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Making deep renovation of historic buildings happen – learnings from the Historic Buildings Energy Retrofit Atlas

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Abstract. The energy refurbishment of historic buildings is necessary for many reasons, for the preservation and continued use of the buildings themselves, but also to achieve a very much needed reduction of GHG emissions. Good examples of such refurbishments show that the conflicting demands between respecting and protecting the heritage significance and achieving high levels of energy efficiency can be met. The case studies documented in the Historic Building Atlas HiBERatlas are used to examine which influencing factors are responsible for the success. This database is one of the main outcomes of the research projects Interreg AS ATLAS and IEA SHC Task 59 to provide a solid knowledge base on deep renovation of historic buildings and includes so far a broad range of about 50 different case studies published. The case studies presented here as examples were carried out under different framework conditions: as part of a research project, with public financial support or with a committed and experienced planning team operating in an integrated design process. It will be assessed how professional preliminary research, ambitious objectives, and the access to technical solutions can affect the results. Finally, the paper will highlight findings of post occupancy evaluations and lessons learned.

Keywords – Renovation, Historic Buildings, Energy Efficiency, Renewable Energy Systems, Integrated Planning

1. Introduction

The need to renovate historic buildings is still the subject of numerous debates, as there are fears of the loss of historic values due to the intervention and the danger is seen that the application of energetic measures will change the external appearance to such an extent that emotional access to the heritage is no longer possible. Yet it is precisely this kind of renovation that can lead to the preservation of historic buildings, in that the user comfort that is achieved allows them to continue to be used, and the reduction in energy costs makes the old building stand up better in competition with a new building. Furthermore, the need to integrate the historic building stock into a wave of renovation is undeniable [1]; after all, more than one quarter of all European buildings date from before 1950.[2] And even if not every monument can become an nZEB building, for most of the historic buildings a significant reduction in energy use is possible. The renovation of historic buildings, a highly diverse stock, faces various socio-technical barriers that are preventing the implementation of solutions already available.[3] Therefore, one need is the access to reliable information and heritage compatible technical solutions. The HiBERatlas (www.hiberatlas.com), available since 2019, is a dynamically growing repository of good practice examples for the energy-efficient renovation of historic buildings. The database is the result of a joint effort from the Interreg Alpine Space Project ATLAS (2018 – 2021) and the IEA-SHC Task59 (2017 – 2021).[4] During an initial development phase in the term of the research projects, more than 40 renovation examples have been documented and published by the ATLAS and Task59 partners - in close consultation with the respective architects and owners involved. In future, the platform will be open to anyone who would like to contribute with case studies. The case studies documented in detail come from different countries and belong to various building typologies. Large complex public renovation projects are the subject of the database as well as small private buildings. Information is provided about the architecture, heritage values, the aim of the retrofit, applied technical solutions, the use of renewable energies and a lot more. The documentation of the renovation projects is accompanied by an evaluation section informing about energy use, costs, internal climate, and environmental aspects. While the inclusion criteria for projects in the database are rather general, all documentation undergo a peer-review process to guarantee the quality of the documentation. Of the projects published to date in the HiBERatlas, those with listed status and those without legally binding protection are balanced. The sources of the projects are also quite diverse in origin; some have been the subject of pilot projects or R&D programs, others have already won awards for exemplary rehabilitation, or designers and owners have been interested in sharing the experience gained with others. In this way, a diverse picture of very different successful renovations has emerged, which can serve as a model for follow-up projects. The various aspects that define the success of the individual examples will be the subject of this paper.

