QUANTIFYING THE ENERGY, CLIMATE, AND AIR EMISSION BENEFITS OF ROCKWOOL PRODUCTS FOR BUILDING INSULATION

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 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, given the underlying assumptions and acknowledging that there are uncertainties and assumptions made where a lack of data exists, as described in this document.

Because no industry standard exists to calculate energy, CO_2 and air emission savings, this document aims to transparently describe Guidehouse's calculation method of ROCKWOOL's energy and emissions savings, give a clear and concise overview of the inputs used, and describe which assumptions the Guidehouse team used to compensate for lack of data.

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 a reference situation:

- In the case of new buildings, a situation where no insulation is applied
- In the case of building refurbishments, the insulation level of the existing building before refurbishment

The high-level calculation approach is shown on page 2. 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. 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[2] for space heating purposes. Upstream emissions related to the extraction, production, and transportation of these fuels are excluded from the calculation due to a high uncertainty of these emissions. Including these upstream emissions would lead to an estimated 5% to 20% increase in the resulting CO_2 savings.[3] Similarly, the inclusion of upstream emissions would lead to a 3% increase in air emissions savings for coal heating, and up to an 89% increase in air emissions savings for gas heating. 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.

About Guidehouse

Guidehouse is a leading international energy and climate consultancy focused on creating value for its clients by developing, implementing, and maintaining sustainable solutions. With over 500 energy and climate experts in its global Energy practice, the company is a trusted advisor to governments, corporations, NGOs, and energy providers worldwide. 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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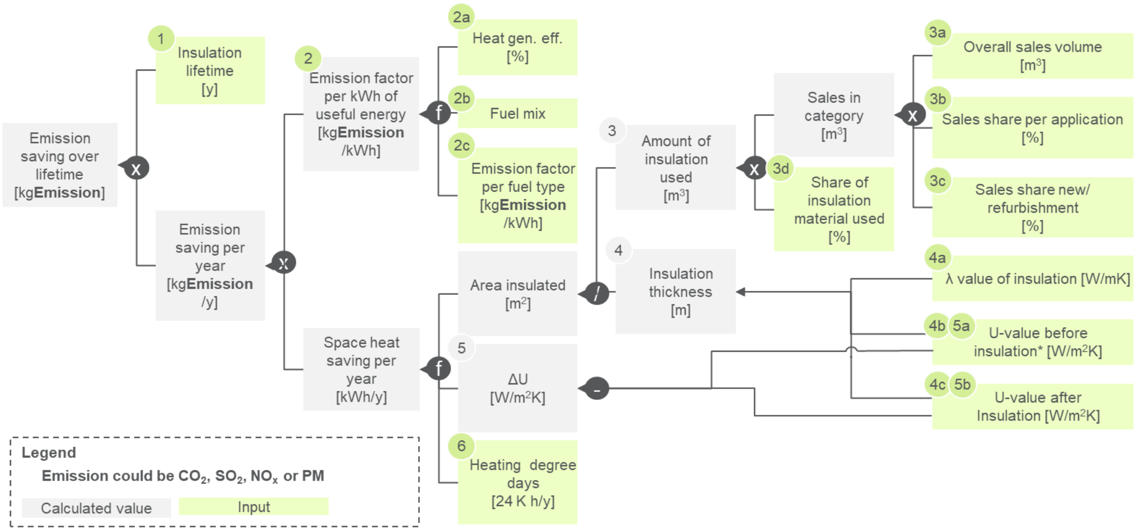
[1] Particulate matter (PM) is defined as PM10 (>90%).
[2] Fuel mix is not corrected for expected changes in this mix over time and, therefore, does not take the potential decarbonisation of this fuel mix into account. However, the fuel mix will be updated every 3 years.
[3] Range is based on a high-level 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.

Methodology

Energy, CO_2, SO_2, NO_x, and PM emission savings over the lifetime of ROCKWOOL products for building insulation are calculated based on sales and application inputs. Calculations are carried out for two product applications (building envelope and flat roof) for both new constructions and building refurbishments. For most of the sales (>80%), the calculation is done by assessing input parameters on a country level. For the remaining countries with lower sales volumes, input values are based on regional estimates.

The calculation methodology and the input values are schematically depicted below. This methodology is used to calculate both the energy savings (in the form of space heat savings) and emission savings (CO_2, SO_2, NO_x, and PM).



