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Socio-economic impact of renovation and energy retrofitting of the Gothenburg building stock

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ABSTRACT

The European building stock was renewed at a rapid pace during the period 1950–1975. In many European countries the building stock from this time needs to be renovated. There is an opportunity to introduce energy efficiency measures in the renovation process, but in this process social aspects should also be taken into account. The purpose of this article is to provide an estimate of the economic and societal challenge of renovating and energy retrofitting the aging building stock. Building specific data on energy usage and previous renovation investments made in the multi-family dwellings in Gothenburg (N = 5 098) is aligned with data on tenure type and average income. Based on conducted energy retrofitting projects, costs are estimated for renovating and energy retrofitting multi-family dwellings that will reach the service life of 50 years before 2026. It is found that the pace of renovation needs to increase and that there is risk of increasing societal inequity due to rent increases in renovated buildings.

1. Introduction

In many European countries the building stock increased at a rapid pace during the period 1950–1975 [1]. This aging building stock needs to be renovated, and there is a need to introduce energy efficiency measures in the renovation process [2–4]. The Directive 2002/91/EC *On the Energy Performance of Buildings* proposed the implementation of Energy Performance Certificates (EPC) for European buildings as a part of addressing energy retrofitting needs. This data has in some European countries been used by researchers to describe the energy usage demand and potential in building energy retrofitting [5–8].

The previous Swedish national target to decrease energy usage in the building stock by 50% by 2050 based on 1990 levels [9] would require extensive energy retrofitting [10]. In Gothenburg, Sweden, 42% of the multi-family dwellings were built during 1961–1975. This era is known as the Million Homes Program named after a large national initiative focused on building one million dwellings to cover an urgent housing need [11,12]. Buildings from the Millions Homes Program era will reach the 50 year service life in the next ten years, and a service life of 50 years is a commonly used as lifespan of buildings in Swedish building stock energy retrofitting studies [13,14]. The Buildings from the Millions Homes Program has been mentioned as a priority for renovation [15] and energy retrofitting [16].

Although the energy retrofitting of the existing building stock has been pointed out as one main area to achieve global, European and Swedish energy and climate goals, many studies have pointed out the economic challenges associated with these energy retrofitting activities [17–22]. First, the difficult economic framework conditions with low energy prices and high labor costs that restricts the (pure) market driven incentives for energy retrofitting results in a return on investment ratio that is often far beyond 10–15 years that e.g. multinational investors accept as the maximum time for return on invest. Second, the fact that (deep) energy retrofitting often results in socio-economic drawbacks, namely increased rents [17,23,24]. Recent concerns [25] for increased societal costs and decreased societal equity as a result of inhabitant relocation after renovation has spurred a debate about the inclusion of social sustainable development criteria in the required national renovation plan [26]. Quantitative studies that include equity perspectives are needed to make informed decisions in such renovation plan [27].

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The purpose of this article is to quantify the economic and societal challenge of renovating and energy retrofitting buildings of the Million Homes Program by adding dimensions of tenure type, average income and rent, to a dataset of potential energy retrofitting and previous renovation investments made in the multi-family dwellings in Gothenburg. Several existing national databases are aligned using a geographical information system (GIS) including: Swedish EPCs containing measured energy usage and estimated energy reduction potentials by certified energy experts; renovation investments and geographical data of buildings from the Gothenburg City Planning Authority (CPA, Swedish translation: Stadsbyggnadskontoret) and the Swedish National Land Survey; socio-economic data from Gothenburg City Executive Office (CEO, Swedish translation: Stadsledningskontoret); and rent levels are provided by the residents' association (Swedish translation: Hyresgästföreningen). These databases are further described under materials and methods.

Increasingly socio-economically disadvantaged groups inhabit the peripheral Million Homes Program areas [28] and a number of researchers have been studying how to take these groups into account. Högberg [29] suggested that a way forward might be that tenants have the option to choose the levels of renovation and subsequent increase in rent. In most Swedish apartments the rent includes heating and domestic hot and cold water, while electricity is paid separately by the residents. In this article rent costs presented includes heating and water but not electricity. During the last 10 years volumetric billing of water has been introduced in mainly economically disadvantaged rental apartments where the water cost is still added to the monthly rent [30].

In this article, rent increases as a result of renovation and energy retrofitting projects are calculated and visualized onto geographical areas with defined income ranges as part of estimating the impact on the equity aspect of social sustainable development [31]. Impact on social sustainable development is also given as number of people that are likely to change dwelling as a consequence of increased rent after renovation projects [25].

