Impact Assessment Methodology
Münchener Hypothekenbank eG
Green Building Portfolio

Rationale, Framework, Data

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on behalf of

MünchenerHyp

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The current method paper represents version 2.0 and refers directly to the MünchenerHyp Green Portfolio Impact Analysis #2023. It is expected that a further update of this methodology will be made available in 2025.

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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 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, 2023)*.

2 Framework

The original input data contains information on the type of buildings and in some cases also the purpose of buildings. Previous impact assessments classified the results according to these building types (e.g., office and storage buildings, or single-family and multi-family homes).

However, the focus of the assessment is to provide the most reliable results which is why a different classification is chosen for the current report (and from 2022 onward). Each building is assigned 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 following sections describe how these data cluster are assigned to the two main asset classes (1) commercial buildings (COM) and (2) residential buildings (RES).

2.1   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.

Table 2-1: Data criteria for selection of data class

Type	A: high data quality	B: medium data quality	C: low data quality	D: no data
COM	financing data net conditioned area energy carrier heat total final energy demand	financing data net conditioned area energy carrier heat primary energy demand	financing data net conditioned area energy carrier heat	financing data net conditioned area
RES	financing data primary energy demand year of construction building type living space	financing data year of construction building type living space	financing data building type living space	financing data building type

Source: own compilation

2.2   Calculation for Commercial buildings (COM)

There are 191 contracts in the commercial portfolio that refer to 168 assessable buildings (portfolio until June 2023). 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), Austria (AT), Spain (ES), France (FR), United Kingdom (UK), Luxemburg (LU), Netherlands (NL) 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 and US building stock of office buildings. In opposition to the previous methodology, data now also allows to incorporate other sources of electricity consumption.

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

$$GHG_{avoid,COM-A} = \left(\frac{FED_{total}}{area_{net-cond}} - fed_{stock}\right) x\ ghg_{carrier}\ x\ area_{net-cond}\ [kg\ CO_2 - equ./\ building\ p.a.]\quad (A_{COM})$$

with

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

FED_{total}:   total final energy demand for heating of the building in [kWh]

$area_{net-cond}$:   net-conditioned area of the building in [m²]

fed_{stock}:   specific total final energy demand in building stock in [kWh/m²]

$ghg_{carrier}$:   GHG intensity of the energy carrier (heat) with highest GHG-intensity 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$_{stock}$).

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. These factors are energy-carrier specific and were drawn from a short study funded by the European Union (Hitchin et al., 2018).

Equation B$_{COM}$ is therefore considered to deliver robust results for Type B data in the following manner.

$$GHG_{avoid,COM-B} = (\frac{1}{PEF_{carrier}} \, x \, \frac{PED_{tot}}{area_{net-cond}} - fed_{stock}) \, x \, ghg_{carrier} \, x \, area_{net-cond} \, [kg \, CO_2 - equ./ \, building \, p.a.]$$

(B$_{COM}$)

with

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

PEF$_{carrier}$: primary energy factor for energy carrier (heat) with highest GHG-intensity in [kWh/kWh]

fed$_{stock}$: specific final energy demand in sampled buildings in specific region in [kWh/m²a]

PED$_{total}$: primary energy demand of the building in [kWh]

ghg$_{carrier}$: GHG intensity of the energy carrier (heat) with highest GHG-intensity in [kg CO2e/kWh]

For buildings of type C, only data on the conditioned area and the heating system is available. We assume that these buildings 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). An additional required variable is the average fraction of the specific final energy demand compared to the specific primary energy demand in the sample (90% for the sample in the current report).

Equation C$_{COM}$ shows how primary energy factors (PEFs) are used to estimate the saving in final heat demand when applying that assumption.

$$GHG_{avoid,COM-C} = (\frac{saving_{PED}}{PEF_{carrier}} \, x \, fed_{stock} \, x \, [\frac{fed_{sample}}{ped_{sample}}]) \, x \, ghg_{carrier} \, x \, area_{net-cond} \, [kg \, CO_2 - equ./ \, building \, p.a.]$$

(C$_{COM}$)

with

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

saving$_{PED}$: primary energy demand saving for light renovation in [%]

PEF$_{carrier}$: primary energy factor for energy carrier (heat) with highest GHG-intensity in [kWh/kWh]

fed$_{stock}$: specific final energy demand in sampled buildings in specific region in [kWh/m²a]

fed$_{sample}$: average final energy demand of buildings in sample which are also provided with a specific primary energy demand in the sample

ped$_{sample}$: average primary energy demand of buildings in sample which are also provided with a specific final energy demand in the sample

$ghg_{carrier}$:   GHG intensity of the energy carrier (heat) with highest GHG-intensity in

[kg CO2e/kWh]

For type D buildings, only the conditioned area is available. Although the estimation is in line with type C buildings, we assume the most conservative case with electricity being the main heat energy carrier (highest PEF with 2.3). The equation (D_{COM}) is therefore very similar.

