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Pending for renovations: Understanding the conditions of the multi-family housing stock from before 1945

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Abstract

The Swedish housing stock is once again in focus for national energy savings, as it was after the oil crises in the 1970s and 1980s. The contemporary debate has a one-sided focus on energy savings and barriers for implementation of existing energy efficient renovation measures but also on large stock of industrialized housing built after 1960. The need for renovation is equally urgent in older stocks of housing, also in those that already have been renovated but are in need for further interventions. In this paper we focus on multi-residential housing built before 1945 in Gothenburg, Sweden, representing cultural and historical heritage values. The opportunities to ensure high energy efficiency with new measures in a second renovation should aim to find a balance with heritage values, social values, function, aesthetics and management aspects. In order to get an understanding of the conditions of the stock in focus, we apply both a top-down and bottom-up approach. In the top-down approach, data are gathered from different sources such as energy performance certificates, the national property register, and geodata from the City of Gothenburg. By combining information from these databases, three data subsets have been defined for the bottom-up approach: non-renovated buildings, buildings renovated to a small extent and buildings renovated to a large extent. Three case study buildings were selected out of these data subsets. The choice of renovation strategy differs between the cases. Case study building 1 has been left virtually untouched while case study building 2 and 3 have been renovated to different extent. The next step in this research project is to identify suitable renovation alternatives for these building typologies.

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Keywords: Renovation; energy use; top-down; bottom-up; cultural heritage; landshövdingehus

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1. Introduction

The Swedish housing stock is once again in focus for national energy savings, as it was after the oil crises in the 1970s and 1980s. The contemporary debate has a one-sided focus on energy savings and barriers for implementation of existing energy efficient renovation measures but also on large stock of industrialized housing built after 1960. The need for renovation is equally urgent in older stocks of housing also those that already have been renovated but are in need for further interventions. In this project we focus on multi-residential housing built before 1945 in Gothenburg, Sweden representing cultural and historical heritage values. The national energy target to reach 50% energy reduction by 2050 (compared to 1995) represents major challenges for conservation of cultural heritage values.

The actual energy savings through renovation measures in housing over time are difficult to evaluate. In the aftermaths of the oil crisis in the 1970s, the Swedish government provided financial support for building owners that took measures to reduce the energy use. These measures involved insulating the exterior façade and exchanging windows, which in many cases resulted in losses of cultural values. The possible energy use reduction through renovation is also dependent on user habits as well as appropriate housing management. In the planning for new renovations it is therefore important to learn from past lessons of energy renovation but also to consider the involvement of the users and housing managers in order to reach the desired outcome. Furthermore, future technological opportunities for energy saving and possibilities for the restoration of cultural values lost in earlier renovations should be considered.

This paper reports from the first phase of a research project in which we aim to get an overview of the building stock, its current conditions in terms of energy use over time (purchased energy), technical status of the thermal envelope (U-values, thermal bridges, air tightness) in relation to cultural values. The aim of the overall project is to evaluate the long-term effects of energy-related renovations carried out during the period 1975 and onwards in the pre-1945 housing stock focusing on a selection of building typologies. This is made in order to map further needs for renovation and propose guidelines for the improved energy efficiency and thermal comfort that does not interfere with existing cultural values. When these buildings now stand for their second renovation, it is beneficial to utilize the experiences on energy performance and to decrease the risk for performance failures in regard of for instance moisture damages. The opportunities to ensure high energy efficiency with new measures in a second renovation should aim to find a balance with heritage values, social values, function, aesthetics and management aspects. To reach the aim we will study earlier renovations and assess the need for further renovations. The relevant research questions are: What information is available and accessible of the current status and earlier interventions of this stock? Is this information useful in order to define renovation strategies? The results from this first phase of the project will provide input for decision-support for continuous property management and the very early stages of renovation.

We apply both a top-down and bottom-up approach. In the top-down approach, data are gathered from different sources such as energy performance certificates (EPC), the national property register (PR), and geodata from the City of Gothenburg. Data from these sources are combined, analyzed and visualized in a Geographic Information System (GIS) using the software ArcGIS 10.2. The EPC provides data on measured energy use of individual buildings, type of energy sources, and year of construction. The PR contains, among others, building co-ordinates, ownership, year of construction, a so-called value year[†], and in some cases a year of renovation. For the top-down analysis, the housing stock is presented in age-type classes, i.e. classes that represent buildings properties related to the year of construction, type of building, attachment, number of stories, and number of staircases. The division is based on a building stock model developed for the whole multi-family housing stock of Gothenburg [2]. For our study, five classes are of interest: timber buildings, brick buildings, Landshövdingehus[‡], slab blocks, and tower blocks.