This article first describes the data that is used, after that the assumptions are detailed to explain how the resulting description of the building stock is obtained. The results are finally discussed against findings in previous studies.

2. Materials

Working on a city scale with data in a GIS application makes it possible to estimate validity, notice anomalies and make the results presentable and usable for local authorities and stakeholders, see Fig. 1.

The datasets that are combined to describe the Gothenburg building stock are presented in Table 1. Different numbers of *base areas*,[1] are available in data from Gothenburg CEO and the Residents association. The total number of inhabited base areas in Gothenburg is 731. Due to the legal limitations to data dissemination it is not possible to access data where there are less than 10 people in a group in one base area, which causes some multi-family dwellings to fall outside of the study. Furthermore, it was also impossible for the Residents' association to provide average rent levels were only one real estate companies operate. This shortcoming was handled by assigning average rent levels from other existing records based on proximity. The total number of EPCs analyzed in this article is 5098 after the removal of: buildings built after 2005, buildings in base areas with less than 10 inhabitants, and the buildings in base areas where the sum of Heated floor area, A_{temp}[2] is less than 10,000 m^2.

The possible pitfalls and limitations with using Swedish EPC data when analyzing building stock were studied by Mangold et al. [34]. The most pressing shortcoming was found to be varying ways of deriving heated floor area, A_{temp}.

2.1. Division of areas and groups

The Swedish housing system is complex and has its current shape due to legacy regulated elements on the one hand and neoliberalised elements on the other [35]. The Swedish multi-family-dwelling building stock consist of primarily three tenure types: municipally owned rental apartments, privately owned rental apartments or resident owned apartments (Swedish translation: bostadsrätt). In the base areas in Gothenburg the type of tenure is on average 87% homogenous. Base areas in which no tenure type reach 50% homogeneity are separated as base areas of mixed tenure. When linking the tenure types with the base areas, four different tenure area groups are defined: Mixed tenure, municipally owned, privately owned and resident owned, see Table 2.

Building age is a commonly used parameter for dividing the building stock since building techniques vary between eras and the renovation needs might be different between different construction periods. Thuvander et al. [36] found the separation in 15 year construction periods useful to describe the Gothenburg building stock, see Table 3. In Table 3 and Table 4 tenure area groups are further divided into construction periods groups, resulting in some groups not being sufficiently large to be statistically representative. The period 1961–1975 is the Million Homes Program era. Building built after 2005 are outside of the scope of this study.

2.2. Renovation costs

When a renovation project is conducted that goes beyond maintenance it is registered by the Swedish Tax Agency and provided to the CPA. The cost of the renovation results in a change in the so-called *value year* of the building as described by Swedish Tax Agency [37]. The purpose of recording a value year is to have an official record of anticipated remaining service life of buildings [37]. The value year is initially the year of construction but as renovation is conducted the value year will increase depending on the cost of the renovation as described in Table 5. Registration of renovation in the tax index usually happen 1–2 years after the renovation.

$$\frac{\textit{Value year} - \textit{Construction year}\,[\textit{year}]}{\textit{Renovation year} - \textit{Construction year}\,[\textit{year}]} = \frac{\textit{Renovation cost}\left[\frac{SEK}{m^2}\right]}{\textit{Cost of new building}\left[\frac{SEK}{m^2}\right]} \quad (1)$$

> Example: if a building built in 1960 was renovated in year 2000 to a cost of 50% of the new building cost the value year after the renovation would be 1980.

The changes in value year only reflect the cost of the renovation, but do not contain what kind of renovation measures were implemented. The value year is an indicator of renovation costs, or an indicator of investments into the building. The changes in value year is an indicator with the following uncertainties:

[1] Base areas are an administrative unit defined as the smallest demographical statistics area containing 50–4000 residents (Swedish translation: Basområde).

[2] A_{temp} is a measure of building floor area specifically developed for EPC in Sweden. A_{temp} is defined as the floor area heated above 10 °C including shared spaces and footprints of walls but not including garages [32].

