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SBE Series

SBE21
Sustainable Built Heritage

14-16 April 2021,
Online conference

DRAFT PAPER

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Prioritize the right energy measures in historic buildings – approach and measure selection

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Abstract. The overall energy goals mean that more and more extensive measures need to be applied on buildings with varying degrees of heritage value. Previous studies show that there are a number of measures that have a beneficial impact on different parts of the energy system in historic buildings. What is now needed is a holistic approach that provides an opportunity to prioritize which measures are most important and should be combined. An ongoing research project is working on a method that will enable the reduction of energy and power needs for historic buildings on a larger scale by allowing different actors to choose optimal combinations of measures out of a number of important parameters. This paper identifies such parameters, as well as five cases for a future case study on combined measures. The effect of the implementation of various measures regarding both energy and power will be reviewed and interviews will be conducted with owners and managers of buildings to gather their quantitative and qualitative experiences regarding such measures. Finally, the most relevant energy measures are listed for further analysis in future simulation studies.

Keywords – Combined measures, energy power, LCA, LCC, heritage value

1. Introduction

During a number of years, the Swedish Energy Agency has invested in the research program “Spara och Bevara” (Save and Preserve), which aims to develop and disseminate knowledge and technology solutions that contribute to reducing the energy use of historic buildings, without destroying or distorting the buildings’ historical and heritage values and features. At the same time, the energy and climate goals in Sweden, and internationally, brings forward the need of making buildings more energy efficient. With regard to such goals, existing buildings constitute a good target for energy renovation measures, since three quarters of the entire heated floor area in the Swedish building stock is older than 30 years [1]. When it comes to historic buildings that are protected, demolition is not an alternative at all.

Although individual energy measures are beneficial, they are insufficient for achieving a reduction in the energy use of heritage buildings that fulfils modern requirements. The benefits of any measure must also be weighed against possible risks and disadvantages, not least in terms of heritage value, but also in terms of indoor environment and moisture safety. Through, for example, the Swedish Energy Agency's program “Spara och Bevara”, there are many results from projects that address energy savings in historic historical buildings, while at the same time preserving aspects of heritage value [2]. Through this program, some measures have been tested, evaluated and been in operation for several years [3]. In the strive to achieve the overall energy and climate goals, more comprehensive measures need to be

applied on the existing building stock, which includes buildings with varying degrees of heritage value. Previous studies show that there are a number of measures that have a beneficial impact on different parts of the energy system in historic buildings. What is now needed is a holistic approach that aids in the prioritization of the most beneficial and important measures, while protecting the buildings' heritage values. Such an approach should provide an opportunity to choose which energy efficiency measures to combine, but also consider the impact that the measures have on other important aspects, such as the indoor environmental quality, the moisture safety, the environmental impact, and, most importantly, the cultural values.

Results from individual projects are valuable and useful, but in order to progress with the improvement of the building stock, a synthesis of the results from several projects is needed. The Swedish Energy Agency's research program “Spara och Bevara” has almost 700 publications on its website. Within the SIRen (*Sustainable integrated renovation*) network, a strong research environment supported by FORMAS [4], about 200 articles and almost 100 degree-projects have been published. Various measures have been investigated within “Spara och Bevara” and in other contexts concern, such as additional insulation on the building envelope, energy-efficient lighting, airtightness measures, ventilation measures, ventilation with heat recovery, updated windows, better operation of systems, reducing use of building electricity, business electricity and household electricity, reducing hot water use, advanced heat management, power management, energy efficient dehumidification, heating cable in roof drainage systems, LED lighting in heritage environments and much more [3,5-14]. The work that has taken place in Sweden, both in the project “Spara och Bevara” and in the SIRen network, has included both academia and industry partners. However, there is now a need for a project that examines how the results from different projects on measures that have been implemented can be used in different combinations, in order to identify optimal renovation packages for the promotion of energy efficiency in historic buildings.

When striving to achieve major energy savings in heritage buildings, there are many risks that need to be considered with regard to the preservation of heritage values. Legislation that aim to protect the values of the buildings need to be considered, together with the impact that measures have on the indoor environmental quality and the moisture safety in the building. Besides mandatory laws and authorities' regulations that must be followed, authorities' provide general recommendations regarding the application of the regulations. With regard to the protection of heritage values, the Planning and Building Act (PBL) has two central sections: 1) The prohibition on distortion: (Chapter 8, Section 13) "A building that is particularly valuable from a historical, heritage-historical, environmental or artistic point of view may not be distorted", and 2) the precautionary requirement (Chapter 8, Section 17): "Modification of a building shall be carried out carefully so that the building's characteristics are taken into account and the building's technical, historical, heritage-historical, environmental and artistic values are taken into account.". In addition, renovations must consider 3) rules on air quality in the National Board of Housing, Building and Planning's building regulations (BBR), 4) the Swedish Work Environment Authority's regulations, and 5) the Swedish Public Health Agency's regulations. Due to these possibly conflicting regulations, those who own or manage historic buildings are therefore often faced with difficulties when considering various measures for energy efficiency and improvement of the indoor environment. A holistic approach should therefore consider different goal indicators that reflect and describe the different important functions of a building.