In the bottom-up approach we use a selection of case studies representing a few of the above mentioned typologies of housing from the studied period. At the moment we have included two types: brick buildings built ~1900-1930 and Landshövdingehus (a typical type of local housing with one level in brick and two plus an attic in wood) built ~1875-

[†] A value year is calculated based on the economic extent of refurbishment activities, improvement of standard, and related to the expected remaining life time of a building. Only costs for larger refurbishments or extensions of a building can result in a change of the 'value year' [1].

[‡] Landshövdingehus (lit: county governor's house) is a building type specific for Gothenburg.

1940. The case studies are used to verify the data in the GIS model. Combining information from these databases has resulted in three data subsets: non-renovated buildings, buildings renovated to a small extent and buildings renovated to a large extent.

2. Status inventory – an important part of a successful renovation

Earlier research point to the crucial importance of the early phases of a renovation project in order to plan and assess possible interventions [3]. The early phases of the renovation already start with the management and continuous maintenance of the building. Most professional housing owners and managers have systems for planned maintenance and perform regular checkups. Still, a renovation project is often initiated by an urgent problem that interfere with the durability, or with the social or economic function of the building, such as leaking roofs, poor thermal comfort or high maintenance costs. Such urgent renovations often grow in scale. For example, if five façade boards are rotten and need to be changed, and more are in a bad condition. This might lead to changing the whole façade. Furthermore, a problem of a technical kind will often interfere with economic and social issues of the housing property which point to the necessity of carrying out a broader investigation in order to find a strategy for the renovation.

The early phases should include a status inventory of problems to be solved but also an inventory of values to be safeguarded or developed in that process [4]. There exist no common procedures that structures the early phases of renovation or common definition of what an inventory or a pre-study should deal with. Existing inventory methods focus on technical and economic issues and have to be developed in order to meet all dimensions for more sustainable renovation. Thuvander et al. [5] have developed a multi-value model for the early stages of renovation emphasizing on the inclusion of inventories of social, architectural and heritage values as a complement to technical and economic aspects. Their framework is useful in order to map social values including recreation, wellbeing (sound, daylight, comfort, etc.), demographics and socioeconomic factors such as rent level and social integration. Architecture and heritage take as a starting point the safeguarding of the original architecture and the 'readability' of additions. Respecting the heritage values usually means using minimally invasive procedures, using traditional materials and traditional techniques, but does not necessarily exclude modern techniques.

The status inventory with respect to technical aspects can be made more or less complex. Normally, the technical status inventory includes the building envelope, the interior of the building, and the building services. Regarding the building envelope, an inventory can include checking the rain and wind protection, the insulation, air leakages, durability of materials, and contain information about the whole building. A more advanced inventory also take into account the building antiquarian aspect in the technical status inventory.

A method to perform risk analysis and status determination, including building antiquarian aspects is being developed by [6]. Until this method is ready to use, a more traditional technical inventory method that focuses on the building envelope and building services is used in the project.

3. Top-down: The multi-family housing stock of Gothenburg constructed before 1945

A study about previous refurbishment activities in Gothenburg linked to spatial distribution of individual buildings indicated where larger changes have been made in the multi-family housing stock [7]. Extensive refurbishment activities were carried out in the stock constructed before 1945. The study evaluated the property register as a valuable source for studying major refurbishment activities in larger stocks but also ask for further studies to obtain a more nuanced picture of the refurbishment activities.

Gothenburg, founded in 1621 and the second largest city in Sweden, is located on the West coast and has about 550 000 inhabitants today. For the whole city of Gothenburg, in the property register, a total of 150 804 buildings are recorded. Out of these, 7 527 buildings are defined as multi-family buildings (February 2014) and 2 217 buildings have a year of construction before 1945. The spatial distribution of the total multi-family residential building stock in Gothenburg and the stock constructed before 1945 is illustrated in Fig. 1. Not surprisingly, our stock in focus can be found close to the city center.