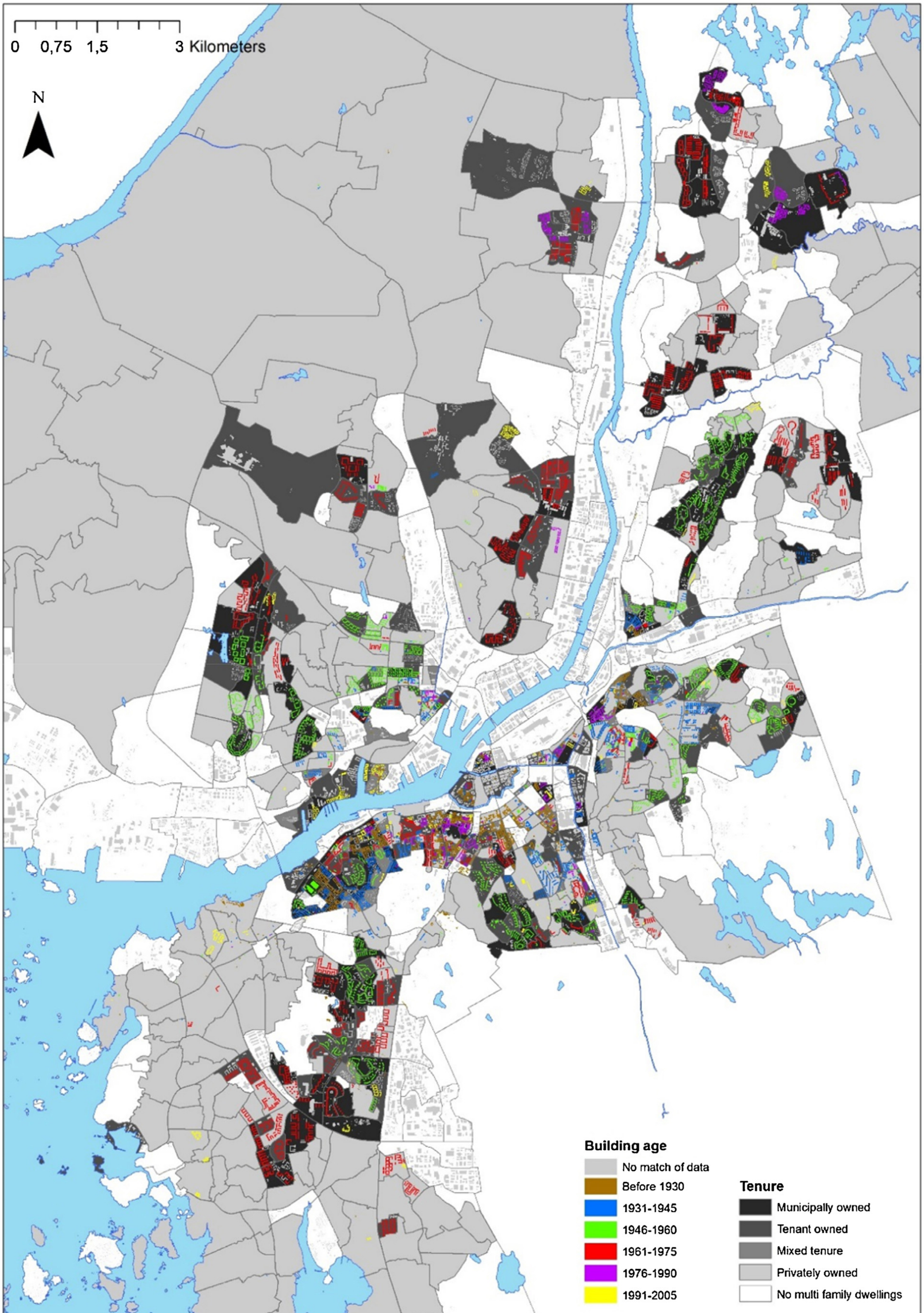

Fig. 1. Gothenburg city divided into base areas (gray scaled classification for tenure area groups and buildings colored classification for construction period). The buildings that are gray are not multi-family dwellings.

Table 1
Details on datasets and data providers for multi-family-dwellings in Gothenburg.

	Boverket	Gothenburg CPA	Gothenburg CEO	Residents' association
Aggregation level	EPC for a building	Structures	Base area	Base area
N	6320	64,600	434	291
Information used in this article	A_{temp}, Energy usage, Building age, Number of apartments	Renovation year, Value year[b]	Average income, Number of people earning less than 60% of the median income[a], Number of inhabitants, Tenure type	Average rent

[a] First definition of poverty by European Commission [33].
[b] Value year is explained in Section 2.2.

Table 2
The tenure area groups.

	Number of EPC [st]	Building area [10^3 m^2 A_{temp}]	Number of base areas [st]	Inhabitants [persons]
Unmatched base area	1 220	950	–	–
Mixed tenure	287	638	21	13,300
Municipally owned	1700	6050	155	142,000
Privately owned	1620	4170	134	95,200
Resident owned	1490	4510	124	87,500
Total matched	5100	15,400	434	338,000

Table 3
Number of EPC for tenure area groups and construction periods.

