THE HEAT IS ON

A study comparing the use of wood for insulation and fuel

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FRONT COVER: Loose wood fiber wool by Andia/Alamy, and wood pellets by Agencja Fotograficzna Caro/Alamy.

Background

The European residential sector represented 26% of final energy consumption in the European Union (EU) in 2022 (EUROSTAT 2024). Of this, 64% was used for heating (EUROSTAT 2024), a share that is expected to decrease only slightly to 54% by 2050 (EC 2013). Considering that 75% of the EU's building stock remains energy inefficient (EC 2024a), and the 2024 revision of the EU Energy Performance of Buildings Directive (EPBD) which sets ambitious targets ("achieving a zero-emission building stock by 2050"), there is an urgent need for insulation materials to both be more sustainable and to contribute to reducing the environmental and economic impact of the EU's building stock.

Various insulation materials can increase the energy efficiency of buildings. On the German market, fossil (i.e., petrol-based) materials currently have a 48% share and mineral-based materials 43% (FNR 2024). Bio-based insulation materials only account for 9%. Of these, wood fibre constitutes the largest proportion, 58%. Non-renewable insulation materials, such as polystyrene and mineral wool, have a considerable cost advantage over bio-based materials. It is clear, however, that bio-based insulation can reduce environmental impacts in comparison to non-renewable materials (Schulte et al. 2021).

Wood fibre insulation is mainly sourced from production forests which, if they are managed sustainably, have natural functions that are vital to our societies. Climate change mitigation is at the forefront of these functions, and is achieved when forest ecosystems photosynthesise and store carbon in living biomass. When trees are harvested, some of the carbon continues to be stored in the harvested wood product (HWP), keeping it from returning to the atmosphere. In addition, HWPs can lead to a net decrease in greenhouse gas emissions if they replace more emission intensive products. This is known as the substitution effect. It is important to note, however, that while almost all wood is good enough quality to be used for material applications, such as insulation, almost half of the woody biomass used in the EU is burned for energy (EC 2024b). In such cases, the carbon dioxide formerly sequestered by forests is returned to the atmosphere after a very short time, reducing the possible global heating mitigation. This is particularly problematic as, in a context of increasingly limited EU sustainable wood supply (JRC 2024), the most efficient uses of wood must be prioritised, as required by the cascading principle introduced in the latest revision of the EU Renewable Energy Directive (EU 2023).

The report begins by considering (i) the hitherto insufficient use of insulation in the EU residential sector, causing greater need for heating, and (ii) the high share of wood that is burnt for energy, resulting in lower levels of carbon storage than would otherwise be the case.

Aim

The aim of this report is to compare the material, climate, economic and public health impacts of using wood as insulation versus turning the same amount of wood into pellets for heating the same house. Germany was chosen as the case study region as it is within the EU and is a major pellets consumer (over 3 million tons in 2022).

Methodology

We began by defining a functional unit (to base comparisons on), a reference scenario, and system boundaries.

The functional unit was based on the quantity of blow-in wood fiber insulation material or wood pellets required to meet the legally determined thermal transmittance requirement per m^2 wall area in Germany. This thermal transmittance requirement amounts to 0.24 W/m^2 K, for which the required insulation material quantity is from Schulte et al. (2021). The corresponding quantity of wood pellets was derived from the amount of energy necessary to maintain the buildings inside-temperature in the absence of any additional insulation. In order to make the results more applicable, they were given for a single m^2 of wall area. This allows the scaling up of the effects for all types of buildings.

For illustration purposes, we defined a representative case study dwelling as a single-family home in Germany with four facades exposed to the open-air still lacking an insulation layer, but with a central wood pellet heating system. The living area was 152 square metres (m^2) (DESTATIS 2024), with six-meter high walls exposed to the open-air - equalling 296 m^2 requiring insulation. We considered legal fire resistance and health and safety standards as well as insulation needs.

The system boundaries are the processes considered in the assessment. The starting point was at the sawmill gate as sawmilling residues can be used to produce either wood pellets or wood fibre insulation. The endpoint was either instalment of the insulation, or incineration of the wood pellets. We considered time periods from one year to 35 and 70 years respectively, the latter being an optimistic service life of the insulation material before its disposal or replacement (Schulte et al. 2021), and 35 years a more conservative time horizon. Processes concerning the tree cultivation and other manufacturing until the sawmill gate are assumed to be the same for both uses.

