



A holistic analysis tool for calculating the economic efficiency, energy efficiency, and environmental impact of construction measures and buildings: NUKOSI

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TECHNIK  
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# Agenda

## Abstract

1. Introduction *or Why we are here?*
2. Literature review *or what we need: Easy handling*
3. LCA and LCA by NUKOSI: *Case study*
4. Conclusion *and future works*

The project started 2015 to create a data base

► Public buildings of the state Rheinland-Pfalz, Germany



► 1.650 Buildings

► 2,5 Mio. NFA

► Public Real Estate Management (PREM)



# Requirements 2015 to calculate use costs

## Simple formula to calculate LCC in Germany?

Baunutzungskosten nach DIN 18960 Muster 7.2

Kostengruppe 100 Kapitalkosten nach DIN 18960		€/m² NGF u.	€/m² BGF u. Jahr <sup>3)</sup> (€/m² BRI u. Jahr)	€/Jahr
110	Fremdkapital			
120	Eigenmittel			
130	Abschreibung			
180	Kapitalkosten Sonstiges			
<b>Objektmanagementkosten (Summe 210 - 290)</b>				
Kostengruppe 200 Objektmanagementkosten nach DIN 18960		€/m² NGF u.	€/m² BGF u. Jahr <sup>3)</sup> (€/m² BRI u. Jahr)	€/Jahr
210	Beschaffungskosten			
220	Sachkosten			
230	Fremdleistungen			
280	Objektmanagementkosten Sonstiges			
<b>Objektmanagementkosten (Summe 210 - 290)</b>				
Kostengruppe 300 Betriebskosten nach DIN 18960		€/m² NGF u.	€/m² BGF u. Jahr <sup>3)</sup> (€/m² BRI u. Jahr)	€/Jahr
310	Versorgung			
311	Wasser			
312	Öl			
313	Gas			
314	Feste Brennstoffe			
315	Ferwärme			
316	Strom			
317	technische Medien			
319	Versorgung sonstiges			
320	Entsorgung			
321	Abwasser			
322	Müll			
329	Entsorgung Sonstiges			
330	Reinigung und Pflege von Gebäuden			
331	Unterhaltsreinigung			
332	Glassreinigung			
333	Fassadenreinigung			
334	Reinigung technischer Anlagen			
335	Reinigung von Regen- und Abwasserkanälen			
340	Reinigung und Pflege der Außenanlagen			
350	Bedienen, Inspektion und Wartung			
351	Bedienung der technischen Anlagen			
352	Inspektion und Wartung der Baukonstruktionen			
353	Inspektion und Wartung der Bauteile			
354	Inspektion und Wartung der Bauelemente			
355	Inspektion und Wartung der Bauglieder			
359	Inspektion und Wartung Sonstiges			
360	Sicherheits- und Überwachungsdienste			
370	Abgaben und Beiträge			
380	Sonstige Betriebskosten			
<b>Instandsetzungskosten (Summe 410 - 490)</b>				
Kostengruppe 400 Instandsetzungskosten nach DIN 18960		€/m² NGF u.	€/m² BGF u. Jahr <sup>3)</sup> (€/m² BRI u. Jahr)	€/Jahr
410	Instandsetzung der Innenanlagen			
420	Instandsetzung der Außenanlagen			
430	Instandsetzung der Außenanlagen			
440	Instandsetzung der Ausstattung			
490	Instandsetzung Sonstiges			
<b>Instandsetzungskosten (Summe 410 - 490)</b>				
Kostengruppen 100 - 400 nach DIN 18960		€/m² NGF u.	€/m² BGF u. Jahr <sup>3)</sup> (€/m² BRI u. Jahr)	€/Jahr
<b>Summe Baunutzungskosten (Summe KGR 100 bis 400)</b>				

2) Wird von der LBB-Niederlassung eingesetzt.  
3) Die zugrunde gelegten Kostenkennwerte (z. B. PLAKODA, fm benchmarking Bericht) sind zu erläutern und als Anlage beizulegen.