Number of EPC	built before 1931	1931–1945	1946–1960	1961–1975	1976–1990	1991–2005	Total
Mixed tenure	120	78	70	1[a]	14	4[a]	287
Municipally owned	178	224	499	587	127	86	1700
Privately owned	244	523	296	434	55	72	1620
Resident owned	340	160	351	417	117	101	1490
Total	882	985	1220	1440	313	263	5100

[a] These groups are removed as the low numbers of EPCs make comparisons with the groups unreliable.

Table 4
Heated floor area [10^3 m^2 A_{temp}] of buildings tenure area groups and construction periods.

	built before 1931	1931–1945	1946–1960	1961–1975	1976–1990	1991–2005	Total
Mixed tenure	256	115	170	7	84	5	638
Municipally owned	542	371	1 500	3030	473	130	6050
Privately owned	527	895	723	1810	102	109	4170
Resident owned	722	331	924	1910	462	163	4510
Total	2050	1710	3310	6760	1120	410	15,400

Table 5
Methods for setting a value year based on renovation costs according to the Swedish Tax Agency [37].

	Renovation cost	Method of setting the value year
Group 1	More than 70% of the new building cost[a]	Value year is set to the year of the renovation
Group 2	20–70% of the new building cost[a]	The value year is set based on the cost of the renovation compared with the cost of constructing a comparable building using Eq. (1).
Group 3	Less than 20% of the new building cost[a]	No change in value year

[a] The new building cost is increasing based on Inflation, changes in construction costs and property value. This is also specified in a Table by Swedish Tax Agency [37].

- More than one renovation can have happened, but only the last renovation year is registered
- It is not known what kind of renovation measure that has been conducted

3. Methods

Changes and required changes in the value year of multi-family dwellings are used to estimate costs. However, the type of renovation and energy retrofitting differ between buildings. The focus of this article is the building stock from the Million Homes Program era, thus studies of renovation projects of such buildings with a component of energy usage reduction are used.

3.1. Pilot renovations

In order to estimate the average cost for renovations, six pilot energy retrofitting projects have been assessed, see Table 6. Common for the projects are that they were all built in the Million Homes Program era and they are all municipally owned. The projects "Backa röd" and "Brogården" were pilot projects specifically for finding ways to energy retrofit buildings from the Million Homes Program era [18].

Table 6
Brief project details of the 6 renovation cases with energy retrofitting aspects of buildings from the Million Homes Program era.

Project	Location	Renovation year	Number of Apartments	Additional wall/roof insulation [mm]	Ventilation installed	Air leakage at 50 Pa [l/s m²]	U-value of new windows [W/m² K]
Nystad	Stockholm	2011	99	80/300	FTX	0.4	0.9
Trondheim	Husby	2013	25	50/200	FTX	1	1
Backa röd	Gothenburg	2012	120	200/500	FTX	0.13	n/a
Brogården	Alingsås	2008	300	450/500	FTX	0.2	0.85
Väsbyhem	Upplands Väsby	2010	100	300/500	FTX	0.4	0.9
Kvarngärdet	Uppsala	2012	500	80/300	FTX	0.4	1

Table 7
Costs and energy usage reduction and related costs in 6 cases [35,36].

		Nystad	Trondheim	Backa röd	Brogården	Väsby-hem	Kvarngärdet	Average
Annual energy usage before energy retrofitting	(kWh/m²)	164	214	178	177	180	190	184
Annual energy usage after energy retrofitting	(kWh/m²)	78	94	52	58	75	85	74
Energy usage reduction	(%)	52	56	71	67	58	55	60
Decreased annual energy usage	(kWh/m²)	86	120	126	119	105	105	110
Cost of renovation (incl. energy retrofitting)	(SEK/m²)	12,800	16,400	14 500	19,800	19,400	13,000	16,000
Cost of energy retrofitting	(SEK/m²)	2140	3490	3000	5600	3500	2600	3340
	(%)	17	21	21	28	18	20	21
Cost energy retrofitting	(SEK/kWh)	25	29	24	47	33	25	30
Rent increase	(SEK/m²)	195	136	244	302	300	459	273
	(%)	24	17	35	40	33	51	33
Rent increase factor[a]	(%)	1.82	1.05	2.12	2.13	1.89	4.41	2.16

[a] Rent increase divided by the Cost of renovation (excl. energy retrofitting).

