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Impact Assessment Methodology Münchener Hypothekenbank eG Green Building Portfolio

Rationale, Framework, Data, Analysis

Dr. Jens Teubler, Christian Buschbeck

on behalf of

MünchenerHyp

Wuppertal Institut

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The current method paper represents version 3.0 and refers directly to the MünchenerHyp Green Portfolio Impact Analysis #2024. It is expected that a further update of this methodology will be made available in 2026.

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Wuppertal Institut für Klima, Umwelt, Energie gGmbH
Döppersberg 19
42103 Wuppertal, Germany

www.wupperinst.org

Authors:

Dr.-Ing. Jens Teubler
jens.teubler@wupperinst.org

Christian Buschbeck
christian.buschbeck@wupperinst.org

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List of Abbreviations

COM	commercial (non-residential) buildings
DE	Germany
ES	Spain
FED	final energy demand
FR	France
GHG	greenhouse gas emissions
GWP	global warming potential
LU	Luxemburg
NL	Netherlands
PED	primary energy demand
PEF	primary energy factor
RES	residential buildings
UK	United Kingdom

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The paper at hand presents the principles and methods applied for the impact assessment of the green building portfolio by the mortgage bank (residential and commercial property financing) MünchenerHyp. For further information and the newest published impact report see https://www.mhb.de/de/unternehmen/nachhaltigkeit/esg-und-gruene-anleihen.

1 Rationale for Methodology

MünchenerHyp aims to quantify the potential positive climate effects from green buildings in their portfolio. Green buildings in this context are expected to have a lower energy demand for heating compared to similar buildings of the same type and in the same countries. The selection of eligible buildings is not part of the impact assessment and entirely in the hands of the mortgage bank (in line with their Green Bond Framework 2021 in MünchenerHyp (2022)). However, a second party opinion is available that corroborates the claim that these buildings fulfil the minimum energy standards and exceed them in most cases (ISS ESG, 2022).

The rationale of the impact assessment is that the financing and/or ownership of commercial and residential buildings with low energy demands avoid greenhouse gas emissions, that would otherwise have been emitted from conventional buildings in the overall stock used for the same purpose. Since other stakeholders are involved in this process (other shareholders, owners, rentals), we define this process as "financing potential greenhouse gas reductions". The functional unit is metric tons CO_2-equivalents (or CO2e) per building and share of financing (1% to 100%). As a normalized unit of comparison, tons CO_2-equivalents (or CO2e) per million € (EUR m) financed are calculated as well. The global warming potential refers to 100 years (GWP 100a) and is calculated with the help of characterization factors for Kyoto-Gases by the IPCC (AR5).

This rationale is in line with current market practices as suggested by the ICMA *Green Bond Principles* as well as *Harmonized Framework for Impact Reporting* (ICMA, 2024). This handbook suggests the two core indicators "Annual Energy Savings" and "Annual GHG emissions reduced/avoided". Both the required GHG accounting methodology and the required definition of benchmark, base-line or reference system are described in the paper at hand.

The core rationale of GHG savings in the MHyp green building portfolio can be operationalized as follows:

- Premise 1: "Green Buildings" have a lower energy demand than buildings in stock in a given country.
- Premise 2: Each unit of saved energy that is provided with the help of fossil fuels thus "saves" GHG emissions compared to a case in which the same building would have been as efficient as an average, but similar, building in stock.
- Premise 3: Each loan or mortgage in the green building portfolio either represents a modernisation, a new construction or a change in ownership (purchasing).
- Conclusion 1: For buildings that are modernized in regard to their energy demand ("becoming green buildings"), these GHG savings are *actualized* as absolute "reduced" emissions in a given country.
- Conclusion 2: For newly constructed green buildings, these GHG savings constitute "avoided" emissions compared to a case in which an average, but similar, building was added to the building stock[1].
- Conclusion 3: For green buildings that are purchased, these GHG savings constitute "avoided" emissions compared to a case in which an average, but similar, building was added to the issuer's portfolio.
- Conclusion 4: In cases in which a single building in the portfolio exceeds the expected GHG emissions of an average, but similar, building in stock (violating P1 and P2), the indicator of reduced/avoided emissions takes on a negative value (thus reducing the overall GHG savings of buildings in the impact report).

2 Framework

The input data from the issuer contains information on the type of buildings and in some cases also the purpose of buildings. The original impact assessments thus classified the results according to these building types (e.g., office and storage buildings, or single-family and multi-family homes). The most recent version of our methodology (2.0) changed that by focusing on so-called data-classes instead. The idea behind is that the reader (e.g. an investor) gets a sense of the reliability of the results in each category based on the details of data available in each category.

This is achieved by assigning each case (buildings in the portfolio) to 1 out of 4 classes for the quality of data and the resulting calculation:

- Type A: high data quality
- Type B: medium data quality
- Type C: low data quality
- Type D: no data (estimates)

The next section describes how these data cluster are assigned to the two main asset classes (1) commercial buildings (COM) and (2) residential buildings (RES) and how

[1] It should be noted that other methodologies (including an approach of the authors in another project), treat newly constructed sometimes differently. A common alternative is to consider the minimum building standard in a country as the baseline, rather than the average energy demand of a building type in a given construction period as defined here.

the current methodology (3.0) differs from the attribution in the last method paper (2.0).

The following sections then describe further changes to the methodology and then lay out the calculation rules for each data class in both asset classes.

2.1 Method Update of the Matrix for Data Quality

The following table summarizes the input data availability for the four data classes for both commercial (COM) and residential (RES) buildings in the portfolio.

The current dataset for residential buildings can be distinguished from the previous data set in the following manner:

- There is now information on the energy-performance rating (EPC class) of a portion of the buildings.
- In cases for which this energy-performance is known, there is information on both the primary energy requirement and final energy demand as well as (in almost all cases) information on the energy carrier or energy supply (e.g. district heating) used to provide heat in the building.

Since this information allows to calculate more accurate GHG savings against the reference stock of buildings, we decided to change the definition of data classes. The best case, or data class A for high-quality data, is now defined by information on both the specific energy demand and the energy carrier for heating. Accordingly, the previous class A data is now considered data class B, which means it is mostly described by the availability of the primary energy requirement of the buildings. Accordingly, former data class B now becomes C, and C becomes D. This corresponds to the data available, since there are no longer buildings in the data set for which the building space is unknown (previous definition of data class D).

These changes are depicted in Table 2-1, which now also better aligns the already very similar approach for COM buildings with the update to RES data classes.

Table 2-1: data criteria for selection of data class and description of data class update for RES

Type	**A:** **high data quality**	**B:** **medium data quality**	**C:** **low data quality**	**D:** **very low data quality**
COM, (3.0)	financing data | final energy demand | building type | net conditioned area* | energy carrier	financing data | primary energy demand | building type | net conditioned area | energy carrier	financing data | primary energy demand*| building type | net conditioned area |	financing data | net conditioned area | building type
COM, old (2.0)	*financing data | final energy demand | building type | net conditioned area | energy carrier*	*financing data | primary energy demand | building type | net conditioned area | energy carrier*	*financing data | net conditioned area | energy carrier*	*financing data | net conditioned area*

<table>
<tr><th>Type</th><th>A:
high data quality</th><th>B:
medium data quality</th><th>C:
low data quality</th><th>D:
very low data quality</th></tr>
<tr><td>RES,
new
(3.0)</td><td>financing data |
final energy demand**
AND fed < ped* |
year of construction |
building type |
living space |
energy carrier*</td><td>financing data |
primary energy demand
|
year of construction
building type
living space</td><td>financing data |
year of construction |
building type |
living space</td><td>financing data |
building type |
living space missing OR below 10 m²</td></tr>
<tr><td>RES,
old
(2.0)</td><td>financing data |
primary energy demand|
year of construction |
building type |
living space</td><td>financing data |
year of construction |
building type |
living space |</td><td>financing data |
building type |
living space</td><td>financing data |
building type</td></tr>
<tr><td colspan="5">* most buildings in the data set are reported as 'living space' but there are a few cases in which this data entry is empty but the 'net conditioned area' is given instead
** new / updated data availability criteria</td></tr>
</table>

Source: own compilation

2.2 Method Update of the conditions for data removal

The small sample of COM buildings allows for a data analysis on a case-by-case basis. This means that only cases in which either the financing data or the building area was not available are excluded from the assessment, as the small sample size also entails that a sample approach to derive an average size to cost ratio is not feasible. However, one building was also removed from the dataset after a second assessment of its eligibility for the green building portfolio by the issuer.

