SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Planning energy retrofits of historic buildings

EN16883:2017 in practice

IEA SHC TASK 59 | EBC Annex 76
Renovating Historic Buildings Towards Zero Energy

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EN16883:2017 in practice

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IEA SHC Task 59 | EBC Annex 76: Deep renovation of historic buildings towards lowest possible energy demand and CO_2 emission (NZEB)

Solar Heating and Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency.

Our mission is *"Through multi-disciplinary international collaborative research and knowledge exchange, as well as market and policy recommendations, the IEA SHC will work to increase the deployment rate of solar heating and cooling systems by breaking down the technical and non-technical barriers."*

IEA SHC members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling.

Our focus areas, with the associated Tasks in parenthesis, include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54)
- Solar Cooling (Tasks 25, 38, 48, 53, 65)
- Solar Heat for Industrial and Agricultural Processes (Tasks 29, 33, 49, 62, 64)
- Solar District Heating (Tasks 7, 45, 55)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58, 67)

In addition to our Task work, other activities of the IEA SHC include our:

- SHC Solar Academy
- *Solar Heat Worldwide*, annual statics report
- SHC International Conference

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Energy in Buildings and Communities Technology Collaboration Programme (IEA EBC)

To reach the objectives of SHC Task 59 the IEA SHC implementing Agreement has collaborated with the IEA EBC Implementing Agreement at a "Medium Level Collaboration", and with the IEA PVPS Implementing Agreement at a "Minimum Level Collaboration" as outlined in the SHC Implementing Agreement's Policy on Collaboration

Contents

This handbook follows the systematic approach outlined by the European standard EN 16883:2017 *Guidelines for improving the energy performance of historic buildings*. It describes how the standard can be applied in practice with chapters on heritage value assessment, building survey and holistic assessment of energy efficiency measures. The book draws on the experience from a team of international leading experts in the field of energy efficiency in historic buildings.

The intended audience for the handbook is professionals working with the refurbishment of existing buildings: architects, engineers, heritage consultants, building surveyors and professional property owners. It points at the possibilities to lower the energy use in existing buildings without compromising their heritage values, and provides practical guidance on how to identify, assess and select energy retrofit measures through a multidisciplinary planning process.

Throughout the book you will follow case studies that illustrate how the different stages of the planning process can be carried out in practice. The text is accompanied by best practice examples, illustrations and links to written and online resources.

HIBERTOOL BEST PRACTICE EXAMPLE [LINK]

An innovative aerogel-based wallpaper

Author: Sara Mauri

The solution is a super-insulating aerogel-based textile wall-paper that can be installed on the inner side of perimeter walls. The innovative wallpaper is based on two completely independent layers with an air gap of about 2 mm in between, combining properties of advanced technical textiles and high-performance insulating materials in few mm of thickness. As a matter of fact, the system is composed of a layer made of a porous, flexible support impregnated with silica aerogel glued to the existing wall, forming the insulating core, and a finishing textile layer. The latter can be easily installed and replaced thanks to a simple tensioning device, consisting of a system of plastic zips fixed to the wall on one side and then connected to the finishing layer on the other side. The top connection, fixed to the wall with nails and/or glue, is based on a PVC strip carrying a plastic zip with a slider on one edge. At the bottom of the wall, the plastic zips are applied on the finishing textile by means of a thermoadhesive tape that is ironed on the fabric.