The optimal type of energy retrofitting measures are building specific and require a thorough analysis [4,38,39]. In order to get general representation, in this article the average costs and energy usage reduction results of the six pilot energy retrofitting projects are assumed to represent possible renovations and energy retrofitting results for the entire stock of multi-family dwellings.

The Stockholm City Environmental Department [40] and Ulrich and Pscheidl [41] studied and summarized the economic aspects of these projects and their findings are used in this article. The results of these energy retrofitting projects are provided in Table 7, where the column 'Average' contain the figures used as assumptions. There are several manners by which rent is increased in connection with larger renovation projects, especially when comparing renovations of buildings with different tenure types. The rent increase factor was calculated by dividing the Cost of renovation (incl. energy retrofitting) by Yearly rent increase for each project. The assumption made in this article is that 2.16% of the renovation cost (incl. energy retrofitting) will be the additional yearly rent, as seen in Table 7. This indicates a longer period of return on invest than usually required [40].

The total cost of renovation was estimated by SABO [20] to 12,000 SEK/m² in 2009, which is lower than the average renovation cost for the examples presented by Ulrich and Pscheidl [41] from Stockholm City Environmental Department [40], see Table 7. SABO [20] used a lower renovation degree and a lower ambition of energy efficiency than the pilot renovations.

3.2. Estimation of renovation costs and needs

Costs for renovation and energy retrofitting varies greatly depending on building type, building characteristics, building condition, building location, inhabitation amongst other. Even if all these parameters are not available for the building stock it is still possible to calculate the cost of previously conducted renovation from the value year of a building as described in Table 5.

Using Equation (1) the previously conducted renovation costs were calculated for all buildings using Cost of new building for year 2012 as a reference, 15 300 SEK/m² (1€ = 9.34SEK on 2015-09-22). For buildings in group 1 and 3 in Table 5 the costs are assumed to be 90% (the Renovation cost may be more than 100% of Cost of new building) and 10% (between 0 and 20%).

Value year is used as a measure of remaining service life. When the service life of the building is 50 years (from the value year) then the building have been assumed to be in need of renovation. A shortcoming in this method of calculating service life is that buildings that have been renovated frequently but to a cost lower than 20% of the new building cost, registered as group 1 renovation in Table 5, have not changed their value year and can mistakenly appear as in higher need of renovation.

For the energy retrofitting, the assumption is made that all buildings are energy retrofitted to not use more than 74 kWh/m².year, taken from the pilot renovations in Table 7. This assumption is in accordance with the energy requirement in the national building code for extensive retrofitting in the climate zone for Gothenburg [42], which is the same requirement as for new buildings.

4. Results

During the next ten years buildings built during the Million Homes Program will reach the 50 year service life. Assuming that the buildings will be renovated when they reach 50 years of service life in a similar way as the average results of the pilot renovation projects presented in Table 7, remaining and upcoming cost have been calculated. Costs of conducted renovations have been summarized for a comparison, see Fig. 2.

As can be seen in Fig. 2 there is a need for additional funds for renovating multi-family dwellings during the upcoming years. There are many buildings that have already reached a service life of 50 years that have not been renovated, but during the next ten years until 2026 there are more buildings that will reach a service life of 50 years. These buildings represent the upcoming challenge for authorities, real estate owners and the construction industry of Gothenburg. The majority of these buildings built during the Million Homes Program era, see Table 8.

The costs of renovations and energy retrofitting are presented in Table 9. The costs are comparable with the estimate 275,000 MSEK by SABO [20] in 2009 for renovating 390,000 apartments in the Swedish municipal building stock from the Million Homes Program