The larger sample of RES buildings on the other hand, does allow for a sample approach to derive the size to cost ratio on average. However, there are a number of buildings for which either the financing data or the building area seem to be a data entry artefact. We thus exclude all cases in which values for the loan volume are lower than 1,000 EUR and all cases in which there is a value for the building size but it is lower than 10m².

Out of a total of 190 buildings in COM, 16 buildings were not assessed and 1 building removed from the dataset. Out of a total of 42,986 buildings in RES, 22 buildings were not assessed.

2.3 Method Update of the assignment of energy-carriers

The dataset by the issuer now includes input data on the type of energy carriers used for some of the RES buildings (this information was already included in previous emissions for COM buildings). This information indicates, limited to Data Class A assets, what type of energy carrier is used to heat each building (including warm water).

There are three options regarding the energy carrier used for energy demand:

- no indication of any of the options

- indication of one particular energy carrier
- indication of more than one energy carrier

However, there is no information regarding the share of different energy carriers in cases for which more than one option is indicated. Our methodology reflects this by introducing a prioritization criterion that results in the selection of one energy carrier in each case.

To achieve this purposes, we first match all options to a set of super-categories that can be represented by average or typical metrics for the primary energy factor (used to compare actual buildings in the portfolio to the reference stock of buildings) and greenhouse gas (GHG) emission intensity in kg CO2e per kWh and m^2. This matching is shown in the following Table 2-2.

After a first test-run, two additional cases had to be distinguished.

The selection of local & district heating can entail both a typical district heating source (represented by an average production of co-produced heat from fossil and renewable sources) and a purely renewable choice. The latter would also logically entail that the primary energy demand of the buildings is lower than its final energy demand (since the primary energy demand from e.g. sun, wind or biomass is usually not accounted for). This can only be tested for category A buildings, which by definition, have information on both energy metrics.

The second problem arises from the selection of the category of environmental energy, since this can entail a whole range of heating options. However, almost all options require auxiliary electricity from a heat pump, which in most cases, would be at least partially provided by installed photovoltaics. Since this information is not available, we opt to use GHG intensities derived from primary energy provision in Germany rather than selecting the average electricity mix in Germany if the final energy demand is known. These intensities are regularly updated for Germany (Lauf et al., 2023a) for different types of heat pumps, with the electric air-water heat pump having the highest electricity demand.

Table 2-2: matching of energy carrier categories in input data to calculation categories

Input Category NRW.BANK (German)	Input Category NRW.BANK (translation)	Calculation Category for GHG effects
Braunkohle	lignite	coal
Steinkohle	anthrazite	
Koks	coke	
Stadtgas	coal gas	
Erdgas H	natural gas, high caloric	gas
Erdgas L	natural gas, low caloric	
Flüssiggas	liquid gas	
Heizöl, leicht	light heating oil	oil
Heizöl, schwer	heavy fuel oil	
Holz	wood	wood
Holzhackschnitzel	wood chips	
Holzpellets	wood pellets	
Nah-/Fernwärme	local heat & district heat	PED < FED: remote biogas
		Other: average district heating mix
Umweltenergie	environmental energy	ped-air-water-pump*
Strom	electricity	electricity
Sonstiges	other	*standard reference mix*

* Several distinct options can lead to the selection of 'environmental energy' in the data set by the issuer. These vary in regard to the GHG intensity of energy provision (e.g. emission-free solar thermal energy versus water-air-heat pumps with electricity demand). We decided to opt for the most likely option here, which refers to the typical primary energy demand for a water-air heat pump on average in Germany.

Source: own development

The second step is to decide which energy carrier is selected for calculation if there are multiple choices (e.g. a building heated by both light heating oil and environmental energy). This selection process is guided by two conventions:

- Convention 1: if electricity (input data indication) and some other energy carrier is indicated, it is assumed that the first is merely used to heat water
- Convention 2: if two or more energy carriers are indicated that are not labelled as electricity, the energy carrier with the higher GHG intensity is selected (with heat pumps considered to be fueled with electricity but in an energy-efficient manner)

Convention 1 is met for pragmatic reasons by assuming that it conforms to reality in almost all cases. Convention 2 on the other hand is a conservative assumptions which ensures that potential GHG savings (the result of the calculations) are not overestimated.

The matching from step 1 and the conventions from step 2 are then used to set-up the following prioritization rules in Table 2-3.

Table 2-3: prioritization rules for energy carrier selection

Case	Rule
No energy carrier is indicated in the input data.	We select the "standard reference mix" for energy carriers for heating in Germany (in accordance with previous impact reports).
Only one particular energy carrier is indicated OR at least two energy carriers are indicated belonging to the same super-category OR one particular energy carrier is indicated as well as electricity or "other".	We select the energy carrier matching in our matching table that is not electricity or indicated as "other" (e.g. light heating oil -> "oil").
More than one energy carrier is selected.	We select the energy carrier with the highest GHG emissions in the following order: coal >> oil >> gas >> district heating >> heat pump >> wood.

Source: own compilation

2.4 Calculation for Commercial buildings (COM)

There are 189 contracts in the commercial portfolio that refer to 173 assessable buildings (portfolio until June 2024). These buildings are large and mainly used as offices for rentals. Some of the buildings are also either fully used as storage facilities or consist of large areas that are not heated. The buildings are located in Germany (DE), United Kingdom (GB), Netherlands (NL), Spain (ES), France (FR), Austria (AT), Luxemburg (LU), and the United States (US).

The calculation method for potentially avoided GHG emissions draws on the difference for the energy demand of the building in the portfolio compared to similar buildings in the European, UK and US building stock of office buildings.

If all the relevant data is available, the following equation (A_{COM}) is used for Type A buildings (99 buildings):

$$GHG_{avoid,COM-A} = (fed_{ref,c} - fed_{case,b})\ x\ ghg_{carrier}\ x\ area_{net-cond}\ [kg\ CO_2 - equ./\ building\ p.a.] \quad (A_{COM})$$

with

$GHG_{avoid,\ COM-A}$:	potentially avoided GHG emissions for type A data in [kg CO2e]
$fed_{ref,c}$:	total final energy demand for heating of non-residential buildings in stock in country [kWh]
$fed_{case,c}$:	specific total final energy demand of building in case [kWh/m^2]
$area_{net-cond}$:	net-conditioned area of the building in [m^2]
$ghg_{carrier}$:	GHG intensity of the energy carrier (heat) in [kg CO2e/kWh]

We use data from the EU Building Stock Observatory for buildings in EU countries (European Commission, 2023), data from Non-domestic National Energy Efficiency Data-Framework for buildings in the UK (Department for Business, Energy & Industrial Strategy, 2022) as well as data from the Commercial Buildings Energy Consumption Survey for buildings in the US (U.S. Energy Information Administration, 2018) to derive the average total final energy demand of non-residential buildings in stock ($fed_{ref,c}$).

It is also assumed that primary data on the primary energy demand of the buildings lead to similarly robust results, although additional data is necessary to convert primary energy demand in a country into the final energy demand for the building user. For this purpose, so-called primary-energy-factors or PEFs are used, which describe the ratio of energy conversion between primary energy used by a certain carrier to provide the final energy demand in a system (here buildings).