2. Methods

In order to be able to draw some interim conclusions, the case studies that have been entered in the HiBERatlas so far have served as a basis for an analysis with regard to their evaluation as best practice examples. The focus is not only on energy efficiency or the conservation of the building fabric. Rather, the aim is to show that exemplary results can be achieved with an approach that takes all aspects into account from the very beginning. This is also in line with the recommendations of the EN16883 standard, the Guidelines for Improving the Energy Performance of Historic Buildings.[5] In this context, no energy efficiency target is proposed for the retrofit of historic buildings, but a procedure that is intended to produce an optimal result by taking all aspects into account. According to the project phases and framework conditions documented in the database, selected case studies from the HiBERatlas are used to show which aspects make each of them a "success story". Chronologically through the individual planning steps from the preliminary investigation, through the setting of objectives, the definition of the planning team and process, to the identification of solutions. Of particular interest is also the retrospective analysis of the renovation results. Renovation projects that have been able to achieve high savings and energy consumption even in the historic stock are highlighted. With the analysis of statements given by users and documented post-occupancy evaluations we assess the obtained living comfort satisfaction. Finally, the framework conditions which favour successful retrofit of historic buildings were examined as examples and their mechanisms of action are shown.

3. Results

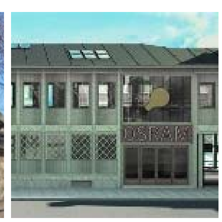
There is still too little data available for a statistical analysis, but the results of the spotlight analysis of existing case studies in the HiBERatlas outline a multitude of factors that can influence the success of a retrofit.

3.1. Pre assessment of case study: heritage value assessment

Any restoration work in historic buildings must be preceded by a historical study, a demand already known from the Venice Charter.[6] Also the process flow chart in the EN 16883 starts with a building survey. The data collected for the purpose of an energy efficient renovation, can be of a very different nature: descriptive heritage values, damage to the construction, materials used, building age determinations, hygrothermal parameters, to mention just some of them.[7] However, while the historical analysis of listed buildings is often financially supported or professionally accompanied by the heritage authorities, non-listed buildings cannot rely on such assistance.

For the protected buildings, a determination of the heritage values is obligatory anyway, however, the quality of the examination is crucial to the success of the measure. For the listed Freihof Sulz a detailed report by the heritage authority provides information about the values of the building and the elements to be preserved. Furthermore, because of the diverse historical findings, a very detailed inventory was carried out including a room-by-room survey. The documentation served as one of the

Table 1. Best practice examples from the HiBERATLAS referred to in this paper.[8]

Freihof Sulz/Austria is a listed building from the 18th century. With the renovation the well-preserved historic restaurant became a lively meeting place. It works as a demonstration object for local culture and quality of life, historic building techniques, as well as energy-saving and ecological renovation.			**Annat Road in Perth/UK is** a traditional building dating to 1927. The thermal upgrade included insulation of the walls, floor, and roof as well as better natural ventilation. The U-values of individual elements was improved considerably. It served as role model for further renovation of other buildings on the estate
House Pernter in Truden/Italy, built in 1923, was formerly used for agricultural purposes with residential house, stable and barn under one roof. The aim to optimize the energy balance, to use regional materials and to preserve the atmosphere of the building was reached with sensitive measures within a limited budget.			**Rebecco farm in Brescia/Italy** consists of two natural stone buil-dings, originally used as living house and stable. Both buildings were abandoned and partially ruined. Given its strategic position, the rural complex of 'Rebecco Farm' has been retrofitted and is used now as a B&B and an educational service.
Villa Castelli in Bellano/Italy is a listed building from the 19th century located at the riverside of Lake Como. It is family-owned for 140 years. The renovation achieved a 90% energy demand reduction and a significant increase in comfort.			**Knablhof in Mareit/Italy** is the former grocer's house with adjoining barn and stable. The building is one of the oldest houses in the village. Through a sensitive energetic renovation, it was made inhabitable again for a young family after being abandoned for 40 years.
Ansitz Kofler in Bolzano/Italy was built in the 18th century. The targets which the owner aimed for were the retrieval of lost orangery character and an advanced energy retrofit of the building. He showed that factor 10 reduction in energy demand is possible also in a listed building.			**Maison Rubens in Schaerbeek, Belgium,** not listed as monument, is part of a typical late 19th century perimeter block development. Since no major renovation has been done, the house was in bad conditions before the renovation.
Solar Silo in Basel/Switzerland is a former coal silo and heating plant of the Sulzer Burckhardt AG. The aim of the retrofit was to remodel the not listed building into office spaces with a maximum use of renewable energies, especially photovoltaic modules, which are implemented into the façade and the roof.			**Klostergebäude in Vienna/ Austria** is part of a listed ensemble from 1904 in Wilheminian style. The northern building was subject of renovation that aimed an energetic refurbishment of the existing building and the highly efficient loft conversion according to the requirements of the monument protection.
Hollyrood Park Lodge in Edinburgh, UK is a listed Victorian building built in 1857 in a neo-gothic style. Designed for the constables who policed the Royal Park, the lower floor today hosts visitor information. The aim of the retrofit was an adaptation to climate change, energy efficiency and management of damp.			**Osramhuset in Copenhagen/ Denmark** was originally built in 1953. The concrete structure was the first prefabricated building in the city. For the conversion of the former industrial building into a cultural centre, particular attention was paid to the use of daylight and natural ventilation to improve the indoor climate.

