Received 19 February 2019
Revised 11 April 2019
6 May 2019
2 June 2019
Accepted 5 June 2019

Long-term effects of additional insulation of building façades in Sweden

Towards a holistic approach

Martin Tunefalk and Mattias Legner
Department of Art History, Uppsala University, Uppsala, Sweden, and
Gustaf Leijonhufvud
Uppsala University, Uppsala, Sweden

Abstract

Purpose – The purpose of this paper is to evaluate long-term effects of previous policies for energy efficiency on energy performance and heritage values. A further ambition is to better understand the relationship between energy and preservation by exploring a quantitative method of combining energy performance data with official heritage designation.

Design/methodology/approach – The study is based on a quantitative analysis of energy performance, completed additional insulations, and official heritage classification for individual buildings. Data have been collected and analysed for a sample consisting of 289 multi-family buildings heated with district heating and constructed 1940–1949 in an urban area in Stockholm, Sweden.

Findings – The data exhibit a significant correlation between the studied features. The study further shows that additional insulation has been installed in roughly half of the buildings. The large majority of them were carried out in the national programme for home improvement called ROT.

Research limitations/implications – The findings indicate that previous policies for energy efficiency had an important effect on energy performance and heritage values in the studied area. They continue to affect urban planning and building permit administration today. Research of the physics of individual buildings would be needed in order to determine the reason for differences in the sample.

Originality/value – By presenting a novel method, the study provides a useful tool for policy makers to bridge the gap between issues of energy and preservation and adopt a more holistic approach towards a sustainable built environment.

Keywords Energy efficiency, Policy evaluation, Built heritage, Additional insulation, Swedish urban planning

Paper type Research paper

Introduction

Purpose and question

The addition of thermal insulation to façades has been a measure to save energy in the Swedish building stock for a long time. It was first supported by national policies in the 1970s. Introduced in the wake of the global oil crisis in 1973, loans and subsidies for installing additional façade insulation were provided in large scale to property owners until the early 1990s. First included in the national programme "Energy savings plan for existing buildings" (*Energisparplan för befintlig bebyggelse,* hence abbreviated EBB), instruments encouraging additional façade insulations were then transferred to the home improvement programme ROT (an acronym for the Swedish words for renovation, refurbishment and extension) (Legnér and Leijonhufvud, 2019; Tunefalk and Legnér, 2019). Most likely, these two long-lasting programmes had an important role in reducing the energy use in the Swedish building stock, while at the same time making a large impact on heritage values in urban areas. ROT in particular had an explicit target of refurbishing older buildings (Tunefalk and Legnér, 2019).

The purpose of the study is to evaluate long-term effects of previous policies for energy efficiency on energy performance and heritage values. A further ambition is to contribute to a

International Journal of Building Pathology and Adaptation
Vol. 38 No. 2, 2020
pp. 374-385

2398-4708
DOI 10.1108/IJBPA-02-2019-0020

better understanding of the relationship between energy retrofits, energy performance (kWh/m^2/year), and heritage values by exploring a quantitative method of combining energy performance data with official heritage classification. The study answers the question:

RQ1. What effects have previous policies for energy efficiency had on energy performance and heritage values in the building stock?

The method presented in this study is a step towards a more holistic approach to current challenges in the building stock. Different values attributed to the built environment are entangled and will inevitably affect each other. Including heritage values in a study of energy-saving policies can therefore be useful for future policy-making. A difficulty in evaluating energy savings and effects on heritage values is the fact that building elements generally have a long lifespan, and retrofits thus keep having effects on both heritage values and energy use long after they have been carried out. It therefore takes time to establish the full effects of policy measures. Studying energy-saving policies from several decades ago provides an opportunity to analyse long-term effects on both heritage and energy. This can hopefully contribute to better informed policy making that can help achieve ambitious targets for energy savings, without affecting other important values in the built environment.