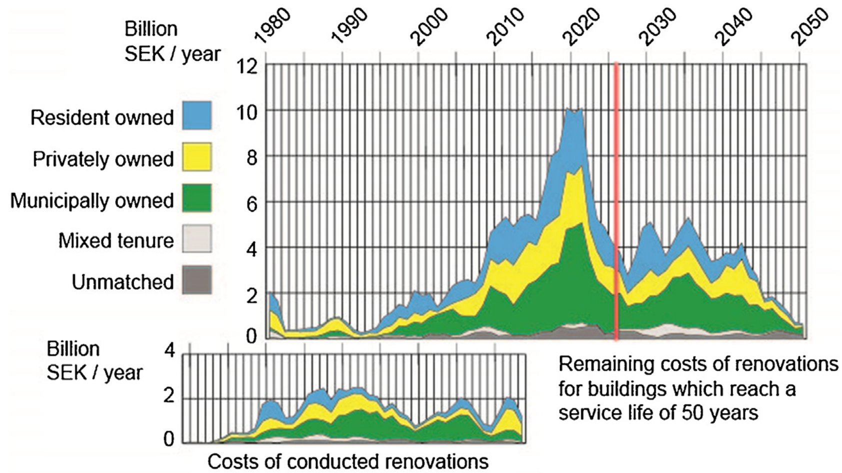

Fig. 2. Comparison between cost of conducted renovations and costs of renovations (incl. energy retrofitting) for buildings which reach a service life of 50 years. The renovation costs in Table 9 are equal to the integral of the remaining costs until the indicated red line of year 2026. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 8
Heated floor area [10^3 m^2 A_{temp}] of buildings that will reach a service life of 50 years before 2026 separated in construction periods.

	Built before 1931	1931–1945	1946–1960	1961–1975
Unmatched	38.4	95	182	205
Mixed tenure	105	72.6	130	0
Municipally owned	272	190	969	2240
Privately owned	332	518	456	1590
Resident owned	352	212	790	1740

Table 9
Renovation and energy retrofitting cost estimates in multi-family dwellings that will reach a service life of 50 years before 2026.

	Heated floor area [10^3 m^2 A_{temp}]	Apartments	Renovations cost (incl. energy retrofitting) [MESK]	Energy retrofitting cost [MESK]	Share of energy retrofitting cost
Unmatched	532	6250	7740	1030	13%
Mixed tenure	309	3840	4560	670	15%
Municipally owned	3700	44,200	54,200	7550	14%
Privately owned	2910	33,900	42,900	6280	15%
Resident owned	3100	34,600	45,100	6030	13%
Total	10,600	123,000	155,000	21,600	14%

Table 10
Heated floor area [10^3 m^2 A_{temp}] of buildings using more than 150 kWh/m^2.year separated in construction periods.

	built before 1931	1931–1945	1946–1960	1961–1975	1976–1990	1991–2005	Total
Mixed tenure	43.5	37.2	75.1	0	2.2	5.5	164
Resident owned	160	129	520	755	35.3	6.3	1600
Municipal	102	200	179	803	8	13.6	1300
Private	151	111	280	394	51.4	16.7	1000
Total	457	476	1050	1950	96.8	42.1	4080

era. SABO [20] assumed a lower renovation degree and a lower ambition of energy efficiency than were implemented in the pilot renovations.

The energy retrofitting costs in Table 9 are a smaller than the energy retrofitting costs in Table 7. This is because the average energy performance of the building stock is better than the average energy performance of the buildings in which the pilot renovations were carried out. The energy retrofitting cost applies to 98.3% of the buildings, which have an energy performance worse than 74 kWh/m^2.year. The average energy usage in the buildings constructed during the Millions Homes Program era is marginally higher than in other building groups, see Table 10. However since more buildings were built during this period, see Table 4, the total energy usage is larger. Furthermore, the heated floor area of buildings that use more than 150 kWh/m^2 in the Million Homes Program group is almost equal to the heated floor area of all the other buildings with a similar energy performance together. Focusing on buildings that use the most energy is one way of prioritizing between energy retrofitting projects [43].

4.1. Renovation costs in different tenure and income groups

The costs of renovation and energy retrofitting of buildings which have and will reach a service life of 50 years before 2026 will be shared by taxpayers, housing companies and residents in different ways depending on the renovation model. In this study, rent increases were calculated by applying the Rent increase factor from Table 7 to the renovation and energy retrofitting costs. Future