The wallpaper system was developed as part of the European project EASEE (Envelope Approach to improve Sustainability and Energy efficiency in Existing multi-storey multi-owner residential buildings). Although this research project did not consider historical buildings, the system characteristics of easy assemblage/dismounting for periodic use, flexibility, reversibility, not destructiveness, lightness, small thickness, also meet the requirements of the intervention of historic buildings. This textile wallpaper represents a technologically improving of a tapestry, a solution coming from the past traditionally used to mitigate the effects of the lower wall temperatures. The improvement due to the textile is valuable, considering the amount of square meters that could reduce the thermal exchange with the colder surface underneath. Therefore, the new wallpaper system decreases the surface temperatures with the advantage to avoid any permanent, invasive, destructive, irreversible intervention. The thermal performances of the new textile wallpaper were compared to other two internal thermal insulation systems, traditional in terms of installation process: they are wet assembled, thicker than the new textile wallpaper, not reversible (advanced insulated perlite board; Laminated panel composed of silica aerogel impregnated unwoven fibrous blankets fixed to a rigid support). The results of the tests showed that the performances of the textile wallpaper are comparable with the one of the interior traditional insulation. As a matter of fact, the insulating layer that composed the system presents the following thermal behaviour: average thermal resistance R = 0.125m2K/W; thermal conductivity λ = 0.036W/mK. Moreover, the solution was defined “permeable insulating wallpaper” because it is open to water vapour diffusion, a crucial aspect from the point of view of building physics.

The chosen test wall for the installation of this inner retrofitting system is part of an eight-storey building called “La Nave” (building n°14), situated at the Leonardo University Campus of Politecnico di Milano. The building was designed by Gio Ponti, a famous architect active from the Twenties to the Seventies, and hosts classrooms and teachers’ offices. It was built in 1965 and classified as Cultural Heritage in 2007. “La Nave” is composed of a concrete and steel structure and the façade is an unventilated cavity wall. The latter, from outside to inside, is composed of: vitrified grey ceramic tiles (dimensions: 15 x 7,5 x 0,7 cm), cement base render (2,5 cm), first layer of hollow bricks (12 cm thick), an unventilated air cavity (34,5 cm thick), second layer of hollow bricks (8 cm thick) and internal cement lime based plaster with gypsum finishing (1,5 cm). The whole thickness of the wall before retrofit is 59.2 cm. It represents the typical massive construction with a low level of thermal insulation as many constructions of that time. The portion of the wall retrofitted is placed at the second floor, South-East and South-West oriented and belong to a meeting/teaching room. The inner surface covered by the wallpaper system is 3,37 m2, with a 7 mm thickness. The insulation layer was glued to the existing wall with a breathable mineral mortar and the finishing layer was the applied in front of the insulation with a bespoken tensioning system.

PROS:

- Low thermal conductivity (λ= 0.036W/mK);
- Thin and lightweight solution
- Controlled fire behaviour
- Water vapour permeability
- Mitigates the effect of the cold surface of the wall
- Ease of transportation and storage
- Ease of installation because all the assembly operations can be performed with common tools (scissors, cutter, hammer and flatiron)
- Insulation layer glued to the existing wall like a standard wallpaper
- Finishing layer completely dry-assembled and removable for any reason (like washing, substituting a failing element, improving the performances or simply changing the appearance of the wall)
- Geometrical adaptability which allows the application on (not always planar) existing walls, following their forms also in correspondence of the corners, thanks to the physical flexibility of all the components.

CONS:

- Applicable only as indoor insulation solution
- Potential thermal bridging and condensation issues
- The use in historic buildings may be restricted due to existing important decorations (i.e. wall paintings)
- High costs of the aerogel material.

5.3 Assessment of measures

The assessment of energy efficiency measures is the most crucial step in the whole planning process, and all the preceding steps underpin and inform the assessment carried out here. The amount of work put into this step will vary with each project. Assessments made in some high-profile projects will resemble or be part of research projects. Smaller projects might use heuristics or back-of-the-envelope calculations. However, too complex or too simplified assessments should be avoided: the requirements, resources and ambitions with the project should determine the level of sophistication.

The basic principle for the assessment is to evaluate the impact of single measures, then combine measures into packages, and finally assess the packages. It is important to understand that the assessment is an *input* to the decision-making process, it is not a mechanical way of prioritizing among different measures.

The assessments should be guided by the objectives of the individual project. Legal requirements should of course always be fulfilled. Essentially, the assessment is a risk and benefit analysis. An energy efficiency measure might cause risks related to the technical compatibility, such as increased risk for mould growth. It might also cause risks related to the heritage significance, such as when a historic window is replaced with a replica. All measures will require an investment cost. On the other side of the equation there are different kinds of benefits, such as improved use, lowered environmental impact or lowered running costs.

