Model for Refurbishment of Heritage Buildings

T. Valdbjørn Rasmussen

Danish Building Research Institute, Department of Construction and Health at Aalborg University, Copenhagen, Denmark

Corresponding author: T. Valdbjørn Rasmussen, tvr@sbi-aau.dk

Abstract

A model intended for the selection of feasible refurbishment measures for heritage buildings was developed. The model showed how to choose, evaluate and implement measures that create synergy between the interests in preserving heritage values and creating cost efficient refurbishment that complies with the requirements for the use of the building. The model focuses on the cooperation and dialogue between authorities and owners, who refurbish heritage buildings. The developed model was used for the refurbishment of the listed complex, *Fæstningens Materialgård*. *Fæstningens Materialgård* is a case study where the Heritage Agency, the Danish Working Environment Authority and the owner as a team cooperated in identifying feasible refurbishments. In this case, the focus centered on restoring and identifying potential energy savings and deciding on energy upgrading measures for the listed complex. The refurbished *Fæstningens Materialgård* is visualised in photos.

1 Introduction

A total of 13% of all buildings in Denmark are assessed to be heritage buildings, and given a status as either listed or worthy of preservation. Approximately 9,000 buildings are listed and approximately 350,000 buildings have been assessed as being worthy of preservation.
All medieval buildings in Denmark, meaning buildings from before the Protestant Reformation in 1536, are automatically listed. In addition, listing requires that the building is of special architectural or cultural heritage value. This includes historic buildings that give both architectural and cultural insights into various periods in the history of Denmark. Listed buildings are not only grand castles and manors, but also farms, merchants' houses, warehouses, villas, town halls, schools, public baths, jails, railway stations and factories. Even very small buildings like telephone booths and gazebos can be listed.
All listed buildings are among the best or most characteristic of their kind and period. They are also of national importance, and in some cases of international importance. Buildings are listed to ensure that they are changed as little as possible.
Buildings considered worthy of preservation are designated by using the SAVE, Survey of Architectural Values in the Environment, method, [1] and protected on a regional level by local authorities. The buildings are assessed and graded from 1 to 9. Grade 1 is the strictest grade and the level just before a listed building.
Most listed and preserved buildings in Denmark are privately owned. Despite listed buildings and buildings worthy of preservation mostly being privately owned, the Heritage Agency is responsible for and administers listed buildings, while local authorities are responsible for buildings worthy of preservation. The owners of a listed building must obtain permission from the Heritage Agency to make any changes to the buildings, including all repairs and restoration work, which means that the decision-making processes of the refurbishment of listed buildings are carried out in cooperation and dialogue with the Heritage Agency.

The decision-making processes of the refurbishment of buildings worthy of preservation are carried out in cooperation and dialogue with local authorities. This means that buildings belonging to the category 'worthy of preservation' can be refurbished but may not be demolished, except by special permission from the local authorities. The rules concerning such buildings are administered by the local authorities.
Tightened energy provisions for new buildings require listed buildings and buildings worthy of preservation to reduce the energy consumption for heating and comfort, in order to reduce CO_2 emissions and to ensure that these buildings can remain part of the attractive private building stock.
A model focusing on the cooperation and dialogue between authorities and owners who refurbish heritage buildings is presented. In addition, the developed model is used for selecting refurbishment measures for *Fæstningens Materialgård*. *Fæstningens Materialgård* is a case study where the Heritage Agency, the Danish Working Environment Authority and the owner cooperated to identify potential energy savings and to decide on feasible and acceptable measures for the listed complex. Throughout the process the owner was supported by architects and engineers. The refurbishment was initiated in 2007, when Realdania, a Danish real estate society, bought the listed complex with the ambition of turning it into offices for renting out. The owner of a listed building is required to maintain the building and as the owner, it was Realdania's responsibility not only to maintain the listed complex but also to restore it. The restored and upgraded listed complex is shown in photos.