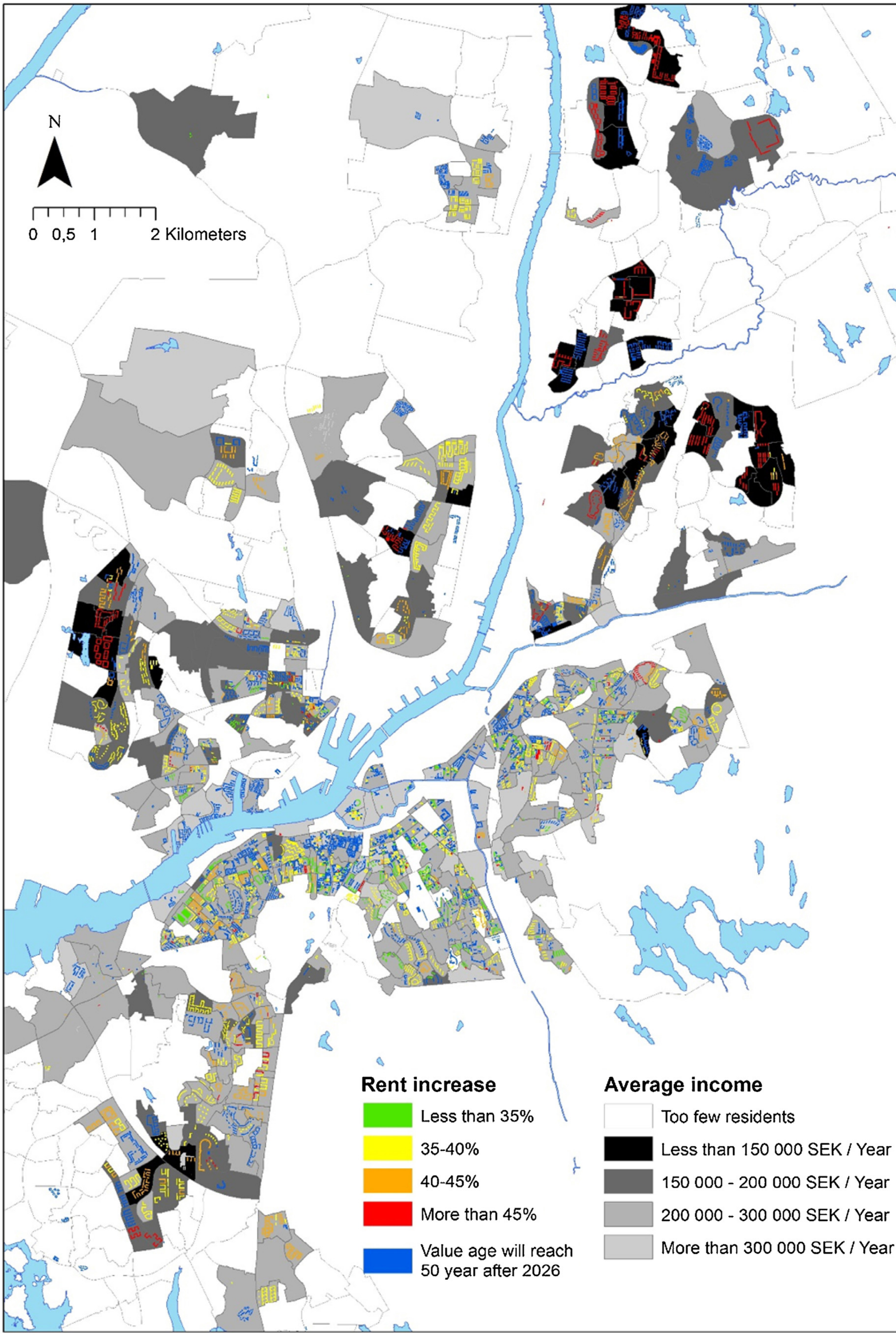

Fig. 3. Estimated rent increase due to required retrofitting and average income in base areas (average and median income in Gothenburg are 258,000 and 246,000 SEK/Year). Blue buildings are not part of the building stock that will reach a service age of 50 years before 2026. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 11
Renovation cost estimates of buildings that will reach a service life of 50 years before 2026 in the areas where average income is less than 200,000 SEK/Year. There are no base areas that have mixed tenure or predominantly resident owned apartments with average income lower than 200,000 SEK/Year.

	Heated floor area [10^3 m^2 A_{temp}]	Cost of renovation (incl. energy retrofitting) [MESK]	Cost of energy retrofitting [MESK]	Rent Increase [SEK/month]	Number of people earning less than 60% of the median income
150 000–200 000 SEK / Year					
Municipally owned	1370	17,200	2550	2260	8970
Privately owned	480	6100	860	2130	2890
Less than 150 000 SEK / Year					
Municipally owned	1200	15,100	2600	2370	13,100
Privately owned	505	6360	1360	2580	5810

rent increases are based on the current base area average rent levels and the estimated rent increases. Building specific estimations of rent increases are illustrated in Fig. 3.

The residents of buildings in base areas that are dark gray and black in Fig. 3 with an average income of 150,000–200,000 and lower than 150,000 SEK/year, are part of socio-economically disadvantaged societal groups. These groups are also over represented as residents of buildings that will reach a service life of 50 years before 2026, see Table 11.