$$GHG_{avoid,COM-D} = (\frac{saving_{PED}}{PEF_{electricity}} \; x \; fed_{stock} \; x \; \left[\frac{fed_{sample}}{ped_{sample}}\right]) \; x \; ghg_{electricity} \; x \; area_{net-cond} \; [kg \; CO_2 - equ./ \; building \; p.a.]$$

(D_{COM})

with

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

$saving_{PED}$:   primary energy demand saving for light renovation in [%]

$PEF_{electricity}$:   primary energy factor for electricity in [kWh/kWh]

fed_{stock}:   specific final energy demand in sampled buildings in specific region in [kWh/m²a]

fed_{sample}:   average final energy demand of buildings in sample which are also provided with a specific primary energy demand in the sample

ped_{sample}:   average primary energy demand of buildings in sample which are also provided with a specific final energy demand in the sample

$ghg_{electricity}$:   GHG intensity of the electricity in

[kg CO2e/kWh]

2.3   Calculation for Residential Buildings (RES)

There are 8,859 buildings in the input data. They are grouped into the categories single-family house (SFH), multi-family house (MFH) and terrace house (TH). The years of construction range from earlier than 1595 to 2016 and newer. No building has 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, the financing data, primary energy demand, living space, building type and year of construction are known (no data on final heat demand and heating system). The equation (A_{RES}) is considered to deliver the most robust result for impact reporting:

$$GHG_{avoid,RES-A} = \frac{ped_{ref}-ped}{PEF_{gas}} * ghg_{gas} * A \; [kgCO_2 - equ./ \; building] \; (A_{RES})$$

with

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

ped: specific primary energy demand of building [kWh/m²a]

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

PEF_{gas}: primary energy factor for gas (representing all heating systems)

$ghg_{carrier}$: GHG intensity of gas for heating in [kg CO2e/kWh]

A: living space as conditioned area in [m²]

For buildings of type B, only the primary energy demand is not known. In accordance with the issuer's requirements, each building is assigned a maximum primary energy

demand of either 70 kWh/a (until 30th of April 2020) or 55 kWh/a (from 1st of May 2020 onward).

The equation (B_{RES}) is therefore only slightly altered:

$$GHG_{avoid,RES-B} = \frac{ped_{ref} - ped_{max}}{PEF_{gas}} * ghg_{gas} * A \; [kgCO_2 - equ./\;building] \; (B_{RES})$$

with

> $GHG_{avoid,RES-B}$: potentially avoided GHG emissions for type B data in [kg CO2e]
> ped_{max}: maximum specific primary energy demand of buildings in portfolio in [kWh/m²]

For buildings of type C, the financing data, the living space and the building type are known. To account for the fact that no suitable reference building can be selected, the lowest primary energy demands for buildings in stock (conservative estimate) are used.

The results from type C buildings are therefore considered to be robust as a conservative estimate (it is unlikely that the actual buildings have higher energy savings) but less accurate:

$$GHG_{avoid,RES-C} = \frac{ped_{min} - ped_{max}}{PEF_{gas}} * ghg_{gas} * A \; [kgCO_2 - equ./\;building] \; (C_{RES})$$

with

> $GHG_{avoid,RES-C}$: potentially avoided GHG emissions for type C data in [kg CO2e]
>
> ped_{min}: lowest specific primary energy demand for building types in stock in [kWh/m²a]

Data for buildings of type D, 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 per square-metre of all other buildings in the sample in order to ensure a conservative estimate for the resulting avoided GHG emissions in equation D_{RES}.

$$GHG_{avoid,RES-D} = \frac{ped_{min} - ped_{max}}{PEF_{gas}} * ghg_{gas} * F * liv_{sample} \; [kgCO_2 - equ./\;building] \; (D_{RES})$$

with

> $GHG_{avoid,RES-D}$: potentially avoided GHG emissions for type D data in [kg CO2e]
>
> F: total costs of building in [EUR]
> liv_{sample}: financed living space per total costs, 3rd 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 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 (MünchenerHyp, 2021)	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 with the hightest GHG intensity
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 C and Class D buildings are assumed to have undergone a light-renovation (16% PED saving)
regional ratio of heat energy demand to primary energy demand	average of buildings in sample (only buildings that have data on both are considered)	COM 6) The ratio in the sub-sample represents all buildings in the sample
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 7) 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) all other intensities are drawn from the Covenant of Mayors (CoM) default emission factor document provided by the European Commission (Koffi et al., 2017)	COM 8) German district heating value (120-400 kW) is used for other countries as well (3 cases)

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 (MünchenerHyp, 2021)	RES 1) All buildings are heated with gas 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) All systems have a primary energy factor of 1.1 (representing oil/gas)
GHG intensity factors	DGNB framework for climate-neutral buildings and locations (DGNB, 2020)	-

3.3 Limitations of the methodology

All data, assumptions and calculations shown here are 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.