For the comparison of using wood as an insulation material versus wood pellets, the functional unit served as the starting point, and we took the quantity per functional unit for the insulation material from Schulte et al. (2021), which amounts to 12.5 kg per m^2. The quantity of wood pellets was defined by

$$Q = P_{specific} \times 24 \times \frac{D}{1000} \, (kW \cdot h)$$

where Q is the energy consumption required to maintain the temperature in the building, expressed in kilowatt hours (kWh), $P_{specific}$ is the building's heat loss, expressed in W per K, and D is the number of heating degree days (HDD). By combining the energy consumption required to maintain the temperature per m^2 with the lower heating value of the wood pellets, expressed in MJ per kg, we determined the required quantity of wood pellets per functional unit, 3.8 kg per m^{-2}.

For estimating the climate impact, life cycle assessment methodology was used. Climate impacts were determined using the climate metric Global Warming Potential with a 100-year time horizon (GWP100) including the influence of the greenhouse gases CO_2, CH_4, and N_2O. Life cycle inventory data (emissions data were retrieved from the Ecoinvent Database 3.8).

For the impacts on human health, a fine particle emission quantity of 55 g per GJ heating by a residential wood pellet boiler was used (CH and DUH 2022). Given a lower heating value of 17.32 MJ per kg for wood pellets (Phyllis2 Database 2024), the fine particulate matter pollution amounts to 1 g per kg wood pellets.

The economic comparison was considered from the perspective of the house owner. Accordingly, the one-time cost associated with the purchasing and instalment of the insulation material is compared to the cost of wood pellets over 35 and 70 years, respectively. An average blow-in wood fibre insulation cost for a German setting of 42 € per m^2 and an instalment cost of 0.81 € per m^2 was considered (Dämmung Nord 2025, gruenes haus 2025, Dachdecker 2025, CO_2 Online 2025, Wirdämmendeinhaus 2025, Einblasdämmung 2025, DasHaus 2025, OBI 2025). A wood pellet price (for pellets delivered at the dwelling) of 0.31 € per kg and a discount rate of 2.25% were applied. The real wood pellet price (price corrected for inflation) was assumed to be constant over time.

Results

The material quantity of the insulation material needed to meet the functional unit of a thermal transmittance of 0.24 W/m^2 K, or the corresponding quantity of wood pellets required to maintain the building's inside-temperature in the absence of any additional insulation, for a single year, as well as 35 and 70 years, is shown in Figure 1. When considering a single year only, the required material quantity of insulation (mass of the final product) is 3.7 times the amount of the wood pellets. Accordingly, already in less than four years, less material is needed for the insulation than for the wood pellets to meet the functional unit. After 35 years, about nine times as much pellets than insulation material are required. When considering the whole outlook period of 70 years - the full service life of the insulation material - the amount of wood pellets required to maintain the indoor temperature is 19 times the amount of the insulation material.

In resource-use terms, to achieve the same energy benefits over 35 years, using wood for insulation would be a nine-fold improvement on continued pellet use. Image: Wood chips are stored for pellet production at a sawmill in Unterbernbach, Germany, by Angelika Warmuth/Alamy

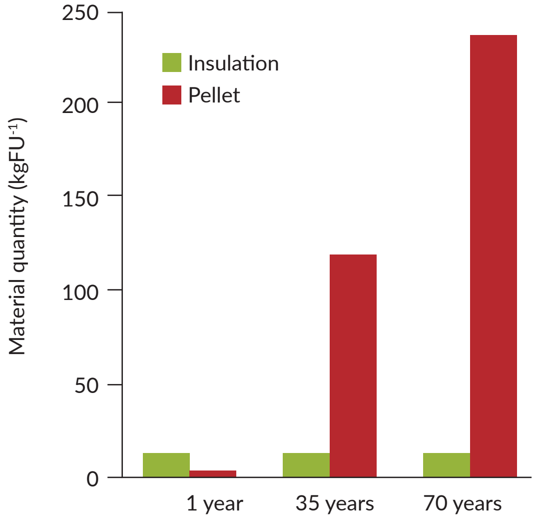

Figure 1 Required quantities of either insulation material or wood pellets to meet the functional unit of a thermal transmittance of 0.24 W/m^{2}K for either 1 year, 35 years or 70 years.