Boverket [25] studied the patterns of changing habitation following larger renovation projects in multi-family rental dwellings (the renovation costing more than 25% of the value of the building). Boverket [25] found that 30% of people earning less than 60% of the median income will move because of larger renovation projects. In Table 11 a column has been added with the number of people earning less than 60% of median income that are living in buildings which will reach a service life of 50 years before 2026.

5. Discussion

The investments in renovation measures should, or will, certainly not happen as described in this article. If energy efficiency is achieved by requiring every building to use less than 74 kWh/m^2, if the buildings were renovated to the assumed levels and if the renovations were financed according to the examples in Table 7 then there will be negative impact on the social sustainable development parameter of social equity [31].

Finding the appropriate level of renovation and energy retrofitting for each building and finding a socially sustainable payment model is needed. The Swedish government earmarked 500 MSEK for energy efficiency measures in renovation of the Swedish building stock in the budget for 2016–2018 [44], which is too little when comparing with the findings in Table 9. However, by changing assumed cost of capital and required pay-off time the cost saving from reduced energy usage will pay for a larger share of the energy efficiency measures [40]. One way forward is to use socio-economic data to analyze renovation feasibility as done by Delmastro et al. [24]. Raising the rent to cover costs of energy efficiency measures is not an advisable way forward for Gothenburg based on the findings in this article.

Lind [45] argues for a deregulation of the rental housing market as a way of preventing unnecessary renovation. Letting residents decide the level of renovation extent and associated rent increase and other cost models might need to be considered [29]. As can be seen in Fig. 2, more investments through renovations have been registered for the municipally owned building stock. The Swedish authorities sold off parts of the building stock built during the Million Homes Program era to finance other renovations [35,45].

The assumption of 50 year lifespan is larger in comparison with most other counties [13], but the actual renovation need depend on a multitude of building specific factors [14]. In Sweden, changes or replacements of main sewage plumbing is usually done after 50 years and is a common reason for conducting a larger renovation.

The system boundaries of the analysis should also be discussed. 90% of the multi-family dwellings in Gothenburg have district heating with a low usage of primary energy sources [18,46]. In Table 10 the buildings that use more than 150 kWh/m^2.year are presented as a priority group for energy retrofitting. However, when socio-economic aspects are included priorities could be set differently. Using energy usage per person as opposed to energy usage per living area could be seen as a more fair measure of energy performance of dwellings [47]. The average living area is 57, 49, 42, and 38 m^2 A_{temp} per person areas for the areas of More than 300,000 SEK, 200,000–300,000 SEK, 150,000–200,000 SEK and Less than 150,000 SEK yearly income respectively. This is an aspect to consider in the discussion on how goals of energy usage reduction are set [48]. Furthermore, increased need of renovation due to crowdedness is not considered when using value year to decide service life and renovation need.

This article has focused on analyzing the renovation needs and costs of the multi-family dwellings of Gothenburg. The same databases exist for most of Sweden and applying a similar approach nationally would provide clarity for policy making for renovation and energy retrofitting. Measured building specific energy usage on a city scale is increasingly available and usable to prioritize and predict development in the building stock in most countries [43,44]. When comparing the results presented in this article with other studies the type of area unit need to be taken into account. The area unit A_{temp} developed for the Swedish EPC includes all heated floor area in the building including stair cases. A_{temp} is on average 34% larger than the sellable living area of apartments [34].

Resch et al. [51] describes how building specific GIS associated data, similar to the data described in this article, could be used to develop comprehensive models of the building stock. It is also possible to use building specific energy usage and characteristics to model building stock [52]. Future research could then evaluate specific energy efficiency measures and give detailed decision support to property owners and managers.

6. Conclusion

This article described the economic and societal challenges of renovating and energy retrofitting the multi-family dwelling stock in Gothenburg. The value year was used to calculate previous renovation costs and to estimate the need of future renovations. Results from six pilot renovation projects were used to estimate costs for future renovation and energy retrofitting projects. The costs of renovating and energy retrofitting the buildings that will reach the 50 year service life before 2026 (10,600,000 m^2 heated floor area) were estimated to 155 000 MSEK, of which 21,600 MSEK are costs for energy saving measures that would improve the buildings energy performance to 74 kWh/m^2.

If these costs are distributed to also include rent increases as was done in the six pilot renovations then the people earning less than 150,000 SEK/year will have an average rent increase of 2420 SEK/month in municipal and 2640 SEK/month in privately owned rental apartments. In these apartments there are 30,600 inhabitants who earn less than 60% of median income and will be further economically disadvantaged by rent increases. These parameters of social equity should be included in sustainability analyzes of coming renovation and energy retrofitting projects.

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