Equation B_{COM} is therefore considered to deliver robust results for Type B data in the following manner (12 buildings in the dataset).

$$GHG_{avoid,COM-B} = \left(fed_{ref,c} - \frac{ped_{case,b}}{PEF_{carrier}}\right) x\ ghg_{carrier}\ x\ area_{net-cond}\ [kg\ CO_2 - equ./\ building\ p.a.]\ (B_{COM})$$

with

$GHG_{avoid,\ COM\text{-}B}$:	potentially avoided GHG emissions for type A data in [kg CO2e]
$fed_{ref,c}$:	specific final energy demand for heating of non-residential buildings in stock in country [kWh]
$ped_{case,c}$:	specific primary energy demand of building in case [kWh/m²]
$area_{net\text{-}cond}$:	net-conditioned area of the building in [m²]
$ghg_{carrier}$:	GHG intensity of the energy carrier (heat) in [kg CO2e/kWh]
$PEF_{carrier}$:	primary energy factor for energy carrier in [kWh/kWh]

For buildings of type C, only data on the conditioned area and the primary energy demand is available, but the heating system is considered to be the "standard mix". Accordingly, the equation for C buildings (14 in the dataset) is very similar to B buildings but relies on an average GHG intensity factor as well as a plausible primary energy factor (we assumed a PEF of 1.1 from gas as main energy carrier):

$$GHG_{avoid,COM-C} = \left(fed_{ref,c} - \frac{ped_{case,b}}{PEF_{gas}}\right) x\ ghg_{standard}\ x\ area_{net-cond}\ [kg\ CO_2 - equ./\ building\ p.a.]\ (C_{COM})$$

with

$GHG_{avoid,\ COM\text{-}C}$:	potentially avoided GHG emissions for type A data in [kg CO2e]
$fed_{ref,c}$:	specific final energy demand for heating of non-residential buildings in stock in country [kWh]
$ped_{case,c}$:	specific primary energy demand of building in case [kWh/m²]
$area_{net\text{-}cond}$:	net-conditioned area of the building in [m²]
$ghg_{standard}$:	average GHG intensity for heat provision in [kg CO2e/kWh]
PEF_{gas}:	primary energy factor for gas in [kWh/kWh]

The remaining cases in the dataset refer to buildings without information on the energy demand. We assume that these buildings of data quality D (48 buildings in the dataset) achieve at least a light renovation standard which corresponds to a primary energy demand saving of 16% compared to the building stock (European Commission et al., 2019, p. 24):

$$GHG_{avoid,COM-D} = (fed_{ref,c}\ x\ 0.16\ x\ ghg_{standard}\ x\ area_{net-cond}\ [kg\ CO_2 - equ./\ building\ p.a.]\ (D_{COM})$$

with

$GHG_{avoid,\ COM\text{-}C}$:	potentially avoided GHG emissions for type C data in [kg CO2e]
$fed_{ref,c}$:	specific final energy demand for heating of non-residential buildings in stock in country [kWh]
$ghg_{standard}$:	average GHG intensity for heat provision in [kg CO2e/kWh]
$area_{net\text{-}cond}$:	net-conditioned area of the building in [m²]

2.5 Calculation for Residential Buildings (RES)

There are 31,021 buildings in the input data, of which 30,997 buildings could be assessed (24 buildings were removed due to implausible or missing data). They are grouped into the categories single-family house (SFH), multi-family house (MFH) and terrace house (TH). No building in the dataset is supposed to have a higher primary energy demand than 70 kWh/a as defined by the issuer's framework or 55 kWh/a if the building was financed after the 1st of May 2020.

For buildings of type A (456 buildings), the financing data, final demand, living space, building type, energy carrier and year of construction are known. The following equation (A_{RES}) is considered to deliver the most robust result for impact reporting (updated in the current version of 3.0 compared to method paper 2.0):

$$GHG_{avoid,RES-A} = (\text{fed}_{ref,b} * ghg_{standard}) - (\text{fed}_{case,b} * \text{ghg}_{case}) * A\ [kgCO_2 - equ./\ building] \quad (A_{RES})$$

with

$GHG_{avoid,RES-A}$: potentially avoided GHG emissions for type A data in [kg CO2e]

$fed_{case,b}$: specific final energy demand of building in case [kWh/m²a]

fed_{ref}: specific final energy demand of buildings of the same type in stock at year of construction [kWh/m²a]

$ghg_{standard}$: GHG intensity of standard mix for heating in residential buildings in Germany in [kg CO2e/kWh]

ghg_{case}: GHG intensity of selected energy carrier for heating of building in case [kg CO2e/kWh]

A: living space as conditioned area in [m²]

For buildings of type B (11,168 buildings), only the primary energy demand is known or the final energy demand is known but it is higher than the primary energy demand. In this case, the standard mix for heating of residential buildings in Germany is attributed to the primary energy saving[2] of the building in question compared to a building in stock in the same construction period. This constitutes the second-best robustness for the results:

$$GHG_{avoid,RES-B} = (\text{ped}_{ref} - \text{ped}_{case,b}) * ghg_{standard} * A\ [kgCO_2 - equ./\ building] \quad (B_{RES})$$

with

$GHG_{avoid,RES-B}$: potentially avoided GHG emissions for type B data in [kg CO2e]

$ped_{case,b}$: specific primary energy demand of building in case [kWh/m²a]

ped_{ref}: specific primary energy demand of buildings of the same type in stock at year of construction [kWh/m²a]

$ghg_{standard}$: GHG intensity of standard mix for heating in residential buildings in Germany in [kg CO2e/kWh]

A: living space as conditioned area in [m²]

For buildings of type C (19,372 buildings), the financing data, the living space, the building type and year of construction are known. Since we do not have information on the actual primary energy demand of these buildings, we use the eligibility criteria of the issuer instead. This means that each building in this sample has a maximum primary energy demand ($ped_{70/55}$) of either 70 or 55 kWh/(m^2a) depending on the year the building was initially financed (with the lower value for buildings financed after 1st of May 2020).

[2] Earlier versions of the methodology additionally calculated the difference in final energy demand on the basis of a so-called primary energy factor (PEF) for all data class types. Although this should, in theory, increase the accuracy of the results (reflecting the building specific energy difference without system-wide energy utility parameters), it also led to additional sources for errors, since this approach requires assumptions on the unknown conversion of primary to final energy in each building.

$$GHG_{avoid,RES-B} = (\text{ped}_{ref} - \text{ped}_{70/55}) * ghg_{standard} * A\ [kgCO_2 - equ./\ building]\ (C_{RES})$$

with

$GHG_{avoid,RES-C}$: potentially avoided GHG emissions for type C data in [kg CO2e]

$Ped_{70/55}$: maximum specific primary energy demand of buildings in portfolio according to issuer in [kWh/m²]

ped_{ref}: specific primary energy demand of buildings of the same type in stock at year of construction [kWh/m²a]

$ghg_{standard}$: GHG intensity of standard mix for heating in residential buildings in Germany in [kg CO2e/kWh]

A: living space as conditioned area in [m²]

Data for buildings of type D (1 building), in addition to the restrictions of type C buildings, also lacks information on the living space of the buildings. As this data is available for all other buildings, a cost factor is calculated the allows to estimate the living space. It is drawn from the 3rd quartile of the total costs[3] per square-metre (or 1st quartile of square-metre per costs) of all other buildings in the sample in order to ensure a conservative estimate for the resulting avoided GHG emissions in equation D_{RES}.

$$GHG_{avoid,RES-B} = (\text{ped}_{ref} - \text{ped}_{70/55}) * ghg_{standard} * F * liv_{sample}\ [kgCO_2 - equ./\ building]\ (D_{RES})$$

with

$GHG_{avoid,RES-D}$: potentially avoided GHG emissions for type D data in [kg CO2e]

$Ped_{70/55}$: maximum specific primary energy demand of buildings in portfolio according to issuer in [kWh/m²]

ped_{ref}: specific primary energy demand of buildings of the same type in stock at year of construction [kWh/m²a]

$ghg_{standard}$: GHG intensity of standard mix for heating in residential buildings in Germany in [kg CO2e/kWh

F: total costs of building in [EUR]

liv_{sample}: financed living space per total costs, 1st quartile of sample in [m²/EUR]

All equations have been integrated into a calculation script that can be found in the

Appendix to this report.