The aim of this paper is to define important characteristics and goal indicators to enable the choice of cases and measures for a future case study on combined energy measures in protected historic buildings, taking into consideration the transdisciplinary problem of different demands on historic buildings. The setup for the simulations will be presented, though it is a matter of future research to perform them. Due to the length and the limitation of this paper, a comprehensive literature study is not the focus of this paper.

2. Method

This paper provides an introduction to a broader research project that has the scope to define possible measures that can be combined and a method that can be used for analysing them with respect to different goal indicators. However, actual simulations and analysis is a matter of future research. The approach is directed towards the Swedish context and sector to make the results as useful as possible for the Swedish society as well as abiding Swedish legislation.

2.1. Choice of generic building types

By using generic building types, the aim is to make the future simulation results as general as possible and to still be able to refer to actual examples. The research group selected generic building types based on their experience from earlier projects [3,4].

2.2. Choice of goal indicators

In any optimization process there is a need for goal indicators, one or many. Goal indicators should reflect important functions of a building connected to the use and management of a building. Based on common functional goals found by the SIRen project [4] and goals used in the HVAC industry [15], the research group defined goals within an open workshop with professionals from the industry. The workshop was held on Zoom due to the Covid-19 outbreak.

2.3. Choice of measures

To make the approach of combining measures applicable for a building sector that deals with protected historic buildings, measures proposed in this paper were suggested at the aforementioned workshop, in which the participants could define different reasonable measures for each of the type buildings. During the workshop, the participants were split into different groups discussing one of the five type buildings based on the participants' area of expertise in their daily work. The idea was to point out possible measures for two different goals: 1) a small energy reduction based on 'Small' measures in order to mitigate specific issues with the buildings, and 2) a large energy reduction based on 'Large' measures for achieving net zero energy use. The following questions were asked to each participant:

- What are the boundaries of the specific type building?
- What measures are needed to achieve a lower energy use?
- What measures are needed to achieve net zero energy use?
- Consider the advantages and disadvantages of the different measures with respect to
    - Applicability and feasibility
    - Protection of heritage value
    - Energy, LCC and LCA
    - Indoor environment
    - Moisture safety
    - Maintenance

3. Results

3.1. Choice of generic building types

Before the workshop, the project research group defined 5 generic building types to be analysed regarding different energy measures together with what the project group considers to be typical status scenarios for the included buildings. The limited amount of five generic building types, makes it possible to conduct future simulations on a number of combined measures without being too extensive. There exists a number of generic building types that are considered to be culturally valuable, which includes special buildings like castles and old churches etc. However, these do not constitute the majority of heritage buildings in Sweden, and it is more common to find heritage buildings of a simpler type, such as multifamily buildings. For the aim of the project, the research group identified the generic building types listed in Table 1. While choosing the included buildings, the research group strived to include a variation of different building technologies, building ages and uses of buildings.

Type 5, a huge apartment block from the late 1960:ies, is very common in Sweden. One million dwelling units where built during a short period of time, and type 5 is a common archetype of those. Lately, these buildings have started to gain heritage value even if they might be considered relatively new. Type 1, the theater building, represents an official building used only intermittently. Type 2, the railway station is an official building which in this scenario will be transformed into an office building, which is a common action taken on old buildings with heritage value that have become obsolete regarding their initial purpose. Type 3 is an older apartment block while type 4 is a single family house. Figures 1-5 shows examples of these 5 buildings.

Table 1. The resulting 5 generic building types, together with typical scenarios of status.

Type	Description of type and typical status scenario
1	A theater in a medium-sized Swedish city. The theater was built in the 1890s in the style of the New Renaissance. Now the ventilation is judged to be substandard and this initiates that a renovation is needed.
2	A railway station built around 1860 in manor style. The building will now be renovated to house a new office.
3	A 3-storey slatted house in folk home style. The house was built around 1950. The status of windows and facade means that the house now needs to be renovated.
4	An Art Nouveau villa built in the 1910s. Now the villa needs to be renovated due to the status of both the roof and windows.
5	A high-rise building built under the million program. Now the trunks and surface layers are worn out and a renovation is needed.

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Figure 1 and 2. Type 1 and 2, a theatre building and a railway station.


