Net zero building renovations: how can both climate justice and social equity objectives be achieved?

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Keywords

deep renovations, social impacts, just transition

Abstract

For its fair contribution to limiting the overshooting time for the 1.5K target of the Paris agreement, the EU would have to decarbonize its building stock by around 2035. In theory, this would even be feasible. A study for Germany showed how an ambitious package of policies could achieve such a target. It needs to increase deep renovations to at least 3 % per year, install 1 million heat pumps annually, and double the share of district heating while greening it. The core policies would be stringent MEPS coupled with lots of financial incentives. In the long run, it would even be cost-effective. Results from this study are forming the first part of this paper.

Reality, however, appears different. In the first days of Russia's war of aggression against Ukraine, the German government adopted the aim to effectively ban all fossil heating by 1 January 2024. But when it drafted the law in early 2023, it missed to prepare plans at the same time to make energy efficiency easy and attractive via enhanced financial incentives and advice. Using targeted misinformation, incumbents and some political parties found it easy to confuse citizens about the social impacts of heat pumps, which led to a significantly watered down ambition in the final legislation. In the second part of the paper, we explain how this process unfolded, and what can be learned for countries that wish to fare better in energy efficiency policy-making.

Finally, we analyse how policies complementing binding energy efficiency legislation could be modified to enable all citizens, including those with lower incomes, to implement and benefit from the transformation of the building stock towards net zero. This particularly concerns targeted financial incentives and advice, including one-stop-shops. It will be decisive for (re-)gaining acceptance for energy efficiency renovation and low-carbon heating systems, and hence for a successful implementation of the new EPBD with regard to ambitious decarbonization of the buildings stock to support climate justice, combined with improving social equity and fighting energy poverty, including through renovation of the worst-performing buildings.

Introduction

For its fair contribution to limiting the overshooting time for the 1.5K target of the Paris agreement, the EU would have to decarbonize its economy, including the building stock, by around 2035 (for Germany, cf. Wuppertal Institut, 2020, based on SRU, 2020, and IPCC, 2018). The first question is, therefore, whether this contribution to climate justice would be feasible in technical and economic terms. If the answer is yes in theory, experience and analysis has shown that it will not be an easy task to achieve it in reality, due to the plethora of barriers that have been analysed for a long time (e.g., Sorrell et al., 2004; Höfele and Thomas, 2011). Strong policy support to all market actors and standards will be needed to overcome the barriers, in a well-designed policy package (e.g., for the IEA: Camarasa, 2023; Höfele and Thomas, 2011; Thomas et al., 2013; Ürge-Vorsatz et al., 2020). What would such an effective and cost-effective policy package look like? This is the second part of the first question about whether the decarbonisation of heating could be achieved as early as 2035.

However, implementing these policies and measures in legislation, budget, and practice may find resistance in the political

arena, too. Who are the stakeholders and their arguments, and what is needed to achieve ambitious policy implementation nevertheless? What is the role of social equity in the debate? This is the second set of questions for this paper.

Not the least, the policy package needs to be socially just: It needs to enable *all* citizens, including those with lower incomes, to implement and benefit from the transformation of the building stock towards net zero. This is not only a political aim in its own right. It will also be decisive for (re-)gaining acceptance for energy efficiency renovation and low-carbon heating systems, and hence for a successful implementation of the new EPBD with regard to renovating the worst-performing buildings and to fighting energy poverty. How, then, could this be achieved in the practice of building decarbonisation policies? This is the third question for this paper.

Building on two recent reports by the Wuppertal Institute and a case study on legislation, this paper intends to shed light on potential answers to the questions raised above for the example of Germany.

- In the next section, related to the first of the above questions, we will report the main results of a study that analysed the possibilities and policies for heating Germany without oil and gas by 2035, addressing both the technical and economic feasibility and a policy package that may be ambitious enough to achieve this target in reality.
- Thereafter, we turn to a case study of politics and political resistance against the necessary ambition. It concerns the German "heating law" that was developed during 2023, with the original aim to effectively ban all fossil heating by 1 January 2024, but ending up with significantly reduced speed and effectiveness in the final text. We will explain how this process unfolded and what can be learned from that, addressing the second question.
- In the third part, we will report the main results of an analysis on how financial incentives and other policies complementing binding energy efficiency legislation could be modified to enable all citizens to implement and benefit from the transformation of the building stock towards net zero. This particularly concerns targeted financial incentives and advice, including one-stop-shops.

We conclude with a summary of what can be learned for countries that wish to fare better in energy efficiency policy-making than Germany did in 2023 around the "heating law".

Heating Germany without oil and gas by 2035

Would it be feasible in technical and economic terms to phase out all oil and natural gas heating in Germany by 2035, in order for the building stock to become greenhouse gas neutral by that year? And what would be an appropriate policy package to make this a reality? To answer these questions, Greenpeace Germany commissioned the Wuppertal Institute in 2021 to develop a six-point immediate action programme for renewable energy-based heating and efficient buildings that may enable achievement of this target. The results were published in early March of 2022 (Thomas et al., 2022). Here, social equity considerations did not play a role, but we will briefly discuss the social impact of the six-point programme at the end of this section.

The first result is that this would be technically feasible, and even cost-effective. However, it means speeding up the heating transition a lot, because today, natural gas and oil boilers constitute more than 70 % of all heating systems in Germany. In accordance with the final GHG-neutral building sector modelled in basically all long-term decarbonisation scenarios for Germany (Samadi, 2022) but considering the accelerated deployment needed to achieve it by 2035 already, it would require:

- energy-efficient building renovation rates of three to four per cent per year, which would be 1.2 to 1.6 million dwellings per year and up to 80,000 non-residential buildings; this would need to be deep renovation to final standards equivalent to current new build requirements, but could be done in stepwise renovation
- the conversion of almost two thirds of the heating systems to heat pumps, from 1 million in 2022 to 13 million in 2035, so around 1 million per year, and a third of the buildings using solar thermal energy in addition
- doubling the number of buildings connected to district heat by 2035 to around one quarter, covering ca. 30 % of the heating demand, which would require connecting 150,000 buildings per year
- at the same time, converting the generation of district heat to 100 % of renewable energy or unavoidable waste heat, up from 17 % in 2021.