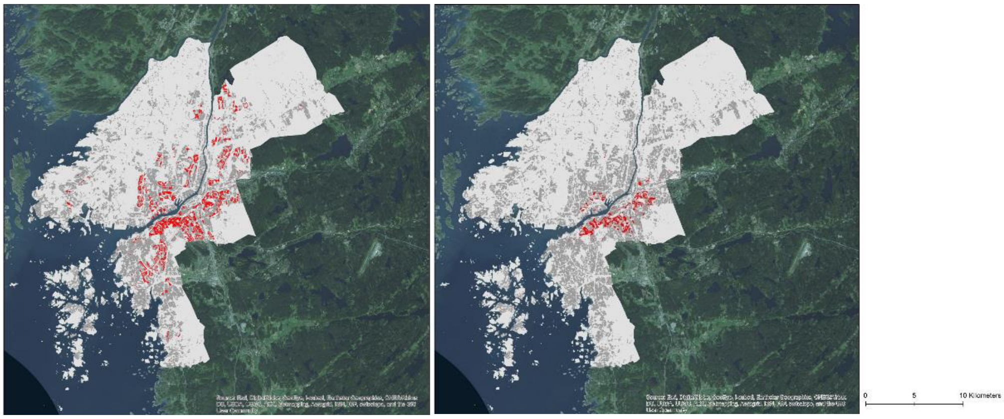

Fig. 1. Multi-family buildings in Gothenburg. The red dots indicate all houses (left) houses constructed before 1945 (right).

One aspect of interest is the energy use in the buildings, which is recorded in the energy performance certificate (EPC) data set. However, not all buildings have an energy certificate yet. For the building stock from before 1945, the number of buildings with a missing energy certificate is 93, approximately 4% of the stock. In order to get a more consistent picture, for the further analysis only buildings with an energy certificate are included. Therefore, the considered stock consist of in total 2 124 buildings.

Table 1 below clearly show that the main part of our stock is constructed after 1929. The number of buildings is extremely high for the year 1929. This is related to the historical process of registering buildings in the PR and a source of error in the data set. In order to get a more nuanced and improved picture of our housing stock, coming studies should focus on a more thorough investigation of the buildings with 1929 as a year of construction using the bottom-up approach including ocular surveys and searches in the building permit archive. Table 1 also shows that about 61% of our housing stock in focus is constructed after 1929, and mainly during the period 1930 to 1939.

Buildings with 1929 as a year of construction are mainly found closest to the city center (Fig. 2). The mapping of the location of the buildings support the planning of a route for the ocular survey.

Table 1. The number of buildings of the multi-family building stock in Gothenburg before 1945 divided into age-classes. (buildings with energy certificates are included).

Year of construction	Number of buildings	Percent
1850 - 1859	9	0,4
1860 - 1869	5	0,2
1870 - 1879	24	1,1
1880 - 1889	54	2,5
1890 - 1899	39	1,8
1900 - 1909	109	5,1
1910 - 1919	122	5,7
1920 - 1929	468	22,0
1930 - 1939	978	46,0
1940 - 1945	316	14,9
Summation	2 124	100,0

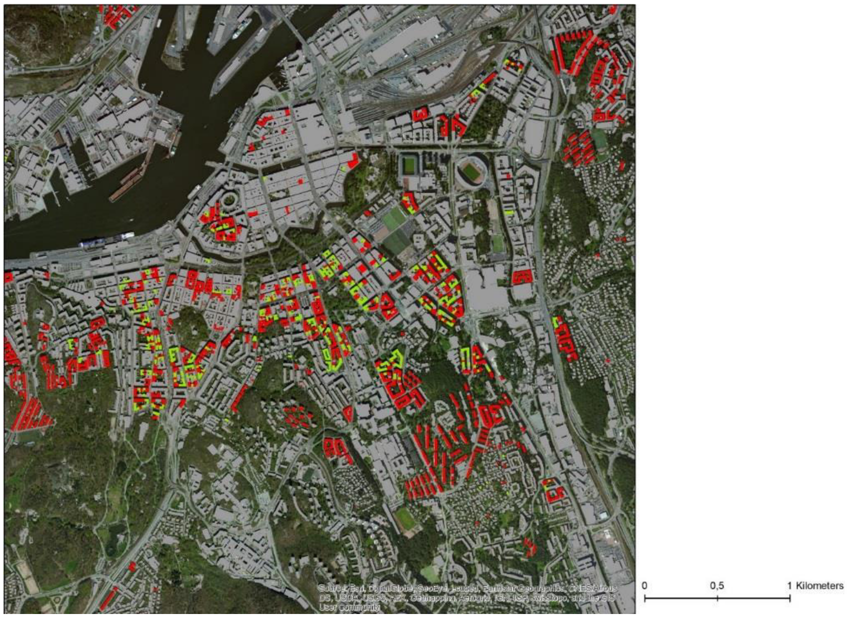

Fig. 2.Spatial distribution of the multi-family building stock in the city center (red and green).
Green buildings: 358 buildings with year of construction 1929.