key elements in the integrated planning workshops. All stakeholders involved were aware of the valuable fabric which has also led to a change in thinking. "Up to thirty different companies involved in the construction were discussing and considering how to preserve as much as possible […].", remembers the owner. The success of the renovation is indicated by an individually adapted renovation concept for each room that considers the existing details.

For buildings that are not under protection, often the charm and character, and the identification with a regional building typology are considered in the description under “Heritage values”. A historic survey and the determination of the heritage values is mostly based on private commitment and sometimes supported by experts. Often details about the corresponding building typology is available, which serves well as a guide: for instance the Maison Rubens is a typical middle-class row house from late 19th century, and the Annat Road Building is a traditional building in Perth and forms part of an ensemble that is worth preserving as a whole. Especially in the latter case, the strength of a building typology approach becomes clear: once a good concept has been developed, it can be transferred to the corresponding group of buildings while adapting to the individual conditions.

3.2. Definition of the Aim

Dividing the design and construction process into several stages and milestones is a common approach in modern practice. A success story starts often, if not always, with a well-defined aim of the retrofit. For instance, the RIBA [9] dedicates stages 0 and 1 of their Plan of Work 2020 to “strategic definition” and “preparation and briefing” respectively, with a recommendation to include considerations about conservation in relation to the client requirements (“*e.g. minimising harm to historic fabric, preservation or conservation or bring into active use*” pp.42) already in Stage 0.

The HiBERatlas gathers some examples where the importance of these preliminary steps is highlighted. For instance, in the House Pernter the aim was to improve occupants’ comfort while maintaining the character of the building, heavily influenced by the rough vernacular external plaster. Thus, the use of regional materials was prioritised during the project resulting in a modern living space that recognises and highlights the value of the pre-existing. Renovation projects are seldom unidimensional and conflicting aspects drive the decision-making process. In the case of House Pernter, a working budget also defined in the early stages of the design process simplifying the decision making and ensuring a final result that met the initial requirements of the owner. For instance, the insulation of the external walls had to balance both aspects, conservation and cost. This led to a solution (insulation only of the most disadvantageous façade in terms of heat loss) that improved energy performance while minimising loss of character and total investment cost.

3.3. Collaborative planning process

The case studies documented in the HiBERatlas have been through very different planning processes. While some are based on the private commitment of individuals, others are the result of an integrative planning process involving all stakeholders. An example of such a process is the Freihof Sulz mentioned above, where the results of the extensive preliminary investigations formed the basis for the negotiation process between the stakeholders involved. This ensures that all arguments are heard and discussed with each other - as described in the EN 16883.

One of the examples following the EN 16883 is the Rebecco farm in Brescia/Italy. Already in the development of a long-term vision for the use of the building, the involvement of various stakeholders, such as farmers, trainers, small local - and extra-local innovators etc., has been worthwhile. The coordination among investors, heritage authorities, designers, energy experts, and the local community worked well during the decision-making process. Interviews and focus groups were used as exploratory tools to deepen the dialogue, engage the community and explore territorial assets.