A convenient way to perform the assessment is to use a spreadsheet with all the individual measures from the short lista and all the assessment criteria. A traffic light system (red, yellow, green) can be used for all the criteria, but quantitative values should also be used when possible (see an example in the library case study).

LIBRARY – SELECTING MEASURES 2

About a month later, the group gathers again to do a holistic assessment of the measures, now backed up with calculated estimates on energy savings and costs, as well as an moisture risk analysis related to the internal insulation. An assessment table is used where a number from 1 to 5 is jointly decided for each criteria. 1 is worst, meaning unacceptable (no benefit/high risk), and 5 is best (no risk/high benefit). In addition to the table, there is also a calculation of the total energy savings and cost for a number of packages of measures.

There are a number of measures which all have low risk and low to high benefit. These are easily distinguished as appropriate. The same is true for a few measures with high risk, either in terms of technical risk or threatening heritage values. The delicate question for the planning team is what to do with the measures in-between, with some risk but also high benefit. There is also a matter of cost. The budget for the project is not yet finally decided.

The meeting ends with a few unresolved issues: Is it possible to exchange some of the windows that are not original? (a dialogue with the heritage authorities is needed), is there enough funding to install the relatively expensive internal insulation system? (a dialogue with the politicians is needed). The intended used as office space for some rooms facing south will lead to problems with overheating, how to deal with that? (a revision of the objectives is needed).

After a few weeks of more meetings and revisions of the original objectives, the planning group can finally agree on a package of energy efficiency measures to be integrated into the refurbishment of the building. The process of getting building consent turns out to be straightforward, thanks to the thorough work based on a detailed multidisciplinary understanding of the building and its use, the well motivated suggestions and the early collaboration with the heritage authorities.

5.4 Combining multiple measures

There will generally be several measures implemented in the building at the same time. It is therefore important to consider how combinations of individual measures affect the assessment. Synergies of packages are mainly related to energy use and indoor climate, LCA and LCC. The energy savings or costs of measures to the building envelope, heating system, ventilation system and use of the building cannot just be added.

A common example is that changing the heat source might affect the cost-effectiveness of measures to the building envelope. Using solar heating or geothermal heat pumps will lower the running costs and make insulation measures less cost-effective. Another common example is that a changed use of the building might affect the indoor temperature, and in turn the estimated savings from other energy efficiency measures.

Packages of measures can be “optimised” from a techno-economic point of view using LCC or LCA. These packages need to be assessed in relation to other objectives, such as heritage value, in a final holistic assessment. Examples of how this can be carried out both at the district and the indidvual level is shown below.

CASE STUDY ON THE OPTIMISATION OF PACKAGES

This section exemplifies the aforementioned approach and discussion in the case of a one family, wooden building from the late 19th century in the Swedish capital of Stockholm. It is not formally protected which means that there is a wide room for negotiation on what type of measures that can be accepted. The Swedish Planning and Building Act mandates, without specifications, that renovations in all buildings, no exceptions, should be carried out carefully with respect to the heritage values.

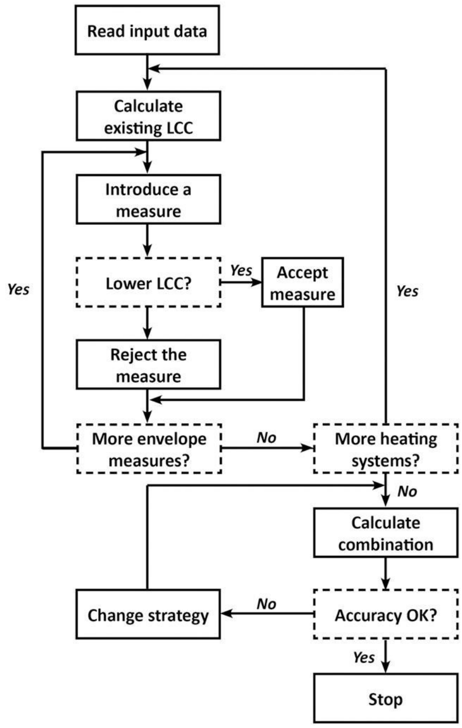
In this case study the energy savings targets used were 20 % and 50 %, corresponding to different targets used in EU and Sweden (Broström et al., 2014)

Based on a gross list of the most common energy efficiency measures in Sweden, a first assessment was made of risks and benefits in relation to the particular building. This step was mainly meant to exclude inappropriate measures and to define a range of acceptable measures. The assessment was carried out by a multidisciplinary group of experts. Based on existing knowledge and experience each measure was assessed with respect to energy savings, economic return, impact on heritage values, durability, moisture risk and effect on the indoor environment.