► Cost indicator of a cost type \* quantity

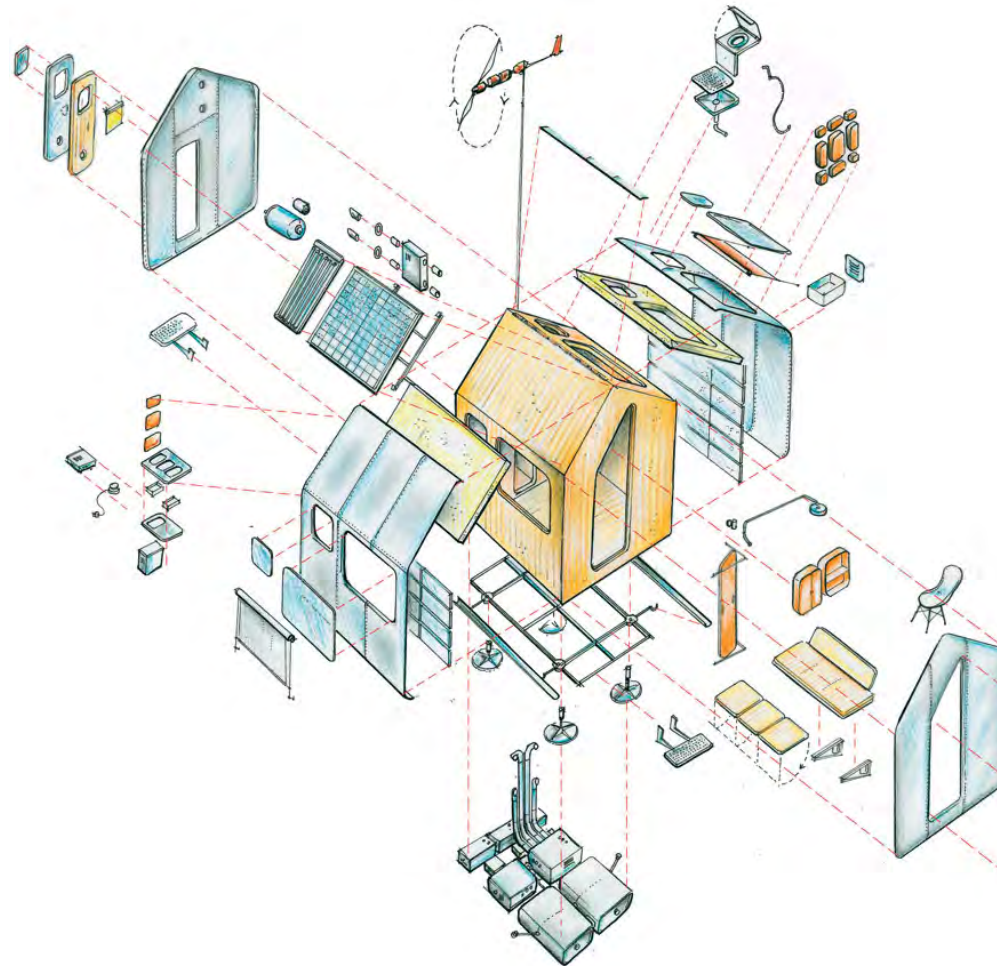
► e.G energy

► Data of LBB  
 ► The underlying cost parameters (e.g. PLAKODA, fm benchmarking report) are to be explained and attached as an annex.

► e.G maintance

Basten, Holger in; [Bogenstätter, U. (2018)] Bogenstätter, Ulrich (Hrsg.): Immobilienmanagement erfolgreicher Bestandhalter; Berlin: 2018, Abb. 6.10, vgl. [fm.rlp RL Bau 2016] Ministerium der Finanzen (Hrsg.): Richtlinien für die Durchführung von Bauaufgaben des Landes Rheinland-Pfalz (RL Bau): Ausgabe 2006, Stand Juli 2016, fm.rlp RL Bau 2016, 1.1.2016.

# New: Requirements of the state Rheinland-Pfalz Considering components



► Many Variables  
e.G  
Facade  
Heating system  
Quality strategy

Detail (Hsrg.: Winzing aber autark: Minihaus „Diogene“ in Weil am Rhein; Internet. <http://www.detail.de/fileadmin/migrated/pics/minihaus-weil-5-explosionszeichnung.jpg> (21.6.2016)