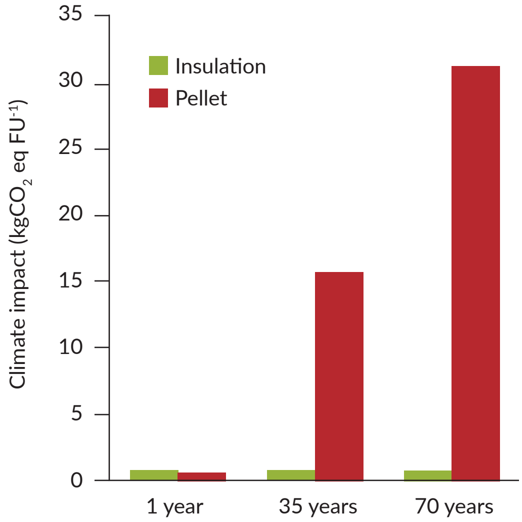

Figure 2 Comparative climate impacts of using either insulation material or wood pellets to meet the functional unit of a thermal transmittance of 0.24 W/m^{2}K for either 1 year, 35 years or 70 years, expressed in kg CO_2 eq.

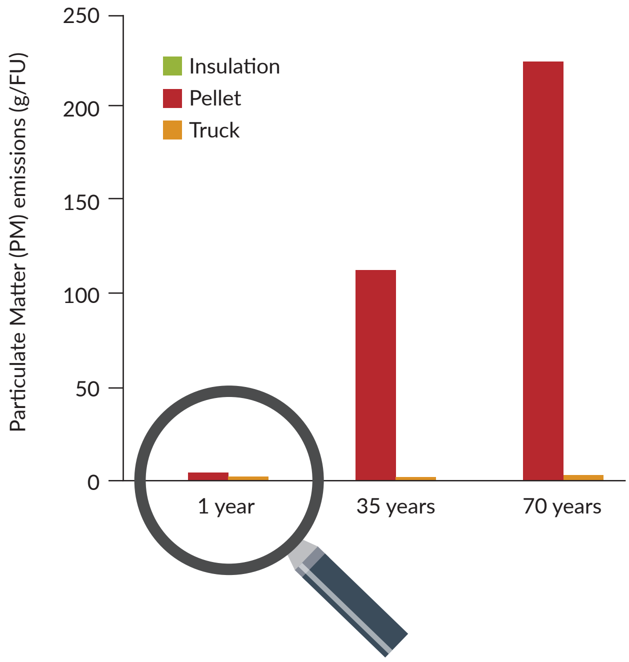

Figure 3 Toxic fine particles pollution caused by using either insulation material or wood pellets to meet the functional unit of a thermal transmittance of 0.24 W/m^{2}K for either 1 year, 35 years or 70 years, expressed in g particles. For comparison, particle emissions of a modern truck are added for the respective time horizon and energy generated. Insulation does not appear as the insulation material causes no fine particle emissions.

The comparative climate impacts of the insulation material and wood pellets respectively are depicted in Figure 2. For a one-year period, the climate impact of the insulation material is 1.6 times that of the wood pellets. However, after the one-time emissions from production of the insulation material, there is already a climate benefit over wood pellets after two years of use, whereas the latter continues to emit greenhouse gases every year. When considering meeting the thermal transmittance of 0.24 W/m^{2}K for 35 years, the continued use of wood pellets amounts to a climate impact 21 times greater than that of the insulation material. When considering the full time horizon of 70 years, the climate impact of wood pellet use is 43 times that of the insulation material. This underlines that the longer the life or use length of the insulation material, the greater its climate benefit becomes compared to continuing to heat with wood pellets.

The air pollution impacts of the insulation material and wood pellets respectively for one year, 35 and 70 years are shown in Figure 3. The insulation material causes no fine particle emissions, whereas wood pellet use causes emissions of 3 g particles per functional unit which accumulates over time to 113 g and 225 g particles per functional unit for 35 and 70 years, respectively. The health benefits of using wood as an insulation material rather than fuel are thus immediate. For comparison, as of 2014, a truck including a filter emits 0.5 g particles per GJ engine power, which represents less than 1% emissions compared to the use of wood pellets (CH and DUH 2022). World Health Organisation Air Quality Guidelines state that "the process of combustion is the greatest contributor to air pollution, in particular the inefficient combustion of fossil fuels and biomass to generate energy" (WHO, 2021).

Economic aspects

Table 1 illustrates the economic costs from a house owner perspective over a 35 or 70-year time horizon. Overall, the costs of purchasing and installing wood fibre insulation and keeping it for either 35 or 70 years remain higher compared to the present value of costs associated with using wood pellets to achieve the same benefits in the absence of additional insulation, even though pellet heating costs obviously increase with time. The continued use of wood pellets represents 59% of the insulation material cost after 35 years and 86% after 70 years (Figure 4).