Previous research

The National Board of Housing, Building and Planning (Boverket) has conducted a survey of the technical status, indoor environment and energy efficiency of the Swedish building stock (Boverket, 2010). It concludes that the knowledge of the relationship between energy and heritage is inadequate and calls for further research on the subject. On the one hand, the survey recommends further additional insulation of existing buildings, especially on façades, with an estimated potential energy saving of 20–40 per cent. On the other hand, it acknowledges the potential risk of façade insulation for existing heritage values, and concludes that additional façade insulation should be limited to a small number of buildings. This ambivalence points to the difficulties of balancing the different values of the built environment, a difficulty that the method presented in this paper may contribute to mitigate.

Johansson and Wahlgren (2017) examine effects of energy-related renovation of buildings erected before 1945, based on inventories assessing historical values and technical status of the thermal envelope. A total of 47 per cent of the buildings in their sample from Gothenburg, Sweden, had visible additional insulation on façades. They conclude that there is a lack of knowledge of the renovation history of buildings. The benefits of long-term historical evaluations of policy measures have been demonstrated by Mallaburn and Eyre (2014), arguing that lessons from 40 years of UK experience with energy efficiency policies were largely ignored in the formulation of the UK Green Deal. Furthermore, Swan *et al.* (2017) surveyed attitudes towards increased energy efficiency in UK social housing in recent years, concluding that there seems to have been a decrease in interest in reducing carbon dioxide emissions while there has been a growing interest in addressing fuel poverty with policies.

Looking at Sweden, Gohardani *et al.* (2015) examine how the decision-making process leading to energy-saving opportunities in tenant owners' cooperatives may be improved. Some research, such as Yarrow (2016), poses a much more sceptical view on the potential of policies, concluding that considerations of historic values intersect with those of energy efficiency in context specific ways that cannot be accounted for in general policies. Instead, informal negotiation characterises decision-making processes.

Sandberg *et al.* provided an historical analysis of energy use and policy-making in Norway. Sunikka-Blank and Galvin (2015), Judson *et al.* (2014) and Rispoli and Organ (2018) studied the relation between heritage values and energy from the perspective of homeowners, in UK and Australia, respectively. Based on interviews, they all conclude that homeowners have broader motivations for renovation decisions than is found in policy statements. In order for policies to be implemented, they need to consider multiple aspects of the building stock and the rationale of homeowners.

Our own previous studies of Swedish energy efficiency policies have concluded that EBB and ROT had a significant impact on heritage values in the built environment, while at the same time resulting in empirically based knowledge of the built environment in Sweden that previously had been missing (Legnér and Leijonhufvud, 2019; Tunefalk and Legnér, 2019). These studies have also demonstrated how the rationale for large energy-saving programmes changed over time from a reduced import of oil, via less dependency on nuclear power, to financial stimulations of the building sector, and in later years a mitigation of climate change. However, the resulting energy savings and their bearings on heritage values have previously not been investigated.

Some evaluations of energy savings were made while policies were still in effect. E.g. a report made by Byggforskningsrådet (The Council for Building Research) at the end of the first wave of energy subsidies concluded that additional insulation to exterior walls was the most common measure, but also the least cost-efficient, considering investment cost and life-time (Bostadsstyrelsen 1984). However, the evaluation was based on calculated effects and did not consider factors such as different methods for installation, etc. This study presents the first statistical analysis of energy savings provided by the extensive façade insulations carried out in the 1970s and 1980s.

Subsidies for additional façade insulations

Subsidies for additional insulation of exterior walls and other measures for increased energy efficiency were available for property owners from the mid-1970s. There were strong incentives for homeowners and housing companies to add insulation to walls and replace windows. Starting in 1975, up to 35 per cent of the cost for energy retrofits could be subsidised, with an additional possibility of lending 65 per cent of the total cost of improvements. This made it possible for property owners to fund the whole investment using governmental grants and loans (Legnér and Leijonhufvud, 2019). These early subsides were part of the national programme EBB and included measures such as new windows, conversion to electric heating and additional insulation.