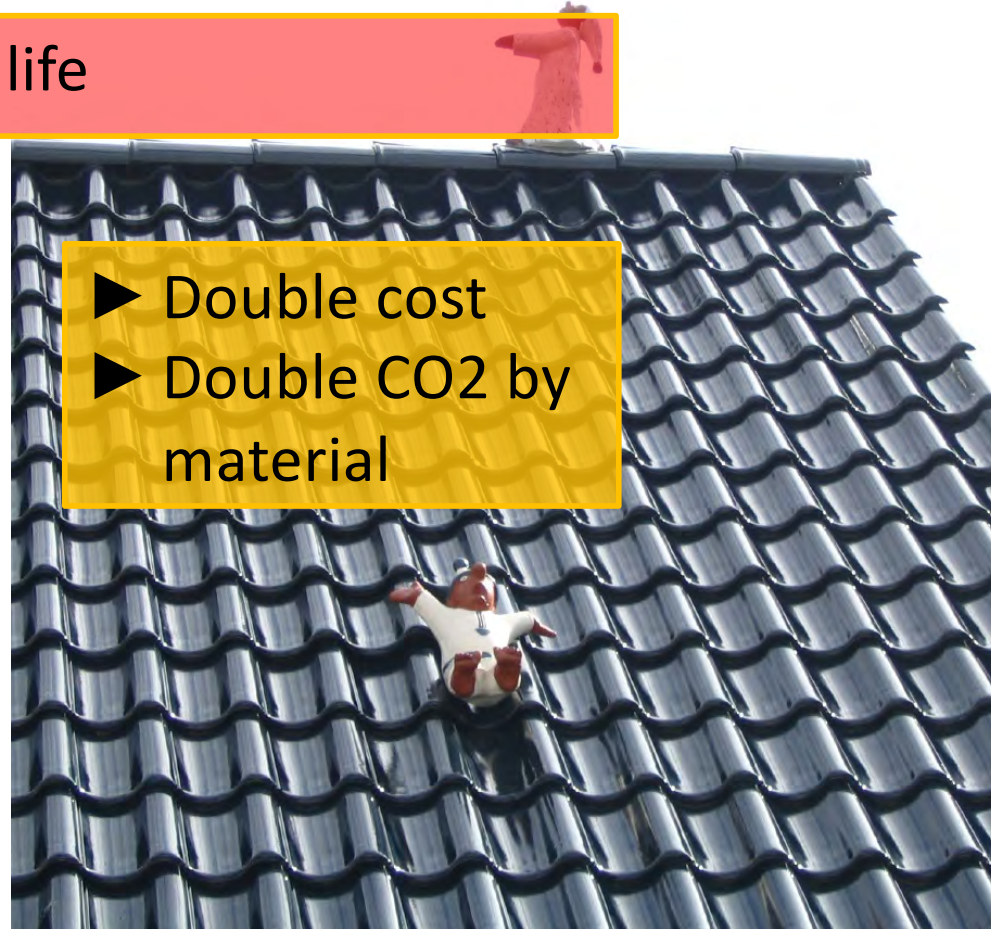
# Quality strategy: Predict the costs

▶ 80 yrs.?

▶ 40 yrs.?

▶ Variable: Technical life

▶ Double cost  
▶ Double CO2 by material



Quelle: Koch Dach Fassaden (Hrsg.): *Unterhalt/Dachreparatur*; Internet: <http://www.koch-bedachungen.ch/images/sdc10250.jpg> (29.4.2012).