2 The listed complex, *Fæstningens Materialgård*

The listed complex, *Fæstningens Materialgård*, is located at *Frederiksholms* Canal, which was dug out in 1681 in the western part of downtown Copenhagen. The ground area of the complex originated as an infill for the expansion of Copenhagen, which included the construction of the ramparts of *Vester Vold*.
The history of the listed complex goes back to the 17th/18th centuries when the old royal materials yard had to be replaced by a new one. The complex was initiated in 1740 with a new, very distinguished, brick residence for the supervisor. The architect of the building is not known with certainty, but is assumed to be the national building master J. C. Krieger, [2]. The buildings form a single listed complex surrounding a courtyard, see Figure 1, consisting of brick buildings with red tile roofs, yellow lime-washed facades, green-painted doors and gates and white-painted windows. Only the original warehouse building of the complex is built as a half-timbered construction.
The use of the individual buildings of the complex has changed several times through its history. Recently the buildings have been used for different office type functions. In 2007, the condition of the listed complex was strongly affected by the many refurbishments of the buildings which did not respect the values of the listed complex. However, it does not appear to have caused serious settlement of the foundations.

3 The heritage preservation status and conditions

The buildings and the courtyard area have listed status. This listing is based on the Danish Act on Protecting Buildings and the Conservation of Buildings and the Built Environment, [3]. The aim of the act is to protect the country's old buildings that are of architectural, cultural, or environmental value, including buildings that highlight residential, working and manufacturing conditions as well as other important features of the development of society. All building work that goes beyond normal maintenance requires permission from the Heritage Agency. When carrying out building work on a listed building, the same techniques and materials should be used that were used to build the original building. Building materials and techniques are characteristic of both the period and the region, both of which are an integral part of the culture of the building, and they are therefore part of its heritage value. This is especially true of materials and techniques which were developed and proven over a long time through experience. If experimental materials or techniques are to be used in a listed building, it should be ensured that they are implemented in such a way that they can be removed again.

Fæstningens Materialgård represents a landmark on the city harbour front. It's a listed complex with a long history and an example of the expansion of Copenhagen in the late 17th/early 18th centuries when the former city ramparts where used for other purposes.