In the next step, a more detailed assessment was made on a short list of measures. The basic tool for selecting measures was a program for life cycle cost (LCC) optimisation (Liu, Rohdin, & Moshfegh, 2018). Using a database with costs and technical specifications for different measures, the program defines a combination of measures that would give the lowest life cycle cost.

The LCC optimisation resulted in the combination of measures that would achieve the given targets at the lowest LCC. The 20 % target could be reached with measures that had little or none effect on heritage values such as weather stripping, heat pumps and attic insulation. In this case LCC was reduced by 15 % (Broström et al., 2014).

In order to reach the national 50 % target, exterior wall insulation and window replacement was necessary, in addition to less intrusive measures. In this case, LCC was reduced by 23 %. If the exterior insulation and window replacement are excluded in the LCC optimisation, the energy saving would be reduced to 29 % and LCC would be reduced by 16 % (Broström et al., 2014).



The results illustrate how the method can be used to assess the consequences of polices and plans related to energy efficiency. For this particular building it could be shown that the European 20 % target can be reached without problems. But the more ambitious national target (50 %) would necessitate measures, such as external insulation and window retrofits, that would change the visual and material character of the building significantly.

The above method allows for an interaction between the quantitative assessment of the techno-economic optimisation and the qualitative assessment of impact on heritage values. Through a multidisciplinary dialogue, stakeholders and experts can arrive at a solution that balances energy conservation and building conservation for a given building. This approach can be used to assess the consequences of national targets for energy savings and let stakeholders and experts, through further iterations, decide on an appropriate level of energy saving in relation to the impact on heritage values.

5.5 Decision or iteration?

When the assessment of individual measures (or packages of measures) is finished, it is time to make a decision. The assessment process should not be understood as a mechanical device that provides an optimised solution. Rather, its purpose is to support decision makers to make a well-balanced and informed decision.

Energy efficiency measures with high risks (either technical risks or risks to the heritage values) should generally be avoided. Measures with no risk and some benefit should generally be implemented. The difficult question is to decide on measures that potentially imply some risk, but also have high benefit.

THE FARMHOUSE: SELECTING MEASURES

Andrea uses her professional network to involve an energy expert in the process to select energy efficiency measures. As a basis they have the previously issued energy certificate. Together they discuss previous projects and consult online resources to get inspiration for new and innovative solutions. Based on their discussion the make a long list of possible measures. Some utopian measures are discarded. A discussion with the owners results in an even shorter list. The resulting measures are then assessed in detail.

The energy expert calculates energy savings and costs for the various measures, and Andrea uses a simple list of pros and cons regarding the other critera. After a dialogue with the owners it is realised that all of the initial objectives cannot be met at the same time. The owners have to accept that the implementation of the project will be more costly than their budget. On the other hand, there will be a lower running cost. After discussions with the bank they are granted a bigger loan and they can finally select a package of energy efficiency measures. Given that no big external alterations will be made to the exterior, they are also quickly given building consent and the implementation phase can begin.

In some occasions, it will not be possible to identify any acceptable measures. No options will fulfil the objectives. Then a decision has to made if an iteration in the decision process is necessary. For example: is there a need to revise the objectives? Is there a need to make a more detailed analysis of some aspect? There is nothing wrong with a decision process that takes two steps forward and one step backward, as long as the final outcome is a good one. The other option is to conclude that no acceptable energy efficiency measures were possible to identify. Remember that doing nothing in this case is not to be considered failure, but in fact the best decision based on the particular circumstances.

Further reading for selecting measures

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