[3] The loan volume and share of financing is known in each case, such that the total costs can be derived even if the market value is not known.

3 Data and Assumptions

3.1 Data and assumptions for commercial building portfolio

The following table summarizes the data sources and assumptions for the calculation of commercial (COM) buildings in the portfolio.

Table 3-1: data and assumptions for impact assessment of non-residential buildings (COM)

Data	Sources	Assumptions
primary data on buildings	direct input data and additional building information (e.g., certificates) by client	COM 1) If specific energy demands or information on heating systems is only available for parts of a building complex, the entire complex is assumed to have this energy demand COM 2) If several heating systems are mentioned, a main heating system is selected according to the prioritization rules described in section 2.3
building stock data	EU Building Stock Observatory for EU countries (European Commission, 2023) Non-domestic National Energy Efficiency Data Framework for UK (Department for Business, Energy & Industrial Strategy, 2022) Energy Information Administration (EIA)-Commercial Buildings Energy Consumption Survey (CBECS) Data for US (U.S. Energy Information Administration, 2018)	COM 3) European and UK data refers to all non-residential building types COM 4) US data refers to office as well as retail buildings
primary energy saving from renovation	average of renovation activities in European non-residential buildings (European Commission et al., 2019, p. 24)	COM 5) Class D buildings are assumed to have undergone a light-renovation (16% PED saving)
primary energy factors	gas, heating oil, district heating, electricity default values according to the 2012 concerted action report (CEN) cited in Hitchin et al. (2018, p. 3) renewables defined to have a PEF of 1 in line with a review of the default primary energy factor (Esser et al., 2016)	COM 6) renewables have a PEF of 1
GHG intensity factors	GHG intensity of district heating refers to oekobau.dat data for Germany cited in the DGNB framework for climate-neutral buildings and locations (DGNB, 2020, p. 61) GHG intensities of gas, oil, coal, biomass and wood are derived from the Joint Research Centre (JRC et al., 2024) The GHG intensity for heat-pumps is based on data by the Federal German Environmental Agency UBA (Lauf et al., 2023b)	COM 7) German district heating value (120-400 kW, conventional as well as renewable) is used for other countries as well

Data	Sources	Assumptions
	The GHG intensities for electricity in a given country are derived from the IFI Dataset of Default Grid Factors v.3.1 (IFI, 2022)	

Source: own compilation

3.2 Data and assumptions for residential building portfolio

The following table summarizes the data sources and assumptions for the calculation of retail buildings (RES) in the portfolio.

Table 3-2: data and assumptions for impact assessment of residential buildings (RES)

Data	Sources	Assumptions
primary data on buildings	direct input data and additional building information by client	RES 1) If several heating systems are mentioned, a main heating system is selected according to the prioritization rules described in section 2.3 | if no heating system can be derived or not information is available, the standard heating mix for Germany is selected RES 2) Primary energy demand at least 70 kWh/a until April 2020 and at least 55 kWh/a from May 2020 onward (defined by issuer)
building stock data	TABULA WebTool (IWU- Institut Wohnen und Umwelt, Darmstadt / Germany, 2012)	RES 3) Building stock are represented by "existing state" in TABULA building typology RES 4) Difference in primary energy demand of two buildings equals difference in final energy demand of two buildings
primary energy factors	GEG Regulation, Annex 4 (Gesetz zur Einsparung von Energie und zur Nutzung erneuerbarer Energien zur Wärme- und Kälteerzeugung in Gebäuden* (Gebäudeenergiegesetz - GEG), 2020)	RES 5) The standard mix has a PEF of 1.1 (representing oil/gas)
GHG intensity factors	GHG intensity of district heating refers to oekobau.dat data for Germany cited in the DGNB framework for climate-neutral buildings and locations (DGNB, 2020, p. 61) GHG intensities of electricity, gas, oil, coal, biomass and wood are derived from the Joint Research Centre (JRC et al., 2024) The GHG intensity for heat-pumps is based on data by the Federal German Environmental Agency UBA (Lauf et al., 2023b)	-
building area	Data on the conditioned size is drawn from the data provided by the client	RES 6) We assume that the 1st Quartile of building size over building costs in the sample

Data	Sources	Assumptions
	In cases, in which this data is not available, the average ratio of size over building costs is derived directly from the sample	represents a conservative estimate for the proxy value.

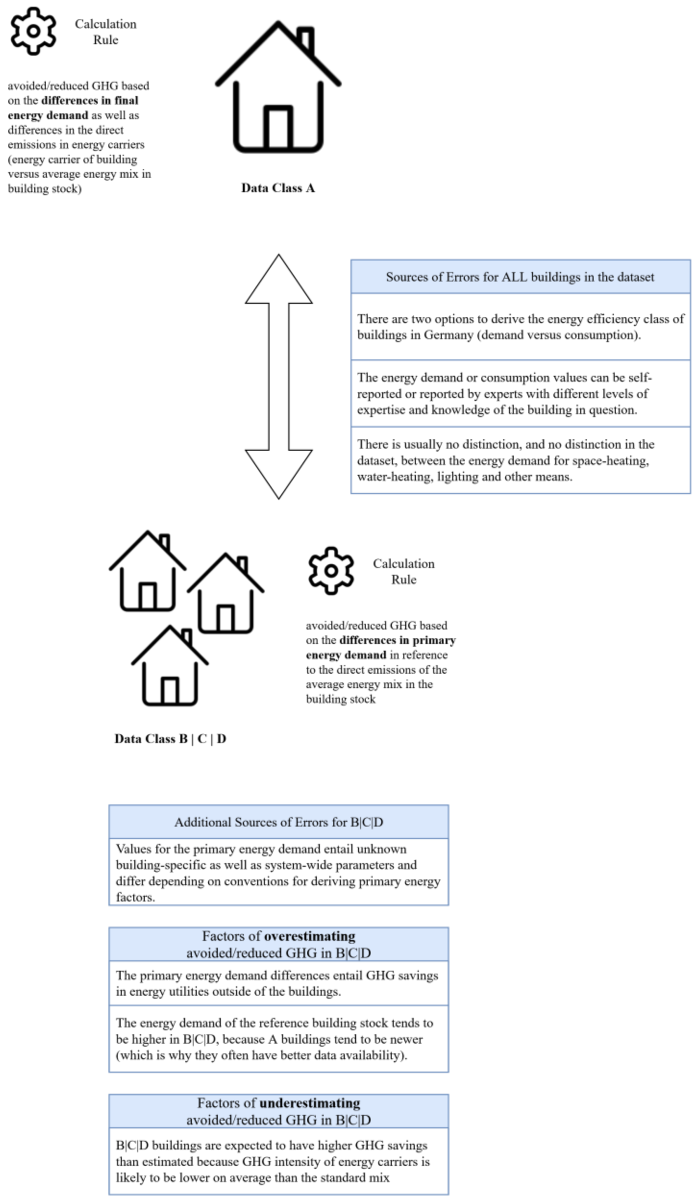
Source: own compilation

3.3 Limitations of the methodology

The methodology prioritizes accuracy over consistency. This means that the result of the impact assessment for each case (one building in the dataset) relies on the available data and thus on a calculation rule that is determined by the data quality that is assigned according to this data availability.