This heating transition would transform Germany's building stock to being greenhouse gas neutral by 2035.

However, from normal renovation and reinvestment cycles of buildings and heating systems, it is evident that this would be very difficult if not impossible with financial incentives alone, but require regulation in addition to these to ensure that the necessary renovations are triggered in reality.

In three central areas, therefore, the six-point immediate action programme that was developed in the project combines legal standards and specific financial support:

- a law on phase-out of fossil fuel heating systems and financial support for electric heat pumps and solar thermal systems
- phased minimum efficiency standards for buildings, along with environmental criteria for insulation material, and corresponding financial support
- development of district heating with renewable energies – legislation with targets and improved framework conditions, and financial support.

The regulations, if implemented with sufficient control, would ensure that the building renovations and boiler replacements will happen, thereby increasing the speed of the heating transition. The financial support would be tailored to make the investment cost-effective for the obligated building owners, at least on an incremental cost basis. In this way, there is no loss of value of the properties, but rather an increase. And therefore, only the combination of regulation and financial incentives would enable the accelerated transition to 2035. However, further measures are needed to overcome other barriers, such as those related to information and transactions costs. These further instruments include targeted advice and professional

Table 1. Overview of the proposed six-point immediate action programme.

Legislation	Financial Incentives
1. Law on phase-out of oil and gas boilers: from 2024, prohibition to install oil and gas heaters; step plan for mandatory exchange of existing boilers by 2035: • from 1/1/2027: all units installed before 2000 • from 1/1/2030: all units installed before 2010 • from 1/1/2035: all remaining units	**2. Existing financial support programme** for sustainable heating in individual units **adapted** to make boiler replacements cost-effective, i.e., setting financial support rates and total amount at the level necessary (estimated to be 20 to 35 % in 2021)
3. Minimum energy performance standards for inefficient buildings: increased standards must be achieved over time, with environmental criteria for the insulation Step model: all buildings of class E to H (59 % today): by 2030 at least D; all by 2035 at least class C, by 2040 class B. German renovation passport scheme to inform the steps for each building. *Background info:* With current German definition of efficiency class: installing heat pump alone would achieve e.g., F => B; would be better to separate efficiency class based on heat input demand and climate class, and then of course redefine the target classes for each target year. (cf. GEG 2.0 Study from Baden-Württemberg)	**4. Existing financial support programme adapted** for deep energy renovation of at least three per cent per year of the building stock with environmental criteria, i.e., setting financial support rates at the level necessary for cost-effectiveness (estimated to be 25 % in 2021) and total budget at the level needed for supporting the target (estimated to be EUR15 bn/yr in 2021)
5. Renewable Heat Network Law to set targets: • District heat completely decarbonised by 2035, • expanded (30 % of heat demand in buildings by 2030), • converted to low temperature heat networks; • Plus further regulations i.a., – mandatory local heat demand and supply plans, – financial support for municipalities to develop them, – price regulation for district heat	**6. financial support programme for future-proof heat networks** (already existing: 45% of investment as grant, but needs tripling of funding to EUR3 bn/yr)

Source: Thomas et al., 2022.

coaching, including through renovation passports and one-stop-shops, innovative technologies and concepts, like project aggregation and serial renovation using prefabricated elements and digital design tools, and a strong professional training initiative. The German CO_2 pricing since 2021 and the new EU emissions trading scheme II will also contribute to making the transition more cost-effective, and the revenues should be used to fund the financial support in the first place.

As a second important result, the study found: Such an accelerated transformation of buildings and heat would be cost-effective for residential and corporate building owners and users *overall* as well as public building owners. They would see net cost savings of 11.5 billion Euros in total in the year 2035. Figure 1 presents the gross cost savings, levelized costs, and resulting net savings for building energy renovation (insulation, heat recovery), heat pumps, and solar thermal systems. The levelized costs are based on the incremental investment for energy efficiency and renewable energies, as discussed below. For the expansion of district heating and its conversion to renewable energies, data did not allow such an analysis, but a gross estimate is that it will be cost-effective as well.

In addition, around 500,000 jobs could be created or secured by the six-point immediate action programme, some 260,000 of which in the construction sector. This is equivalent to around 12 per cent of today's workforce in the sector, and just over one third of those occupied with new build. To the extent that it would be possible to satisfy the demand for affordable housing through a more efficient use of the existing building stock (Bierwirth and Thomas, 2019), thereby reducing the need for new build, capacities for planning, building, and installation would become available for the heating transition in the building stock. Still, a large-scale professional training initiative will be needed in any case.

Furthermore, this six-point immediate action programme would also have been able to reduce natural gas demand in Germany by more than 250 TWh per year by 2030 already. This would be more than the planned capacity of LNG import terminals on the German coast (E3G, 2022).