As Table 2 illustrates, a large share of the stock, about 80%, is privately and tenant owned and less than 20% is municipally owned. This division deviates considerable from the average distribution of the whole multi-family building stock which is on an aggregated level rather homogenous, 34% is privately owned, 32% is municipally owned, and 28% is tenant owned [7].

Table 2. Number and percentage of buildings from before 1945 related to ownership categories.

Ownership category	Number of buildings	Percentage of buildings
Municipally owned	411	19%
Tenant owned	792	37%
Privately owned (limited companies except municipally owned housing companies, limited partnerships, trading companies, decedent estate, and foundations)	910	43%
City owned	11	1%
Total	2 124	100%

Regarding the energy use, more than 80% of the housing stock have an energy performance class D and poorer, corresponding to 101 kWh/m^2 (D), 135 kWh/m^2 (E) and 176 kWh/m^2 (E), see Fig. 3. The energy use includes the energy for heating and domestic hot water supply of individual buildings. For comparison, the building regulations for new multi-family housing in the region of Gothenburg demand an energy performance of 75 kWh/m^2. This number also includes energy use for appliances. From an energy performance perspective, there is a large potential for improvement when renovating the stock.

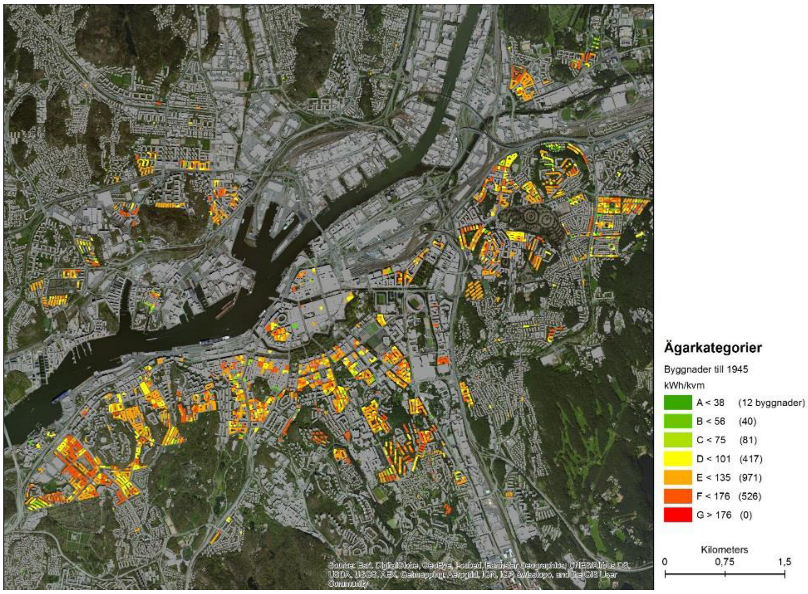

Fig. 3. Spatial distribution of individual buildings' energy use for heating and domestic hot water, divided into energy labels.

4. Bottom-up: Case studies

Three case studies were selected representing the subdivisions; non-renovated, renovated to a small extent and renovated to a large extent. The three cases, see Table 3, also represent two typologies, Landshövdingehus (case 1) and brick buildings (case 2 and 3). Landshövdingehus is a type of working class housing (1875-1940) that is very characteristic and specific for Gothenburg. In 2001, there were 1380 Landshövdingehus in Göteborg [8] of which many will be in need of extensive renovation in the up-coming years. Case 2 and 3 represent taller inner city brick buildings of National Romantic style, a kind of Nordic Art Noveau. This stock is of high heritage value, although still in need of interventions in order to deal with high energy and maintenance costs. Normally, these buildings were built in brick and wood [9]. The wall construction varies with floor level, starting with a 2 brick veneer (64 cm) in the ground floor, 1.5 bricks (49 cm) in the middle floors and 1 brick (32 cm) on the upper floor walls. The roof is normally a wooden structure with sheeting of steel or brick [10].