3.4. Decision-making towards the identification of solutions

The use decision guidance tools (such as the Retrofit Guidance Wheel, proposed by STBA [10]), was rarely observed in the buildings documented in the HiBERatlas. However, the most common and successful approach for defining retrofit solutions is characterised by the interdisciplinary cooperation of all experts involved in the project. Retrofit measures are identified by repeatedly discussing the applicability and assessing the sustainability in terms of conservation, ecological, and economic efficiency. A key element of the decision-making process is the investigation of the suitability in terms of building physics and the validation about the accordance with the retrofit aims defined beforehand. Often this process is accompanied by appropriate assessment tools for energy calculation and hygrothermal simulation.

Depending on the renovation target, priority was given to highly efficient solutions or the smallest possible intervention in the substance.

3.4.1. The well-planned maximum variant

The retrofit project of Villa Castelli is characterized by a decision-making process that was supported by the cooperation and exchange of different experts (architect, energy consultant, conservator). This is particularly evident for the interior insulation, which required a detailed in-depth planning.

The ambitious energy saving targets, defined with the building owner at the beginning and assessed with energy demand calculations, required a holistic highly efficient solution for the building envelope and thus among others the use of 20 cm of interior insulation. Only then a U-value of 0,19W/m²K could be achieved to meet the criteria of the ClimaHouse R certification [11]. To avoid any condensation risk or moisture problem, extensive hygrothermal simulations were carried out. The moisture transport was simulated with WUFI. In addition, all nodes were designed and planned in detail with special attention to air tightness, vapor diffusion and convection and the solutions were assessed and verified with dynamic hygrothermal simulations in Delphin. The project shows that ambitious energy saving targets can also be achieved with respect for the heritage aspects and prevention of moisture related risks.

3.4.2. Well-considered repair measure

The owners of “Knablhof” chose a different approach aiming at persevering as much as possible the building fabric while making the building comfortable for a young family. The building should remain as “authentic as possible” and preserve its character. The building owner wanted to also implement some “modern elements” and use harmless materials. This resulted in very targeted, well-considered repair measures, developed in collaboration with the craftsman. Historic building components were restored in their functionality and enhanced also in terms of energy efficiency. One examples of the measures implemented is the refurbishment of the historic box-type windows, which could be largely preserved, only the single glazing was replaced by insulating glazing and a seal was applied on the inner window.

3.5. Post occupancy evaluation and feedback from users

Once implemented, the above-described measures have to demonstrate their performance in real life conditions – and a look back “ex-post” helps future implementations, both re-assuring that targets were reached with qualitative and quantitative assessments and pointing out possibly weak points. While comprehensive energy and comfort monitoring and POEs (post occupancy evaluations) are usually only available for renovations included in research projects in the case studies analysed in the HiBERatlas, a qualitative feedback from the occupants on the reached indoor climate is provided in the majority of cases, e.g. orally in interviews with building owners but also guests and tenants, thus not just those who had taken the decisions.

Actually, in most of the cases comments from users on the reached thermal comfort are recorded, in the big majority of cases underlining the improvement. With answers in around two thirds of the cases, indoor air quality seems to be a bit less immediate to be assessed by the occupants. Answers include both comments on the ventilation strategy, the deliberate decision for natural ventilation or the satisfaction with a controlled ventilation system, and in a few cases also issues like annoying noise but also awareness that manual ventilation is needed both for good air quality and to avoid mould. Answers on daylight and acoustic comfort are given in about half of the cases, the first sometimes mentioning that small windows limit of course the daylight but were characteristic elements of the building and how with slim frames the best was made out of it.