So, what are the chances for a political agreement on such an accelerated transition, which would not only benefit the climate,

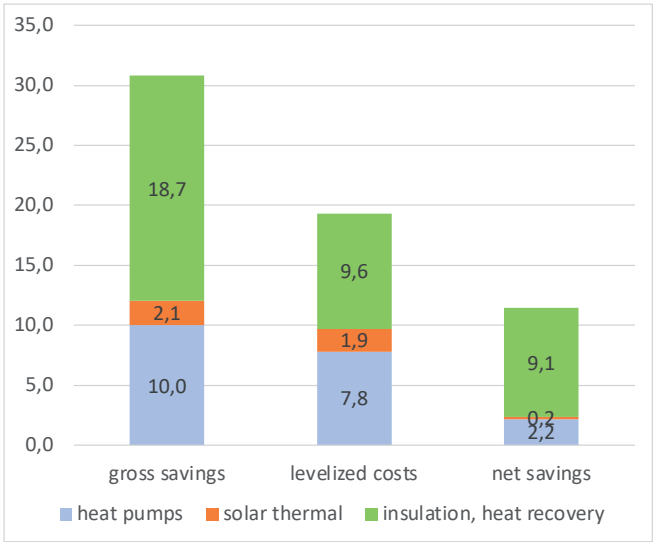

Figure 1. Levelized incremental investment costs and energy cost savings in 2035. Source: Thomas et al., 2022.

but also security of energy supply, and enable large net cost savings? The complete investment for the accelerated renovation or replacement required for decarbonisation by 2035 already may be a challenge both for the economy overall and for individual building owners. That is why it is important to provide the financial incentives and also soft loans for those building owners who do not have the capital at hand. However, all of this is based on pre-2022 data and projections of renovation and heating system costs as well as energy prices, and does not distinguish between landlords and tenants. In Germany, most lower-income households live in rented apartments, so it is very important for social equity that they too see net benefits from building decarbonisation. A more detailed analysis assessing this question will be presented in the third part of this paper below.

As we have witnessed over the past year, it remains politically difficult particularly for regulation to implement it. At the EU level, the European Commission hat proposed minimum energy performance standards for existing buildings in its proposal for the recast of the EU's Energy Performance of Buildings Directive (EPBD). They have survived the negotiation process into the final text adopted in the trilogue for the non-residential buildings, but not for the residential sector. In Germany, during 2022 and 2023, there was an attempt to create a law that would effectively ban the installation of new oil and gas boilers. This attempt was only partially successful, as we examine in the next section.

When political targets hit reality – how Germany's "heating law" became what it is

BACKGROUND AND THE GOVERNMENT'S ORIGINAL PLANS

Since 2021, the legislation on energy efficiency and renewable energy in buildings has been consolidated in the building energy law (Gebäudeenergiegesetz, GEG). By then, there were already requirements for the use of renewable energies in heating systems in new buildings, but they were quite weak. When the new federal government of social democrats, greens and liberals took office in late 2021, their coalition treaty included a goal that from 1 January 2025 onwards, any newly installed heating system should be operated on the basis of 65 % of renewable energy (or more). This was already a technology-neutral formulation, but it was meant to boost electrification of heating and water heating, either directly through heat pumps, or indirectly through district heat. The time horizon here is not 2035 but 2045, when Germany intends to achieve GHG neutrality. Although electricity generation in Germany is expected to reach 100 % of renewables only at some point between 2035 and 2045, a heat pump with a SCOP of at least 3.0 will use at least 65 % of ambient heat, which is classified as renewable. In practice, this provision was expected to ban the installation of new gas or oil boilers. This would be in line with the major decarbonisation scenarios for Germany, as stated above.

When the Russian army invaded Ukraine in February of 2022, the German government even decided to advance the starting date for the 65 % renewables rule to 1 January of 2024, in a move to improve energy security by saving natural gas and oil more rapidly. Although the government made an agreement with the heating industry to provide at least 500,000 heat pumps from 2024 onwards and to train the installation workforce by then, it was clear that this was not enough to satisfy the demand, which is at least around 700,000 heating systems that need to be renewed each year in Germany, from 2024 already.

In August of 2022, the leading ministries – economic affairs and climate action led by the green minister Robert Habeck and dwelling, city development and construction affairs led by the social democrat Klara Geywitz – published a consultation document. It became clear that the new law would be even more technology-neutral. In addition to heat pumps and district heating, direct electric heating for very well insulated buildings, solar thermal heat, a heating system with green or blue hydrogen or their derivatives, biomass for existing buildings only, and a hybrid system of a heat pump or solar thermal system providing at least 65 % of the heat with a fossil-fuel heating system for the remaining 35 % would have been allowed. All of this would be available in Germany in the short term, except for the green or blue hydrogen. The 65 % rule would have been required for any newly installed heating system in both new and existing buildings, but nobody would have had to immediately replace a running system under 30 years old. However, there was a schedule to require replacement of heating systems older than 30 years and slowly reducing that deadline to 22 years, the latest to go out by 2045, by when Germany wants to become greenhouse-gas neutral. Even before the amendment, the GEG stipulated that oil and gas heating systems that are more than 30 years old must be replaced under certain conditions.

MEDIA CAMPAIGN AND LOBBYIST ACTION AGAINST THE PLANS

This list of options was also included in the first draft of the law, which was due to be published in March of 2023. But on 28 February, Germany's leading tabloid, 'Bild', titled "Habeck wants to prohibit oil and gas heating" (own translation) and started a months-long campaign against "Habeck's heating hammer". The paper and other media created the impression that everybody would have to immediately replace their running heating system by a heat pump; and in order for that to work properly, insulate their homes. Articles insinuated that investments of, e.g., 280,000 Euros for a single-family home would be needed. Although the ministries had planned to combine the new requirement with an improved financial incentive programme, they did not have it ready by that time to counter such reports. In addition, there had been plans for mandatory heat plans of municipalities to provide the information basis for building owners on whether they could expect the supply of district heating or would have to go for a heat pump or other individual heating system. But that legislation was not ready for debate either.

