The effect of weighting factors on income-related energy inequalities: The case of Sweden’s new building code

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Abstract. To ensure building construction with low heating demand, efficient use of sustainable energy carriers, and neutrality between heating technologies, Sweden recently introduced weighting factors (WFs) for different energy carriers which are now used in Energy Performance Certificates (EPCs). As EPC ratings are gaining increased influence in Swedish energy policy and regulation, with recent examples of buildings’ EPC rating acting as base for imperative regulatory requirements, the introduction of WFs is likely to have significant effects on how policy and regulations are distributed in the multifamily building stock. As residents often are directly or indirectly affected by policy that either impose or trigger measures to be undertaken in their building, the aim of this paper is to analyse how WFs affect the assessed energy performance of buildings in different resident income groups. The results show that overall, reduced energy performance from WFs was more common in high-income areas than in low-income areas. However, although the total number of buildings in the lowest EPC ratings was reduced after introducing WFs, the resulting income distribution among worst-performing buildings was more skewed towards low-income households than before introducing WFs. As imperative regulatory requirements previously have targeted worst-performing buildings, these results indicate that energy-related inequalities in the housing stock have become more prominent and should be considered as to not disproportionately burden low-income residents in the energy transition of the housing stock.

1. Introduction

With 40% of EU’s final energy use taking place in buildings [1], improved energy performance of the building stock continues to be a central tenet in the transition towards energy efficient and decarbonised societies. As the energy transition of the building stock proceeds, there are however changes to the overall energy system to account for. To ensure an optimal use of resources, robust building construction, and minimal environmental and climate impacts from buildings’ energy use, the system boundaries of buildings’ energy use in the EU have expanded to include ‘primary energy’. Primary energy is the “energy from renewable and non-renewable sources which has not undergone any conversion or transformation process” [2], and thus alters the building’s system boundaries from merely considering the amount of delivered energy to accounting for energy needed for extraction, processing, transport, and conversion of energy carriers. To determine and monitor buildings’ primary
energy use, directive 2013/10/EU on the energy performance of buildings (EPBD) demands member states to establish primary energy factors (PEFs) based on national or regional yearly average values. These should then be used when determining buildings’ energy performance for the issuing of Energy Performance Certificates (EPCs).

Sweden is one of few EU member states that use operational rather than predicted values for energy use in EPCs [3], and all owners of multifamily buildings are obliged to issue EPCs for their buildings since 2008 [4]. The fact that EPCs based on operational values are available for close to all multifamily buildings have made EPCs increasingly influential in Swedish energy policy and regulation, with recent examples of buildings’ EPC rating acting as base for imperative regulatory requirements [5] as well as for granting of support [6]. PEFs were briefly introduced in the Swedish building code and in the EPCs in 2019, but were quickly replaced by the similarly conditioned weighting factors (WFs) that include more energy-system aspects than PEFs.

The increasing influence of multifamily buildings’ EPC rating on energy policy in Sweden makes the introduction of WFs in the building code an important case for scrutiny. Although it can be argued that the most important function of WFs is to promote technical neutrality between energy carriers and technologies during construction of new buildings, the increasing policy influence of EPC ratings means that WFs are likely to have direct effects for the existing multifamily building stock as well – let alone for residents. In Sweden, there are positive correlations between buildings’ energy performance and residents’ income [7], meaning that energy performance tends to be better in high-income areas than in low-income areas. As energy policy often targets the worst-performing parts of the building stock, previous work has shown that the existing energy-related inequalities risk leading to disproportionate burdens among low-income households in the energy transition of the housing stock [8]. Such burdens can e.g. arise from costs associated with imperative regulatory requirements in worst-performing buildings in low-income areas, and there is thus a need to analyse how the introduction of WFs affects the energy performance of multifamily buildings in different income groups in general, and among worst-performing buildings in particular. If regulations and policies in the energy transition of the housing stock are implemented without recognising potential asymmetries between different groups in society, there is a risk that inequalities and injustices are aggravated and that marginalized or vulnerable groups of residents are disproportionately burdened.

The aim of this paper is thus to investigate how the updated building code – which should be understood as an influential regulation in the transition towards a more energy efficient and decarbonized building stock – affects the energy performance of multifamily housing in different income groups.