There are, however, also several cases with full POEs included in the HiBERatlas, the most comprehensive perhaps Ansitz Kofler (Italy), which embraces a monitoring of (i) energy consumption, (ii) indoor comfort and (iii) hygrothermal performance (of three kinds of insulation systems – interior with mineral wool, interior with wood fibre and exterior – as well as temperatures at thermal bridges). The latter confirms calculated values, both the calculated U-values and the moisture levels within the wall staying low enough. Indoor comfort was verified both for winter and summer conditions and the difference in energy consumption with around 50 kWh/m²a compared to calculated 30 kWh/m²a could be explained partly by tenants using the shading for privacy and thus reducing solar gains (showing that once the energy balance goes towards zero, the influence of user behavior becomes crucial). A higher energy consumption was also reported for Ryesgade 30 (Denmark), where the 83 kWh/m²a compared to expected 56 kWh/m²a were attributed to higher indoor temperature of 22-23°C (compared to 20°C as assumed) chosen by tenants, which results in 53% savings rather than 63% (also known as rebound effect). That the measured demand can, however, also be lower than calculated shows the Glaserhaus in Affoltern (Switzerland), where the consumption in the monitored period was actually 10% lower than expected.

3.6. Financing schemes to support the energy retrofit of historic buildings

In addition to the classic financial incentive models (tax reductions, subsidies, soft loans), interesting alternative approaches were recognised in the HiBERatlas case study screening, such as sponsoring by private companies and private investors. Furthermore, the public sector can have a significant impact as owner with implemented role model renovations and the development of innovative solutions also communicated to the public. In particular, national research programmes have proven successful that focus on the high-quality renovation of historic buildings and thus enable the implementation, but also the documentation and detailed monitoring of pilot case studies. In addition, in some countries national or regional authorities provide targeted financial incentives.

3.6.1. Public financing schemes and financial incentives

For Villa Castelli three different renovation scenarios were compared regarding their live cycle cost: the minimum option (6cm internal insulation), the base option (12cm insulation) and a renovation scenario towards nZEB (20cm insulation).[REF] Without considering any tax bonus, all three result in the same cost over the life cycle. Tax bonus, in this case the Italian Eco-bonus, brings advantage for both, the base case and the nZEB, while the minimum option could not profit from. The funding also reduces the payback times, which is even for the nZEB version shorter than for the minimum one. The Italian eco-bonus is an income tax reduction with variable rates ranging from 50% to 65% (up to 75% in the case of condominium works) for interventions aiming to improve the energy efficiency of buildings.[12]

Another project documented in the HiBERATLAS that was enabled via public funding is the Maison Rubens/Belgium. Here the owner received subsidies for the renovation within the program "low energy renovation premium" by Brussels Environment (~10% of total investment costs). In fact, the owners commissioned a planning office to check whether the limit value for this low energy bonus could be achieved. As a result of the planning process, the buildings energy performance is now 45 kWh/m²a, which is well below the required limit of 60 kWh/m²a.

3.6.2. Alternative financing approaches (private investors, PPP)

The former coal silo and heating plant Solar Silo in Basel/Switzerland provides an exceptional example of private investors getting involved into the transformation of an old industrial site into an area for cultural, social and commercial uses. After Kantensprung AG was able to attract private investors to contribute one-fifth of the purchase price for the site, the Abendrot Foundation used its network of contacts to convince two other institutional investors, the Social Fund Foundation and the Basel Pension Fund, as well as private investors, to join the project. Furthermore, the project was developed in close cooperation with the department for building conservation and with scientific partners.

3.6.3. R&D programs / Integration into research projects

The inclusion of projects in public funded research programmes not only enables the renovation of the project itself, but serves the purpose of quality assurance. Through the publicity of the case studies other projects can benefit directly from the results of the research work.