From 1984 subsidies for energy efficiency were included in the ROT programme. Although the regulations took a somewhat new form, the governmental objectives for energy savings were still ambitious and subsidies remained extensive. The target for the ten-year programme was to modernise 275,000 apartments and 150,000 detached houses older than 30 years, including cutting the energy use in buildings with 30 per cent. Included in the programme were energy efficiency subsidies of 10–15 per cent of the cost of investments for, e.g. additional insulation and new energy efficient windows. The programme also included interest subsidies amounting to roughly half the interest cost for loans for energy efficiency measures, including additional façade insulation. Also, an advantageous housing loan was provided for home improvement and energy efficiency. The financial instruments could in some, but not all, cases be combined (Tunefalk and Legnér, 2019).

Throughout the era of the two big energy-saving programmes loans and subsidies were administered by regional housing committees subordinate to the Board of Housing. Applications of property owners were evaluated based on potential energy savings, cost of investment and the age and state of the building (Bostadsstyrelsen, 1984). Measures that affected the character of the building, e.g. additional façade insulation, also demanded building permits administered by the local municipalities.

After 1993 many national policies on energy efficiency in the building stock were both introduced and quickly cancelled. None, however, has had such a profound effect on the built environment as the programmes of the 1970s and 1980s. Additional insulation has not been a targeted measure for later policies.

Policies for built heritage

The study relates energy retrofits to the designation of heritage values made by the city of Stockholm. The designation is made by the city museum and is based on a definition of heritage value as "the possibility to detect and convey information about, and understanding of, different time-periods and contexts" (Riksantikvarieämbetet, 2014, p. 12). It also includes experience values, such as aesthetic or symbolic value. This designation is used in the day-to-day administration of building permits, and therefore has a direct impact on the development of individual buildings and urban areas.

The Planning and Building Regulation of Sweden stipulates that all changes to a building must be made in consideration of its specific character regarding building technique and historic, heritage and aesthetic values (Plan och bygglagen). Buildings with particular or extraordinary heritage values may not be altered. The definition of values is, however, not articulated in the legislation, but is instead left to the individual municipalities. For this reason, the designation made by the city is of direct importance to the urban environment of Stockholm; it determines which buildings are subject to which paragraph. This study sets out to establish to what degree the designation is affected by additional façade insulations, i.e. if previous policies for energy efficiency affects today's administration of buildings permits and planning. It is also possible that the designation of heritage buildings obstructs energy retrofits, and thus hampers the pace of energy efficiency improvements.

Material and methods

The study is based on a quantitative analysis of data collected from three databases: The National Energy Performance Certificate Database (EPCD), The National Database of Built Heritage (Bebyggelseregistret, abbreviated BeBR), and The Stockholm Heritage Designation Map (Stadsmuseets kulturhistoriska klassificeringskarta). The importance of each for the study is described in brief below:

(1) The EPCD is provided by The National Board of Housing, Building and Planning (Boverket). It is a result of EU directive 2002/91/EC, demanding that all buildings constructed, sold or rented have an approved energy performance certificate. The certificate is used both as information to potential buyers or tenants, and as a verification that new buildings meets current EP demands. Data included in the EPCD is building-specific EP, defined as kWh/m^2/year, energy use corrected to a normal year, heat source, year of construction, A_{temp}, location, adjacent walls, etc. c. 90 per cent of all multi-family buildings are represented in the database, and c. 15 per cent of the single-family buildings. In this study, the EPCD was used to determine the EP of individual buildings, as well as to draw a sample of buildings.

Unlike most EU countries, the energy certificates in Sweden are based on measured data for energy use and issued by certified energy experts, making it a reliable data source (Mangold *et al.*, 2018). However, certain ambiguities remain. For some properties with more than one building EP has been reported for the whole property and divided between included buildings. In theory, this reduces the benefits of a study of correlations between additional façade insulation, heritage protection and EP on a building level. In the studied area, this proved to be of no significance for the results since all properties contained buildings with the same heritage code, and either all or none of the buildings on a single property had additionally insulated façades.