This, in turn, influences whether the results in each data quality category are under- or overestimated compared to the results in each other data quality category. The following Figure 3-1 depicts this on the example of data A buildings in the RES dataset compared to data B buildings (and in fact also data C as well as data D buildings). It also briefly introduces the sources of errors that all buildings in the sample suffer from. These errors are either caused by the way in which Energy Performance Certificate values are reported in Germany or by the way in which the datasets does not allow for a distinction between energy use for space-heating compared to any other type of energy use in the buildings.

Figure 3-1: sources for errors in GHG emission savings of type B|C|D versus type A buildings



Source: own compilation

All data, assumptions and calculations shown here are, nonetheless, suitable to estimate conservative estimates for the avoided GHG emission potentials. The energy savings in the actual buildings compared to buildings in stock are often expected to be larger than shown here and in the impact assessment. It is also likely that many of the residential buildings achieve their low primary energy demands with the help of heating systems other than gas and oil. In these cases, an additional GHG saving effect would have to be considered that is caused by the difference in GHG intensities of the energy carriers (e.g., biomass versus gas).

In terms of overall accuracy, the lack of data for electricity use leads to less accurate results. This affects the primary energy demand of the buildings, as the share of heat and electricity use might differ strongly compared to the building stock. Commercial buildings in particular are also expected to be more electricity-efficient than their counterparts in the building stock, while many residential buildings are equipped with photovoltaic panels for their own electricity production (at less than 50 g CO_2-equivalents per kWh).

Moreover, that stock approach can – and has indeed – led to increased GHG emissions for some buildings in the sample. This is the case when the actual energy demand of a building exceeds the expected energy demand of similar buildings in stock. These values have been included in the calculation and thus led to lower GHG savings overall than a sub-sample of buildings for which only savings are considered.

3.4 Reference data for comparison with literature

The quantification method results in a number of specific characteristics of both building samples. The specific final heat demand (fed) for COM and the specific primary energy demand (fed|ped) for RES buildings are documented here (see following table). These values can be compared to literature to evaluate the energy efficiency of the buildings in the portfolio.

Table 3-3: average specific energy demand of COM and RES buildings in the current sample

Data type	**specific energy demand, COM**	**specific energy demand, RES**
A	fed: 98 kWh/m²a	fed: 27 kWh/m²a
B	fed: 122 kWh/m²a	ped: 31 kWh/m²a
C	fed: 113 kWh/m²a	ped: 63 kWh/m²a
D	fed: 150 kWh/m²a	ped: 70 kWh/m²a
weighted Average	fed: 129 kWh/m²a	not applicable

Source: own compilation

4 Analysis

Previous impact reports utilized 'what-if' questions to show the impact of the methodology, and in particular the influence of the data classification, on the results. This was a feasible approach due to the nature of data-processing. However, with an increasing number of buildings in the residential data set, automatic data-filtering and -processing via a R-script was not only feasible, but necessary to calculate the results. This enables us to look at the results in a more traditional, descriptive statistical, manner.

The following sections analyse the results in the residential data in the current report under this perspective. The reason why we limit this analysis to the residential data set is, again, data availability and sample size. While we can derive meaningful insights from looking at 'habitable' buildings in a sample of more than 30,000 buildings in Germany, the same does not apply to a much smaller sample (189 assessed buildings) of non-residential buildings in 8 different countries (with the USA as one country outside of Europe with distinctly different climate zones within its borders). Moreover, these non-residential buildings are a lot larger in size and are put to different purposes (e.g. office space versus storage space). This means that a few 'outliers' can have a large influence on the overall results and average values, although calculated, do not provide the same type of 'meaningful' insights here. Even a comparison between the commercial (non-residential) dataset in the current report versus the dataset in the previous report, will likely not help with this endeavour, because most of the buildings in the current assessment were already assessed in the previous one.

4.1 Influence of the changes in data classification for residential buildings

The following Table 4-1 compares the current results (also shown in the impact report) with the results, if we had continued to use the previous methodology and database. There are three main differences: (i) slight changes in the reference values of buildings in stock (after an update of the TABULA database), (ii) slight changes in the rules for excluding single loans from the assessment, and (iii) a new data class A that considers specific energy carriers of buildings as well as their final energy demand. We can thus focus our attention on data class A buildings in the old methodology compared to the sum of data A and data B buildings in the new methodology.

We find that

- there is a minor difference in the loan volumes (explained by changes in the rules for exclusion),
- financed emissions with the new method are higher than financed emissions with the old method (despite a smaller loan volume and despite lower energy demand of buildings in stock),
- and consequently, that the so-called investment efficiency is higher with the new method (both for the smaller set of higher data classes and the total data set).

We can thus conclude that the new method provides results in favour of the issuer (higher potential GHG savings). Moreover, we find that this is warranted, since the new method requires more, and more detailed data and uses the newest available dataset for buildings in stock. We can further predict that either the final energy demand or the use of specific energy carriers for data type A buildings or both are responsible for the slightly higher GHG savings.

Table 4-1: comparison of results with previous compared to current methodology

Metric for comparison	New Method	Old Method	Matching
Loan Volume from buildings with PED values	3,179 mEUR	3,182 mEUR	Data Class A&B in new method vs A in old method
Financed GHG emission savings from buildings with PED values	14.5 kt CO2e/a	13.5 kt CO2e/a	
Investment Efficiency from buildings with PED values	4.56 t/(mEUR*a)	4.35 t/(mEUR*a)	
Loan Volume	7,499 mEUR	7,506 mEUR	totals
Total financed GHG emission savings	26.7 kt CO2e/a	25.1 kt CO2e/a	
Total Investment Efficiency	3.6 t/(mEUR*a)	3.3 t/(mEUR*a)	

Source: own compilation

4.2 Comparisons between type A and type B residential buildings

Our main metrics of comparison between data categories are 'building efficiency' (specific energy demand), 'impact efficiency' (heat saving per building) and 'investment efficiency' (financed GHG savings per loan volume). All three are influenced by a number of factors, such as the ratio of living space over market value and the energy performance of buildings, which in turn, depend on further metrics such as the construction year or type of building. Given our methodology, only data class A does not rely on additional 'relevant' assumptions here, whereas data class B only relies on the additional 'relevant' assumption of an average energy mix for heating that can be controlled for.

This means that an analysis should be restricted to these two data classes in light of the differences in these three metrics, which are listed in the following Table 4-2.

Table 4-2: metrics for analysis of residential dataset

Data type	**no of buildings [1]**	**building efficiency [kWh/(m²*a)]**	**impact efficiency [kWh/(m²*a)]**	**investment efficiency [t CO2e/EURm]**
A	456	fed: 26.8	51.6	2.1
B	11,168	ped: 31.1	70.3	4.7
A+B+C+D	total:	not applicable	average: 49	average: 3.6

Source: own compilation

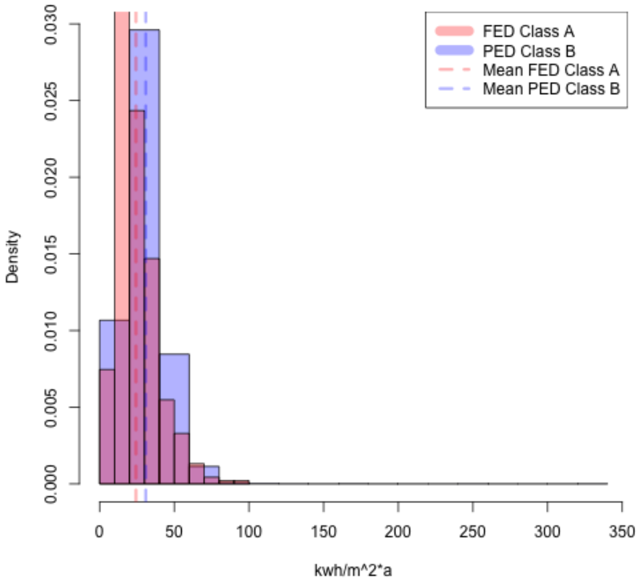
Looking at these metrics as well as the methodological framework, we can establish the following facts:

1 | The sample of data A buildings is a lot smaller than the sample of data B buildings (by a factor of 24).
2 | Type A buildings come with information on the specific energy carrier, which might or might not be associated with higher or lower GHG emissions per area compared to type B buildings.
3 | Although the type A buildings are slightly better performing in regard to their energy performance, this comparison is flawed because the one refers to final (A) and the other to the primary energy demand (B).
4 | The overall energy savings on the level of buildings are larger in type B than type A (circa 36% higher), which is likely influenced by the difference between the energy performance of the building and the average demand of the referenced building stock.
5 | The investment efficiency for type B buildings is a lot higher than for type A buildings (factor 2.2), which is likely influenced by the market value of these buildings.

