Quantifying the energy, climate, and air emission benefits of ROCKWOOL products for building insulation

Prepared for:

ROCKWOOL

guidehouse.com

1. Introduction

The ROCKWOOL Group is a global leader in stone wool solutions. To assess the energy, carbon and air emissions savings by the usage of sold ROCKWOOL building insulation products, there is a need for a robust and transparent calculation methodology. Therefore, ROCKWOOL asked Guidehouse Inc. to develop a methodology to calculate the energy, CO_2, SO_2, NO_x, and particulate matter (PM)[1] emission savings of its building insulation. Guidehouse developed this methodology independently of ROCKWOOL and approves the outcomes, based on the underlying assumptions. ROCKWOOL acknowledges that uncertainties and assumptions were made due to data limitations, as described in this document.

The methodology was first developed in 2017. The emission factors were updated in 2021 and in 2024. Although there are no industry standards for calculating energy and emission savings, this methodology aligns with the five steps for calculating avoided emissions proposed by the World Business Council for Sustainable Development (WBCSD) (1). These steps include defining a time frame, establishing a reference scenario, assessing the life cycle emissions of both the solution and the reference scenario, calculating the avoided emissions, and finally, evaluating these avoided emissions at the company scale.

About Guidehouse

Guidehouse is purpose built to help commercial and public sector clients navigate complex challenges across industries and geographies with an integrated model that breaks down silos to maximize efficiency.

Consultants work with clients to ‘imagine’ a new future, team across our digital and technology services to ‘build’ new resilient solutions, and then often ‘operate’ programs for clients to ensure sustained value.

At Guidehouse, we’re united by a shared commitment to purposeful impact. Moreover, our approach is rooted in an innovation-first mindset that ensures lasting change. The Sustainability Solutions team includes industry-leading experts in climate finance risks and opportunities, science-based targets, circular economy, lifecycle analysis, climate policy, adaptation strategy, biomass solutions, and carbon pricing.

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The energy, CO_2, SO_2, NO_x, and PM emission savings calculated using the approach described in this document consist of the energy, CO_2, SO_2, NO_x, and PM emission savings of ROCKWOOL products for building insulation over their complete lifetime, and are compared to the following reference scenarios:

- In the case of new buildings, a situation where no insulation is applied.[2]

[1] Particulate matter (PM) is defined as PM10 (>90%).

[2] Additional (more conservative) scenarios may be considered in the future to more closely align with WBCSD guidance

- In the case of building refurbishments, the insulation level of the existing building before refurbishment with an estimated U-value between 0.5-1.5 depending on the location.

The high-level calculation approach is shown on page 4. In this approach, annual space heating savings are defined as the reduction in space heating demand with respect to the reference situation. Note that the energy savings are expressed as a reduction in space heating demand. This number isolates the effect of ROCKWOOL's insulation products, as it does not reflect the effects of other factors that change over time (such as heat generation efficiency), which are included in final energy use.[3] The CO_2 and air emission savings are calculated based on the direct or combustion-only emission factors (respectively) of the current fuel mix per country or region for space heating purposes[4]. Upstream emissions related to the extraction, production, and transportation of these fuels are excluded from the calculation. Including these upstream emissions would lead to an estimated 5% to 20% increase in the resulting CO_2 savings.[5] By excluding the upstream processes, Guidehouse and ROCKWOOL are using a conservative approach for calculating CO_2 and air emission benefits. For heat generated by electricity and district energy, transport losses between the location where the emissions occur (e.g., the power plant) and the location where the energy is used for space heating purposes (i.e., the building) have been included.

[4] The fuel mix is not adjusted for anticipated changes over time, so potential decarbonization is not currently reflected. However, the fuel mix will be updated every three years. Additionally, the air emission factors are based on projected 2030 values, incorporating future developments.

[5] Range is based on a high-level assessment of different sources for the upstream impacts of fuels, including life cycle analysis (LCA) software, public sources (like UK Defra and the Dutch government), and Guidehouse's own research.

2. Methodology

Energy, CO_2, SO_2, NOx, and particulate matter (PM) emission savings over the lifetime of ROCKWOOL insulation products are calculated based on sales data and application inputs. These calculations cover two primary applications: building envelopes and flat roofs[6], applied in both new constructions and building refurbishments. For over 80% of sales, input parameters are assessed at the country level, ensuring precise calculations. For countries with lower sales volumes, regional estimates are used.

ROCKWOOL entities in Russia and Switzerland operate on different SAP systems, resulting in fewer entries in the input data. Consequently, some columns in the respective Excel file in the column “ROCKWOOL sales data” are not populated. This does not, however, lead to less accurate calculations or results since all the necessary inputs required to calculate overall avoided emissions are still included in these datasets.

2.1 Rationale behind inputs

For each of the four application groups[7], several generic and specific assumptions are made (see table 1). In case high uncertainty exists on a specific input, the most conservative option is used—i.e., the option that leads to the lowest energy and emission savings.

Regarding the **insulation lifetime**, a 50-year lifespan is assumed, consistent with ROCKWOOL's Environmental Product Declaration (EPD) (**2**) and the Product Category Rules (PCRs) for thermal insulation products (**3**). These guidelines typically base thermal performance characteristics on a minimum lifespan of 50 years. While the Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) (**4**) recommends a 60-year lifespan for thermal insulation of outer walls, and ROCKWOOL studies have indicated a potential lifespan of up to 65 years, the available data does not yet provide sufficient robustness to adopt these longer durations. Therefore, the conservative estimate of 50 years is used, rather than opting for 60, 65, or an average of these values.

To calculate the **emission factor for space heating in each country** *(2)*, the following inputs are factored in: the heat generation efficiency per fuel type *(2a)*, the fuel mix of each country where insulation is applied *(2b)*, and the emission factor of that fuel *(2c)*. As also depicted in the calculation methodology figure above, this emission factor indicates the emission per kWh of useful heat in the building and not the emissions per kWh of final energy delivered to the buildings (e.g. fuels). The difference between these two values is caused by the efficiency of the heating system (e.g. the boiler). The fuel mix of each country has been updated to the most up-to-date sources as seen in Appendix B.

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[6] “Flat roof” is part of the “building envelope” and contributes to buildings’ energy savings. “Flat roofs” are marked as contributing to energy savings but with a slightly different lambda value than products that are classified as “building envelope”.