Table 1 Economic costs of either using wood fibre insulation material or wood pellets for the time horizon of 35 and 70 years

	Costs for 70 years			Costs for 35 years	
Wood use alternative	Per building	Per m^2	Wood use alternative	Per building	Per m^2
Wood pellets	10,733 EUR	36 EUR	Wood pellets	7,357 EUR	25 EUR
Insulation material	12,442 EUR	42 EUR	Insulation material	12,442 EUR	42 EUR

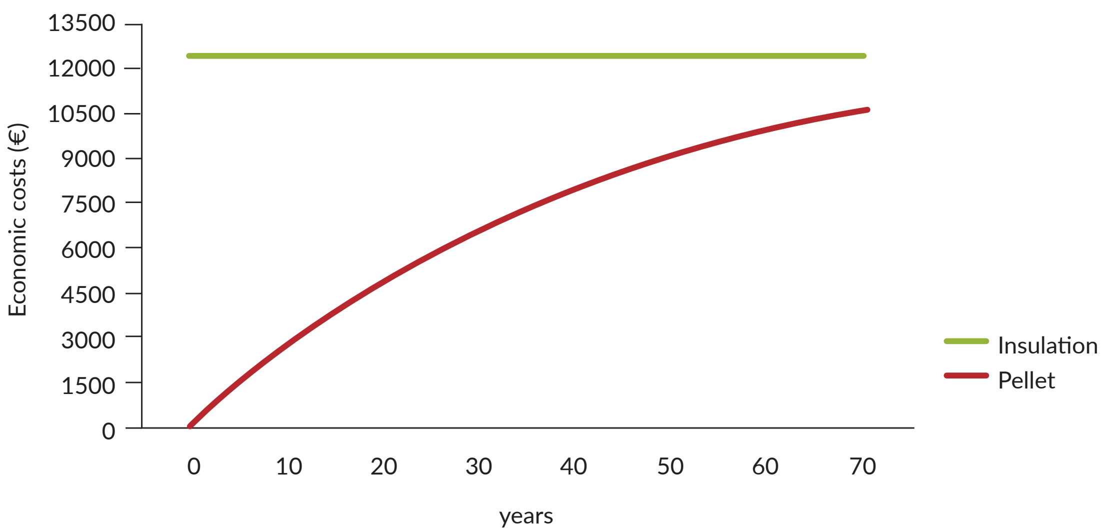

Figure 4 Costs (present value) of using either insulation material or wood pellets per building over time (installation of insulation at time = 0 year).

Discussion and conclusions

The EU housing stock continues to be insufficiently insulated, thereby increasing the need for energy, while ignoring opportunities to reduce emissions from wood use.

This study compared the energy, climate, health and economic impacts of using wood for insulation versus energy in the form of wood pellets. The comparison was based on meeting a legally determined thermal transmittance for a single year, as well as for 35 and 70 years and was set in Germany.

In resource use terms, wood is far more efficient as an insulator than a fuel. Over 35 years, it is possible to make a nine-fold saving when using wood as insulation material instead of continuing pellet use. In the optimistic case of a 70-year use, the savings are nineteen-fold. In terms of comparative climate benefits benefits, the reduction in greenhouse gases after 35 years is twenty-one-fold and after 70 years forty-three-fold. Additionally, the use of renewable low-carbon insulation would reduce buildings' embodied emissions compared to the use of synthetic counterparts, which is in line with targets set out by the EU Energy Performance of Buildings Directive.

Furthermore, as the insulation material does not emit fine particles, health benefits in the form of better air quality are immediate (burning wood releases toxic fine particles, polycyclic aromatic hydrocarbons (PAHs), nitric oxide, carbon monoxide and more).

However, for the house owner the economic costs of using wood as an insulation material remain considerably larger than the continued use of wood pellets. Even considering 70-year usage, the total cost of wood insulation would still be some 16% higher than that of continuous wood pellet use.

The health benefits [of using wood as insulation compared to fuel as pellets are immediate: better air quality (burning wood releases fine particles, nitric oxide, carbon monoxide and more); lower fire risk; and a reduction in toxic synthetic petrol-based insulation.

In summary, an increased shift from using wood for energy to using wood for insulation would deliver multiple benefits, but current pricing of wood pellets and wood-based insulation does not reflect that. The best way to help EU residents access these benefit would be to ensure the upfront cost of installing insulation is made more affordable for as many people as possible.

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