It is easy to conceive that someone who wanted to torpedo the new 65 % requirement informed the 'Bild' paper of the draft law. The targeted misinformation and the uncertainty that it created among building owners made it easy for lobbyists of the gas industry to weaken the requirement substantially. After all, it would be the gas industry to lose their business, with around 50 % of all heating systems being gas-fired today in Germany. There appears to be evidence that such lobbyists could be found in many parties, including those of the government, as the paper 'Frankfurter Rundschau' revealed (21 July 2023). According to that source, an MP of the social democrats with good connections to the gas industry was a co-negotiator of the final compromise. An MP of the liberal party with good connections to the oil and gas industry reached a decision of a party convention against the 65 % requirement by raising the

argument that liberals needed to be guardians of the freedom of choice.

THE LEGISLATION THAT RESULTED

After months of hefty negotiations, the final result was that, since the law came into force on January 1, 2024,

- the 65 % rule only applies to new development areas immediately, but not to new buildings that are constructed in a gap between existing buildings and to special buildings in urban outskirts
- in all other new buildings and for existing buildings, it applies as soon as the municipality has finalised its local heating plan. The corresponding legislation is now also in force. Cities above 100,000 inhabitants have to achieve this by 30 June, 2026, smaller towns and villages by 30 June, 2028
- in addition to the types of heating systems listed above, gas and oil boilers can continue to be installed until these timelines in 2026/28 but have to use an increasing share of 'green fuels' from 2029 (starting with 15 %, then 30 % from 2035 and 60 % from 2040), and no fossil fuels may be used from 2045
- even after 2026/28, it will be possible to install a new or used fossil fuel boiler for a transition period of five years in exchange for an old boiler
- and of course, no one will have to remove their existing and running heating system unless they are older than 30 years and installed in rented houses, as the law had already stipulated before the last reform; in condominiums or buildings with individual gas heaters per dwelling or per room, there are transition periods of five to eight years after the first heater failed, so that a careful decision on installing a central heating or another option can be taken.

In some more detail: There will be no obligation to install a heat pump, as some media reports have suggested. In principle, other heating technologies are also possible, such as solar thermal energy or biomass such as wood or wood pellets. In the case of existing buildings, the decisive information for making the choice will be what kind of supply is planned for the respective area according to the municipal heating plans, in particular whether local and district heating networks are planned and where the existing natural gas network will be converted to other energy sources that meet the criteria. These can be based on biomass or on hydrogen. However, the potential for both will be quite limited, for hydrogen at least in the next ten years or so; and the costs for hydrogen will be quite high, given that 4 to 5 times as much green electricity is needed to heat a building via hydrogen compared to a heat pump (e.g., Thomas et al., 2022).

SHORT-TERM IMPACTS AND MID-TERM UNCERTAINTIES

It is already foreseeable that all local authorities will initially have to undertake a great deal of planning work and later make considerable investments in municipal energy networks. Above all, there is a lack of specialists who are able to carry out such complex planning. The federal state of Baden-Württemberg is a pioneer in this regard, as it was the first federal state to enshrine this obligation for municipalities in law back in 2020. According to initial evaluations, 104 municipal heating plans should have been completed by the end of 2023. Shortly before the end of the year, however, only 22 heating plans were ready (SWR, 2023). This means that although the legal obligation exists, it maybe cannot be complied with. If so, the 65 % rule will apply from 2026/28 under the GEG, but the information basis from the heat plans will be lacking. Even according to the new federal law, there will be no penalty for municipalities if they do not complete the planning on time.

However, in the course of upcoming heating renovations, many citizens will want to have certainty as quickly as possible as to which heat supply is intended for them through municipal heating planning. Although the installation of new gas heating systems is not prohibited under the new law, the installation will be subject to a prior mandatory consultation, in which heating system owners are informed that they must expect rising operating costs due to the rising CO_2 price and cannot assume that the gas heating system will have an unlimited service life; the law still prohibits the use of fossil gas from 2045. The German government is planning an awareness campaign to inform citizens about the emerging disadvantages of a heating system based on fossil fuels. Above all, the financial risks, which initially became clear in the wake of the sharp rise in gas prices following Russia's war against Ukraine, will be included in the decision-making process. Accordingly, citizens will have expectations of their local authorities regarding the heat planning and the supply of district heat or hydrogen, which the authorities may not be able to fulfil despite their best intentions.

Overall, the legislative process of the Building Energy Act and the media coverage have led to great uncertainty among many citizens and municipal decision-makers. The 'technological openness' now anchored with regard to the heating of buildings and the disagreement within the governing coalition that has emerged in this context have resulted in more questions being raised than answered, especially among homeowners. This is despite the strong increase in subsidy rates for heating systems based on renewable energy sources that came into effect in parallel to the new law on 1 January 2024 (see next section).

The existing uncertainty has already led to frustration and over-hasty behaviour of building owners. This has led to an increase in premature heating system changes or replacement investments in new heating systems with old oil and gas technology. For example, it was found that sales of gas boilers are still at a very high level and were 50 % higher than the average of previous years in 2023 (BDH, 2023). At the same time, installations of heat pumps grew by about 50 % over the whole year of 2023, but they dropped considerably in the second half, following the political turmoil and due to the attendance for the new funding scheme.

WHAT CAN WE LEARN FROM THIS CASE STUDY?

Overall, the recast GEG is still very likely to accelerate the exchange of heating systems, but with considerable delay and uncertainty for building owners. The connection to heat planning is useful to create clarity, but municipality and consultancy resources to achieve this in the timeframe are likely to be missing. In combination with the technology neutrality, this is opening the door for delays, and the danger remains that many local gas utilities and building owners may bet on an uncertain future of inefficient and costly green hydrogen.