[7] New buildings – Buildings Envelope; New buildings – Flat roof; Refurbishments – Building Envelope; Refurbishments – Flat roof

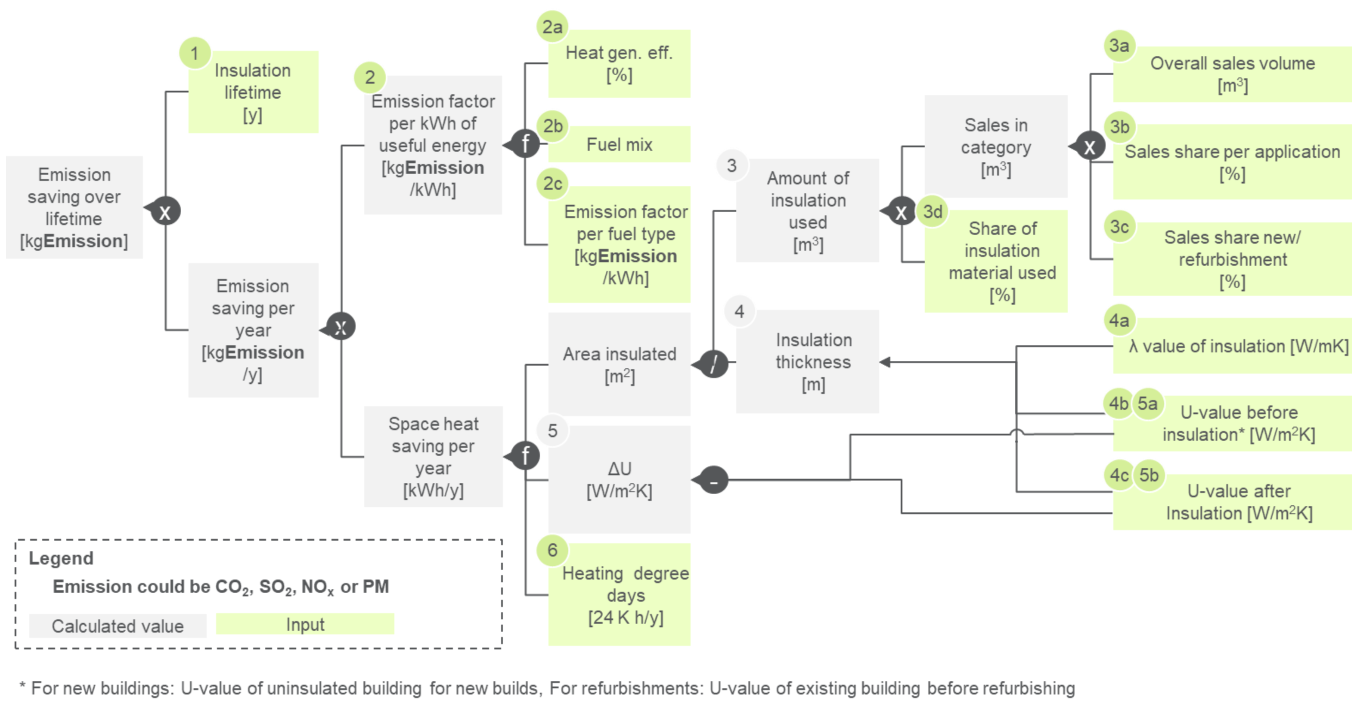

Figure 1: Calculation methodology items

		Application			
		New Envelope	New Flat Roof	Refurbished Envelope	Refurbished Flat Roof
1. **Insulation life time**		50 years			
2. Emission factor of space heat in each country	2.Emission factors of space heat in each country	0.011-0.353 (kgCO_2 /kWh of space heat), depending on fuel mix			
	2a. Heat generation efficiency (%)	85% for coal, 95% for biomass, 98% for oil, 95% for gas, 99% for district heating, 100% for direct electricity and 520% for air heat pumps			
	2b. Fuel mix	Varying per country			
	2c. Emission factor per fuel type	Varying per type of emission (CO_2, SO_2, NO_x,and PM) and per country			
3. Amount of insulation used per category	3a. Overall sales (m^3)	Please refer to tab "ROCKWOOL sales data”			
	3b. Sales share per application (%)	Assumption of 50-50% based on ROCKWOOL expert judgement			
	3c. Sales share new/refurbishment (%)	Please refer to tab “Data market”			
	3d. Share of insulation used (%)	98%			
4. Insulation thickness	4a. Λ value of insulation (W/m^2K)	0.035-0.043	0.037-0.038	0.035-0.043	0.037-0.038
	4b. U-value before insulation	1.5	1.5	0.6-1.5	0,29—1.5
	4c. U-value after insulation (W/m^2K)	0.17-0.53	0.09-0.39	0.17-0.53	0.09-0.39
5. ΔU		See U-value before and after insulation			
6. Heating degree days		464-5404			

Table 1 – Overview application methods

The assumptions regarding the heat generation efficiency *(2a)*, are based on the assumed best available technologies between 2021 and 2030 according to the study by Ecofys and IEEJ (**5**) and by technical Guidehouse experts. To yield conservative outcomes, efficiencies on the high end of the range are used, as lower efficiencies would lead to higher outcomes (emission savings). This is because more fuel is needed to cover the same amount of useful space heating demand. In practice, average generation efficiencies are expected to be lower. The most conservative estimate for gas from the study by Ecofys and IEEJ (**5**).

Based on this, the following assumptions on the heat efficiency were made (please refer to Table 1 point 2a)

The fuel mix of each country where insulation is applied (2b) is based on a variety of different sources, since data for the different countries/regions is not available from one source. The share of fuels in the final energy consumption of the residential sector for space heating in 2022 of oil, gas, coal, and electricity for European countries is based on Eurostat (**6**). For the UK and Canada, information on the share of these energy carriers is from the international energy agency (IEA) (**7**) (**8**). For the USA, data was obtained from the US Energy Information Administration (EIA) (**9**). The fuel mix for China (10) is based on a national forecast for China from DNV (**10**) and for Russia data from the World Bank data was used (**11**). The data for "Asia" is based on the fuel mix for Central Asia from the World Bank (**11**).

The percentage share for the energy carriers ambient heat, biomass and district heating in the European countries were originally based on the study for the European commission (**12**) in 2019 when the methodology was created. The values used in the study are from 2012. The expected increase/decrease until 2050 from the study was applied to the numbers from 2012 for the European countries (**see Appendix B for more detailed information**). For the other countries/regions the values from the respective sources were applied.

The emission factor of each fuel type *(2c)* is specific to the type of emission being calculated (CO_2, SO_2, NO_x, or PM). Emission factors, especially those for air emissions, can vary by country and are sourced from internationally recognized databases, which are described below.