Figure 3 and 4. Type 3 and 4, a three storey apartment block and a single family detached house.

3.2. Choice of goal indicators

The SIRen project formed a matrix of all process steps in a renovation process on one axis and all involved actors on the other axis. The third dimension is located inside each column and describes all actions that may take place [4]. Based on those possible parameters, the following list of goal indicators was specified to be included in this project, together with some considerations:

Figure 5. Type 5, a high rise apartment block.

- Practical applicability – It is important that the sector is able to apply the proposed combinations of measures. Thus, the sector needs to be part in specifying the possible measures.
- Energy use – This is both a cost for the building owner and a goal for the society as whole.
- Power – High power demand makes it difficult for the society to become fossil fuel free.
- Initial cost – In all possible renovation situations, there is a need to finance the initial cost of the renovation.
- LCC – Life Cycle Cost, is a crucial choice criterion for the sector.
- LCA – Life Cycle Assessment, considers embodied energy and resources.
- Indoor environment – The buildings' most crucial outcome must be taken into account to avoid buildings that are not useful.
- Moisture safety – Energy measures, inside the building or its envelope usually influence the moisture safety, and in case of high damage risks the renovation cannot take place.
- Heritage value – This is the most specific parameter for this project focusing on buildings with heritage values.

3.3. Measure selection

The measure selection was based on the aforementioned workshop, which included 17 stakeholders and actors connected to owning, managing or consulting on protected historic buildings. The measures selected for further analyses were proposed by the participants. General comments for some of the measures are that ventilation measures as well as insulation measures are very depending on the possibility in the actual case. Maintenance and technical management measures were emphasised as they can be non-intruding to implement. The participants also proposed the lowering of ventilation airflow, and avoidance of heat recovery systems even if it may influence the indoor environmental quality. Demand controlled ventilation was only pointed out as a measure for the small apartment block (Type 3) and the theatre (Type 1). A change of windows was proposed for the large apartment block (Type 5). A common suggestion in the open workshop was to not change the use of an old building in an unreasonable way.

3.4. Goal combination procedure

In order to evaluate different combinations of measures for the different generic building types, the research group formed the procedure seen in Figure 6.

Table 2. Results from the open workshop with 17 participants involved in protected historic buildings from the building sector. 'Small' means that the measure was meant to lower the energy use with a small amount while simultaneously mitigating the mentioned issues with each building. 'Large' was meant to lower the energy use to come close to a net zero energy building.

	Measure	System	Type 1	Type 2	Type 3	Type 4	Type 5
			Theater 1890	Railway station 1860	Three storey apart-ment block 1950	A detached singel famlily house 1910	High rise apart-ment block 1970
1	Heat recovery from exhuast ventilation	HVAC	Small		Small		Small
2	Heat recovery from balanced ventilation	HVAC	Small		Small		Small
3	Supply air from ground duct	HVAC				Small	Small
4	Change from 1 to 2 pipe heating system	Services					Small
5	Better balancing and managament of heating system	HVAC			Both		Large
6	Annual ventilation flow variation	HVAC					Large
7	Demand controlled ventilation	HVAC	Small		Small		
8	Advanced heating control	HVAC			Small		
9	Seewage heat recovery	Services			Small		
10	Heating supply pipes renovation	Services			Small		
11	Added indoor insulation	Envelope	Small		Small		Small
12	Leakage proving the facade	Envelope					Small
13	Change windows	Envelope					Both
14	Remove leaks from the facade	Envelope					Both
15	Renovation of indoor building services	Envelope		Large			
16	Renovation of windows	Envelope	Small		Both	Both	
17	Added attic insulation	Envelope		Small	Small		
18	Added outdoor facade insulation	Envelope		Small			
19	Education of management staff	Other	Small		Both		
20	PV on roof	Supply	Small	Small	Small	Small	
21	Blinds	Supply		Small			
22	Ground source heat pump	Supply		Small			

Based on the widespread findings of the proposed measures from the open workshop with the building sector, it is probable that more combinations than the proposed ones should be tested for other building types. A number of goal indicators can be quantitative or be given a quantitative value, but particularly the heritage value must be added as a qualitative input to the analysis, and it is important to be transparent with weighting procedures in the future.