(2) The BeBR is provided by The Swedish National Heritage Board. It includes descriptions, photographs and retrofit history (e.g. major changes, including additional insulation) for buildings in Sweden, including almost all individual buildings

in Stockholm. The studied area is based on a survey from 2005. In this study, BeBR is used to mine data on additional insulation of buildings.

Based on historical documents and building inspection, the BeBR is a secondary source. The reliability of this study is partially dependent on the work of The Swedish National Heritage Board. However, the many photographs in the database have allowed us to verify the data. There is no reason to doubt the reliability of the BeBR.

(3) The Stockholm Heritage Designation Map is a legal document used in urban planning and building permit assessment in Stockholm. It provides a classification to each building based on its heritage values. The city conservation director is responsible for the heritage designation. Buildings are graded into three categories: blue, green and yellow. Blue represents the highest degree of protection and is applied to buildings with extraordinary heritage values; green represents particularly valuable buildings; yellow means that the building has a positive influence on the area and/or has some heritage values. Buildings that are not referred to any of these categories are classified as grey (Stockholms stadsmuseum, 2018).

Combining these sets of data enables a quantitative analysis of relations between the parameters EP, completed additional insulation, and heritage protection level, fulfilling the purpose of this study.

Sample selection

A sample of buildings based on location, building type, year of construction and heat source was made using the EPCD. Data have been collected and analysed for a single-stage cluster sample, consisting of all multi-family buildings heated with district heating and constructed 1940–1949 in the urban area of Årsta in Stockholm, Sweden. By identifying a homogenous sample of buildings, the number of factors that can interfere with the results are limited. These buildings are not of a very high age but they have been designated historically valuable.

The location was chosen because it is a cohesive area of multi-family buildings from the 1940s. The study is located to Stockholm, the capital and largest city, due to the advantages of studying a densely populated area, with larger possibilities to retrieve a feasible sample. In a country with large variations in climate as is the case in Sweden, it is appropriate to make a sample from the same location.

The sample is limited to multi-family buildings because: EP data are available for most of them (as opposed to single-family dwellings), providing a good basis for statistical analysis; they have a homogenous and measurable heat source (district heating), allowing reliable comparisons; they have a homogenous building fabric, also allowing comparisons; and they consume a large portion of the provided energy in the housing stock. Buildings used as residence to at least 50 per cent and have more than two apartments are classified as multi-family buildings.

For the sake of comparability, the sample is limited to buildings constructed in the years 1940–1949. Compared to previous decades many buildings were constructed in Sweden during these years, of which many also remain today (Nylander, 2013). It is also likely that they have been subject to additional insulation. According to the policy statement of ROT, buildings from 1930 to 1945 had the biggest need for additional insulation.

The heat source is a crucial factor for the EP of a building. Buildings with heat pump consume c. half of the delivered energy compared to those with district heating, which is the dominant heat source in the area. Mangold *et al.* (2015) recommend using one heating type when using EPC data to create an overview of the building stock. In order to correctly analyse the effects of additional façade insulations on the EP, buildings that are not heated to at least 90 per cent with district heating have been excluded from the sample.

Delimitations

Even though loans and subsidies were provided for a variety of measures, such as installation of new windows or boiler, this study is limited to analysing additional façade insulations. Unlike, e.g. new windows, it is a measure with the sole purpose of improving the energy efficiency. On the contrary to a new boiler, it is a measure that affects the character of a building, allowing a study of relations between energy savings and heritage values.

The analysis does not account for the degree of additional insulation in buildings. All entities have been given a value of either "insulated" or "not insulated". A thick insulation has the same value as a thin. Buildings that have only partially been additionally insulated, e.g. one of the façades, have been given the value "insulated". Admittedly, this reduction does not account for the many variations displayed in the building stock. However, it allows for an overall evaluation of the measure.