For CO_2, the emission factors are derived from the 2019 refinement of the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories for coal, gas, and oil (**13**). Since 2019, these guidelines have not been updated, the emission factors remain consistent. Moreover, the IPCC's emission factors closely align with those published by the German Environmental Agency in 2022, verifying their continued accuracy (**14**). The biomass emission factor is set at a conservative value of 0 to only include CO_2 emissions from fossil fuels. The electricity emission factors are calculated on a country-by-country basis using the IEA emission factors from 2023 (**15**). The emission factors are calculated by including generation emissions per kWh and Transmission & Distribution (T&D) losses but excluding trade adjustments and converted CH_4 and N_2O emissions. IEA publishes data with a two year lag. Thus, the tool's grid carbon intensity data is based on 2021 figures, as the 2022 data will not be available until September 2024.

The emission factor for district heating is determined by multiplying the proportion of each fuel type used in heat generation, as reported by the IEA (**16**), with the country-specific emission factor for that energy carrier (**17**). The total emission factor is then obtained by summing these individual contributions. Further details can be found in Appendix B.

For air emissions (SO_2, NO_x, and PM), most emission factors are derived from the GEMIS database, version 5.1, published in March 2023 (**18**). The data used in the tool data primarily reflects the processes modeled in GEMIS for 2030 across various fuel types. For the USA, where GEMIS lacks data on air emission factors for natural gas and oil combustion, the figures were sourced from the U.S. Energy Information Administration's 2023 report (**19**).

When 2030 process data was unavailable in GEMIS for a European country, the lowest emission factor from equivalent processes within the EU for 2030 was applied to ensure a conservative estimate, resulting in minimal emission savings. For regions or countries outside Europe where 2030 data was also missing, the most recent available process data from GEMIS (**18**) was used. If no relevant processes were available, the minimum values from Europe were applied to these regions.

For district heating, the most recent data available in GEMIS is based on 2020. “No allocation” was selected for any cogeneration processes that were part of the district heating energy mix. The lowest available emission factor from all countries was applied to countries for which no data on air emissions from district heating in 2020 was available.
More detailed information on the processes used in GEMIS and the data sources referenced in the tool can be found in Appendix B

For biomass emission factors across all countries, the data is derived from the average values of the processes "wood-pellet-EU-heating-2030" and "wood-logs-heating-EU 15kW-2030" as provided by GEMIS. These values are used as a general proxy for all countries and regions due to the lack of more specific, localized data.

The **amount of insulation used per category** ***(3)*** for each application (building envelope and flat roof) and market (new construction and building refurbishment) is based on ROCKWOOL Building Insulation sales data in m^3 *(3a)*, sales share per application *(3b)*, sales distribution based on value in Millions of EUR over new construction and building refurbishments *(3c)*, and the share of insulation that is used in buildings *(3d)*. The sales distribution over new construction and building refurbishments in percentage was updated in 2024 for the most significant markets based on 2023 sales data.[8] More detailed information is included in Appendix B.

ROCKWOOL sales data *(3a)*, broken down into application—building envelope and flat roof—*(3b)* are provided by ROCKWOOL. Guidehouse does not validate the data but conducts a general review by comparing the data with the previous year's figures and scanning the document for any reference errors.

To calculate the amount of insulation that is used *(3d)*, a waste percentage of 2% is assumed. This assumption is based on the Product Environmental Footprint Category Rules (PEFCR) (**20**), which is part of the European Commission’s Single Market for Green Products initiative for thermal insulation products and a report by the European Insulation Manufacturers Association

[8] The sales distribution was not updated in 2024 for Portugal, Montenegro, Bosnia-Herz., Turkey, Greece and Switzerland. However, in sum these countries only add up to 0.23% of the total sales volume. For these countries data from 2016 was used.

(EURIMA) (21). KNAUF (22) also assumes a loss of materials in construction site of 2% in its product environmental declaration, which is verified until 2026.[9]

The **insulation thickness** *(4)* is calculated based on the weighted average λ-value of the insulation material *(4a)*, the U-value of the building before insulation or refurbishment *(4b)*, and the U-value after insulation *(4c)*. For refurbishments, an assumption must be made on the share of situations where old insulation material is removed before placing the new insulation material versus the share of situations where new insulation material is installed on top of the old insulation material. In the latter case, less new insulation material is needed per square meter of building envelope (or flat roof) to reach the desired U-value. In this calculation, a 50-50 split is assumed based on ROCKWOOL market experience.[10]

The weighted average λ-value of the insulation material *(4a)* is calculated based on ROCKWOOL sales data for each product type and the average λ-value of these product types. It is calculated on a country level for building envelope and flat roof insulation applications separately.

The U-value of the building before insulation *(4b)* differs between new construction and building refurbishments. For new construction, the reference case is defined as the situation where insulation material is applied between two brick walls[11] and then removed, leaving an air gap in between. This yields a U-value of 1.5 W/m^2K. An alternative for placing insulation in between two brick walls is to place insulation on top of a brick or concrete wall. If insulation is removed in this situation, it does not leave an airgap, yielding a higher U-value. If this U-value is used as a reference case, higher emissions savings would be estimated. However, as no solid data is available to back up the distribution between these options, the most conservative option is used for this calculation. In consultation with technical experts at ROCKWOOL and Guidehouse, the U-value before insulation has remained unchanged since the tool was created in 2017.

The calculation for building refurbishments uses baseline insulation before refurbishment based on typical insulation thicknesses in the building stocks of five representative countries. For these countries, the U-value of the existing building stock is estimated by Guidehouse and ROCKWOOL building experts based on the following sources: the EPISCOPE and TABULA webtool (23)[12]; a published paper on energy saving potential of Moscow apartment buildings (24) and Guidehouse estimates based on publications from the Ministry of Housing and Urban-Rural Development (MOHURD) F17, the China Academy of Building Research (CABR), and the US Department of Energy through its Building Energy Codes program.

The U-value after insulating *(4c)* is based on local building regulations and standards for both new construction and refurbishments. Based on the sources mentioned in appendix B (25) proxy u-values were identified for different regions (North, South, West, Northern Europe etc.) and respectively applied to the European countries. To take the most conservative approach resulting in the lowest avoided emissions, the minimum u-value per applicable region was chosen for the respective country. Appendix B provides more detail on the other sources that were used for the countries/regions other than Europe.

[9] However, this parameter is not critical, as even doubling the amount will only decrease the overall outcome by 2%.

[10] The number is based on a conservative calculation based on ROCKWOOL U-value calculator. This is not a sensitive assumption, as using 100% of either option would change the outcome by only approximately 1%.