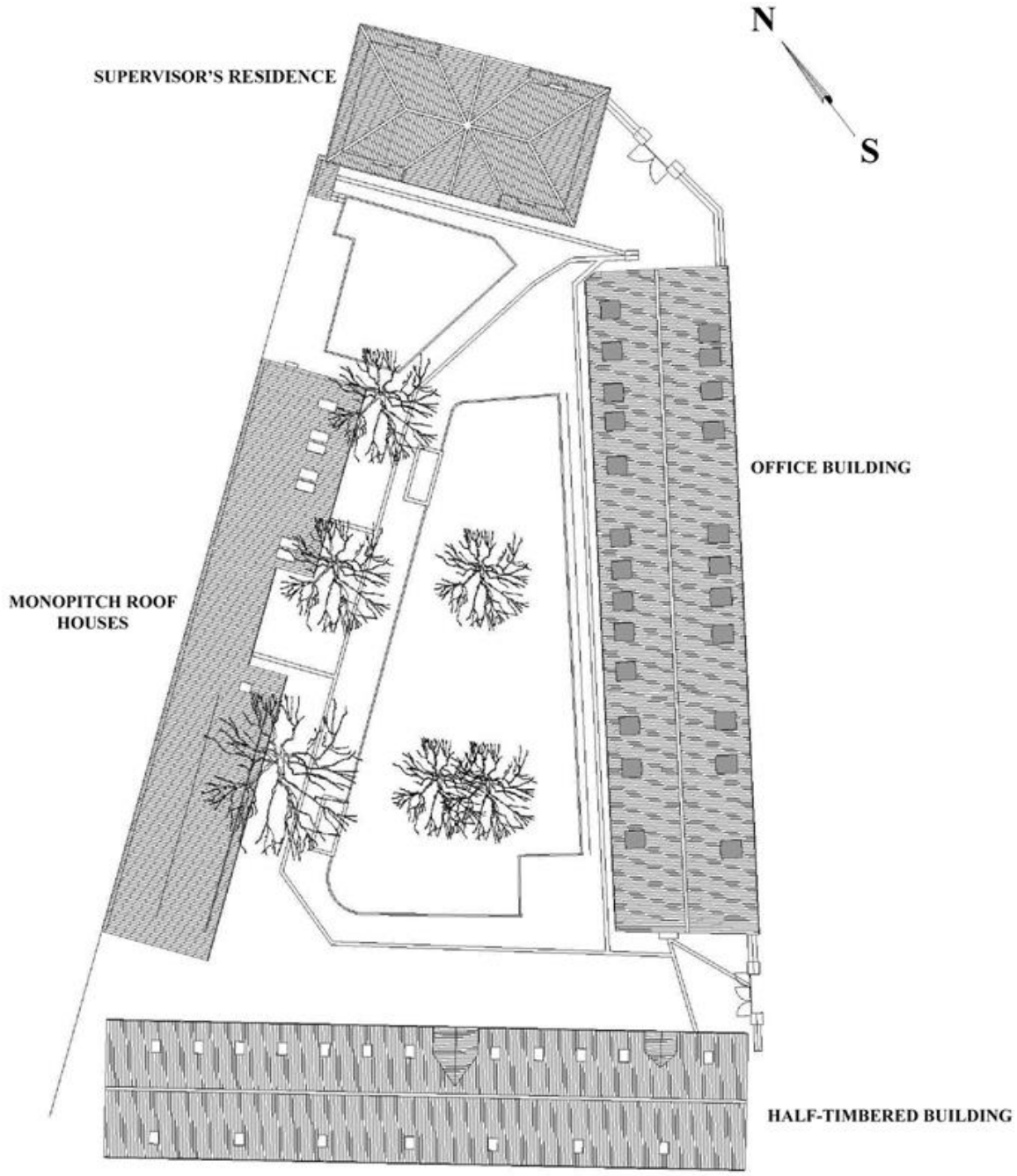


Figure 1. Site plan of the listed complex, *Fæstningens Materialgård*.

Each of the buildings in the complex has fundamental heritage values. The supervisor's residence was used for the case determining feasible refurbishment measures, as it is recognised as the main building in the complex. The supervisor's residence, see Figure 2, is recognised by its representative character and position in the hierarchy of the complex, the hierarchy between the storeys, the rooms and interiors containing a mix of historic styles and the joinery detailing. The supervisor's residence is characterised as the 'grandest' building in the complex, and there is a desire to expose and enhance the fine, richly furnished interiors.

Figure 2. Structural section of the supervisor's residence included in the listed complex, *Fæstningens Materialgård*.

4 Model

The model was used to restore and to detect feasible refurbishment measures that reduced the energy consumption of the listed complex.

4.1 Relevant assessment authorities and parties

The model assumes the presence of relevant assessment authorities and parties. In the case of refurbishment of *Fæstningens Materialgård*, the relevant assessment authorities and parties were,

- The Heritage Agency, which had to evaluate each measure specifically for each building from a conservation and heritage point of view. Assessments were only for guidance. The final, official approval was only to be given once the entire project was submitted.
- The Danish Working Environment Authority, has to evaluate each measure specifically in terms of the acceptability of the workspace.
- Owner/Developer who had to evaluate each measure specifically for each building from the owner's perspective. The impact of each measure was evaluated in relation to cost-benefit, rental opportunities, operation and maintenance.

- Architects who had to evaluate each measure specifically for each building from an architectural point of view. Among other issues, the form, appearance, functionality and interior design were evaluated. These evaluations were further supplemented wherever possible with more general assessments and views.
- Structural engineers who had to evaluate each measure specifically for each building from a structural design perspective. The impact of each measure on the existing construction was risk assessed, especially with respect to building physics, i.e. moisture levels. Wherever possible, a more general assessment of the individual measures was given, with references to relevant literature.
- HVAC engineers, Heating, Ventilation and Air Conditioning engineers, who had to evaluate each measure specifically for each building from an energy and indoor climate point of view. The impact of the measure in terms of energy-saving effect and room temperature was critically evaluated. Wherever possible, a more general assessment of the measure was given, with references to relevant literature.

4.2 Relevant terms

The model identified feasible refurbishment measures that reduced the energy consumption of the listed complex on the basis of a number of terms, including:

- Feasible Refurbishment Measures. The identified refurbishment measures that fulfill the requirements of creating synergy between the interests of preserving heritage values and developing reasonable cost-benefit solutions that meet the requirements for the future use of the complex.
- Design Brief. A construction brief was elaborated and was needed to form the basis for choosing feasible refurbishment measures and to carry out energy evaluation calculations. The brief was to include: building history, current condition of the construction and individual building materials and identified heritage values connected with the individual buildings and the listed complex.
- General List. A list of all the potential energy-saving measures was prepared. It was important that the General List initially contained a comprehensive list of refurbishment measures that could be used in connection with energy upgrading measures. As a starting point the list should be elaborated to include all energy upgrading measures regardless of the architectural and heritage value of the buildings, as the proposals should not take into account the location, actual building geometry, costs, use and function of the building or similar features that could immediately mean that the proposed measures were not to be implemented. The General List was created in order to consider all available measures as broadly as possible.