Finally, it should be noted that the empirical part of this paper is a case study of a specific area and building type. The purpose of the study is largely exploratory, and it is uncertain if extrapolations of the results to a larger building stock can be made. Further studies are needed to determine the effects of energy savings subsidies on the built environment as a whole. The results are nevertheless of interest since they demonstrate the practical applicability of a novel and robust method for evaluating effects of previous policies for energy efficiency on EP and heritage protection.

The case of Årsta

The area Årsta in Stockholm, Sweden, was first planned in 1939 and mostly constructed between 1943 and 1947, with additions made in the early 1950s. The area was extended to the south in the first half of the 1960s (Stockholms stadsmuseum, 2009). It is predominantly a residential area, consisting of 316 properties. Almost all residential buildings are multi-family buildings. Characteristic for the environment in Årsta – and other close suburbs in Stockholm – are slim, typically three-story lamellar buildings, with a majority of one- and two-room apartments (see Plate 1). The original façades are plain, without decorations, typically in lightly coloured plaster (Stockholms byggnadsnämnd, 1983). When constructed, the area was located outside of the city. After massive expansions of suburbs in the 1960s and 1970s, it is now considered to be located relatively close to the city centre.

Source: Bebyggelseregistret

Plate 1.
Typical three-storey lamellar buildings in Årsta

Results

There are 289 multi-family buildings constructed 1940–1949 in Årsta. 141, or 49 per cent, of these have additional façade insulation. 140, or 48 per cent, have not been additionally insulated. In eight buildings the study has not been able to determine whether additional façade insulation has been installed or not. BeBr has not provided clear information on these buildings.

The EP of the buildings in the study varies widely, from 106 to 266 kWh/m^2/year. The average EP is 165 kWh/m^2/year. Buildings with additional façade insulation have an EP of 147 kWh/m^2/year, which is 20 per cent less than buildings with original insulation, which have an EP of 183 kWh/m^2/year (see Table I).

The correlation between additional façade insulation and EP is statistically significant ($T = -8.4$, $R_s = 0.65$). A total of 12 per cent of the buildings with additional façade insulation and 73 per cent of those without have an EP that is higher than mean. Grading the buildings by EP, 92 per cent of the first quartile (the lowest EP) have additional façade insulation, and 15 per cent of the fourth quartile. However, a few of the buildings with additional façade insulation have a conspicuously high EP. In fact, the building with highest EP by far, 266 kWh/m^2/year, had additional façade insulation installed in the 1980s. As Figure 1 demonstrates, the spread in EP is even among the buildings with original insulation; all four quartiles are approximately the same size. The EP of buildings with additional façade insulation has a positive skew. There is a longer span between the highest and lowest EP, and the first and second quartiles are significantly narrower than the third and fourth.