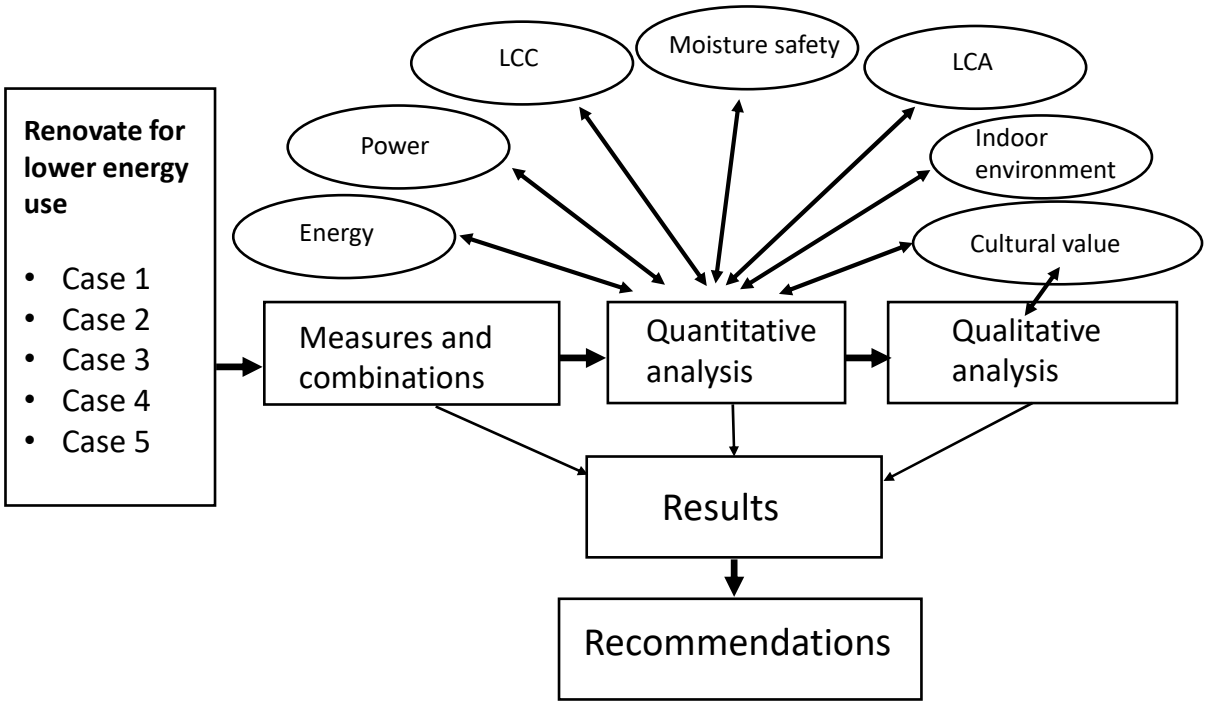

Figure 6. An outline of the future procedure to investigate the defined measures and the combinations of those. Both quantities and qualitative analysis is needed to weight different goal indicators together.

4. Discussion

To be able to continue with future research on combinations of energy measures for buildings with heritage value, a starting point has been to define what generic building types to investigate, what parameters to use in an optimization goal and what measures are preferred by the building sector involved in historic buildings. This paper presents the result to specify typical cases to analyze (e.g. trough building performance simulations), functional parameters to use as optimization goal indicators, and applicable measures to combine in the typical cases respectively. The measures, specified by the building sector, ranges from education and smaller maintenance and technical management measures to more extensive renovation measures on the building envelope including its windows and the building services and HVAC system including in particular ventilation and heating systems. Both heat transmission, leakage, ventilation losses, equipment and lighting electricity and the energy supply system has been mentioned but for different buildings.

Based on the widespread suggestions of the workshop group, we establish two hypotheses. One is that the end result in the future will be a method to find suggestions for the most optimal combination of measures and not a direct solution that fits every situation in a certain building type. The other is that more combinations of measures probably applies to all or several of the different generic building types, but the participants of the workshop were often focused on one building type. The resulting difference between the five different generic building types shown in Table 2 may be a result from different experiences more than a limitation to what can be used for a certain building.

The goal indicators and the weighting of them is an important task for the future. In some cases it may be logically necessary to reach a certain level of a certain parameter while for other parameters, a

continuous description with weighting factors can be used. Also for this procedure, it may be important to involve the building sector. Another question connected to the weighting may be the limitations on how to use old buildings and if it is impossible to fulfil several necessary demands at the same time. The starting point on how to determine generic building types, goal indicators and relevant measures has been based on ideas from Swedish projects and the Swedish building sector. Still many countries, particularly with an outdoor climate generating a general heating need, should have the same issues, and they have in many cases the same heritage restrictions.

5. Conclusions

To be able to recommend proper, and in the best case optimal, combinations of energy measures for historic buildings, generic building types a set of goal indicators and a number of certain energy measures have been determined for future simulations and analyses. Recommendations will be made on a general level for each generic building type in order to work as a guide to possible solutions. Probably it will be difficult to give recommendations for all buildings of a type, because buildings are so different.

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