efficient goals and regulations in order to reach the set goals of a 20% reduction of energy by 2020 and 40% by 2030.

Although the importance for the sector and despite some studies and institutional work about the subject, there are no central database information in the country about Best Practice Examples for Energy Efficiency in Historic Buildings.
Nevertheless, a list of organisations and references intents to give an idea of the available options in Portugal for who searches the subject.

3.4.1 National Laboratory of Civil Engineering (LNEC)

LNEC's mission is to undertake, coordinate and promote scientific research and technological development, aiming to the continuous improvement and the good practice of Civil Engineering.

It is also LNEC’s responsibility to pursue the public interest, by providing services of Science and Technology to public and private, national and foreign entities, contributing to innovation, dissemination of Knowledge and technology transfer.

Since its foundation in 1946, LNEC has been establishing networks and partnerships with national and international entities, giving it the ability to promote and foster the globalization of Science and Knowledge, positioning LNEC as an important partner in its area of expertise. Around 450 people work there, plus 100 grants PhD students.

LNEC integrates several consortia, referring to research programmes or projects and infrastructures with other organisations. At international level, cooperation actions developed with European partner institutions and with the engineering laboratories of the CPLP (Community of Portuguese Speaking Countries) stands out.

In this context, there are several investigation programs:
The Doctoral Program called “EcoCoRe PhD programme” in “Eco-efficient Construction and Rehabilitation” involves a partnership between five universities (University of Lisbon, University NOVA of Lisbon, University of Coimbra, University of Porto and University of Minho) and the National Laboratory of Civil Engineering. The program is focused on the following main research domains within Civil Engineering:

(i) Life-cycle analysis
(ii) Strategies for deconstruction, re-use and recycling;
(iii) Sustainable and durable materials/products
(iv) Durability for sustainability
(v) Rehabilitation for safety, comfort and energy efficiency.

More information can be found from: http://ecr.tecnico.ulisboa.pt/

Some information about sustainability, eco-performance and eco enhancement of existing buildings is available also in English, but only to buy online from the link: http://www.lnec.pt/en/research/publications/papers/?

From the group, it stands out an article that calculates and combines embodied energy and operational energy, proposing a methodology for the assessment of building components life-cycle energy, suitable for the assessment of repairing and replacing scenarios. The methodology is applied to a case study, comparing walls repair or replacement and considering different scenarios of users' requirements of thermal comfort. Results show the advantages of preserving building components and materials in terms of whole life cycle energy demand.

https://www.sciencedirect.com/science/article/abs/pii/S0378778819300738?via%3Dihub

3.4.2 Directorate General for Cultural Heritage (DGPC)

The Directorate-General for Cultural Heritage (DGPC) is responsible for managing the cultural heritage in mainland Portugal. A large team covering virtually all technical and scientific areas is based in Lisbon (central services) and in museums and monuments located in Lisbon, Mafra, Alcobaça, Batalha, Tomar, Coimbra and Porto. Amongst their responsibilities are the management of the architectural and archaeological built heritage – in urban and rural areas –, including conservation works in monuments under their care, but also the management of National Museums, World Heritage monuments and museum collections.

By law, they are the guardians of the listed built heritage. They have a permanent liaison with public and private entities, in Portugal and abroad, with legal effect measures from allowance to supervision. Any intervention on a listed building must have their written approval, based on a compulsory and comprehensive list of pictures, written elements and drawings.

The DGPC is also responsible for the study, research and dissemination of heritage information, and for the conservation and restoration of movable heritage assets, including the research, dissemination of results and awareness activities.

Amongst several publications, it looks relevant for the subject of the project the Sustainable Common Concept Milestone [Marco Conceitual Comum em Sustentabilidade (MCCS)]. This is an Iberian guide for sustainable museums, written in Portuguese and Spanish, with a holistic approach, from economic to social and environmental management. The guide is organised in five steps: the first focus on the concept of sustainable development; the second, approaches sustainability to museums; the third elaborates on the development of sustainable museums, their reality and special requirements; the fourth looks over policies on the Iberian space and Iberian-American regarding museums; the fifth gives operative and transversal implementation guides and definitions.

http://www.ibermuseos.org/pt/recursos/publicacoes/marco-conceitual-comum-em-sustentabilidade/

3.4.3 Ordem dos Arquitectos (OA)

The Architect's Order is the public association representing those who exercise the profession of architects in Portugal. It establishes the rules to be followed when joining the profession, the conditions for charging the architects membership fees, as well as exemptions, deductions, infringements and registration suspension requests.