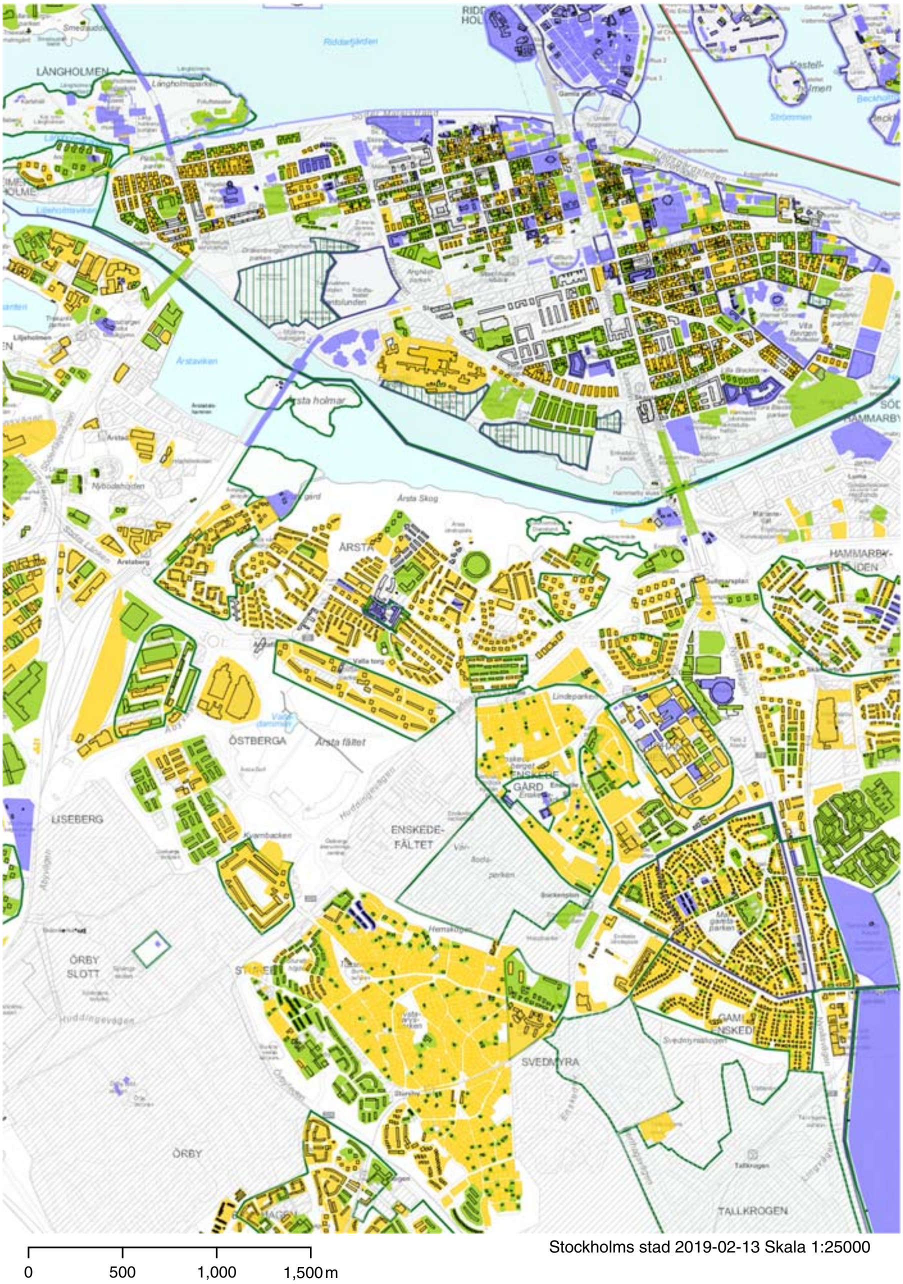
The time from the first introduction of energy-saving subsidies can be divided into three periods of c. one decade each. The first period consists of EBB and its precursory policies, stretching from 1973 to 1982. The second period is the ROT programme, 1983–1993, which took up many of the policies included in EBB. The third period is 1994–2005, when no major energy-saving programme was active. The study ends with the year 2005, when the inventory of the retrofit history was performed. During the first two periods, major subsidies were available for additional insulation.

As demonstrated in Figure 2, this division shows that the majority of the additional façade insulations in the sample was made during the ROT programme. A total of 19 (13 per cent) of the additional façade insulations were made during EBB; 96 (68 per cent) were made during ROT; 17 (12 per cent) were made later. Nine insulations (6 per cent) have not been dated. The study shows only small differences in EP between insulations made in the different periods. Buildings that had additional façade insulation installed during EBB have an EP of 150; those that were insulated during ROT have an EP of 147; buildings with later additional façade insulation have an EP of 141.