At first glance, it thus seems to support the hypothesis that type A buildings (H_1) have a similar energy performance, (H_2) are compared to a stock of buildings with lower energy demand (reducing the effect of saved GHG emissions lineated in chapter 1), and (H_3) have a higher market value per area. Additionally, we can test whether fact (2) (specific versus generic energy provision) has influenced the results as well (H_4) to the detriment of GHG savings for type A buildings.

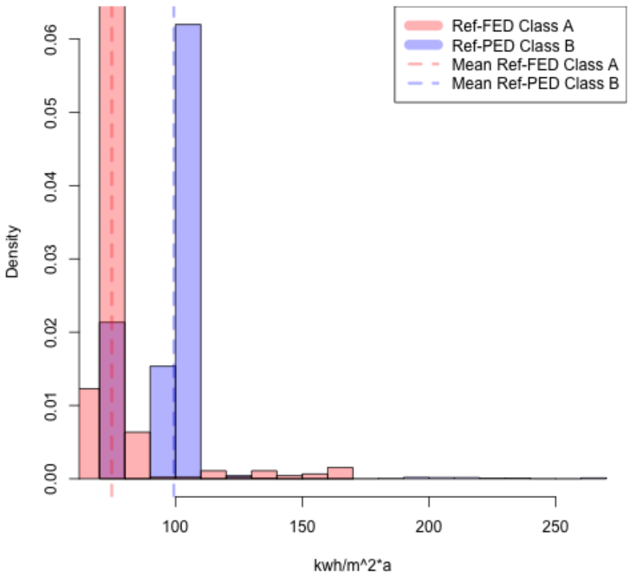
The following Figure 4-1 depicts the energy performance (building efficiency) of type A and type B buildings (H_1), and Figure 4-2 the referenced energy demand of buildings in stock that these buildings are compared to (H_2). The first figure clearly shows that there is a very similar distribution of energy demand, with type B buildings lightly skewed to the right compared to type A buildings. The average energy demand of both classes is very similar as a result. The second figure than shows that reference buildings for type A are more broadly distributed than their counterpart for type B, but that the majority of these referenced datapoints exhibit a lot lower energy demand (with type B buildings averaging around 100 kWh/(m^2*a) versus less than 50 kWh/(m^2*a) for type A buildings). This lends credence to the hypothesis that type A buildings perform weaker than type B buildings because, among possibly other reasons, their slightly lower energy performance does not compensate for the already better performing set of reference buildings in stock.

Figure 4-1: histogram of specific energy demand of type A and type B buildings



Source: own compilation

Figure 4-2: histogram of referenced energy demand of buildings in stock for A and B

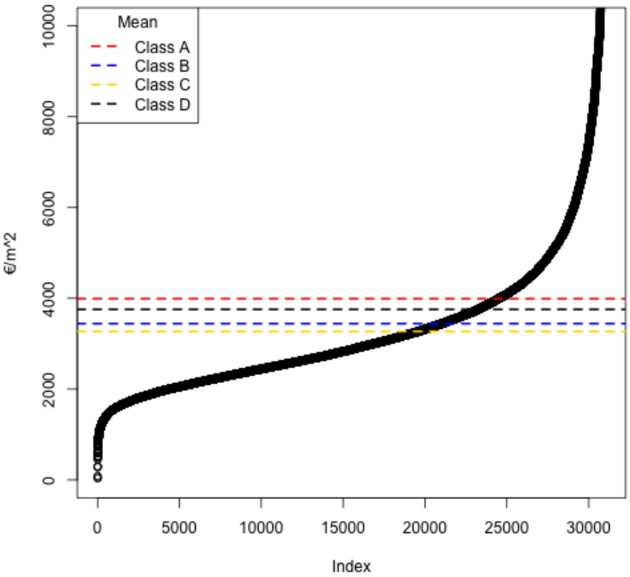


Source: own compilation

As to the question of building costs (H_3), the following Figure 4-3 depicts the prices of the buildings in the data set (derived from the living space, the market value and share of financing by the issuer). We find that buildings in data class A are indeed more expensive and thus any 'financed' GHG effect will be lower if buildings would be compared that only differ in price but nothing else.

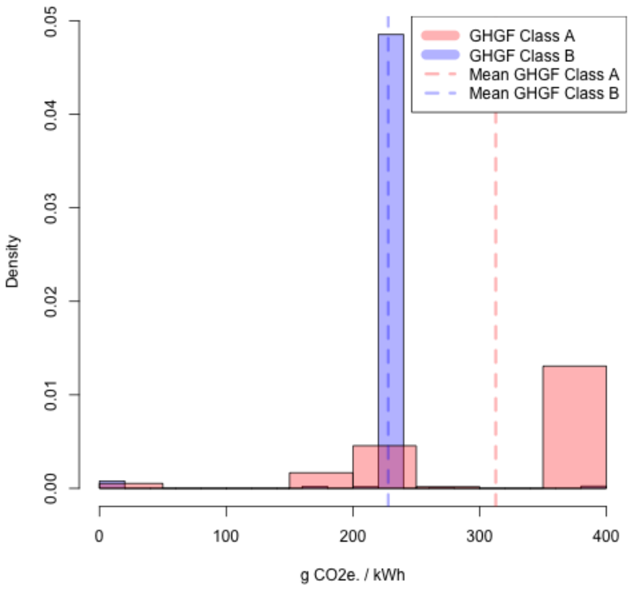
The final hypothesis (H_4) explained the lower performance of type A buildings by assuming that their specific GHG intensity is higher than for the average value used in type B buildings. The following Figure 4-4 depicts a histogram of GHG intensities (GHG emissions per kWh and m²) used in both building types. It clearly shows that, while there are some type A buildings with very low GHG intensities (likely from renewable sources), the average value for A is a lot higher than for B. It stands to reason that affected the GHG savings from type A buildings to their detriment and that it is mainly caused by a large share of buildings that used electricity as their main source of energy for heating (see section 2.3).

Figure 4-3: price per square-metre of buildings in the dataset and their average values



Source: own compilation

Figure 4-4: histogram of used GHG factors for Class A and B



Source: own compilation

4.3 Synthesis of Analysis

The main insights from the analysis are:

1 | The use of more detailed data on the final energy demand and specific energy sources of buildings (new data class A) not only leads to more accurate results but also revealed that the actual energy savings of the issuer's building are higher than previously thought.

2 | These buildings with data class A distinguish themselves from other buildings in the dataset in that they are (a) younger buildings, are (b) more expensive, and (c) often rely on energy carriers that are more GHG intensive than average buildings in Germany.

We know from (1) that more data in the future is not only likely to improve accuracy but also the impact potential of the issuer's buildings. Our findings on (2) on the other hand show that the surprisingly low investment efficiency of type A buildings can be explained by the differences between type A and type B buildings. This, in turn, suggests that data availability happens to be higher for buildings from a more recent construction year, as this metric would also explain the availability of information on energy use and carriers as well as higher prices.