* For new buildings: U-value of uninsulated building for new builds, For refurbishments: U-value of existing building before refurbishing

Rationale Behind Inputs

For each of the four application groups, several generic and specific assumptions are made (see the table below). 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.

Concerning insulation **lifetime (1)**, a 50-year lifespan is used. This is in line with the ROCKWOOL environmental product declaration (EPD) and the product category rules (PCRs) for thermal insulation products, which state that the thermal performance characteristics of thermal insulation products are usually based on a minimum of 50 years. In contrast, the Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB)[4] states 60 years for thermal insulation of the outer wall. Because this is an uncertain number, the most conservative value of 50 years is used instead of using either 60 years or an average of these numbers.

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).

For the heat generation efficiency (2a), assumptions from Guidehouse buildings experts are used based on available studies[5] and considering typical values of different heating systems. 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 efficiencies used in this methodology are:

- 70% for coal

[4] More information 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.

- 80% for biomass in EU and 75% for biomass in Asia, Russia and other regions
- 90% for oil
- 95% for gas
- 97% for district heating
- 100% direct electricity
- 350% for heat pump electricity

Input		Application			
		New Envelope	New Flat Roof	Refurbishment Envelope	Refurbishment Flat Roof
1. Insulation lifetime		50			
2. Emission factor of space heat in each country	2. Emission factor of space heat in each country	0.026-0.278 ($kgCO_2$/kWh of space heat) Depending on fuel mix			
	2a. Heat generation efficiency (%)	70% for coal, 80% for biomass EU and 75% for biomass in all other regions, 90% for oil, 95% for gas, 97% for district heating, 100% for electricity, 350 % heat pump electricity			
	2b. Fuel mix	Varying per country			
	2c. Emission factor per fuel type	Varying per type of emission (CO_2, SO_2, No_x, PM) and per country			
3. Amount of insulation used per category	3a. Overall sales (m³)	Confidential			
	3b. Sales share per application (%)	Confidential			
	3c. Sales share new / refurbishment (%)	Confidential			
	3d. Share of insulation used (%)	98%			
4. Insulation thickness	4a. λ value of insulation (W/mK)	0.034 - 0.042	0.038	0.034 - 0.042	0.038
	4b. U-value before insulation (W/m²K)	1.5	1.5	0.6 - 1.5	0.29 - 1.5
	4c. U-value after insulation (W/m²K)	0.15 - 0.7	0.11 - 0.45	0.15 - 0.7	0.11 - 0.45
5. ΔU		See U-value before and after above			
6. Heating degree days		460-5307			

**data sources are described in the text*

The fuel mix of each country where insulation is applied (2b) is based on different data sources. For European countries, the input is based on Eurostat.[6] For heat pump electricity additional studies for the European Commission have been used.[7] For North America, data from the US Energy Information Administration (EIA) is used for the US[8] and data from Natural Resources Canada (NRCan)[9] for Canada. For Russia, the IFC study *Energy Efficiency in Russia: Untapped Reserves*[10] is used, and for China, an expert judgement is made based on International Energy Agency (IEA)[11] data and previous Guidehouse studies.

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 based on the 2019 refinement to the 2006 Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National Greenhouse Gas Inventories* for coal, gas, and oil. The electricity emission factor is calculated per country based on IEA data[12]. The biomass emission factor is set at a conservative value of 0 to only include CO_2 emissions from fossil fuels. For district heating, the emission factor is calculated for the EU, Russia, China, and the US based on IEA data. For Denmark and Sweden, additional country-level data has been collected given the combination of a high share of district heating and substantial sales of ROCKWOOL building insulation material in these countries. For Denmark, this is based on Danish Energy Agency statistics and for Sweden, on the *Energy* journal article "District heating and cooling in Sweden."