OA also defines the rules that should be followed when investigating and punishing the activity of architects in the event of disciplinary infraction for a failure to fulfil duties enshrined in the Statues and Ethics Regulations of Ordem dos Arquitectos.

OA gives free access online to several mini-books, thematic guides for better fulfilment of the profession. The most relevant for our project would be "Rehabilitation and Conservation of Architectural Heritage", where an entire chapter is dedicated to the enhancement of thermic and acoustic performance of historical buildings:
https://www.oasrs.org/media/uploads/4_CT_Conservacao.pdf

3.5 Examples from Spain

Research has been carried out to have more knowledge and technical information about how to intervene on the constructive elements that integrate the assets of Cultural Heritage, especially the monasteries, as well as the different solutions that the current technology offers to improve their energy performance. In this sense, it is worth highlighting the doctoral thesis published by the University of Seville file:///C:/Users/user/Downloads/TESIS.pdf

The improvement of energy efficiency in protected buildings, is starting to be a topic that provokes interest. In fact, there are European research groups and projects that are addressing this issue from different perspectives. One of these projects is RENERPATH: Methodology of energy rehabilitation of heritage buildings, in which a methodology that was subsequently applied in two protected buildings, one in Ciudad Rodrigo (Salamanca-Spain) and another in Portugal. Other important projects in the EU on efficiency Energy and Cultural Heritage, such as: EFFESUS (Effesus 2012) (focused on urban districts, not buildings) and 3ENCULT (EURAC research 2013) (focused on reduction of energy demand and improvement of habitability in historic buildings). In general, many actions are being developed and applied to individual private cases.

There is a wealth of information relating to solutions for energy saving measures in Spain. These can be divided into two types: the solution catalogues and the guidelines of recommendations or good practices. Work is underway to encourage the use of materials, equipment and systems that increase thermal insulation in buildings with less energy consumption. The objective is to minimize CO_2 emissions linked to these constructions, promote the use of higher quality and longer durability materials, promote the use of low electrical consumption equipment, materials and systems and promote the use of taps and sanitary systems with low consumption of drinking water. A good example is the Efficient Building Rehabilitation and Habilitation Manual: https://issuu.com/e-weber/docs/weber_manual_de_rehabilitacion_y_habilitacion_efic

A thesis of interest is by Aitziber Egusquiza Ortega, entitled “Multiscale information management for historic districts’ energy retrofitting” (Egusquiza-Ortega 2015). This deals with energy rehabilitation in historic centres.

The existence of interventions in Goods of Cultural Interest, reinforces the idea that, although the action on these goods is not without complexity, these are not impossible interventions in which very good results can be obtained. As an example, the Stone Monastery (in Nuévalos, Zaragoza) has undertaken a series of measures to obtain an A grade in the energy certificate.

3.5.1 Technoheritage, the Network on Science and Technology for the Conservation of Cultural Heritage

Technoheritage, the Network on Science and Technology for the Conservation of Cultural Heritage started up in March, 2011, joining 77 research groups and institutions, which are organized in three activity areas: research groups of CSIC, Spanish National Research Council (Consejo Superior de Investigaciones Científicas in Spanish) and several Spanish universities; cultural institutions, foundations and museums; and sector companies. Technoheritage aims to support the cooperation between the agents of the science-technology-companies system in order to share ideas and experiences easily, helping to solve problems and allowing technology transfer, with the common objective of contributing to the conservation of Cultural Heritage.

The International Congress of Science and Technology for the Conservation of Cultural Heritage was held in the context of the activity of the Technoheritage network with the support of IAPH, Andalusian Institute of Historical Heritage (Andalusian Institute of Historical Heritage). This Congress is an international meeting for researchers and specialists in different areas that share the interest in the knowledge and preservation of Cultural Heritage.

3.5.2 Art-Risk (Artificial Intelligence applied to preventive conservation of heritage buildings)

The main objective of the research project "Artificial intelligence applied to preventive conservation of heritage buildings" (Art-Risk) is to investigate and develop a new computerized tool for preventive conservation of heritage in urban centres based on models of artificial intelligence. Art-Risk will be available to organisations and companies dedicated to the restoration and rehabilitation.

Developing this new method of vulnerability and risk analysis applied to Monuments implies to meet in the project a multidisciplinary team specialized in the protection and conservation of Heritage. Art-Risk team is researchers and professionals of the following fields of knowledge: Chemistry, Architecture, Archaeology, conservators, art history, geology, biology, mathematics and computer science.