1.1. The Swedish energy system and building code

In Sweden, energy for heating has been decarbonised to a great extent since the oil crises in the 1970’s, and buildings’ energy performance continues to improve [9]. District heating (DH) has come to be the dominating energy carrier in multifamily buildings [10], whereas heat pumps have constituted an important technology for the continued energy performance improvements in single-family houses [11]. To some extent, heat pumps have come to compete with DH in multifamily buildings as well, which has spurred a debate regarding the lack of energy performance neutrality between heat pumps and DH. With heat pumps converting one unit of electricity to multiple units of heat, it is easier to comply with building codes regarding energy performance in new construction as the amount of delivered energy (which is the subject of regulation) can be significantly lower than the heat demand, meaning that the building’s U-value can be higher than if energy was supplied through DH. Given that DH plays a significant role in the Swedish energy system, enabling reuse of waste heat from industries, incineration of waste and cogeneration in combined heat and power plants, there has been a strong will to promote more neutrality between heat pumps and DH. More so, owing to increasingly intermittent electricity generation and incentives to reduce overall electricity use and reduce power demand though peak shaving, there are benefits on system level of ensuring low U-values in new buildings. A strong, albeit not united [12, 13], industry has thus emphasised that energy
efficient buildings should primarily be achieved through well-insulated construction rather than through efficient heat pump technology [14, 15].

Primary energy factors (PEFs) were first introduced in the Swedish building code in 2019, but were then replaced by weighting factors (WFs) in 2020 (see Table 1). As Table 1 shows, the first PEFs that were introduced only differentiated electricity from other energy carriers. WFs replaced PEFs in 2020 and further increased the differentiation between energy carriers by increasing the burden on electricity (heat pumps as well as direct electric heating) and fossil fuels, and by lowering the burden on DH, district cooling and biofuels [16]. With these new WFs, there is improved neutrality between heat pumps and other technologies, meaning that the U-value gains more equal importance in construction regardless of energy carrier for heating.

Table 1. Initial PEFs and revised WFs for energy carriers in the Swedish building code.

| Energy carrier         | Primary energy factor (PEFs) 2019 | Weighting factor (WF) 2020 |
|------------------------|----------------------------------|---------------------------|
| Electricity            | 1.6                              | 1.8                       |
| District heating       | 1                                | 0.7                       |
| District cooling       | 1                                | 0.6                       |
| Biofuels               | 1                                | 0.6                       |
| Fossil oil and gas     | 1                                | 1.8                       |

2. Materials and Methods

To analyse the effect of WFs on the energy performance of multifamily buildings in different income groups, building-specific and nation-wide data on buildings’ energy use and residents’ income were combined and used in quantitative analyses. Details of data can be seen in Table 2. Energy use data were retrieved from EPCs, which are mandatory for multifamily buildings since 2008 and valid for 10 years. EPCs were retrieved from the National Board of Housing, Building and Planning (NBHBP), the administrative authority of EPCs, in January 2020 when approximately 50% of EPCs for multifamily buildings had been renewed since 2008 and EPCs were available for 80% of the multifamily building stock.

Data on residents’ income were retrieved from Statistics Sweden in 2018 but is valid for 2016. Income data were provided as median income per property, and as several buildings can exist on one property, median income was assumed to be valid for all buildings on each property. For analysis, income deciles were calculated based on total area in the multifamily building stock, meaning that the building area is equal in all income deciles.

Table 2. Metadata regarding the data used for analysis.

| Variable            | Data source      | Year | Level of aggregation | Coverage of stock |
|--------------------|-----------------|------|----------------------|-------------------|
| Energy use data    | NBHBP           | 2020 | Building             | 80%               |
| Median income      | Statistics Sweden| 2016 | Property             | 100%              |

As most EPCs in NBHBP’s register were issued before enforcement of the new building code and WFs, energy performance$_{WF}$ had to be calculated for older EPCs in order to compare energy performance (before PEFs and WFs) and energy performance$_{WF}$ (with WFs from 2020) to analyse the effect of WFs for each individual building. Based on energy use data in EPCs, energy performance$_{WF}$ was calculated for each individual building using the new primary energy factors (WFs), seen in Table 1, and Equation 1.

$$\text{Energy performance}_{WF} = \frac{\sum_{i=1}^{6} \left( \frac{E_{\text{heat}}}{A_{\text{heat}}} + E_{\text{cool}} + E_{\text{DHW}} + E_{f,i} \right) \times WF_{f,i}}{A_{\text{heat}}}$$ (1)
3. Results
To get a broad overview of the effect of WFs on multifamily buildings’ energy performance in different income groups, this section will first cover such effects in the entire multifamily building stock (section 3.1), and then further analyse such effects among buildings that got a reduced energy performance after the introduction of WFs (section 3.2).