Two main narratives were very influential in the political debate leading to this result. One was the narrative that heat pumps

may not be able to heat older homes, unless lots of money would be invested in thermal insulation and/or exchange of radiators. And the other one was that this would particularly overburden homeowners and small private landlords. So social equity aspects played a big role in some of the media and the discourse of some of the political parties who argued in favour of the technology neutrality. However, it was not the perspective of the tenants, to which the vast majority of low-income households in Germany belong. Particularly people affected by energy poverty tend to live in rented apartments in inefficient buildings. In the long run, they would benefit from deep energy renovation and the switch to heat pumps, and they are likely to be more affected by rising prices of gas or hydrogen-based heating. But this perspective did not win the discourse. With the technology neutrality, the big private landlords, not only the small landlords, will save on the higher investment that would be needed for deep energy renovation and the switch to heat pumps.

As an ambitious legal requirement was impossible to achieve, the government will have to use financial incentives to convince people of an early changeover to heat pumps and other future-proof heating systems. And they will need to enable every building owner to make the necessary investments to win back the acceptance for deep energy renovation and heat pumps. What is needed to make this feasible and a net gain also for low-income tenants and owners will be the focus of the next section.

What would be needed to reconcile net zero building renovations and social equity objectives

In this third major part of this paper, we will turn to the economic impact of the heating transformation on building owners and users. Starting from the current (2024) financial incentive schemes (BEG) in Germany, what is the net benefit or cost per year of building energy efficiency refurbishment and heating system exchange for owner-occupiers, landlords, and tenants? And if there still are gaps to cost-effectiveness or other barriers: How could policy design and implementation enable all citizens to implement, and benefit from, the transformation of the building stock towards net zero? We were not able to perform a comprehensive study using a large number of building types, but found that the following analysis was already able to provide plausible answers to these questions. As said above, low-income households in Germany predominantly live in rented dwellings. Therefore, ensuring that the impact of energy renovations on tenants is positive will also ensure that these households will benefit as well. In this way, social equity objectives will be met.

At the level of two sample buildings, the financial effects of various energy efficiency renovation actions (called 'modernisation' in German legislation) were examined. A single-family house (SFH) with 121 m^2 of living space and a specific final energy requirement of 178 kWh/(m^2*a) and a multi-family house (MFH) with 420 m^2 of living space, spread over six residential units, and a specific energy requirement of 146 kWh/(m^2*a) were analysed. It was assumed that the thermal insulation resulted in savings of 110 kWh/(m^2*a) for the detached house and 90 kWh/(m^2*a) for the apartment block. Running the calculations with different subsidy rates, it was investigated at which subsidy rate the respective modernisation could be carried out without increasing the 'warm rent', i.e., the total of basic rent and space and water heating costs.

ENERGY EFFICIENCY RENOVATION OF THE BUILDING SHELL

Taking into account the sharp rise in construction cost indices in recent years and in particular the price indices for external thermal insulation composite systems, the full costs of the building refurbishment, i.e., thermal insulation, window exchange, and potentially adding a heat recovery ventilation, were set at 500 Euros per m^2 for the apartment block and one and a half times this amount (750 Euros per m^2) for the single-family home due to its lower compactness. Incremental energy-related costs, i.e., thermal insulation exceeding pure maintenance or the cost of a passive house window over a double-pane low-E window, were estimated to be half of these full costs. This analysis also takes a 2045 decarbonisation perspective, so no early building envelope renovation or replacement of heating systems is assumed. Therefore, the incremental energy-related investment can be compared to the savings in energy costs, because the renovation without insulation or replacement with standard technology would have happened anyway. For the interest rate, we assume 2 % per year, based on average interest rates for savings or government-subsidised soft loans in Germany; for the lifetime 30 years. From the national economy perspective, investments should be calculated over the entire lifetime to create a level playing field between energy efficiency and energy supply. However, many investors wish a shorter payback. Therefore, we have modelled an alternative scenario, with a payback period of 20 years, equivalent to the usual tax depreciation period in Germany. In addition, the energy cost savings are based on an average until 2040 for the future natural gas price of 11.75 Euro cents per kWh and a CO_2 price of 125 Euros per tonne, using estimates in recent literature from Germany (Prognos et al., 2022). Figure 2 displays the results for the annual net gain or loss resulting from the renovation for the owner-occupied SFH as well as for landlords and tenants in the MFH.

It was found that a subsidy rate of 30 % or more of the full costs would be needed to make such a building refurbishment be 'rent-neutral', i.e., feasible without an increase in the total rent, for a tenant in the example of the MFH apartment block, while it will always yield a net gain for the landlord, irrespective of the subsidy rate. This assumes that the landlord uses the German legal provision allowing an increase of the annual basic rent of 8 % of the incremental energy efficiency investment net of subsidies, called the 'modernisation levy'. The allocation of the CO_2 price between landlords and tenants in accordance with the German law was also taken into account here. This law stipulates that the lower the energy efficiency, the higher will be the share to be paid by the landlord, up to 90 %, and vice versa, down to 0 % for an almost zero-carbon building.

In the example of the owner-occupied single-family house, a subsidy rate of 15 % of the full costs will already be sufficient to make the investment cost-effective for the owner, as illustrated in Figure 2. This is the grant rate available for energy efficiency renovation of the building shell in the current German financial incentive scheme BEG. However, a risk-averse homeowner requesting a payback in 20 years would need to see a grant rate of 25 % to break even. A certified whole-house refurbishment to an 'efficiency house' 55 standard would be required to receive this grant level. If the single-family house was rented out, a higher subsidy rate of 30 % would be required in order to design the modernisation in a rent-neutral way for the

tenant. However, this case of a rented single-family home is not so common in Germany.

Under the current financial incentive scheme of the German government, however, a subsidy rate of 30 % cannot be achieved with the subsidy for 'individual measures', which is limited to 15 %. A certified whole-house refurbishment to an 'efficiency house' standard would be required to receive the 30 % of investment grant, which would currently only be achievable if a worst-performing building – for which a 10 % bonus will be granted – were refurbished to an efficiency house standard of at least EH55 EE class (adding renewable energies) or EH40 plus heat pump bonus. This finding holds regardless of the depreciation period, because the modernisation levy and the allocation of the CO_2 price are unaffected by it.