For the individual measures to reach the level of feasible refurbishment measures, measures were carefully evaluated. For each energy-saving measure on the General List, an Assessment Scheme was made. The scheme was used to evaluate and keep track of the evaluation made for every measure as a reminder of why/why not the energy-saving measure was/was not recommended for further development through the process. Measures that were not feasible were removed from the General List and a Project Specific List was elaborated. Measures on the Project Specific List were quantified to estimate the energy-saving potential, simple pay-back time, expected $C0_2$ savings, cost-benefit, indoor climate effect and its ability to comply with the design brief.

For the entire project submitted quality levels of indoor climate conditions in primary rooms, as well as being able to describe a desired future level, the standard DS/EN ISO 7730 [4] was to be implemented as the building was to be used as an modern office building.

4.3 Relevant workgroup assessment meetings

Feasible refurbishment measures were found from a series of workgroup assessment meetings. Four workgroup assessment meetings were held.

I) Workgroup Assessment Meeting I roughly sorted the measures of the General List. All the project team members made an overall assessment. Thus, each General List proposal could be

subjected to a first interdisciplinary evaluation. Based on the first overall assessment, an upgraded General List of proposals suitable for further work was produced.

ll) Prior to Workgroup Assessment Meeting II, it was recommended, based on the existing reading of the consumption of domestic hot water, heating and electricity, to produce an estimated overview of how the existing consumption of heat loss, domestic hot water supply and electricity were distributed and consumed in the building.

At this time, the building must be entered into a computer model using a simulation program for indoor climate evaluation and energy consumption, measurement and evaluation. The individual buildings in the listed complex must be entered with the existing components, construction, floor areas and their orientation. The computer simulation model can be supplied with their existing consumption data from use and lighting systems. The computer simulation model provides an opportunity to see the existing energy consumption distributed on the individual building components, but can also be used to get an idea of the existing thermal environment in the different buildings, areas, floors and rooms.

The info sheets can be provided with the calculated figures and further elaborated for energy-saving proposals on the General List that, based on the first evaluation, were recommended for further development. The info sheet describes the scope of each measure and its estimated effect on the future consumption.

The result of Assessment II was to create a more detailed description of the energy-saving proposals, as well as the impact of the proposed refurbishment measures on energy consumption, $C0_2$ savings and their effect on the indoor climate. Results were also entered on the Project Specific List.

lll) Workgroup Assessment Meeting III was based on the results of Workgroup Assessment Meeting II. Each energy-saving proposal on the Project Specific List was to be evaluated and considered in detail.

Workgroup Assessment Meeting III was held in order to make a solution-specific selection of energy-saving measures that created synergy and that was reasonable in relation to the requirements for the interior layout.

IV) Workgroup Assessment Meeting IV was undertaken to go through and correct the adopted measures, in case the measures did not create synergy or did not meet the overall expectations or lead to the expected effects on $C0_2$ reduction, energy savings and the indoor climate as well as its ability to comply with the Design Brief.

A sketch of the model for selecting feasible refurbishment measures through a series of workgroup assessment meetings is shown in Figure 3.

5 Result

For the building with the supervisor's residence, the use of the model resulted in the agreement on 11 feasible measures for energy upgrading including:

1) building envelope air permeability (0.5 h^{-1} in the basement, 0.2 h^{-1} on the ground floor and 0.2 h^{-1} at the first floor)
2) ventilation by opening windows
3) combined heating/cooling unit designed so that it looked like a flat panel radiator
4) cooling via a centrally placed unit where excess heat is transferred to the outside air
5) centralised domestic hot water supply
6) energy-saving light sources
7) daylight-controlled lighting
8) centralised control of electrical components
9) shared canteen
10) shared meeting facilities
11) shared conference facilities.