[11] Made from solid brick with a density of 1800 kg/m^3

[12] Assumption: Building from 1960, 106 m^2

The **ΔU** ***(5)*** is calculated based on the difference between the U-value in the reference case (*5a, as described under 4b above*) and the U-value after applying ROCKWOOL building insulation material (*5b, as described under 4c above*).

The number of **heating degree days (HDD)** ***(6)*** are obtained from different sources (as outlined in appendix B). For European countries, the values represent a 5-year average of EUROSTAT data covering the period from 2019 to 2023 (**26**). Similarly, for the United Kingdom and Canada, the most recent UK government data (**27**) and Canadian government's environment and climate change data (**28**) are used respectively, based on a five-year average from 2019 to 2023. For the USA, the values are based on a 5-year average from 2019 to 2023, provided by the Statista Research Department (**29**). The values for China and Russia are based on the locations of ROCKWOOL production locations in these countries combined with the heating degree day map in a published paper on heating degree days for building applications (**30**). However, due to the lack of updated data for Russia and China from 2016, the figures were adjusted by applying a 4,9% average decrease of heating degree days, based on the European EUROSTAT data. The assumption of a general decrease is in line with literature published on the development of the HDD. For Russia, this assumption is supported by the G20 Climate Risk Atlas from 2021 (**31**) in which it states that substantial decreases in heating needs are expected all over the country. For China, the development of the HDD depends on the region; however, overall, a substantial decrease in the HDD can be observed (**32**).

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Appendix A. References

1. More information on the avoided emissions methodology from the World Business Council for Sustainable Development can be retrieved from: https://www.wbcsd.org/resources/guidance-on-avoided-emissions-helping-business-drive-innovations-and-scale-solutions-towards-net-zero/

2. More information on ROCKWOOL`s environmental product declaration can be retrieved here: https://p-cdn.rockwool.com/syssiteassets/rw-pl/materialy-do-pobrania/dokumentacja-produktowa/deklaracja-epd/epd-rw-cee-2023-pl.pdf?f=20230828134916

3. More information on the Product Category Rules (PCRs) for thermal insulation products can be retrieved from here: https://www.ul.com/resources/product-category-rules-pcrs

4. More information on the German Sustainable building council can be retrieved from: http://www.dgnb.de/en/

5. Ecofys & IEEJ (2015): Development of sectoral indicators for determining potential decarbonization opportunity. A joint study by IEEJ and Ecofys

6. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households - Table: Share of fuels in the final energy consumption of the residential sector for space heating, 2022

7. More information on the heating fuel mix in the UK (Coal, gas, oil and electricity in the UK): **https://www.iea.org/data-and-statistics/charts/proportion-of-residential-heating-energy-consumption-by-fuel-source-in-selected-countries-2020**

8. More information on the heating fuel mix in Canada (Coal, gas, oil and electricity in Canada): https://www.iea.org/data-and-statistics/charts/proportion-of-residential-heating-energy-consumption-by-fuel-source-in-selected-countries-2020

9. More information on the heating fuel mix in the US (Coal, gas, oil and electricity in the US): https://www.iea.org/data-and-statistics/charts/proportion-of-residential-heating-energy-consumption-by-fuel-source-in-selected-countries-2020

10. More information on the heating fuel mix in China: https://safety4sea.com/wp-content/uploads/2024/04/DNV-Energy_Transition_Outlook_China_2024_04.pdf

11. More information on the heating fuel mix in Russia and “Asia” : **World Bank Document**

12. Study for the European Commission: Mapping and analyses of the current and future (2020-2030) heating/cooling fuel deployment (fossil/renewables), TU Wien, Observ'ER, Fraunhofer ISE, TEP, IREES, Fraunhofer ISI.

13. More information on stationary combustion values: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf/ Refinement

2019: https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/2_Volume2/19R_V2_2_Ch02_Stationary_Combustion.pdf

14. More information on CO2 emission factors by the German Environmental agency: https://www.umweltbundesamt.de/sites/default/files/medien/361/dokumente/co2_ef_liste_2022_brennstoffe_und_industrie_final.xlsx

15. Retrieved from: https://www.iea.org/reports/co2-emissions-in-2023

16. More information on the heat generation by source: Energy Statistics Data Browser – Data Tools - IEA

17. More information about the specific emission factors related to district heating can be found here: Emission factors for electricity, district heating, and fuels 2022 (vda.de)

18. GEMIS 5.1 download can be found here: https://iinas.org/downloads/gemis-downloads/

19. More information on the air emissions from the US can be retrieved from here: https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-technical-support-document-tsd

20. More information can be retrieved from: https://www.filmm.org

21. More information on the waste percentage of 2% from the EURIMA report can be retrieved from here eurima.org/uploads/files/modules/articles/1678707364_EURIMA_CN2050 Roadmap_February 2023.pdf

22. More information on the assumed loss of materials can be retrieved from: https://www.knauf.co.uk/-/media/isolator-test-reports/knauf-insulation-rocksilk-ewi-slab-epd.pdf?la=en&hash=BBA8B17CE69904F27D6FDB6824E91DD4&hash=BBA8B17CE69904F27D6FDB6824E91DD4

23. Can be retrieved from: http://episcope.eu/building-typology/webtool/

24. S. Paiho et al. (2014), Energy and Buildings, “Energy saving potentials of Moscow apartment buildings in residential districts”

25. The building regulations including Building Regulation Office; Ministry for Transport and Infrastructure Malta 2015, Bundesgesetzblatt 2020, CSTB and CSTB, 2023, Ministry of Ecological Transition France 11.2018, Department of Housing, Local Government and Heritage of the Government of Ireland 2022, Government of the Republic of Bulgaria 2015, Government of Walloon 2016, Ministry of the Environment, Finland 2017, Ministry of transport, mobility and urban agenda Spain 6/14/2022, Swedish National Board of Housing, Building and Planning (Boverket). 2019, The Netherlands Enterprise Agency 3/14/2022, Ministry of development, public works and administration of Romania, 2023, The Ministry of Industry and Trade of Czech Republic 5/29/2020, Minister of Development,

Public Works and Administration, Romania 1/17/2023, and Ministry of Transport, Building and Housing, Denmark 1/4/2018 are taken into consideration

26. More information on the data base about the heating degree days in Europe: https://ec.europa.eu/eurostat/databrowser/view/nrg_chdd_a__custom_12259291/default/table?lang=en

27. More information on the data base about the heating degree days in the UK: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiLxpHRyOCHAxVEwAIHHZkdPJAQFnoECAgQAQ&url=https%3A%2F%2Fassets.publishing.service.gov.uk%2Fmedia%2F66a00f55ab418ab055592bed%2FDUKES_1.1.9.xlsx&usg=AOvVaw3Gp8jkCseh34eKtkKeczig&opi=89978449