If the full costs of modernisation are 200 Euros per m^2 higher, as it was often the case in the heated market situation of 2023, even a 35 % subsidy rate will be necessary. This rate is at present only available for the refurbishment of a worst-performing building to an EH40 EE class efficiency house standard. At this point, the subsidy effect of reduced loan interest rates in the 'efficiency house' funding has not been taken into account.

As said above, energy efficiency modernisation is definitely worthwhile for landlords in single-family as well as in multi-family homes. In addition to the modernisation levy as the most important factor, the distribution of the CO_2 price also contributes significantly to the financial advantage.

CONVERSION OF THE HEATING SYSTEM TO HEAT PUMPS

In addition to thermal insulation, the financial impact of a heating system changeover was analysed. The costs of an air source heat pump and a ground source heat pump were compared with those of a gas condensing boiler for both sample buildings, both with an existing gas connection and with a gas connection to be installed first. The data basis (BDEW, 2021) was partially updated for the heat pump costs, see below. A distinction was also made between retaining and replacing the radiators in the investment. A heat pump will be more energy-efficient at a lower heating system supply temperature. This supply temperature is often up to 75 °C or more on cold days in existing heating systems with gas or oil boilers. Exchanging some or all radiators for units with a bigger heat exchanger surface may be needed to reduce the supply temperature. The need for replacing radiators (and possibly some of the piping) is highly building-specific (Pehnt et al., 2022). An estimate for the average cost was taken from the literature (BDEW, 2021). It increases the total cost for an air source heat pump by about 20 % to 30 %. Insulating the building will also reduce the required supply temperature and may reduce or avoid the need to exchange radiators (Pehnt et al., 2022). Therefore, the case without radiator exchange may be taken as a proxy for the insulated houses.

Furthermore, in the base scenario, a 20 % reduction in the cost of heat pumps was assumed, which appears possible due to a learning curve by 2026/27. An electricity price for heat pumps of 25 EUR cents per kWh was used in the calculations (Prognos et al., 2022). The alternative Scenario 1 investigates the annual financial gain or loss if heat pump costs remain at the current levels, while the electricity price is higher at 28 EUR cents per kWh, whereas Scenario 2 covers the situation of heat pump costs at the current levels and an equal electricity price as in the base scenario. As an example of the research results, the financial impact of a heating system changeover in favour of an air heat pump in a multi-family home is illustrated in Figure 3 for the base scenario and for Scenario 2.

The subsidy rates that were modelled are those of the current German financial incentive schemes for heat pumps. Since January 2024, they are:

- 30 % Basic subsidy: applicable for landlords
- 35 % Basic subsidy plus efficiency bonus (cooling agents with low GWP, ground source HP): for landlords
- 50 % Basic subsidy plus 'climate speed' bonus: owner-occupiers
- 55 % Basic subsidy plus 'climate speed' bonus plus efficiency bonus: owner-occupiers
- 70 % Maximum rate for owner-occupiers incl. income bonus (taxable household income max. 40,000 €/yr)
- 15 % for radiator replacement

Although the higher subsidy rates of 50 to 70 % are not available for rental dwellings, we modelled them nevertheless to examine their impact on cost-effectiveness.

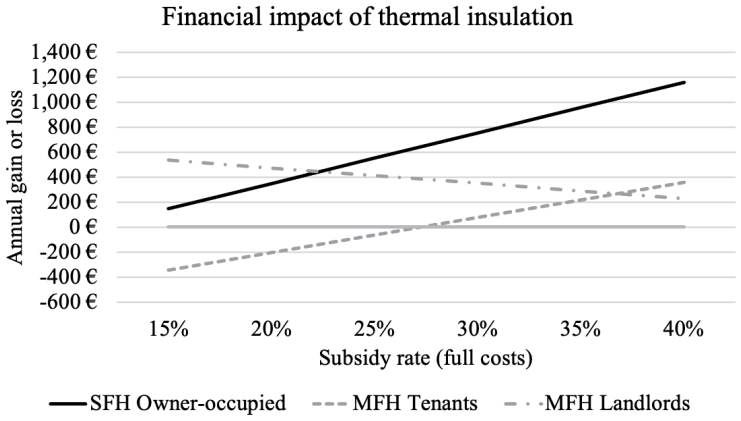

Figure 2. Financial impact of thermal insulation on different housing situations and at different subsidy rates.

In both scenarios, a financial loss can be seen in Figure 3 for the tenants in the multi-family home, while the landlords experience a financial gain. Both these trends are irrespective of the level of subsidies between 30 % and 70 %, with an exception for the case, in which no exchange of radiators will be needed, see below. Generally, the air source heat pump tends to be more economical for single-family homes, whereas in multi-family homes, it is the ground source heat pump. For tenants, converting to an air source heat pump with the current subsidy of 30 % or 35 % is uneconomical in most cases. This is particularly true in less well-insulated buildings, where a replacement of a large proportion of the radiators often is necessary, if the costs are passed on via the modernisation levy of 8 %. In apartment blocks, an increase in the subsidy through the 'climate speed' bonus of initially 20 % could achieve or bring within reach warm rent neutrality. The 'climate speed' bonus was decided to be extended to rental houses at the construction summit in September 2023 for the years 2024 and 2025, but was cancelled again following the ruling of the Federal Constitutional Court on the 'debt brake' only two months later. Yet, in order to achieve warm rent neutrality, a 20 % reduction in the cost of heat pumps is required, which appears possible by 2026/27 and should be the top priority. If the subsidy was increased to 55 % through the 'climate speed' bonus (basic subsidy 30 % plus 'climate speed' bonus 20 % plus efficiency bonus 5 %), all cases would be economically viable for landlords, even the ground source heat pump in single-family homes.