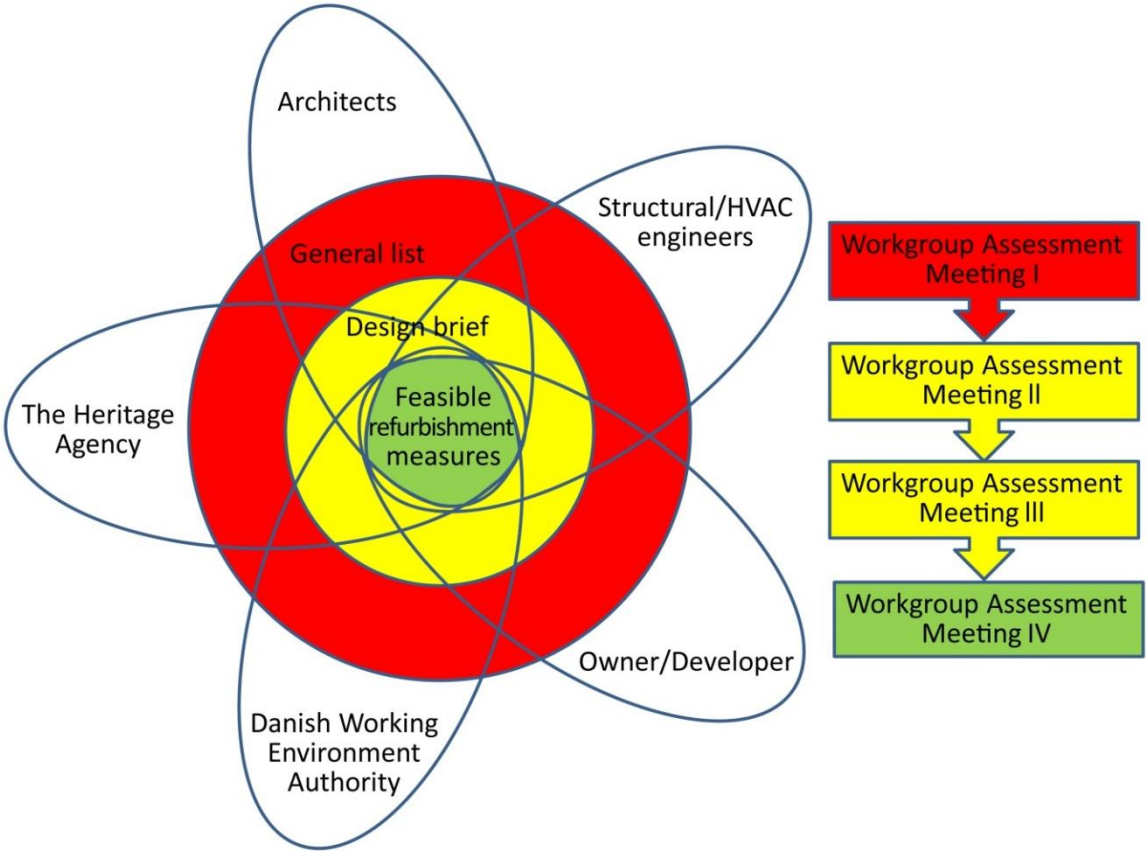


Figure 3. A sketch of the model for cooperation between parties that refurbish heritage buildings.

Calculations were carefully reviewed and for the supervisors dwelling they showed an overall reduction in transmission loss of 27% and an overall CO_2 reduction of 20% achieving an acceptable workspace with a thermal indoor climate level of Class C. The refurbished supervisor's residence is shown in photos in Figure 4 a) to Figure 4 f).

Individual feasible refurbishment measurements were found for the restoration and energy upgrading of each of the individual buildings included in the listed complex. The refurbished complex is shown in Figure 4 g).

Calculations of the whole refurbished listed complex showed an overall CO_2 reduction of 18%. Achieving an acceptable workspace with a thermal indoor climate level of Class C, was seen to result in a total CO_2 reduction calculated to be 7.8%. The indoor climate level was raised from an unacceptable level to an acceptable level, and rearranging the layout made room for another 40 workstations.

6 Discussion

A model describing the process for selecting feasible comprehensive refurbishment measures, including energy upgrading for heritage buildings, has been presented. The model was used for the restoration and refurbishment of the listed complex, *Fæstningens Materialgård*. The study shows how the model for cooperation between authorities and the owner of a heritage building leads to the selection of feasible measures, including energy upgrading that preserves heritage buildings. Using the model for individual feasible refurbishment, measurements were found for the restoration and energy upgrading of each of the individual buildings included in the complex. Calculations of the whole refurbished listed complex showed an overall CO_2 reduction of 7.8%, achieving an acceptable workspace environment with a thermal indoor climate level of Class C. The indoor climate level was raised from an unacceptable level to an acceptable level, and rearranging the layout made room for another 40 workstations.