28. Government of Canada 'Environment and Climate Change of Canada' Open Data portal, retrieved from: https://toronto.weatherstats.ca/charts/hdd-yearly.html

29. More information on the data base about the heating degree days in the USA: https://www.statista.com/statistics/245632/number-of-heating-degree-days-in-the-united-states/

30. M. Mourshed (2016), Renewable Energy, "Climatic parameters for building energy applications: A temporal-geospatial assessment of temperature indicators"

31. More information on the expected development of heating degree days in Russia: https://files.cmcc.it/g20climaterisks/Russia.pdf

32. More information on the expected development of heating degree days in China: Changes of heating and cooling degree days over China in response to global warming of 1.5 °C, 2 °C, 3 °C and 4 °C; https://www.sciencedirect.com/science/article/pii/S1674927817301

Appendix B. Detailed Description on the methodology/ emission factors

<table>
<tr><th>Type of change</th><th colspan="3">Description</th></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">(2) Emission factor for space heating in each country</td></tr>
<tr><td rowspan="9">Heating fuel mix per country (2a)</td><td rowspan="7">Gas, oil, coal, and electricity are updated to the most recent data (The year in brackets indicates the year the data was reported)</td><td>EU: Eurostat (2022)[13]</td><td>EUROSTAT was used due to incomplete IEA data for all EU countries and EUROSTAT’s 2022 data is more current</td></tr>
<tr><td colspan="2">UK: IEA (2020)[14]</td></tr>
<tr><td colspan="2">Canada: IEA (2020)[15]</td></tr>
<tr><td colspan="2">USA: IEA (2020)[16]</td></tr>
<tr><td colspan="2">China: IEA (2021)[17]</td></tr>
<tr><td colspan="2">Russia: World Bank (2023)[18]</td></tr>
<tr><td colspan="2">Asia: World Bank (2023)[19]</td></tr>
<tr><td rowspan="2">Biomass, ambient heat, and district heating are not included in the publicly available EUROSTAT, IEA or EIA data set. In previous updates these values were still publicly available

For 2024 we applied the yearly</td><td colspan="2">Biomass: - The share of biomass is expected to increase by 10% between 2012 and 2030 based on the building codes. Assuming a uniform annual increase this translates to an approximate growth of 0,55% per year and an overall increase of 6,5% between 2012 and 2023.</td></tr>
<tr><td colspan="2">Ambient heat: - The share of ambient heat is expected to increase by 42% between 2012 and 2030 based on the current building codes. Assuming a uniform annual increase, this translates to an approximate growth of 2.3% per year. This results in an increase of 25,3% between 2012 and 2023..</td></tr>
</table>

[13] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households

[14] https://www.iea.org/data-and-statistics/charts/proportion-of-residential-heating-energy-consumption-by-fuel-source-in-selected-countries-2020

[15] https://www.iea.org/data-and-statistics/charts/proportion-of-residential-heating-energy-consumption-by-fuel-source-in-selected-countries-2020

[16] https://www.iea.org/data-and-statistics/charts/proportion-of-residential-heating-energy-consumption-by-fuel-source-in-selected-countries-2020

[17] https://www.iea.org/countries/china/energy-mix

[18] https://documents1.worldbank.org/curated/en/099092023140527206/pdf/P1777440fed3230ce089060ff8ce59c9f5e.pdf

[19] Based on Central Asia: https://documents1.worldbank.org/curated/en/099092023140527206/pdf/P1777440fed3230ce089060ff8ce59c9f5e.pdf

<table>
<tr><td></td><td>average projected decrease/increase of a study by the European Commission[20] of energy carriers in space heating of each energy carrier to the numbers from the study from 2012.[21]</td><td>District heat: - The share of district heating is expected to decrease by 12% between 2012 and 2030 based on the current policy scenario. Assuming a uniform annual decrease this translates to an approximate decrease of 0,66% per year and an overall decrease of 7,26% between 2012 of 2023</td></tr>
<tr><td>Emission factor of the fuels (District heating)</td><td>Emission factors for district heat in gCO2/kWh was calculated by multiplying the proportion of each fuel type used in heat generation, as reported by the IEA, with the country-specific emission factor for that energy carrier. The total emission factor is then obtained by summing these individual contributions.</td><td>An example for the calculation for the district heating emission factor for Russia is included below. The same procedure was applied to all the other countries :

Heat generation by source in Russia (data from IEA: Energy Statistics Data Browser – Data Tools - IEA

<table>
<tr><th>Energy source</th><th>TJ</th><th>% of total</th><th>Emission factor (according to the study from VDA[22] for district heating in Russia)</th><th>Calculated emission factor</th></tr>
<tr><td>Natural Gas</td><td>3.896.134</td><td>75%</td><td>213 g/kWh</td><td>0,75*213</td></tr>
<tr><td>Coal</td><td>956.265</td><td>18%</td><td>409 g/kWh</td><td>0,18*409</td></tr>
<tr><td>Oil</td><td>154.479</td><td>3%</td><td>322 g/kWh[23]</td><td>0,03*322</td></tr>
<tr><td>Biofuel</td><td>22.893</td><td>0,4%</td><td>0 g/kWh</td><td>0</td></tr>
</table>
</td></tr>
</table>

[20] Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables) - European Commission (europa.eu)

[21] The percentages of the emission factors do not sum to 100% because renewable energy sources and "other fossil fuels"—which only make up a very small amount—are excluded. However, this is addressed in column H of the "Processing Emissions" tab, where a weighted average calculation is performed to correct for these omissions.