On the other hand, our analysis found that for both the owner-occupied single family-home as well as for an owner-occupier living in a multi-family home, the economic result of converting to a heat pump will always be positive, not matter if 30 or 70 % of subsidy. Only for a ground-source heat pump in a single-family home, at least 50 % would be required. Therefore, Germany's current subsidy rates for heat pumps are flawed with respect to the impact for owner-occupiers vs. tenants. The higher rates that were introduced in January of 2024 for owner-occupiers may be needed for incentive and acceptance reasons, but they are not necessary for economic reasons. On the other hand, they are not available for rented buildings, while 50 to 70 % of subsidy would be needed to make it at least close to rent-neutral for tenants. Alternatively, the modernisation levy could be reduced from the current 10 % for heat pumps and 8 % for the radiator exchange.

Another trend to be derived from both Figure 3 is the great influence of the radiators on the financial outcome of the modernisation. If they don't need to be exchanged, the tenants will see a slight net benefit at subsidy levels of 50 % to 70 % in the base scenario (Figure 3), or at 70 % in the Scenario 2 (Figure 4). Another exception in our example cases is the geothermal heat pump in the well-insulated single-family home, because the radiators can be maintained and the modernisation levy for the heat pump is capped at 50 Eurocents per m^2. This highlights the importance of energy efficiency first, i.e., thermal insulation before exchange of the heating system, but also of additional grant funding for radiator replacement, which currently is at 15 %. If the radiators have to be replaced in the course of modernisation, tenants still suffer a financial loss in both scenarios for all types of heat pump, even with a subsidy rate of 70 % of the heat pump costs. The distribution of the CO_2 levy further contributes to this effect. Thus, an increase of the subsidy for radiator replacement to 30 % might be a more viable option. However, the better choice would be to insulate the building first. The cases without the need for exchanging radiators can be seen as a proxy for such low-energy buildings. For example, the MFH that we used as a case study will then get close to the unrenovated SFH case in terms of total energy consumption and, hence, investment in the heat pump without the need to exchange radiators.

Buildings differ widely, so our modelling is as typical as it could be but cannot cover all cases. We nevertheless found clear tendencies on the financial support levels that are needed from the perspectives of owner-occupiers, tenants, and landlords. A special problem with low-income households, however, is that they may often not be able to afford keeping their homes warm enough. In this case, they would receive less monetary benefit, but on the other hand, they would be able to afford higher thermal comfort levels at last.

POLICY RECOMMENDATIONS

Based on our example calculations and further considerations, what should German policy do to make the heating transition a just transition, including for low-income households, whether

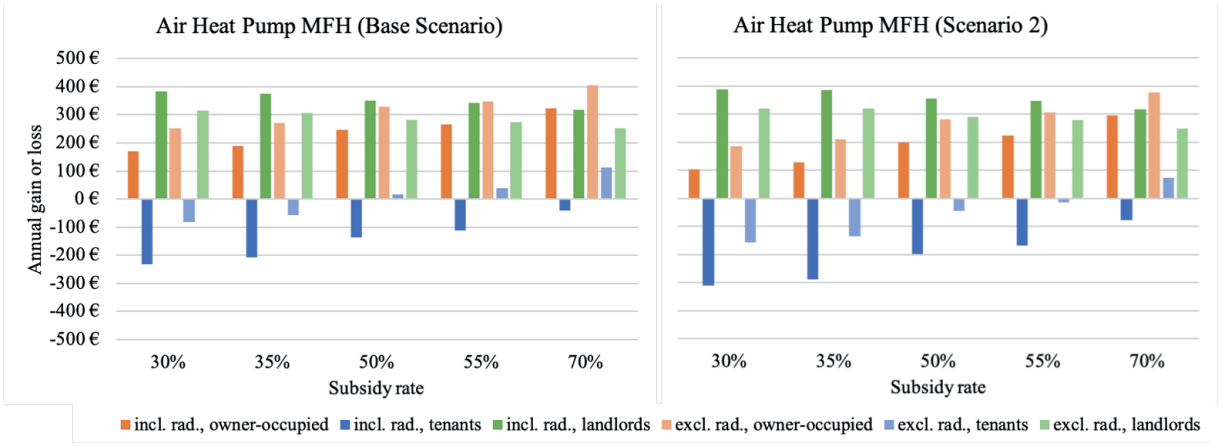

Figure 3. Financial impact of a heating system changeover in favour of an air source heat pump in a multi-family home, for different housing situations and subsidy rates. Left: Base Scenario with 20 % reduced heat pump costs and an electricity price of 25 Eurocents per kWh. Right: Scenario 2 without reduction in heat pump costs; electricity price 25 Eurocents/kWh.

they live in rented dwellings or own homes? Based on the analysis in the third part but bearing the policy process around the legislation in mind, we suggest the following.