The novelty of this challenge lies in its approach and results, free software to evaluate decisions in regional policies, planning and management of Heritage, with a transversal development that includes urban, architectural, cultural heritage value, and the analysis of environmental and socio-demographic situation around the monuments. This new tool will allow performing decision-making based on scientific criteria and minimize risks of losing cultural assets.

This project will develop a new predictive model based on fuzzy logic (by Xfuzzy 3.3), which for the first time includes a multi-scenario study, assessing environmental risks and climate change, the use level of buildings and structural risks together with historical data from monuments life, through historical series, pre-vulnerability matrices (array cluster) will allow to weight the involvement degree of each variable. Two types of Monuments (very common in Spain) will be studied (churches, walls and bastions). The validation of these two models-types will be performed by a blinded inter-laboratory diagnostic exercise in order to establish whether the prediction approaches the decision of separated workgroups https://www.upo.es/investiga/art-risk-en/

3.5.3 Santa María la Real Foundation for Historical Heritage

The Santa María la Real Foundation for Historical Heritage has developed a Heritage Monitoring System (MHS) (I) marketed by Telefónica. The MHS system is an innovative solution in the management process integral and conservation of cultural and historical assets. This tool is composed of a network of wireless sensors that register and transmit to a control centre multiple factors that affect the preservation of historical sites and the assets they house.

Among the main types of sensors used by the solution, the following stand out:

- Environmental sensors: taking measurements of physical variables such as temperature, relative humidity, atmospheric pressure, luminosity and the concentration of polluting gases.
- Structural sensors: inclinometers, fisurometers, accelerometers, dynamometric tapes and xylogaphic detectors.
- Lighting and access control sensors: presence and smoke detectors, pressure sensors and microwave barriers.

In addition, the MHS system is integrated with the Intelligent Rural Territory platform of Castilla y León, a public services management platform through IoT sensors, offered by the Junta de Castilla y León to the Local Administrations of the community.

Carried out in collaboration with Telnet, the MHS-EnerCon2 project will serve to develop an application that helps improve the management of historic buildings, combining the technology and knowledge necessary to improve their energy efficiency and facilitate their conservation, without losing sight of comfort of the users.

The project is part of the State Program for Research, Development and Innovation Oriented to the Challenges of the Society, within the Plan of Scientific, Technical and Innovation Research 2013-2016, of the Ministry of Economy, Industry and Competitiveness.

For its implementation, three pilot buildings have been determined: the San Antolin Cathedral and the Palace of the Provincial Council in Palencia and the Museum of the Royal Academy of Fine Arts in Madrid http://www.mhsproject.com/es/inicio

3.5.4 TEP Group, Universidad de Sevilla

Research on energy efficiency and architectural heritage on an urban scale, within the framework of the development of the doctoral thesis of Rosana Cano entitled "Decarbonization and historic city. Impact on the environment and heritage. Seville as a case study".

3.5.5 CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas)

The Center for Energy, Environmental and Technological Research (CIEMAT) is a Spanish public research body of excellence in energy and environmental matters, as well as in multiple cutting-edge technologies and in some areas of basic research attached to the General Secretariat of Coordination of Scientific Policy of the Ministry of Science, Innovation and Universities.

3.5.6 Colegio Oficial de Arquitectos de Madrid (COAM)

Official College of Architects of Madrid (COAM) celebrates conferences on innovative systems and technologies in the conservation of cultural heritage, within the EsPatrimonio program, in collaboration with the General Directorate of Housing of the Community of Madrid.

It has a working group of Architects in the face of climate change that works on energy efficiency projects in the building and rehabilitation.

3.5.7 COL·LEGI D'ARQUITECTES DE CATALUNYA (COAC)

The Association of Architects for Defence and Intervention in Architectural Heritage (AADIPA) of the College of Architects of Catalonia (COAC) has been organizing the International Heritage Workshop for 35 years, dedicating each edition monographically to a field of conservation and restoration. This trajectory has allowed it to consolidate as an appointment of reference in the heritage field at national and international level.

More than forty of the best international experts related to the conservation of architectural heritage and the efficient management of energy in historic buildings gathered to work on "Heritage values and energy efficiency. Conflicts and solutions". The architect José Luis González Moreno-Navarro was the Director of the course.

In recent years the social and political consensus on the need to reduce and make more efficient the energy consumption of buildings has been fully consolidated. The Technical Building Code (CTE) or the Catalan, Spanish and European energy efficiency regulations is a good test.