The Stockholm Heritage Designation Map classifies the majority of the buildings in the area, 250 buildings or 87 per cent, in yellow category, "having a positive influence on the area and/or has some heritage values" (Stockholms stadsmuseum, 2018) (see Plate 1). A total of 26 buildings or 9 per cent are categorised as green, "particularly valuable buildings". Only two buildings are categorised as blue, "buildings with extraordinary heritage values". A total of 11 buildings or 4 per cent are categorised as grey, the lowest assessment of heritage values.

Table I. Energy performance of buildings with additional insulation, with original insulation and those there is some uncertainty about

	Number	Share (%)	kWh/m^2/year
Additional insulation	141	49	147
Original insulation	140	48	183
Uncertain	8	3	162
Total	289	100	165



Notes: Blue objects have a particularly high historical value. Green objects have a high value, while yellow ones have some value
Source: Stockholms stadsmuseum (2018)

Figure 1.
The Stockholm heritage designation map of Årsta

Of the 141 buildings with additional façade insulation 130, or 92 per cent, are categorised as yellow and 11, or 8 per cent, as grey. None of the buildings with additional façade insulation have been designated as being "particularly valuable" or having "extraordinary heritage values". Of the 250 buildings in the yellow category, 52 per cent have additional façade insulation. The 11 buildings in the grey category all have additional façade insulation.

As expected, considering the rate of additional façade insulation in each category, there is a significant difference in EP in relation to heritage classification. Buildings in the yellow category have an overall EP of 160; the green category has an EP of 190; and the blue, i.e. the most valuable buildings, 221.

Discussion

The case study displays a strong correlation between completed additional façade insulations and lower EP. Based on the sample for this study the difference is 36 kWh/m2/year, or 20 per cent between buildings with additional façade insulation and those without. The rate of additionally insulated façades is high – c. half of the buildings – considering that installation of additional insulation is a costly retrofit with a large impact on the buildings' character. Generally, the measure was successful in saving energy: the savings per m^2 were substantial and a large share of the buildings was affected (Figure 3).

It comes as no surprise that additional insulation has effect on the EP of buildings. However, the study also shows that the EP varies widely, even among the buildings with additional façade insulation. In fact, the building with the highest EP has had additional façade insulation installed. This might be a coincidence. Although the benefit of additional façade insulation for the EP was significant, the range is wide between the most and least

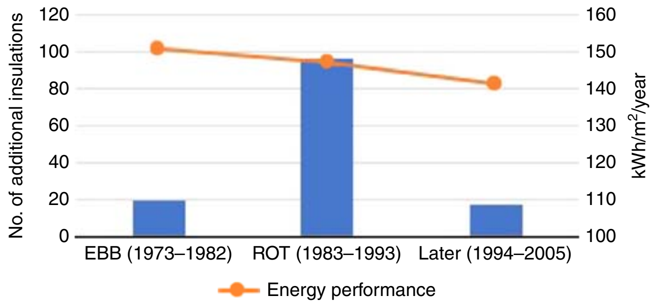


Figure 2.
Energy performance of buildings according to the period in which they were given added insulation

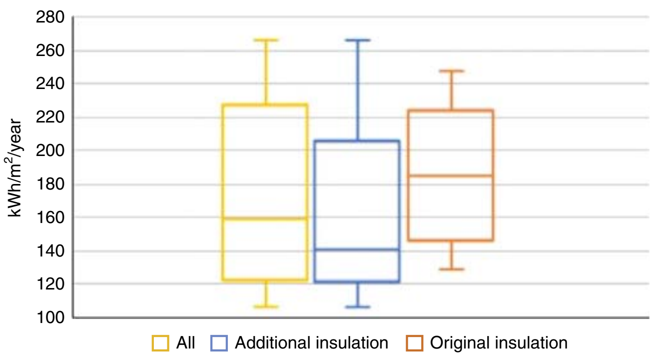


Figure 3.
Energy performance in all buildings (yellow), in ones with additional insulation (blue), and in ones with original insulation (brown)

efficient additional insulations. Regardless of insulation or no insulation, it is worth noting the big difference in EP among a group of very similar buildings. Although the material qualities of the buildings show great similarities the difference between the best and worst EP is c. 250 per cent. Further research, including detailed studies of the physics and use of individual buildings, is needed to determine the reason for this gap. Still, the results from this study indicates potential problems in policy-making based on grouping of the building stock by year of construction or building type.