- It was the right proposal at the construction summit in September 2023 to increase the grant rates by a 'climate speed bonus' of 10 % of the costs of thermal insulation for all building owners and of 20 % for heat pumps and other renewables-based heating systems for landlords. It was wrong to withdraw these bonuses when aiming to consolidate the budget following the ruling of the supreme court. These bonuses should be reintroduced, and ideally also an income bonus lifting the total subsidy to a maximum of 70 % for houses with many economically disadvantaged people or social housing. This would be the same maximum that is already available for low-income owner-occupiers. It may still not be enough in all cases, but higher subsidy rates may be difficult to justify politically. We believe that the enormous amount of more than 16 billion Euros for the heating transition in the German budget for 2024 will be large enough to fund these bonuses, because demand for grants and soft loans may be sluggish to recover from the 2023 turmoil.
- At the same time, the modernisation levy could be further reduced from 8 % (and 10 % for heat pumps) to 3 to 5 %, while landlords would still see net gains from the investments.
- It was a good decision by the government to introduce soft loans for the remaining investment in insulation or heating system changeover, because this is important for homeowners or private landlords who do not have financial reserves to invest, sometimes not even for the regular replacements.
- Minimum energy performance standards would also be effective, because low-income households often live in worst-performing buildings. However, it is unlikely that they will be introduced at the national level in Germany. The government's financial support programme, therefore, offers a 10 % bonus for renovation of worst-performing buildings.
- There is also the need for financial support to one-stop-shops in every city or county, and for community/city district managers, who directly address homeowners and private landlords, bundle projects, and organise serial renovation with prefabricated elements for whole streets or settlements, in order to bring down costs and speed up the transition, particularly for worst-performing buildings and social housing, in which many low-income tenants live.
- Getting the heat planning straight and plausible will also be important to inform all building owners.
- Finally, the existing programme by social support organisations to offer individual advice to low-income households free of charge through specially trained peers should be expanded as much as needed to reach the whole target group. Through the advice and free energy-saving products, such as low-flow aerators, time switches, LED lamps etc., energy savings of around 10'% and cost savings of ca. 250 Euros/year on average can be achieved with costs of ca. 650 Euros per household (numbers derived from Hesse et al., 2023).

Such a targeted enhancement of the policy package for energy efficiency in buildings would not only make energy renovation a financial net benefit for most low-income households, but also enable them to enjoy the multiple benefits related to improved comfort, health, or productivity of study or home office work. In addition, it would improve public acceptance and is therefore likely to accelerate the transition, thereby contributing to climate justice, although probably not enough for achieving building sector decarbonisation by 2035 already.

Conclusions and learnings

In this paper, we have combined three pieces of analysis. First, we found that it would be technically feasible to decarbonise heating in Germany's building sector by 2035, taking climate justice objectives seriously. Moreover, with the right combination of cost degression and financial incentives, it would even be cost-effective for owner-occupiers as well as landlords and tenants in their combined economic perspective to invest in this transformation. However, in order to grasp every opportunity of a renovation or heating system replacement, so as to achieve the necessary increase in renovation rates and heating systems changeover, financial incentives alone would not be sufficient, but regulation, such as ambitious minimum energy performance standards and a ban on fossil-fuel heating systems would be needed.

The prospects of achieving this regulation are dull, however. Although the recast EPBD requires Member States to introduce minimum energy performance standards for non-residential buildings, they are not very ambitious: only the 26 % of very inefficient buildings will need to comply within 9 years from now, and no deep energy renovation is required for that. And they are not required for residential buildings. The experience from the political turmoil around Germany's heating law in 2023, which we examined in the second part of this paper, confirms that ambitious regulation will only be feasible if it is introduced as part of a package, combined with guidance through local heat supply plans and renovation passports, financial incentives and soft loans at a level that make the necessary investment feasible and a financial gain for the building owners, along with strong communication of examples and testimonials proving this gain, and coaching building owners through the renovation journey, e.g., through one-stop-shops. Furthermore, legislation needs to achieve a fair division of costs and benefits between landlords and tenants to address the social equity objective. Lack of such a comprehensive approach, as we have seen in the second part of this paper, allowed that the selective use of arguments around threats to social equity has been successful in delaying the building decarbonisation in Germany. This is to the detriment of climate justice, while special financial support has only been created for a smaller group of low-income households, i.e., owner-occupiers.

And finally, how about the gas industry? The boiler manufacturers and installation contractors are on their way towards replacing boilers by heat pumps. But the gas (and oil) supply industry will see their core business disappear. Since hydrogen and its derivative gases and liquids are likely to remain too expensive for heating and will first be needed to decarbonise industry and parts of the transport sector, only a part of the gas network may be converted to hydrogen pipelines. For the rest, regulators will probably have to allow an accelerated depreciation to avoid stranded assets, and/or the government needs to pay compensations for the cost of dismantling. And the oil and

gas supply companies should be invited and possibly supported to invest in district heating, renewable electricity, hydrogen, and other new energy transition technologies.

Germany has, finally, introduced at least the local heat supply plans and strongly increased subsidy rates for heat pumps and other low-carbon heating systems. There is also financial support of 80 % for renovation passports. The EED and EPBD recasts require Member States to introduce a network of one-stop-shops or similar organisations covering the whole country. There are also now considerations on how to compensate the gas industry. But is the revised financial incentive scheme able to turn the heating system transition into a net economic benefit for all?

As our analysis in the third part of this paper shows, this is not yet the case. Owner-occupiers do not actually need the subsidy rates that have been increased beyond 30 % for heat pumps or biomass boilers, neither the 'climate speed' bonus of 20 % nor the income bonus, which increases the total subsidy to 70 % for households with a taxable income of up to 40,000 Euros per year. For reasons of policy reliability, however, we suggest it should not be withdrawn or reduced at this point. On the other hand, at least the 'climate speed' bonus should be introduced for rented flats after all, and ideally also an income bonus for houses with many economically disadvantaged people or social housing. Otherwise, the tenants will see a net financial loss from the heating system transition. In addition, the modernisation levy that allows landlords to increase the rent by a certain percentage of the incremental investment could be reduced somewhat, while still keeping the net financial gain for the landlords, but shifting more of it to the tenants.

However, the country will also need to strongly enhance all the practical guidance and support, prefabrication and project bundling, communication and training efforts to make the investment cheaper and easier for private building and dwelling owners. Only with all these further steps could the transition be accelerated to support climate justice, while also addressing social equity objectives in an appropriate way.

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Acknowledgements

The first chapter of this paper is based on a project funded by Greenpeace Germany. Our colleagues Anja Bierwirth, Dietmar Schüwer, and Florin Vondung also contributed to this project. The third chapter benfited from core funding of the Wuppertal Institut that is provided by the state government of North Rhine-Westphalia.