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 (fhd) for COM and the specific primary energy demand (ped) for RES buildings are documented here (see following table). These values can be compared to literature data (fhd of commercial, ped of residential buildings) to evaluate the energy efficiency of the buildings in the portfolio.

Table 4-1: specific final energy demand (COM) and specific primary energy demand (RES) values in the current sample for comparison with literature

Data type	[fed, total] specific final energy demand, COM	[ped] specific primary energy demand, RES
A	101 kWh/m²a	29 kWh/m²a
B	111 kWh/m²a	61 kWh/m²a
C	146 kWh/m²a	no buildings in 2023
D	183 kWh/m²a	55 kWh/m²a a
weighted Average	131 kWh/m²a	42 kWh/m²a

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6   Appendix

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2023-11-10

1. Load the necessary packages and input data

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

```r
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,"03 Reporting")[[1]][1]
input <- read_excel(paste(path,"01 Inputs/231020_ImpactReporting2023_Daten_gesamt_WI_mit Proxi.xlsx",sep=""))

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

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

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). In the next chunk, the data points are classified according to this scheme.

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

idx_A <- 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[idx_A,"class"] <- "A"

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

# Delete last row because there are no entries except monetary value
to_delete <- which(is.element(1:nrow(input),c(idx_A,idx_B,idx_C,idx_D))==F)
input     <- input[-18859,]
```

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 3rd quantile of financing costs per square meter derived from the other classes is used to estimate values for living area.

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

idx_without_energy <- c(idx_B,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),]$`Wohnfläche` / input[c(idx_A,idx_B,idx_C),]$`Effektivkapital in Vertragswährung`
ratio_area_cost     <- as.numeric(quantile(ratio_area_cost_vec)[4])

input[idx_D,"Wohnfläche"] <- input[idx_D,"Effektivkapital in Vertragswährung"] * 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 and added to the main data frame (here called table).

```r
ref_codes           <- read.csv(paste(path,"01 Inputs/ref_codes.csv", sep=""), sep=";")
ref_energy          <- read.csv2(paste(path,"01 Inputs/ref_energy.csv",sep=""))
ref_energy["other"] <- (ref_energy$SFH + ref_energy$TH + ref_energy$MFH)/3

table               <- merge(input, ref_codes[,c("Schlüssel","Haustyp")],by.x ="Objektart",by.y="Schlüssel")
table["ref energy"] <- numeric(nrow(table))

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

  bj <- table$Baujahr[i]
  idx <- which(ref_energy$BJ.min <= bj & ref_energy$BJ.max >= bj)

  table[i,"ref energy"] <- ref_energy[idx,table[i,"Haustyp"]]
}
```

3 Impact assessment

3.1 Impact calculation

The wanted values are calculated by: 1) Subtracting the primary energy demand of the building from the reference value. 2) Multiplying that difference with the living area to retrieve energy savings. 3) Multiplying energy savings with a ghg factor. The same procedure is applied to the primary energy demand of the building instead of its difference to a reference value to retrieve total absolute emissions. Finally, the financed share of these indicators and the impact reduction per unit of financing is calculated.

```r
table["difference energy consumption"] <- table["ref energy"]/pef - table["Jahresprimär-energiebedarf"]/pef # in final energy

table["energy savings total"]          <- table["difference energy consumption"] * table["Wohnfläche"]              # in kWh
table["co2 savings total"]             <- table["energy savings total"]       * ghg_factor                # in g CO2-eq.
table["absolute emissions total"]      <- table["Jahresprimär-energiebedarf"]    * table["Wohnfläche"] * ghg_factor # in g CO2-eq.

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.

table["reduced per unit financed"]        <- table["energy savings financed"] / table$`Effektivkapital in Vertragswährung` # in g CO2 / eur
```

3.2 Finalize Result

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

```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)))

### Einheiten ###

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)
}

write.xlsx(res, paste(path,"02 Outputs/Mhyp_GB_2023_result.xlsx",sep=""),
           colNames = T, rowNames = T)
```

Other indicators for comparison

```
## [1] "Pimräry energy demand, weighted average"
```

```
## [1] "A:29.2"
```

```
## [1] "B:60.8"
```

```
## [1] "C:NaN"
```

```
## [1] "D:54.7"
```

```
## [1] "All:41.7"
```

```
## [1] "Energy savings, weighted average"
```

```
## [1] "A:67"
```

```
## [1] "B:32.3"
```

```
## [1] "C:NaN"
```

```
## [1] "D:31.4"
```

```
## [1] "Energy savings all, average"
```

```
## [1] "All:51.6"
```

```
## [1] "Costs per sqm"
```

```
## [1] 1331.161
```

```
## [1] "Sum of Area per dataclass"
```

```
## [1] "A: 1769856.25 m2"
```

```
## [1] "B: 1158827.64 m2"
```

```
## [1] "C: 0 m2"
```

```
## [1] "D: 1167.42190066932 m2"
```