These regulations exclude from their compliance buildings with recognized heritage values. However, architects and other professionals involved in the conservation and rehabilitation of heritage, as well as owners and managers of heritage buildings do not want to be left out of the application of energy efficiency criteria.

The main objective of the International Heritage Days is to contribute to finding this balance based on the dialogue between all the agents involved: architects, technical architects, engineers, restorers, administrations, investors, managers and, especially, the end users of the buildings.

An example of this work is the incorporation of energy efficiency criteria in the restoration of the modernist compound of the Hospital de la Santa Creu and Sant Pau.

In this sense, other interventions that were successfully carried out are those of the monastery of Santa Maria de Vallbona, the castle of Montjuïc, the Amatller house, Ca l'Aranyó, the historic city of Santiago de Compostela, the cathedral of Burgo de Osma, the Santa Ana de Alcover convent, the Carmen convent and the Sagunto museum, and the adaptation as a museum of the Ponferrada thermal power plant.

3.5.8 IAPH The Andalusian Institute of Historical Heritage

The Andalusian Institute of Historical Heritage has organized congresses and courses on the sustainable rehabilitation of the historical and architectural heritage of Andalusia, seeking greater sustainability and energy efficiency in the historical and architectural heritage.

These projects are part of the VIOLET project, promoted by the European Union in order to encourage the application of energy efficiency measures in rehabilitation and/ or conservation processes that are undertaken in buildings of architectural and heritage interest. In this project the Ministry of Development and Housing participates as a partner through the Agency of Housing and Rehabilitation of Andalusia.

3.5.9 IPCE

The Cultural Heritage Institute has a group of Climate Change Work and Heritage.

4. CONCLUSIONS

4.1 Main Results

All the European countries participating in this PRO-Heritage project have one thing in common - the lack of a database where information concerning energy efficiency measures can be shared and utilised for good practice. Legislation relating to the protection of the Historic Environment is also relatively similar, although it is fair to say that its strength and implementation varies widely throughout Europe.

However, pockets of good practice are available within Government and private organisations, which demonstrate the impact that individual measures will have on the improving u-values and therefore energy efficiency for historic buildings.

This is best shown through the use of case studies, where actual data has been taken and can prove the difference that specific measures make. This is most advanced in the UK and in Austria. In the UK, Historic Environment Scotland in particular have undertaken a series of excellent examples funded by the Government. Key data from these case studies is set out and assessed within this element, with links provided to the relevant websites. Similarly, the Burghauptmannschaft Österreich, which is responsible for the historic buildings and monuments of the Government has made considerable strides in retrofitting energy efficiency measures, and the results of these can be seen in several case studies within this document.

The availability of such examples of good practice within each country and Europe was a key target for the PRO-Heritage initiative, and the insular pockets of good practice can now be widely shared. This information will also form part of the wider training package available to Craftspeople from all relevant trades who are responsible for maintaining and 'upgrading' historic buildings.

4.2 Contact to the Coordinator`s Data Protect Officer

DPO Roland Lehner, cert, MHA/THA
Head of Construction Management II
Hofburg-Schweizerhof
A-1010 Vienna
Phone: +43 (1) 53649-814631
Mail: datenschutz@burghauptmannschaft.at

5. Acronyms and Terms (All)

BS............................ British Standards
Cert.......................... Certified
DoA .... Description of the Action
DPO.......................... Data Protection Officer
EU .... European Union
GW .... Author Gerald Wagenhofer
IoT .... Internet of Things
MHA .... Maintenance Manager for Heritage Asset
NHTG .... National Heritage Training Group
EPC .... Energy Performance Certificate
PAS .... Post-Approval Study
PIR .... Polyisocyanurate
QA .... Quality Assurance
RH .... Relative Humidity
RC .... Author Rory Cullen
STN .... Slovenská technická norma (Slovak Standards)
THA .... Trainer for Heritage Asset
WP........................... Work Packages

6. REFERENCES

All references are set out in the main body of the document, except:

Kovar & Partners for Bundesimmobiliengesellschaft (Federal estate company in Austria), Institut für den Wirtschaftsstandort Oberösterreich (Institute for Upper Austria as a Business Location), Österreichischer Burgenverein (Austrian Historic Houses Association) and Burghauptmannschaft Österreich (BHOe): *“Better Legal Framework for Architectural Monuments”*

7. APPENDICES

All relevant documents are included as links rather than as Appendices.