The case studies “Klostergebäude” and the residential building “Mariahilferstraße” in Vienna/Austria benefited a lot from being part of the Austrian R&D programme “City of the Future” (managed by the Ministry for Climate Action). Due to the funding, it was possible not only to set up a clear renovation strategy and detailed renovation concept based on a sound analysis of the buildings but also to establish a detailed monitoring as part of the full documentation. The Austrian R&D programme “City of the future” created since its launch in 1999 not only about 75 demonstration projects, many of them with focus on renovation of existing buildings, but also an innovation friendly environment for architects, planners, real estate owners and buildings technology providers.[13]

Another public funded program in Austria is the “Mustersanierung” run by the Austrian Climate and Energy Fund which supports the deep renovation of non-residential buildings focussing more on the market uptake. This programme was launched in 2008, and since then about 90 renovation projects have been realized and documented. One of these examples documented in the HiBERATLAS is the former fire station in Velden/Carinthia, which was transformed into a music school. The “Mustersanierung” program [14] has shown that it can provide very effective incentives, especially in the public sector (municipalities, cities), if promoted by committed and competent architects and engineers.

3.6.4. Support at local and municipal level

The role of city administrations becomes a crucial one for the renovation of (well-known) public buildings or buildings located in a prominent urban environment. Furthermore, with the designation of redevelopment areas, local authorities have an instrument to promote renovations on a large scale.

The OSRAM building in Copenhagen/Denmark is a good example to demonstrate the positive effect of cities´ engagement. The project was intended to minimise the need of resources for both the renovation and the maintenance of the building. In connection with the Climate Change Conference (COP 15, 2009) the City of Copenhagen initiated a strategic cooperation with several Danish enterprises for the purpose of mutual profiling on climate-friendly buildings. The renovation of the OSRAM Culture Centre was a part of this cooperation and acted as role model for the conversion of old industrial buildings worth preserving. The project received public funding from several institutions and initiatives.

In the case of the Hollyrood Park Lodge, it was Historic Environment Scotland and the City of Edinburgh that emphasised the exploitation of the results achieved and thus a sustainable investment beyond the individual building. The measures taken, have been made visible to visitors using inspection panels. The exhibition, but also the building itself, demonstrate that a listed building can be thermally upgraded in a sensitive and proportionate way, yet respecting the existing historic fabric. As it is an accessible site, it has been effective in allowing people to view the measures and understand what can be done in other traditional buildings.

4. Discussion and conclusion

It remains to be clarified which of the above-mentioned aspects are responsible for the designation as a "success story". The success achieved is just as varied: in one case, this consists of saving the building by enabling a suitable use, another is characterised by overcoming difficult technical problems, while others show an exemplary energy balance.

The analysis of the examples has shown that especially the framework conditions - i.e. the available financial means, the integration into research projects or the public support through advisory services - have a considerable influence on the objective of the project. Several case studies in HiBERATLAS have been implemented as part of a research project or a national research programme, thus providing additional expertise and resources, e.g. a detailed building survey and evaluation of the historical value of the building, an integrated planning process right from the start, life cycle cost analysis, detailed monitoring of energy flows, comfort parameters and costs during operation of the building and user surveys (POE). For the selection of the technical solutions, the screening of the case studies shows that automated decision guidance tools are rarely used. The selection of solutions is still mostly based on the experience of designers and engineers or supported by consultants. The most common approach is the decision making within an integrated design process accompanied by the use of assessment tools for hygrothermal simulation and energy calculation. Complex refurbishment projects can only be realized with an ambitious planning team and an open-minded client. Continuous coordination between an experienced designer/engineer and the heritage authority is necessary. The latter also applies to private owners - the small projects, where cooperation with the authorities has worked well, have been able to benefit from this.

The public sector plays an important role in facilitating innovative projects but also in ensuring the transfer of knowledge, whether within research programmes or via advisory services.

In many of the examples we can observe the interaction and overlapping of several favourable framework conditions: e.g. the involvement in a research project that goes hand in hand with financial support for innovative measures and where at the same time a committed and experienced planning team works together from the very beginning of the process. Some of the framework conditions determined in the case studies have considerable potential for transferability. However, it has been shown that good examples are not only dependent on a well-funded budget, but that with appropriate planning, showcase solutions can also be achieved with a limited budget. And sometimes it is exactly this kind of action within a defined framework that can serve as a role model for other projects.

In the end, it is important that the experiences gained are well documented and passed on to the next ones, that the success stories are told.

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