[22] Emission factors for electricity, district heating, and fuels 2022 (vda.de)

[23] Assumption: Heavy fuel oil

<table>
<tr>
<td></td>
<td></td>
<td>
<table>
<tr><td>Nuclear</td><td>14.596</td><td>0,3%</td><td>10 g/kWh[24]</td><td>0,03*10</td></tr>
<tr><td>Waste</td><td>149.341</td><td>3%</td><td>495 g/kWh[25]</td><td>0,3*495</td></tr>
<tr><td>Total</td><td>5.193.708</td><td>100%</td><td></td><td><u>258,93 g/kWh</u></td></tr>
</table>
</td>
</tr>
<tr>
<td>Emission factor of the fuels (2c) (air emissions biomass)</td>
<td>To calculate the air emission factors for biomass, data from the German Environmental Agency[26] on the emissions balance of renewable energy sources was used. The emission factors were calculate based on the provided heat from solid biomass in private households and the respective emission factors per fuel/technique (see page 96 of the study). This average value was applied uniformly across all countries,</td>
<td>
<u>Biomass emissions based on UBA Study 2023</u>

Distribution according to UBA study in 2022 in GWh
<table>
<tr><td></td><td>GWh</td><td>%</td></tr>
<tr><td>Individual room furnaces</td><td>52.190</td><td>52,5%</td></tr>
<tr><td>Central firing systems</td><td>31.448</td><td>31,7%</td></tr>
<tr><td>Pellets</td><td>15.680</td><td>15,8%</td></tr>
<tr><td>Total</td><td><u>99.318</u></td><td></td></tr>
</table>
<table>
<tr><td>Average emission factor</td><td>SO2</td><td>NOx</td><td>Particulates</td><td></td></tr>
<tr><td>Brennholz Einzelraumfeuerung</td><td>0,031</td><td>0,199</td><td>0,309</td><td>g/kWh</td></tr>
<tr><td>Briketts (Holz) Einzelraumfeuerung</td><td>0,018</td><td>0,457</td><td>0,096</td><td>g/kWh</td></tr>
<tr><td>Briketts (Holz) Einzelraumfeuerung</td><td>0,016</td><td>0,36</td><td>0,083</td><td>g/kWh</td></tr>
<tr><td><u>Individual room furnaces TOTAL</u></td><td>0,021667</td><td>0,338667</td><td>0,16267</td><td>g/kWh</td></tr>
<tr><td></td><td><u>2,17E-05</u></td><td><u>0,339E-04</u></td><td><u>0,00016</u></td><td>kg/kWh</td></tr>
</table>
<table>
<tr><td>Average emission factor</td><td>SO2</td><td>NOx</td><td>Particulates</td><td></td></tr>
<tr><td>Brennholz Kessel</td><td>0,018</td><td>0,379</td><td>0,114</td><td>g/kWh</td></tr>
<tr><td>Bricketts(Holz)Kessel</td><td>0,016</td><td>0,353</td><td>0,05</td><td>g/kWh</td></tr>
<tr><td>Holzhackschnitzel kleiner Kessel</td><td>0,016</td><td>0,36</td><td>0,083</td><td>g/kWh</td></tr>
<tr><td>Holzhackschnitzel großer Kessel</td><td>0,016</td><td>0,374</td><td>0,043</td><td>g/kWh</td></tr>
<tr><td><u>Central firing systems TOTAL</u></td><td>0,0165</td><td>0,3665</td><td>0,0725</td><td>g/kWh</td></tr>
</table>
</td>
</tr>
</table>

[24] Nuclear is not included in the study from the VDA, the assumption is based on: Steffen Schlömer (ed.), Technology-specific Cost and Performance Parameters, Annex III of Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2014)

[25] Assumption: Emisison factor for Therm. Waste incineration

[26] https://www.umweltbundesamt.de/sites/default/files/medien/11850/publikationen/20231219_49_2023_cc_emissions bilanz_erneuerbarer_energien_2022_bf.pdf

based on the assumption that emissions from burning wood do not vary significantly between countries.

	1,65E-05	**3,67E-04**	**7,3E-05**	kg/kWh

Average emission factor	**SO2**	**NOx**	**Particulates**	
Pellets Einzelraumfeuerung	0,018	0,457	0,096	g/kWh
Pellets Kessel	0,018	0,31	0,06	g/kWh
Pellets TOTAL	0,018	0,3835	0,078	g/kWh
	1,8E-05	**3,84E-04**	**7,8E-05**	kg/kWh

Calculation total based on % distribution.

SO2	**NOx**	**Particulates**[27]
(0,525* 2,17E05)+(0,317*1,65E-05)+(0,1568*1,8E-05)= **1,945E-05**	(0,525* 0,339E-04)+(0,317*3,67E-04)+(0,1568*3,84E-04)= **3,55E-04**	(0,525* 1,6E-04)+(0,317*7,3E-05)+(0,1568*7,8E-05)= **1,2E-04**

Emission factor of the fuels (2c) (air emission other fuels)

Country	***Fuel type & Source/ name of process in GEMIS***	
Austria	***Gas***	GEMIS 5.1: gas-heating-AT-2030
	Oil	GEMIS 5.1:oil-heating-AT-2030
	Coal	GEMIS 5.1: Lignite-briquettes-heating-AT-2030
	Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
	Electricity	GEMIS 5.1: el-generation-mix-AT-2030
	District Heating	GEMIS 5.1;district-heat-mix-AT-2020/en
Belgium	***Gas***	GEMIS 5.1: gas-heating-BE-2030
	Oil	GEMIS 5.1: oil-heating-BE-2030

[27] Dust includes the total emissions of suspended dust of all particle sizes

		Coal	No new process available, thus the smallest emission factor from the EU for the 2030 processes for coal (Czech Republic) was applied)	
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated	
		Electricity	GEMIS 5.1: el-generation-mix-BE-2030	
		District Heating	GEMIS 5.1;district-heat-mix-BE-2020/en	
	Bulgaria	***Gas***	GEMIS 5.1: gas-heating-BG-2030	
		Oil	GEMIS 5.1: oil-heating-BG-2030	
		Coal	GEMIS 5.1: Lignite-briquettes-heating-BG-2030	
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated	
		Electricity	GEMIS 5.1: el-generation-mix-BG-2030	
		District Heating	GEMIS 5.1;district-heat-mix-BG-2020/en	
	Croatia	***Gas***	No new process available, thus the smallest emission factor from the EU for the 2030 processes for gas (from Sweden/Germany) was applied	
		Oil	No new process available, thus the smallest emission factor from the EU for the 2030 processes for oil (from Sweden/Germany) was applied	
		Coal	No new process available, thus the smallest emission factor from the EU for the 2030 processes for coal (Czech Republic) was applied	
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated	
		Electricity	No new process available, thus the smallest emission factor from the	

			EU for the 2030 processes for electricity (Norway) was applied
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Cyprus	***Gas***	No new process available, thus the smallest emission factor (from Sweden/Germany was applied)
		Oil	GEMIS 5.1: oil-heating-CY-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-CY-2030
		Biomass	See explanation in the column right to “Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-CY-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Czech Republic	***Gas***	GEMIS 5.1: gas-heating-CZ-2030
		Oil	GEMIS 5.1: oil-heating-CZ-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-CZ-2030
		Biomass	See explanation in the column right to “Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-CZ-2030
		District Heating	GEMIS 5.1;district-heat-mix-CZ-2020/en
	Denmark	***Gas***	GEMIS 5.1: gas-heating-DK-2030
		Oil	GEMIS 5.1: oil-heating-DK-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-DE-2030
		Biomass	See explanation in the column right to “Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated

		Electricity	GEMIS 5.1: el-generation-mix-DK-2030
		District Heating	GEMIS 5.1;district-heat-mix-DK-2020/en
	Estonia	***Gas***	GEMIS 5.1: gas-heating-EE-2030
		Oil	GEMIS 5.1: oil-heating-EE-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-EE-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-EE-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Finland	***Gas***	No new process available, thus the smallest emission factor (from Sweden/Germany was applied)
		Oil	GEMIS 5.1: oil-heating-FI-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-FI-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-FI-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	France	***Gas***	GEMIS 5.1: gas-heating-FR-2030
		Oil	GEMIS 5.1: oil-heating-FR-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-FR-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated

		Electricity	GEMIS 5.1: el-generation-mix-FR-2030
		District Heating	GEMIS 5.1;district-heat-mix-FR-2020/en
	Germany	***Gas***	GEMIS 5.1: gas-heating-DE-2030
		Oil	GEMIS 5.1: oil-heating-DE-2030
		Coal	No new process available, thus the smallest emission factor from the EU for the 2030 processes for coal (Czech Republic) was applied
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-DE-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Greece	***Gas***	GEMIS 5.1: gas-heating-GR-2030
		Oil	GEMIS 5.1: oil-heating-GR-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-GR-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-GR-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Hungary	***Gas***	GEMIS 5.1: gas-heating-HU-2030
		Oil	GEMIS 5.1: oil-heating-HU-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-HU-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated

		Electricity	GEMIS 5.1: el-generation-mix-HU-2030
		District Heating	GEMIS 5.1;district-heat-mix-HU-2020/en
	Ireland	***Gas***	GEMIS 5.1: gas-heating-IE-2030
		Oil	GEMIS 5.1: oil-heating-IE-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-IE-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-IE-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Italy	***Gas***	GEMIS 5.1: gas-heating-IT-2030
		Oil	GEMIS 5.1: oil-heating-IT-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-IT-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-IT-2030
		District Heating	GEMIS 5.1;district-heat-mix-IT-2020/en
	Latvia	***Gas***	GEMIS 5.1: gas-heating-LV-2030
		Oil	GEMIS 5.1: oil-heating-LV-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-LV-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-LV-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for

			district heating (Norway) was applied
	Lithuania	***Gas***	GEMIS 5.1: gas-heating-LT-2030
		Oil	GEMIS 5.1: oil-heating-LT-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-LT-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-LT-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Luxembourg	***Gas***	GEMIS 5.1: gas-heating-LU-2030
		Oil	GEMIS 5.1: oil-heating-LU-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-LU-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-LU-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Malta	***Gas***	No new process available, thus the smallest emission factor (from Sweden/Germany was applied)
		Oil	GEMIS 5.1: oil-heating-MT-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-MT-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-MT-2030

		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Netherlands	***Gas***	GEMIS 5.1: gas-heating-NL-2030
		Oil	GEMIS 5.1: oil-heating-NL-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-NL-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-NL-2030
		District Heating	GEMIS 5.1;district-heat-mix-NL-2020/en
	Norway	***Gas***	No new process available, thus the smallest emission factor from the EU for the 2030 processes for gas (from Sweden/Germany) was applied
		Oil	No new process available, thus the smallest emission factor from the EU for the 2030 processes for oil (from Sweden/Germany) was applied
		Coal	No new process available, thus the smallest emission factor from the EU for the 2030 processes for coal (Czech Republic) was applied
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-NO-2030
		District Heating	GEMIS 5.1;district-heat-mix-NO-2020/en
	Poland	***Gas***	GEMIS 5.1: gas-heating-PL-2030
		Oil	GEMIS 5.1: oil-heating-PL-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-PL-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to

			understand how this values was calculated		
		Electricity	GEMIS 5.1: el-generation-mix-PL-2030		
		District Heating	GEMIS 5.1;district-heat-mix-PL-2020/en		
	Portugal	***Gas***	GEMIS 5.1: gas-heating-PT-2030		
		Oil	GEMIS 5.1: oil-heating-PT-2030		
		Coal	GEMIS 5.1: Lignite-briquettes-heating-PT-2030		
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated		
		Electricity	GEMIS 5.1: el-generation-mix-PT-2030		
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied		
	Romania	***Gas***	GEMIS 5.1: gas-heating-RO-2030		
		Oil	GEMIS 5.1: oil-heating-RO-2030		
		Coal	GEMIS 5.1: Lignite-briquettes-heating-RO-2030		
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated		
		Electricity	GEMIS 5.1: el-generation-mix-RO-2030		
		District Heating	GEMIS 5.1;district-heat-mix-RO-2020/en		
	Slovakia	***Gas***	GEMIS 5.1: gas-heating-SK-2030		
		Oil	GEMIS 5.1: oil-heating-SK-2030		
		Coal	GEMIS 5.1: Lignite-briquettes-heating-SK-2030		
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated		
		Electricity	GEMIS 5.1: el-generation-mix-SK-2030		

		District Heating	GEMIS 5.1;district-heat-mix-SK-2020/en
	Slovenia	***Gas***	GEMIS 5.1: gas-heating-SL-2030
		Oil	GEMIS 5.1: oil-heating-SL-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-SI-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-SL-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Spain	***Gas***	GEMIS 5.1: gas-heating-ES-2030
		Oil	GEMIS 5.1: oil-heating-ES-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-ES-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-ES-2030
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
	Sweden	***Gas***	GEMIS 5.1: gas-heating-SE-2030
		Oil	GEMIS 5.1: oil-heating-SE-2030
		Coal	GEMIS 5.1: Lignite-briquettes-heating-SE-2030
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-SE-2030
		District Heating	GEMIS 5.1;district-heat-mix-SE-2020/en

	United Kingdom	***Gas***	GEMIS 5.1: gas-heating-UK-2030	
		Oil	GEMIS 5.1: oil-heating-UK-2030	
		Coal	GEMIS 5.1: Lignite-briquettes-heating-UK-2030	
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated	
		Electricity	GEMIS 5.1: el-generation-mix-UK-2030	
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied	
	Canada	***Gas***	Latest available process was used: gas-heating-CA-2015	
		Oil	Latest available process was used: oil-heating-CA-2015	
		Coal	There is no comparable process for space heating through coal, and thus the smallest value from the EU is used	
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated	
		Electricity	GEMIS 5.1: el-generation-mix-CA-2030	
		District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied	
	USA	***Gas***	Data for gas is based on EPA data	
		Oil	Data for oil is based on EPA data	
		Coal	There is no comparable process for space heating through coal, and thus the smallest value from the EU is used	
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated	