3.1. Effect of WFs on entire multifamily building stock
In Figure 1(a), it can be seen that the overall energy performance in the multifamily building stock has improved owing to the introduction of WFs. Given that approximately 90% of the heated floor area in the entire stock is heated by DH (seen in Figure 1(b)), this result is expected. The positive correlation between energy performance and residents’ income persists after the introduction of WFs, and no prominent differences in the effects of WFs appear between different income deciles.

![Figure 1(a-b). WFs overall effect on energy performance in the multifamily building stock (a) and main source of heating (b).](image)

3.2. Characterisation of buildings with reduced energy performance from WFs
To study the effects of the introduction of WFs in more detail, separate analyses of multifamily buildings that got a reduced energy performance after introduction of WFs were performed. Figure 2 shows all multifamily buildings for which the energy performance was reduced, in total 13.6% of the multifamily building stock. The figure shows a division of multifamily buildings based on their main source of energy, i.e. the energy carrier providing >50% of total energy demand. Buildings with DH and biofuels as main source of energy are present in this sub-group of buildings, despite these energy carriers having WFs below 1. This is because these buildings had mixed sources of energy where the share of energy carriers with WFs of 1.8 was great enough to contribute to a reduced energy performance. In total, 14.1% of the multifamily building stock relies on a mix of energy carriers.

Figure 2 shows that in total (black line), more buildings in higher-income segments were negatively affected by WFs than in lower-income segments. The break-down on energy sources shows that buildings with DH (in combination with other energy sources) and heat pumps as main energy sources dominate among buildings with reduced energy performance, and increase with increasing income. Buildings with electric heating or fossil fuels as main source of energy are rather equally represented among buildings with reduced energy performance, but opposed to DH and heat pumps, these energy carriers decrease with increasing income. Buildings with biofuels as main source of energy (in combination with other energy sources) are very few.

The fact that energy performance (without WFs) tends to be lower in low-income housing than in high-income housing (Figure 1) combined with the fact that mixed heating solutions with DH are
more common in high-income housing than in low-income housing (Figure 2) means that WFs will have unequally strong effect in low- and high-income housing. This can be seen in Table 3 and in Figure 3(a-b). Table 3 shows that owing to a higher share of DH with mixed heating solutions in high-income housing, the ratio between energy performance\textsubscript{WF} and energy performance tends to be lower in high-income housing (decile 8-10) than in low-income housing. The initial differences in energy performance among income deciles also mean that an equal ratio between energy performance\textsubscript{WF} and energy performance will cause a greater absolute increase in yearly energy use (kWh/m\textsuperscript{2}) in low-income housing, which too can be seen in Table 3.

The effects of these differences between income deciles are shown in Figure 3(a-b). Buildings with reduced energy performance that got an EPC rating between A-E after the introduction of WFs are to a great extent buildings in high-income areas with DH (in combination with other energy sources) and heat pumps as main energy source (Figure 3(a)). Among these buildings, fossil fuels and electric heating are barely present. On the other hand, Figure 3(b) shows that among buildings with reduced energy performance that ended up with an EPC rating of F or G (lowest ratings) after the introduction of WFs, there is a domination of low-income residents and a rather even mixture of the different energy sources.

![Figure 2. Multifamily buildings with reduced energy performance after introduction of WFs.](image)

**Table 3.** Ratio and difference between energy performance\textsubscript{WF} and energy performance in different income deciles (1-10, low to high income).

|   | 1\textsuperscript{st} | 2\textsuperscript{nd} | 3\textsuperscript{rd} | 4\textsuperscript{th} | 5\textsuperscript{th} | 6\textsuperscript{th} | 7\textsuperscript{th} | 8\textsuperscript{th} | 9\textsuperscript{th} | 10\textsuperscript{th} |
|---|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Ratio | 1.58 | 1.52 | 1.51 | 1.53 | 1.51 | 1.51 | 1.53 | 1.48 | 1.43 | 1.42 |
| Difference [kWh/m\textsuperscript{2}] | -69 | -58 | -52 | -54 | -49 | -48 | -46 | -41 | -34 | -34 |

High-income housing is disproportionally burdened by the introduction of WFs (Figure 2), but the fact that buildings in low-income and high-income groups are characterised by different energy carriers and unequal initial energy performances gives the implications of WFs different characteristics in different income groups. As energy policy often focuses on the worst-performing buildings in the stock, an analysis of income distribution in the worst-performing buildings (EPC rating F and G) before and after the introduction of WFs was conducted, which can be seen in Figure 4(a-b). Comparing Figure 4(a) and 4(b) shows that overall, the amount of buildings with EPC rating F or G has been significantly reduced, from approximately 75 Mm\textsuperscript{2} to 30 Mm\textsuperscript{2}. This is expected as the results in Figure 1 shows that the overall energy performance of the stock was improved after the introduction of WFs.