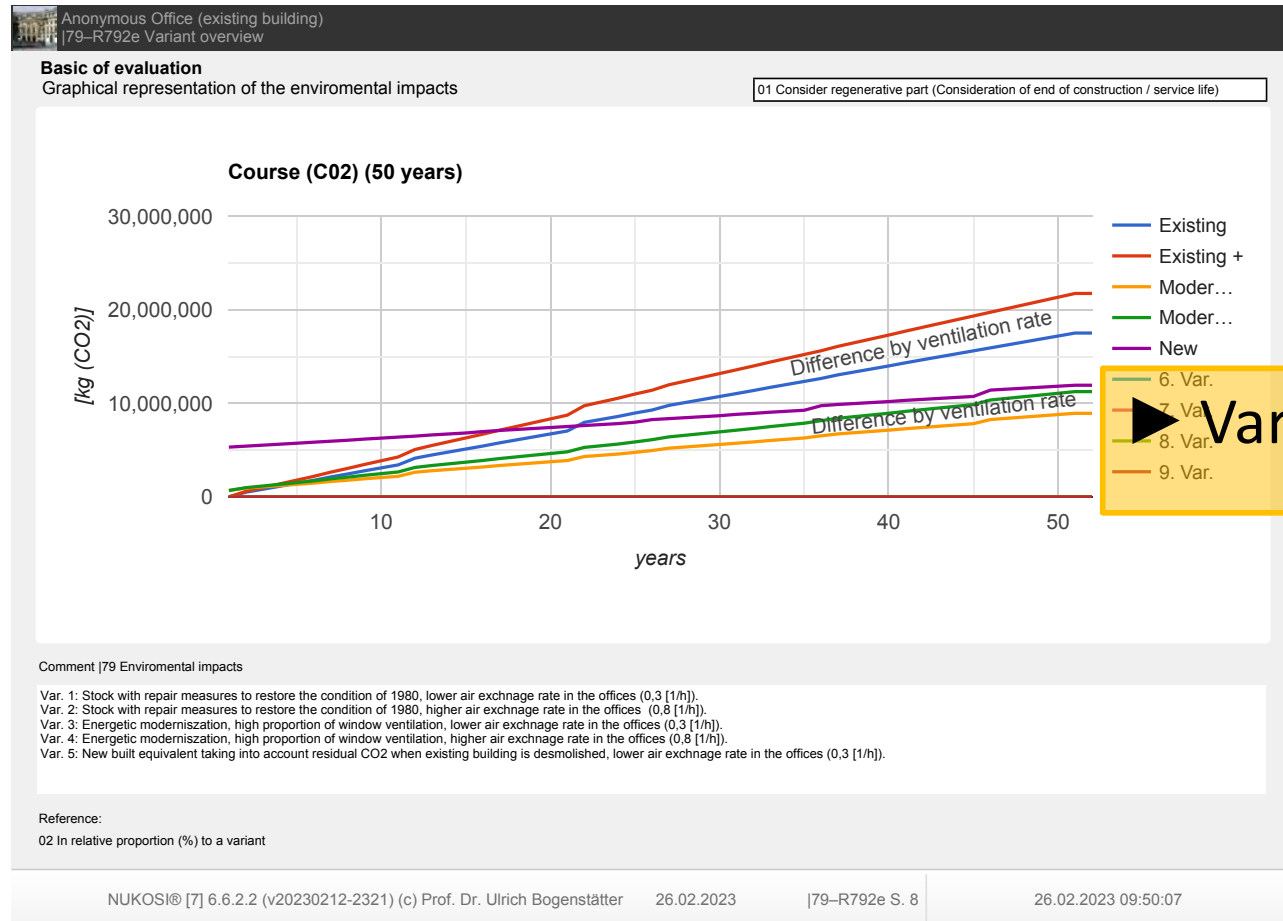
Quelle (rechts: Dachdeckerbetrieb Matthias Grünewald (Hrsg.): *Dacharten*; Internet: <http://www.dachdeckerei-gruenewald.de/images/img0905.jpg> (29.4.2012).