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Appendix:
Documentation of Impact Assessment of RES buildings

Documentation Impact Reporting Mhyp 2023

2024-08-19

1. Load the necessary packages and input data

First, the necessary packages and input data is loaded and minor data ajustments are performed.

```
library(readxl)
library(collapse)
library(openxlsx)
library(stringr)

#ghg_factor  <- 231 # gCO2 / kWh
#pef         <- 1.1 # primary energy factor

### Input ###
path <- str_split(rstudioapi::getSourceEditorContext()$path,"02 CALCULATION")[[1]][1]
coltypes <- c(rep("guess",20),rep("text",16),rep("guess",12))
input <- read_excel(paste(path,"01 INPUT/Input Data Residential_update.xlsx",sep=""),sheet="Input Residential",col_types = coltypes)

# Zeros are transformed into NAs
input[which(input$Wohnfläche==0),"Wohnfläche"]                                    <- NA
input[which(input$`Jahresprimär-energiebedarf`==0),"Jahresprimär-energiebedarf"]  <- NA

# Some values were manually corrected by MHyp. The corrected values are drawn from an additional column
idx_corr_fed <- which(input$`FED, korrektur`!=0)
input[idx_corr_fed,"Jahresendenergie-kennwert (kWh/m2*a)"] <- input[idx_corr_fed,"FED, korrektur"]

idx_corr_ped <- which(input$`PED, korrektur`!=0)
input[idx_corr_ped,"Jahresprimär-energiebedarf"] <- input[idx_corr_ped,"PED, korrektur"]

# Lifetime is calculated based on start end ending
input["laufzeit"] <- as.numeric((input$`Zinsbindungs-ende` - input$Laufzeitbeginn) / 365)

# Transform share in percent (misleading header, column contains shares)
input["Anteil MHB in %"] <- input["Anteil MHB in %"] * 100

# Energy carriers "others" to standard mix
input[which(input$WI_energycarrier == "other"),"WI_energycarrier"] <- "standard_mix"

# Import Energy Carrier
energy_carriers <- read_excel(paste(path,"01 INPUT/Input Data Residential_update.xlsx",sep=""),sheet="GHG-Intensity (energy_carrier)")
```

2. Classification

Not all required information is given for all buildings. In order to adress this problem, a scheme for data quality classifiaction was introduced (see Mhyb GB 2022). With the current bond, this scheme was updated:

- Class A is now defined by the presence of data regarding final energy demand and specific information on the used energy carrier.
- Class B is the former class A (Primary Energy Demand, Area, Building Type and Year of construction needed)
- Class C is the former class B (Area, Building Type and Year of construction needed)
- Class D is defined by the presence of data regarding Building Type and Year of Construction.

If none of these conditions are met or the financial volume is less than 1000 € (which is regarded as outlier), the class “noclass” is given. In order to not mix up indexes, these outliers are kept and will be discarded at the very end.

```
input[which(is.na(input$Wohnfläche)),"Wohnfläche"] <- input[which(is.na(input$Wohnfläche)),"Bezugsfläche gem. Ausweis"]

input["class"]    <- character(nrow(input))

idx_A <- which( input$WI_energycarrier != "standard_mix"
                & is.na(input$`Jahresendenergie-kennwert (kWh/m2*a)`)==F
                & input$`Jahresendenergie-kennwert (kWh/m2*a)` < input$`Jahresprimär-energiebedarf`
                & is.na(input$`Wohnfläche`)==F)
input[idx_A,"class"] <- "A"


idx_B <- which( is.na(input$`Effektivkapital in Vertragswährung`)==F
                & is.na(input$`Jahresprimär-energiebedarf`)==F
                & is.na(input$`Wohnfläche`)==F
                & is.na(input$Objektart)==F
                & is.na(input$Baujahr)==F
                & input$class != "A")
input[idx_B,"class"] <- "B"

idx_C <- which( is.na(input$`Effektivkapital in Vertragswährung`)==F
                & is.na(input$`Wohnfläche`)==F
                & is.na(input$Objektart)==F
                & is.na(input$Baujahr)==F
                & is.element(input$class,c("A","B"))==F)
input[idx_C,"class"] <- "C"

idx_D <- which( is.na(input$`Effektivkapital in Vertragswährung`)==F
                & is.na(input$Objektart)==F
                & is.na(input$Baujahr)==F
                & is.element(input$class,c("A","B","C"))==F)
input[idx_D,"class"] <- "D"

idx_noclass <- which(input$class=="")
idx_noclass <- c(idx_noclass, which(input$`Effektivkapital in Vertragswährung` < 1000 | input$Wohnfläche < 10))
input[idx_noclass,"class"] <- "noclass"


idx_A <- idx_A[which(is.element(idx_A,idx_noclass)==F)]
idx_B <- idx_B[which(is.element(idx_B,idx_noclass)==F)]
idx_C <- idx_C[which(is.element(idx_C,idx_noclass)==F)]
idx_D <- idx_D[which(is.element(idx_D,idx_noclass)==F)]

# Check length of classes
print(paste("The class 'A' contains ", length(idx_A)," buildings",sep=""))
```

```
## [1] "The class 'A' contains 456 buildings"
```

```
print(paste("The class 'B' contains ", length(idx_B)," buildings",sep=""))
```

```
## [1] "The class 'B' contains 11168 buildings"
```

```
print(paste("The class 'C' contains ", length(idx_C)," buildings",sep=""))
```

```
## [1] "The class 'C' contains 19372 buildings"
```

```
print(paste("The class 'D' contains ", length(idx_D)," buildings",sep=""))
```

```
## [1] "The class 'D' contains 1 buildings"
```

```
print(paste("The class 'noclass' contains ", length(idx_noclass)," buildings",sep=""))
```

```
## [1] "The class 'noclass' contains 24 buildings"
```

2.1 Fill missing data

According to the classification scheme the data gaps are filled. primary energy demand is assumed to be 70 kWh/m^2a if "laufzeitbeginn" is after april 2020. If it was before that date, primary energy demand is assumed to be 50 kWh/m^2a. Where no data regarding living area is given, the 1st quantile of financing costs per square meter derived from the other classes is used to estimate values for living area.

```
### Fill Primary Energy Demand ###

idx_without_energy <- c(idx_C,idx_D)

idx_u2020 <- which(input$Laufzeitbeginn <= "2020-04-01 UTC")
idx_a2020 <- which(input$Laufzeitbeginn > "2020-04-01 UTC")

idx_tofill_u2020 <- idx_without_energy[which(is.element(idx_without_energy,idx_u2020))]
idx_tofill_a2020 <- idx_without_energy[which(is.element(idx_without_energy,idx_a2020))]

input[idx_tofill_u2020,"Jahresprimär-energiebedarf"] <- 70
input[idx_tofill_a2020,"Jahresprimär-energiebedarf"] <- 55

### Fill living area ###

ratio_area_cost_vec <- input[c(idx_A,idx_B,idx_C),]$`Wohnfläche` / input[c(idx_A,idx_B,idx_C),]$`Verkehrswert`

ratio_area_cost     <- as.numeric(quantile(ratio_area_cost_vec)[2])
input[idx_D,"Wohnfläche"] <- input[idx_D,"Verkehrswert"] * ratio_area_cost
```

2.2 Get reference data

Data containing building types and reference values for primary energy demand of each building type is imported. For the class A different reference data is needed compared to the other classes because final energy demand is used, not primary energy demand.

```
# Class A buildings
ref_A            <- read_excel(paste(path,"01 INPUT/Input Data Residential_update.xlsx",sep=""),sheet="REF-Energy Demand")[c(1:14),c(2:4,10:12)]
colnames(ref_A)  <- c("Cluster","BJ_min","BJ_max","SFH","TH","MFH")
ref_A            <- ref_A[-c(1,2),]
ref_A$BJ_min[1]  <- -Inf
ref_A$BJ_max[12] <- Inf

# All other buildings
ref_all            <- read_excel(paste(path,"01 INPUT/Input Data Residential_update.xlsx",sep=""),sheet="REF-Energy Demand")[c(1:14),c(2:7)]
colnames(ref_all)  <- c("Cluster","BJ_min","BJ_max","SFH","TH","MFH")
ref_all            <- ref_all[-c(1,2),]
ref_all$BJ_min[1]  <- -Inf
ref_all$BJ_max[12] <- Inf

# Import building codes
ref_codes           <- read.csv(paste(path,"01 INPUT/ref_codes.csv", sep=""), sep=";")
```