However, although energy performance was reduced to a greater extent in high-income housing compared to low-income housing (Figure 2), the income distribution in buildings rated F or G has
become more skewed towards low-income housing after the introduction of WFs, as seen in Figure 4(a-b). This can be explained by the fact that high-income housing in general had better energy performance to start with than low-income housing, meaning that the reductions in energy performance induced by WFs in general were not great enough to result in EPC rating F or G (as seen in Figure 3(a-b)). This is further understood by the high share of heat pumps in high-income housing (Figure 3(a)) which significantly contributes to a better-than-average energy performance in the absence of WFs. At the same time, low-income housing initially had worse energy performance and a lower share of heat pumps, and was thus to a greater extent rated F or G as seen when comparing Figure 3(a) and 3(b).

Figure 3(a-b). Multifamily buildings with reduced energy performance rated A-E (a) and F-G (b).

Figure 4(a-b). Income distribution among worst-performing buildings before (a) and after (b) WFs.

The changes in income distribution are rather small, and the total amount of buildings rated F or G have decreased in all income groups, but this increased skewedness is noticeable and has increased the ratio between buildings in the 1st income decile and the 10th income decile from 1.5 (12% / 8%) to 2 (14% / 7%). Consequently, there are now twice as many buildings in the lowest income decile as in the highest income decile among the worst-performing buildings.

4. Discussion and conclusions
The results of how WFs affected energy performance in different income groups are multifaceted and highlight existing energy inequalities in the multifamily building stock. The relatively high share of heat pumps, an energy efficient technology, in high-income housing can be considered an advantage
for these households as it is one of the cheapest alternatives for heating. Reduced energy performance from WFs in these buildings thus primarily acts as a “correction” of a technology that according to many has been disproportionately favoured. However, in low-income housing, reduced energy performance from WFs is not related to new efficient technologies. Rather, low-income households are bearing a disproportionate burden of outdated technologies and energy carriers such as fossil fuels, and the introduction of WFs only emphasise the technological lag in this part of the housing stock. Consequently, it can be argued that while WFs in high-income areas help correct for disproportionate benefits, they amplify the burden already carried by low-income households. This also explains why the share of low-income households increased among buildings with EPC rating F or G although high-income housing to a greater extent was negatively affected by WFs. It could thus be argued that while high-income households are disproportionally affected by WFs, low-income residents are disproportionally burdened.

As previously mentioned, reduced energy performance from WFs does not in itself constitute a burden for residents. A re-defined and re-calculated energy performance does nothing with the functioning of the building or cost of energy services. However, the increasing influence of EPC ratings in Swedish energy policy suggests that WFs will have implications for the distribution of policy, of benefitting or burdening character, among different income groups.

4.1. Policy implications
The results of this paper show that WFs highlight the different challenges that exist in various parts of the multifamily building stock. The fact that low-income households carry a disproportionate burden of inefficient, unsustainable, and relatively expensive heating sources, such as direct electric heating and fossil fuels, is an energy-related inequality that should be remedied. Although the disproportionate representation of low-income households in worst-performing buildings calls for correcting measures, such measures require considerations of potential risks and burdens for residents; such risks include costs for increasing energy performance by insulating the building envelope or installing new heating and ventilation systems, as well as procedural justice in retrofitting decisions.

Adopting socially motivated and designed policies is important given the multiple challenges that exist in low-income rental housing, including low affordability among tenants and a generally low tenant influence. A recent example of an imperative regulation targeting the worst-performing buildings in the Swedish multifamily building stock showed how a lack of consideration of potential burdens for residents risked leading to aggravated inequalities such as energy poverty [8]. Beyond such specific policy examples are several documented cases of landlords more or less intentionally trying to replace low-income residents through refurbishment [17] or energy retrofitting [18]. Given these already existing risks for low-income residents, energy policies should be designed to alleviate burdens without imposing further risks or hardship on vulnerable groups in the housing stock.

4.2. Concluding remarks
Owing to the dominance of DH in the multifamily building stock, overall energy performance was improved after the introduction of WFs and the number of buildings in the worst-performing EPC ratings F and G was reduced. However, owing to different distributions of energy carriers in low- and high-income housing, the overrepresentation of low-income households among worst-performing buildings is now more prominent than before WFs were introduced. This means that there are increased incentives to ensure social sustainability when imposing imperative regulations on worst-performing buildings. For a just transition, this must be considered in all policy that imposes or triggers measures in this part of the housing stock.

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