For air emissions (SO_2, NO_x, and PM), the majority of emission factors are from the GEMIS[13] database. Where data is not available from GEMIS, or more specific data is available, alternative data sources were sought and are included in the model. For the USA electricity SO_2 and NO_x emission factors are taken from the U.S. Energy Information Administration's (EIA) 2018 Electricity Profile[14]. Where data is unavailable for a specific country, default emission factors based on the average European Union values from GEMIS are applied. For electricity and district heating emission factors have were calculated by applying a reduction factor reflecting the corresponding CO_2 reduction on country and energy carrier

[6] Eurostat 2018, Energy statistics in households by type of use (Name of electronic data collection: ENERGY_ESH_A).
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.
[7] Ecofys Study for the European Commission 2016: Ex-ante evaluation and assessment of policy options for the EPBD
Study for the European Commission 2019: Space and combination heaters. Task 2. Market analysis
[8] Energy Information Agency, RECS statistics 2018: https://www.eia.gov/consumption/residential/
[9] Natural Resources Canada, Energy use statistics 2018: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=HB&sector=res&juris=00&rn=1&page=0
[10] Retrieved from: http://www.ifc.org/wps/wcm/connect/de1e58804aababd79797d79e0dc67fc6/IFC+EE+in+Russia+Untapped+Potential.pdf?MOD=AJPERES
[11] More information can be retrieved from: https://www.iea.org/
[12] Retrieved from: https://www.iea.org/reports/global-energy-co2-status-report-2019/emissions
[13] GEMIS version 5.0 is available for download from: http://iinas.org/gemis-download.html
[14] U.S. Energy Information Administration, United States Electricity Profile 2018 retrieved from: https://www.eia.gov/electricity/state/unitedstates/

level. For biomass emission factors in all countries, data is sourced from a study of the German Umweltbundesamt (UBA)[15], using an average of combustion-only data for wood logs and pellets.

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 over new construction and building refurbishments (3c), and the share of insulation that is used in buildings (3d).

ROCKWOOL sales data (3a), broken down into application—building envelope and flat roof—(3b) are provided by ROCKWOOL and are not further validated by Guidehouse.

The breakdown of products into the market for new construction and building refurbishments (3c) is based on ROCKWOOL's country-level market share assessment.

To calculate the amount of insulation that is used (3d), a waste percentage of 2% is assumed. The Product Environmental Footprint Category Rules (PEFCR) for thermal insulation products and the French mineral wool association FILMM[16] use 2% as a default. PEFCR is part of the European Commission's Single Market for Green Products initiative.[17] This parameter is not critical, as even doubling the amount will only decrease the overall outcome by 2%.

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. This is not a sensitive assumption, as using 100% of either option would change the outcome by only approximately 1%.

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[18] 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.

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[19]; a published paper on energy saving potential of Moscow apartment buildings[20] and 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. For most European countries, the values are extracted from two different sources: The Heat Roadmap Europe 2050 developed by Fraunhofer ISI, TEP Energy GmbH, University Utrecht, and ARMINES and the 2018 concerted action Energy Performance Building Directive (EPBD) report outcomes.

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[15] Umweltbundesamt (2008), "Effiziente Bereitstellung aktueller Emissionsdaten für die Luftreinhaltung"
[16] More information can be retrieved from: https://www.filmm.org
[17] More information relating to the policy background can be found at: http://ec.europa.eu/environment/eussd/smgp/policy_footprint.htm.
[18] Made from solid brick with a density of 1800 kg/m^3
[19] Can be retrieved from: http://episcope.eu/building-typology/webtool/
[20] S. Paiho et al. (2014), Energy and Buildings, "Energy saving potentials of Moscow apartment buildings in residential districts"

In addition, for some countries, the local regulatory documents are used—e.g., the Bouwbesluit for the Netherlands, the National Energy Code of Canada, the thermal protection of building regulations of Russia. For Sweden and China, the Global Building Performance Network database is used. For building envelope in the US, requirement of climate zone 3 (warm-humid) has been applied to yield conservative outcomes.

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 amount of **heating degree days (6)** are obtained from different sources and where data is unavailable or has not been updated the data from 2016 has been used and extrapolated based on the TIMER model. TIMER is an energy-system simulation model that is part of the IMAGE 2 integrated assessment model. It describes long-term development pathways of the energy system in the broader context of impacts on climate change, air pollution and sustainable development. For European countries, values are a 5-year average of EUROSTAT data[21], where Norway is assumed to have the same amount of heating degree days as Sweden. For North America, the values are based on data from the Canadian government[22]. 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[23].

[21] Retrieved from: http://ec.europa.eu/eurostat/web/energy/data

[22] Government of Canada Open Data portal, retrieved from: http://open.canada.ca/data/en/dataset/fd8efb83-b73d-5442-ab60-7987c824f5fd

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