Most of the additional insulation of buildings covered by the study was carried out during the ROT programme in the 1980s and early 1990s. This is likely connected to the age of the buildings in the sample. Previous studies have shown that the pace of energy retrofits in buildings from the 1930s was highest in the 1970s, during EBB (Leijonhufvud *et al.*, 2018). It is likely that areas from the 1940s were considered "good enough" during EBB, just to be targeted in the succeeding programme. When ROT was launched, these buildings were more than 30 years old, a requirement in order to receive funding at the beginning of the programme (Tunefalk and Legnér, 2019). Only a few buildings had additional façade insulation installed after ROT, either because there were fewer financial incitements for property owners after the beneficial subsidies during EBB and ROT were cancelled, or because there was less need since the most urgent measures had already been taken.

There seems to be a small improvement taking place in the way additional insulation was carried out. Buildings insulated in the period 1994–2005 have slightly lower EP than those insulated 1983–1993, which in turn are slightly more energy efficient than those insulated 1973–1982. The differences are however small, and it is questionable whether methods for lowering the EP by additional insulation of façades were improving during the period, or if the difference is a coincidence. It is however possible that the same EP was achieved with a thinner insulation in later times, increasing the energy efficiency with less effect on the character of buildings. Qualitative studies are needed to determine the effects in individual cases.

The study demonstrates a strong relationship between completed additional façade insulation and official heritage designation. All buildings that are categorised as lacking heritage values have had additional façade insulation installed, and none of the buildings categorised as "particularly valuable" or having "extraordinary heritage values". It is possible that the most valuable or vulnerable buildings were exempt from façade alterations, but it is nonetheless likely that additional insulation has affected the valuation of buildings. Since the city's heritage designation of buildings is used in the day-to-day administration of building permits and planning, and determines what legal statute is invoked, additional façade insulations made in the past – and by extension the policy measures included in EBB and ROT – continue to have effects on the character of the built environment.

The study has implications for both future policy-making and further research. The results indicate that policy measures were decisive in order for additional façade insulations to be carried out. In order to further improve the EP of the existing building stock, policy measures are most likely needed. The results further indicate that very few property owners will redo completed additional insulations. The study shows no evidence for this being done, even though 40 years have passed since the first ones. This implies that the emphasis in policy design and implementation should be on qualitative measures. It is however important that future policy-making acknowledges the small number of buildings that are classified as particularly valuable or having extraordinary heritage values. Although the results from this study indicate that these buildings have a significantly higher EP than other buildings, they constitute only a small part of the building stock. As demands for energy efficiency increases, it is important to ensure a satisfying protection for heritage values. For further research, the study has presented a method of combining data for EP, energy retrofits, and heritage protection, as well as identified a number of additional research questions.

Conclusion

The study indicates that energy-saving policies during the 1970s and 1980s were widely implemented in the built environment. They had a profound effect on the EP of buildings as well as on the heritage values in urban areas. Most likely they continue to affect the planning and administration of building permits today. The study demonstrates how a quantitative analysis, combining energy data with official heritage designation, can contribute to a better understanding of the relationship between energy retrofits, energy performance, and heritage values. In order to achieve a sustainable development, future policy making must bridge the gap between the issues of energy and heritage and take a holistic approach to the challenges in the built environment. Such an approach is made possible using methods for combining data related to different aspects of the built environment.

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Corresponding author
Martin Tunefalk can be contacted at: martin.tunefalk@konstvet.uu.se