# Different measures: the economical calculation considering all components





# Different measures: the ecological calculation considering all components

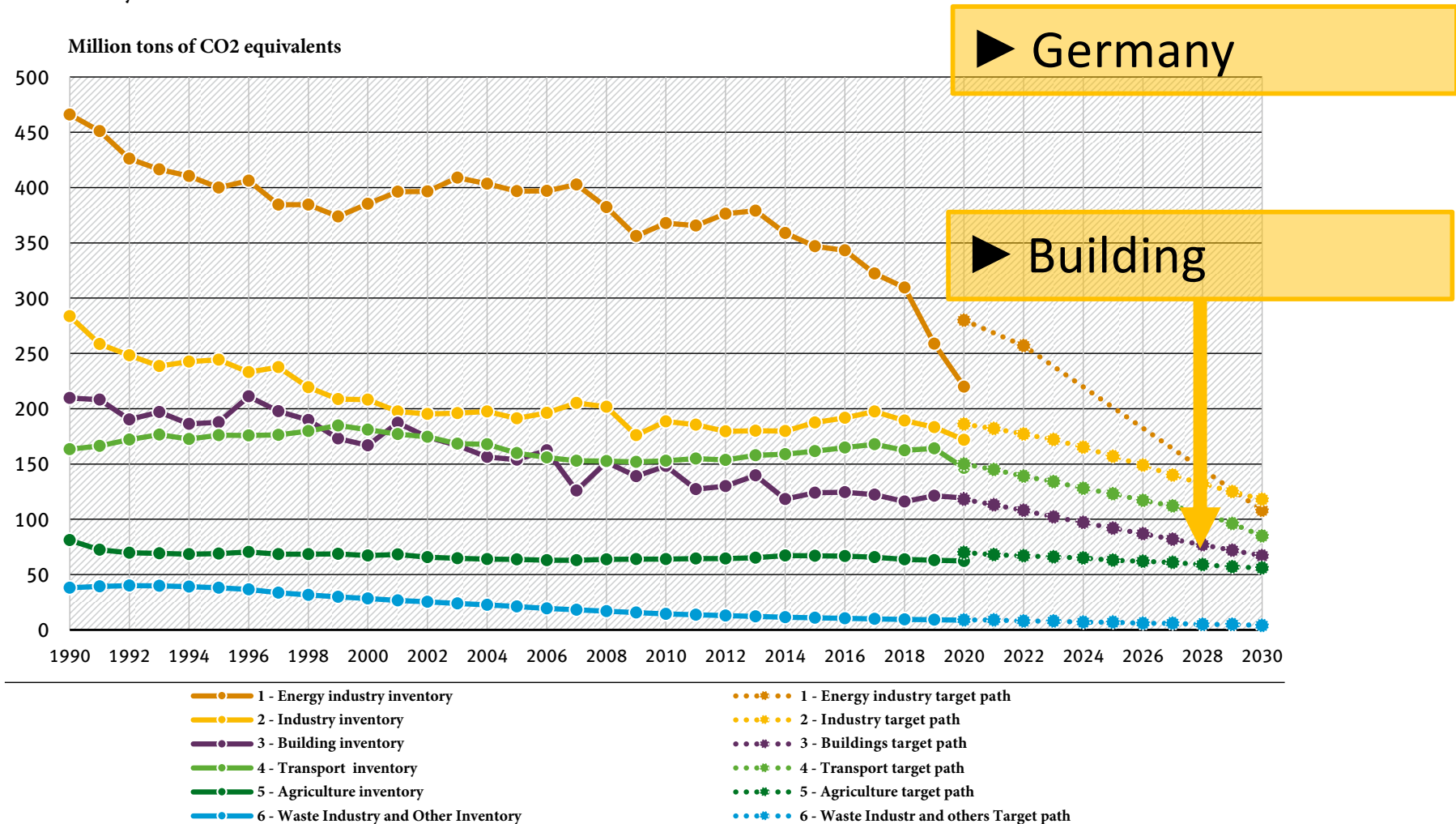


Introduction or *Why we are here?*

1

# Development of Greenhouse Gas Emissions

Development and target achievement of greenhouse gas emissions in Germany as defined by the sectors of the German Federal Climate Protection Act\*.



\* The breakdown of emissions differs from UN reporting, total emissions are identical

Source EM data 1990-2019: Federal Environment Agency, German Greenhouse Gas Inventory 1990-2019, final status as of 04/15/2021 Source previous year's estimate (VJS) for 2020: Federal Environment Agency, Press Release 07/2021, as of 03/15/2021 Source Targets 2020 & 2030: Amendment to the Federal KSG as of 05/12/2021.