For the investigation of the cases, the first step has been to perform a literature survey on the typical design and construction from the eras. Current investigations of the buildings include following activities:

- Technical drawings and data about original architecture and renovations both from the property owner and from the building permit archive of the City of Gothenburg.
- Energy performance data from the property owner were collected and compared to data from the energy performance certificate.
- Site visits with ocular inspection of the building. Checklists for the status of different building components and details were used to systematically collect information about the building and its status.
- Field measurements using infrared thermography to study thermal bridges and two-pin moisture meter to assess durability and to detect potential water leakages (present and historical).
- For case 1, work-shops have been carried out with the tenants, as part of a Master's Degree project, in order to capture their expectations, interests and ideas for the up-coming renovation. The inventories in all the case studies are to be complemented with social information regarding rent levels and demographics. Workshops as in case 1 will not be carried out in all cases as this is not relevant when no major renovation is planned at this moment.

Table 3. Summary of information on the case study buildings in Gothenburg [11].

Case study building	Non-renovated building	Renovated to a small extent	Renovated to a large extent
Location	Banérsgatan 6	Geijersgatan 14	Föreningsgatan 34
Construction year	1929	1932	1929
Value year	1929	1932	1970
Number of floors (+attic)	3+1	6+1	6+1
Slab, construction	Wooden beams + concrete	Wooden beams + concrete	Wooden beams + concrete
Ownership	Municipality	Privately owned	Privately owned
Brick color	Red	Yellow	Red
Roof	Brick tiles	Slate	Brick tiles and metal roof
Windows	Mainly original 1+1 panes	Original windows	New windows (1980), 2+1 panes
Walls	Solid brick level 1, level 2-3 wood	Solid brick	Solid brick and 100 mm mineral wool
Energy performance (kWh/m^2, year)	no data	145	135
BOA (living area) (m^2)	no data	1 108	2 085
LOA (other premises area) (m^2)	no data	193	285

4.1. Non-renovated building

Case 1, Fig. 4, is built in 1929 and has not been renovated apart from smaller repair. The building is not categorized as housing but rented by the city as such. The standard is very low. Only four larger apartments out of approximately 20 have bathrooms, the rest have common showers in basement and shared WC on each level. The tenants profit from very low rents but they have pay high electricity bills as the building is only equipped with electric heating. It was supposed to be demolished to make way for a new plan for the area. The plan is now to renovate the building for continued function as housing. Workshops have been carried out in order to understand the tenants' expectation for an up-coming renovation. Tenants complain about draught, high electricity bills but are otherwise satisfied with the low standard and the high level of social interaction between tenants.

Fig. 4. Case study building 1 is a Landshövdingehus on Banérsgatan 6. Left: façade with brick on ground floor and wooden weather board on the upper two floors. Right: common shower in basement.

There is no energy performance certificate for the building but after an ocular inspection it was concluded that the building is poorly insulated. Some of the tenants' electricity bills have been retrieved which point to a possible energy use of over 200 kWh/m^2. A number of windows have been exchanged, mainly to units of two panes. However, both newer and old windows are in poor condition and our view is that all windows are in need of renovation. The façade consists of brick and wood, see Fig. 4. The brick is in good condition in most places but the wooden part needs painting. On the interior, some water leakage into the attic was detected. Further investigations need to be performed to determine whether the leakages are old or ongoing. On the first floor, some of the internal brick walls have been severely damaged by water. There seem to be water suction through the basement floor, which also has resulted in biological growth. The common bathroom is in bad condition, with for example cracked tiles. Interior surfaces need to be painted, plastered or replaced.

In terms of cultural value, the building has not been renovated and has some original indoor qualities seldom seen any longer such as the attics for drying clothes and wood stoves. In Gothenburg, there is no general program for the conservation of Landshövdingehus. The city heritage program mentions the housing stock in this part of the city as having valuable environments from the period 1900-1930 with individual buildings of heritage value [12]. The value of the case study building has yet to be verified with the Museum of Gothenburg.

4.2. Building renovated to a small extent

The building built in 1932, see Fig. 5, is located on Geijersgatan in the centre of Gothenburg. The area as a whole is protected and 'represents an excellent example of the late 19th century upper-class urban areas and is one of the country's most well-preserved environments of this kind' [13]. The building was and is consisting of dwellings on the upper floors and shops on the ground floor. It is situated in a bend of the block with the façade facing the street pointing at south and south-east. The inner courtyard is facing north, north-west. The façade is a yellow brick, most likely the same brick type is used consistently in the construction. The inspection of the façade indicates large exposure to weather and wind, since exterior damages can be seen on the façade facing the street. The condition of the bricks was better on the façade towards the courtyard than on the other one.