	Electricity	GEMIS 5.1: el-generation-mix-US-2030
	District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
China	***Gas***	Based on latest available process in GEMIS: gas-heating-CN-2015
	Oil	Based on latest available process in GEMIS: oil-heating-CN-2015
	Coal	There is no comparable process for space heating through coal, and thus the smallest value from the EU is used
	Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
	Electricity	GEMIS 5.1: el-generation-mix-CN-2030
	District Heating	No 2020 process available, thus the smallest emission factor from the EU for the 2020 processes for district heating (Norway) was applied
Asia	***Gas***	Based on China
	Oil	Based on China
	Coal	Based on China
	Biomass	Based on China
	Electricity	Based on China
	District Heating	Based on China
Europe	***Gas***	Average of all listed European countries
	Oil	Average of all listed European countries
	Coal	Average of all listed European countries
	Biomass	Average of all listed European countries
	Electricity	Average of all listed European countries
	District Heating	Average of all listed European countries

	North America	***Gas***	Average of the US and Canada
		Oil	Average of the US and Canada
		Coal	Average of the US and Canada
		Biomass	Average of the US and Canada
		Electricity	Average of the US and Canada
		District Heating	Average of the US and Canada
	Russia	***Gas***	Based on latest available process in GEMIS5.1 : gas-heating-RU-2015
		Oil	Based on latest available process in GEMIS 5.1 : oil-heating-RU-2015
		Coal	There is no comparable process for space heating through coal, and thus the smallest value from the EU is used
		Biomass	See explanation in the column right to "Emission factor of the fuels (2c) (air emissions biomass) to understand how this values was calculated
		Electricity	GEMIS 5.1: el-generation-mix-RU-2030
		District Heating	GEMIS 5.1;district-heat-mix-RU-2020/en
	Other	***Gas***	Average of Europe, North America, Asia and Russian region.
		Oil	Average of Europe, North America, Asia and Russian region.
		Coal	Average of Europe, North America, Asia and Russian region.
		Biomass	Average of Europe, North America, Asia and Russian region.
		Electricity	Average of Europe, North America, Asia and Russian region.
		District Heating	Average of Europe, North America, Asia and Russian region.
(3) The amount of insulation used per category			
(3c) Sales distribution based on value in MEUR over new construction &	Information of sales share was not updated for all countries with 2023 data. Yet in total the sales	The sales split for Portugal, Montenegro, Bosnia-Herz., Turkey and Greece is based on the sales split from 2016.	

building refurbishments	volume of the countries not updated only sums up to 0,23% of the total sales volume.	
	(4) Insulation Thickness	
U-value of the building after insulation or refurbishment (4c)	Building envelope and flat roof for both new buildings and refurbishments are updated based on the latest residential building codes	For European countries (despite the UK): The building regulations including Building Regulation Office; Ministry for Transport and Infrastructure Malta 2015, Bundesgesetzblatt 2020, CSTB and CSTB, 2023, Ministry of Ecological Transition France 11.2018, Department of Housing, Local Government and Heritage of the Government of Ireland 2022, Government of the Republic of Bulgaria 2015, Government of Walloon 2016, Ministry of the Environment, Finland 2017, Ministry of transport, mobility and urban agenda Spain 6/14/2022, Swedish National Board of Housing, Building and Planning (Boverket). 2019, The Netherlands Enterprise Agency 3/14/2022, Ministry of development, public works and administration of Romania, 2023, The Ministry of Industry and Trade of Czech Republic 5/29/2020, Minister of Development, Public Works and Administration, Romania 1/17/2023, and Ministry of Transport, Building and Housing, Denmark 1/4/2018 are taken into consideration
		UK: Heat Roadmap Europe 2050, baseline scenario of the heating and cooling demand in buildings in the 14 MSs until 2050[28]
		Canada: Government of Canada (2020)[29]
		USA: IECC (2021)[30]
		Russia: Literature review (2021)[31]
		China: Literature review (2023)[32]
	(6) Heating degree days	
		EU: Eurostat data (2024)[33]

[28] https://epbd-ca.eu/wp-content/uploads/2019/05/CA-EPBD-IV-UK-England-2018.pdf
[29] National Energy Code of Canada for Buildings: 2020 - NRC Publications Archive - Canada.ca
[30] CHAPTER 4 CE COMMERCIAL ENERGY EFFICIENCY - 2021 INTERNATIONAL ENERGY CONSERVATION CODE (IECC) (iccsafe.org)
[31] Energy performance criteria for residential buildings: A comparison of Finnish, Norwegian, Swedish, and Russian building codes - ScienceDirect
[32] https://www.mdpi.com/2071-1050/15/8/6931
[33] ec.europa.eu/eurostat/databrowser/view/nrg_chdd_a__custom_12259291/default/table?lang=en

Heating degree days per country (6)	Heating degree days per country are updated using the mean from 2019-2023	UK: UK Gov (2024)[34]
		Canada: Canadian Gov Environment and Climate Change Canada (2024)[35]
		USA: Statista (2024)[36]
		Russia and China: As no updated data is available, we applied the average annual decrease from the EUROSTAT European data (2019-2023) (excluding UK) to adjust the figures for Russia and China. The latest available data from Russia and China is based on 2016 data.[37] To calculate a proxy for the decrease in HDD between 2016 and 2023 we applied the average yearly decrease for the European Countries to these countries. For Russia, this assumption is supported by the G20 Climate Risk Atlas from 2021[38] in which it states that substantial decreases in heating needs are expected all over the country. For China, the development of the HDD really depends on the region; however, multiple sources state that overall, a substantial decrease in the HDD can be observed.[39]

[34] https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fassets.publishing.service.gov.uk%2Fmedia%2F66a00f55ab418ab055592bed%2FDUKES_1.1.9.xlsx&wdOrigin=BROWSELINK

[35] https://toronto.weatherstats.ca/charts/hdd-yearly.html

[36] U.S. heating degree-days 2023 | Statista

[37] https://www.sciencedirect.com/science/article/pii/S0960148116302051

[38] https://files.cmcc.it/g20climaterisks/Russia.pdf

[39] Changes of heating and cooling degree days over China in response to global warming of 1.5 °C, 2 °C, 3 °C and 4 °C; https://www.sciencedirect.com/science/article/pii/S1674927817301