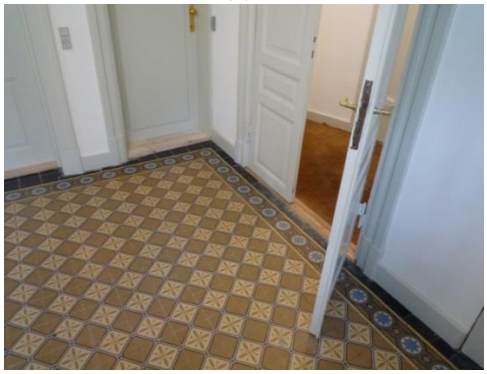

(a)


(b)


(c)


(d)


(e)


(f)


(g)

Figure 4. Photos of the refurbished listed complex, *Fæstningens Materialgård*. a) The supervisor's residence including the photos Figure 4 b) to Figure 4 f), b) Entrance to the main living rooms, c) The living rooms, three rooms in a row lying towards the street, d) Layers of paint found during the restoration and now reviled, e) A window in the staircase, f) The floor-tiles in the entrance hall and staircase, g) Panorama view over the courtyard of the refurbished listed complex, *Fæstningens Materialgård*.

Heritage buildings can include listed buildings and buildings worthy of preservation. In Denmark, these two categories of buildings are handled differently by the authorities. However, in principle the model for cooperation between authorities and the owner of a heritage building can still be used to implement feasible refurbishment.

For listed buildings, the decision-making processes related to upgrading are carried out in cooperation/dialogue with the Heritage Agency. The Heritage Agency possesses the expertise and has to agree to nearly all issues. The Heritage Agency is an agency under the Ministry of Culture, which has the overall responsibility for the management of Denmark's cultural heritage. The agency is an authority on listed buildings and conservation, historic and archaeological relics.

For buildings worthy of preservation, the decision-making processes related to upgrading are carried out in cooperation/dialogue with local authorities. Non-Government Organisations have examples and knowledge from practice and possesses the expertise in these cases.

The model consists of a series of meetings identifying feasible measures to refurbish and upgrade a heritage building in order to achieve a reduction of the energy consumption. Every process is gathered around a body of decision-making meetings called the workgroup assessment meetings. The aim of the process was to select feasible, acceptable measures. For the shown case, *Fæstningens Materialgård*, the authorities were represented both by the Heritage Agency and the Danish Working Environment Authority. Each specific case might need expertise from a different set of experts and authorities. Figure 3 shows a sketch of the model. The refurbished *Fæstningens Materialgård*, [5] is shown in photos in Figure 4.

7 Conclusion

Denmark has carried out a number of case studies demonstrating comprehensive refurbishment projects including energy upgrading of heritage buildings, [6, 7 and 8]. These case studies demonstrate that a model for cooperation between the authorities and the owner of a heritage building on the implementation of feasible measures is necessary for carrying out refurbishment, including energy upgrading, when preserving heritage buildings.

In Denmark, heritage buildings include listed buildings and buildings worthy of preservation. These two categories of buildings are handled differently by the authorities. However, in principle the model for cooperation between the authorities and the owner of a heritage building can still be used to implement feasible measures required for refurbishment, including carrying out energy upgrading.

The presented model describes the selection of feasible measures for refurbishments and energy upgrading of the listed complex, *Fæstningens Materialgård*, including the process of

- how to tackle restoration and refurbishment of a listed building,
- how to compose and organise an interdisciplinary workgroup consisting of the building owner, authorities, architects and engineers,
- how to evaluate a single measure for reducing the overall energy consumption.

The model consists of a series of meetings held to identify feasible measures to refurbish and to upgrade and hence restore and achieve a reduction of the energy consumption of the listed complex *Fæstningens Materialgård*. Every process was gathered around a body of decision-making meetings called the workgroup assessment meetings. The aim of the process was to select feasible, acceptable measures. For the case of *Fæstningens Materialgård*, the authorities were represented both by the Heritage Agency and the Danish Working Environment Authority.

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