The reference data is merged with the input data to create the data frame in which the calculation will be performed (table). Because merging reorders the rows, the indexes are set anew.

```
table                             <- merge(input, ref_codes[,c("Schlüssel","Haustyp")],by.x ="Objektart",by.y="Schlüssel",all.x = T)
table["ref energy ped"]           <- NA
table["ref energy fed"]           <- NA
table["energy demand building"]   <- NA
table["ghg factor"]               <- numeric(nrow(table))
table["ghg factor ref"]           <- energy_carriers[which(energy_carriers$enerrgy_carrier == "standard_mix"),"GHG-Intensity [2]"]
```

2.3 Assign energy demand and GHG factor

For each row the energy demand of the respective building and a reference value are assigned. This step is nessecary because for class A final energy demand is used but for alle the other classes primary energy demand is used. Additionally, the GHG factor for the respective energy carrier is added.

```
for(i in 1:nrow(table)){

  bj <- table$Baujahr[i]
  if(table$class[i] == "noclass")next
  if(table$class[i] == "A"){
    # For class A FED is used for the impact assessment
    table[i,"energy demand building"]  <-  table$`Jahresendenergie-kennwert (kWh/m2*a)`[i]

    idx <- which(ref_A$BJ_min <= bj & ref_A$BJ_max >= bj)

    table[i,"ref energy fed"]           <- as.numeric(ref_A[idx,table[i,"Haustyp"]])  # in kWh final energy demand
    table[i,"energy demand reference"]  <- table[i,"ref energy fed"]
  }
  if(table$class[i] != "A"){
    # For all non-A-classes PED is used for the impact assessment
    table[i,"energy demand building"]  <-  table$`Jahresprimär-energiebedarf`[i]

    idx   <- which(ref_all$BJ_min <= bj & ref_all$BJ_max >= bj)

    table[i,"ref energy ped"]          <- as.numeric(ref_all[idx,table[i,"Haustyp"]])  # in kWh primary energy demand
    table[i,"energy demand reference"] <- table[i,"ref energy ped"]
  }

  ec_idx <- which(energy_carriers$enerrgy_carrier == table$WI_energycarrier[i])
  table[i,"ghg factor"]    <- energy_carriers[ec_idx,"GHG-Intensity [2]"]
}

### !!! Attention "energy demand building" and "energy demand reference"  can be FED or PED
```

3 Impact assessment

3.1 Impact calculation

The values for CO2- and energy savings are calculated based on the differences in energy demand the living area. Finally, the financed share of these indicators and the impact reduction per unit of financing is calculated.

```
table["co2 savings total"]        <- ((table["energy demand reference"] * table["ghg factor ref"]) - (table["energy demand building"] * table["ghg
factor"])) * table["Wohnfläche"]
table["energy savings total"]     <- (table["energy demand reference"]  - table["energy demand building"])  * table["Wohnfläche"]
table["absolute emissions total"] <- table["energy demand building"] * table["ghg factor"]     * table["Wohnfläche"]

table["energy savings financed"]       <- table["energy savings total"]     * table$`Anteil MHB in %` / 100 # in kWh
table["co2 savings financed"]          <- table["co2 savings total"]        * table$`Anteil MHB in %` / 100 # in g CO2-eq.
table["absolute emissions financed"]   <- table["absolute emissions total"] * table$`Anteil MHB in %` / 100 # in g CO2-eq.
```

3.2 Finalize Result

The data frame is collapsed to summarize the results depending on data quality. Rownames and Columnames are set manually.

```r
####################
#### Result #########
####################
res_cols <- c("class",
              "Effektivkapital in Vertragswährung",
              "laufzeit",
              "energy savings total",
              "energy savings financed",
              "co2 savings total",
              "co2 savings financed",
              "absolute emissions total",
              "absolute emissions financed")



res <- table[,res_cols]
res <- collap(res, ~ class, custom=list(fmean = c(3), fsum = c(2,4:9)))


### Units ###

res["Effektivkapital in Vertragswährung"] <- res["Effektivkapital in Vertragswährung"] / 1000000     # eur -> mio eur
res["energy savings total"]               <- res["energy savings total"]               / 1000000     # kWh -> GWh
res["energy savings financed"]            <- res["energy savings financed"]            / 1000000     # kWh -> GWh
res["co2 savings total"]                  <- res["co2 savings total"]                  / 1000000000  # g -> kt
res["co2 savings financed"]               <- res["co2 savings financed"]               / 1000000000  # g -> kt
res["absolute emissions total"]           <- res["absolute emissions total"]           / 1000000000  # g -> kt
res["absolute emissions financed"]        <- res["absolute emissions financed"]        / 1000000000  # g -> kt

res["reduced per unit financed"]          <- res["co2 savings financed"]*1000 / res["Effektivkapital in Vertragswährung"]  #  t CO2 / mio eur
res["share"]                              <- res["energy savings financed"] / res["energy savings total"]

rownames(res) <- res$class

res <- res[c("Effektivkapital in Vertragswährung",
             "share",
             "laufzeit",
             "energy savings total",
             "energy savings financed",
             "co2 savings total",
             "co2 savings financed",
             "reduced per unit financed",
             "absolute emissions total",
             "absolute emissions financed")]

colnames(res) <- c("Signed Amount in mio EUR",
                   "Share of Total Portfolio Financing [%]",
                   "Average Portfolio Lifetime [a]",
                   "Energy Savings full effect [GWh/a]",
                   "Energy Savings financed [GWh/a]",
                   "Reduced/Avoided annual GHG emissions (heat) full effect [kt CO2-eq. / a]",
                   "Reduced/Avoided annual GHG emissions (heat) financed [kt CO2-eq. / a]",
                   "Reduced/Avoided annual GHG emissions (heat) per unit of financing [kt CO2-eq. / a]",
                   "Absolute annual GHG emissions (heat) full effect [kt CO2-eq. / a]",
                   "Absolute annual GHG emissions (heat) financed [kt CO2-eq. / a]")

for(col in 2:ncol(res)){
  res[,col] <- round(res[,col],3)
}

res <- res[-which(rownames(res)=="noclass"),] # Class "noclass" is discarded

write.xlsx(res, paste(path,"02 CALCULATION/Mhyp_GB_2024_result_mit_update_250324.xlsx",sep=""),
           colNames = T, rowNames = T)
```

Other indicators for comparison

```
## $`Building Efficiency (Final energy demand [kWh/m2a] , area-weighted average)`
##   Class.A
## 1    26.8
##
## $`Building Efficiency (Primary energy demand [kWh/m2a], area-weighted average)`
##   Class.B Class.C Class.D
## 1    31.2    63.3      70
##
## $`Impact Efficiency (Energy savings [kwh/a] per area)`
##    All Class.A Class.B Class.C Class.D
## 1 48.8    51.6    70.3    35.7    24.5
##
## $`Average Timespan all Credits`
##   Years
## 1 23.39
##
## $`Excluded Buildings`
##   Number Credit.Volume.in.MioEur
## 1     24                   6.468
##
## $`Energy savings [kwh/a], area weighted average`
##   Class.A Class.B Class.C Class.D
## 1 17793.1 23852.6  8786.7    4641
##
## $`Energy savings [kwh/a] all, average`
##      All
## 1 8114.8
##
## $`Costs per sqm`
##   Euro.per.area
## 1      3410.608
##
## $`Sum of Area per dataclass in m2`
##    Class.A Class.B Class.C  Class.D
## 1 85599.49 1912029 3159075 189.4269
```