The façade facing the street has an extra window pane added on the inside of the existing windows. The original window frame was kept and with an external cover layer so that the wooden frame is no longer visible, but the original shape of the window remains. The walls are unchanged with the original brick wall with different thickness dependent on the floor level. The façade facing the inner courtyard is not so different from the façade towards the street. There is no added insulation, the window construction is the same as for the other façade. The entrance doors of the building are original from 1932. The foundation is a crawl space underneath the bottom slab due to uneven excavations underneath the building. The roof of the building was replaced due to water leakage. The original structure of the roof was kept and slightly improved with a double layered roofing felt. The roofing tiles are made of slate [11].

4.3. Buildings renovated to a large extent

The more renovated building, see Fig. 6, is situated in the inner city of Gothenburg and was built in 1929. The building contains rental apartments. Today the bottom floor consists of two shops and one restaurant. The façade facing the street is original with red bricks and the entrance doors are original. The attic has partly been re-constructed to create additional apartments. The only apparent exterior change is new dorm windows in the new attic seen in the far left in the picture, a change that has been approved by the Museum of Gothenburg. There is still a small unheated attic on top of the apartments, close to the ridge.

The original windows were changed around 1980, but the original windows were kept in the stairwell. The newer windows are chosen with the same design as the original in order to respect the architecture. On the façade facing the courtyard, 100 mm mineral wool was added on the exterior which was plastered. This added insulation unfortunately covers detailing on the eaves. The windows were kept in the same depth in the wall construction after the insulation was added. Many of these kind of houses had stucco on the façades heading to the yard in original. Therefore it is hard to say how far the façade is from its original appearance after the insulation was added. The only interior changes are re-painting and new wall papers [11].

Fig. 5. Case study building 2 is a brick building located on Geijersgatan 14.

Fig. 6. Case study building 3 is a brick building of National Romantic style located on Föreningsgatan 34. Left: Photos show before (left) and after (right) renovation.

5. Discussion and conclusions

The choice of renovation strategy differs between the cases. In the case study building 1, the municipal property owner wants to have a dialogue with the tenants in order to understand their needs. The tenants wish to keep the renovation to a minimum in order to keep the low rents. They are willing to keep the low standard in order to reach that goal, but the high heating demand, and the indoor climate and comfort needs to be improved. The tenants are interested to safeguard the character of the Landshövdingehus and are willing to pay for that quality. So far there is no decision taken on how to improve the comfort and reduce the energy use at the same time as the low rents and the original architecture is safeguarded. Changing energy supply system might be one option.

In case study building 2, the largest renovation measure is changes to the windows by adding a new window pane. The energy use in the building is quite high, and there are often complaints about the thermal comfort. There is a large potential for improving the energy efficiency in the building.

Case study building 3 has additional insulation on some walls and some windows are changed. The energy use in this building is lower than in building 1 and 2. In order to further reduce maintenance and energy costs, insulation of the attic is being discussed. By insulating the exterior roof of the building, another floor will be inhabitable and the specific energy use (kWh/m^2) will decrease.

The reported initial research cast light upon the situation for property owners to plan renovation projects. The top-down data in the database has a lot of unverified data and missing data. The database need to be verified through empirical studies regarding building typologies and the state of the renovation that has been conducted. We have complemented the database with case studies. Also the case studies provide us with challenges. Some buildings are better documented than others. The gathering of empirical data from different archives and through ocular inspections are time consuming. The reliability of data has to be considered. It is not always easy to distinguish what is original and what is later additions as renovations are not always documented. It is difficult to find correct figures of the actual energy use and how this has changed over time.

The project will progress with the collection of complementary data from the here presented case studies and with additional case studies. A way forward is to identify well documented renovation projects that can be guiding in order to generalize not only of building but also of earlier renovation strategies – what we could call renovation typologies. These renovation typologies should then connect to the three sub-categories identified in Table 3: non-renovated, renovated to a small extent and renovated to a large extent and with respect to different building typologies and age classes.

The step after that will be to identify good renovation measures for these renovation typologies (with respect to building physics aspects, building antiquarian aspects and social aspects). The evaluation categories for the different renovation alternatives are: energy use, durability (moisture and effect of extra load), conservation values on the interior and the exterior, indoor air quality, robustness, maintenance, functionality (effect on usability of the building, including social aspects). Numerical simulations are ongoing in the present case studies to determine risk for moisture damage in a selection of renovation measures. The final outcome is to present guidelines to property owners as a support for them to plan for up-coming renovation in housing stock built before 1945. As seen in these initial studies, different property owners have different knowledge on the status of their own stock and consequently we might have to aim for diversified guidelines.

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