# EU Taxonomy 2020, Appendix Nr. 7

▶ The Green Deal

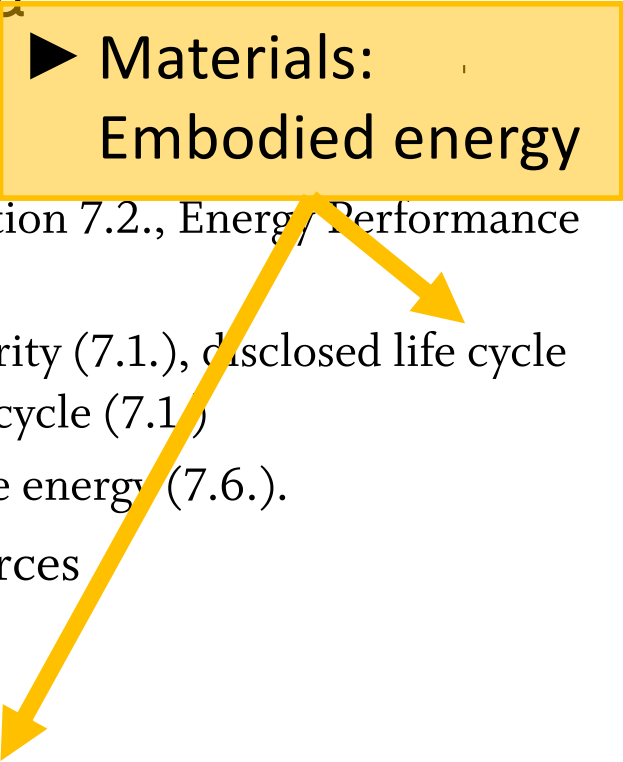
## 7. Construction and real estate

1. New construction (7.1.)
2. Renovation of existing buildings (7.2.)
3. Installation, maintenance and repair of energy efficient appliances (7.3.)
4. Installation, maintenance, and repair of electric vehicle charging stations in buildings (and in parking lots associated with buildings) (7.4.)
5. Installation, maintenance, and repair of equipment for measuring, regulating, and controlling the energy performance of buildings (7.5.)
6. Installation, maintenance and repair of renewable energy technologies (7.6.)
7. Acquisition and ownership of buildings (7.7.)

[EU Taxonomie - Anhang 2020] EU Taxonomie - Anhang: Verordnung (EU) 2020/852 des Europäischen Parlaments und des Rates vom 18. Juni 2020 über die Einrichtung eines Rahmens zur Erleichterung nachhaltiger Investitionen und zur Änderung der Verordnung (EU) 2019/2088 (Text von Bedeutung für den EWR), 2020, URL: [https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=PI\\_COM:C\(2021\)2800&from=EN](https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=PI_COM:C(2021)2800&from=EN) (letzter Aufruf: 10.11.2022)

# EU Taxonomy 2020, No. 7.1. - 7.7. Technical Evaluation Criteria

► Materials:  
Embodied energy

A yellow rectangular box with a black border contains the text '► Materials: Embodied energy'. Two yellow arrows originate from the box: one points to the first criterion '1. Significant contribution to climate protection' and the other points to the fourth criterion '4. Transition to a circular economy'.

## 1. Significant contribution to climate protection

- Primary energy demand (PEB) (Limitation 7.1., Reduction 7.2., Energy Performance Certificate 7.8.)
- Buildings > 5,000 m<sup>2</sup>: Air tightness and thermal integrity (7.1.), disclosed life cycle greenhouse potential (GWP) for each phase in the life cycle (7.1.)
- Energy measures (7.3.), smart control (7.5.), renewable energy (7.6.).

## 3. Sustainable use and protection of water and marine resources

- Water saving measures (7.1./7.2.)

## 4. Transition to a circular economy

- Adaptability of buildings: resource efficiency, adaptability, flexibility and dismantling capability Reuse and recycling and other material recovery (7.1./7.2.)

## 5. Pollution prevention and control

- Reduction of noise, dust and pollutant emissions (7.1./7.3.)

[EU Taxonomie - Anhang 2020] EU Taxonomie - Anhang: Verordnung (EU) 2020/852 des Europäischen Parlaments und des Rates vom 18. Juni 2020 über die Einrichtung eines Rahmens zur Erleichterung nachhaltiger Investitionen und zur Änderung der Verordnung (EU) 2019/2088 (Text von Bedeutung für den EWR), 2020, URL: [https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=PI\\_COM:C\(2021\)2800&from=EN](https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=PI_COM:C(2021)2800&from=EN) (letzter Aufruf: 10.11.2022)

# The role of taxonomy in the risk management of Public Financial Institutions (PFI).

- Expectations of the European Central Bank
  - Consideration of climate-related / ecological factors<sup>3)</sup>
- Rating of the object(s) in risk management
  - Taxonomie: „PFIs expect that apply the taxonomy can be benefit for them in **many ways**. (...) Its potential to reduce risk, including risks related to sustainability and greenwashing accusations. (...). **Costs, coverage and interpretation are also topics of interest for PFIs**. (...) – over 33% of PFIs thus plan to or already provide improved financial conditions for taxonomy-aligned activities. (...)“<sup>1)</sup>
  - Leerstand (Höhe der Betriebskosten)<sup>2)</sup>
  - ...
- Rating of the company
  - Credit rating<sup>1)</sup>, Risk management<sup>2)</sup>

► Money makes the world go round

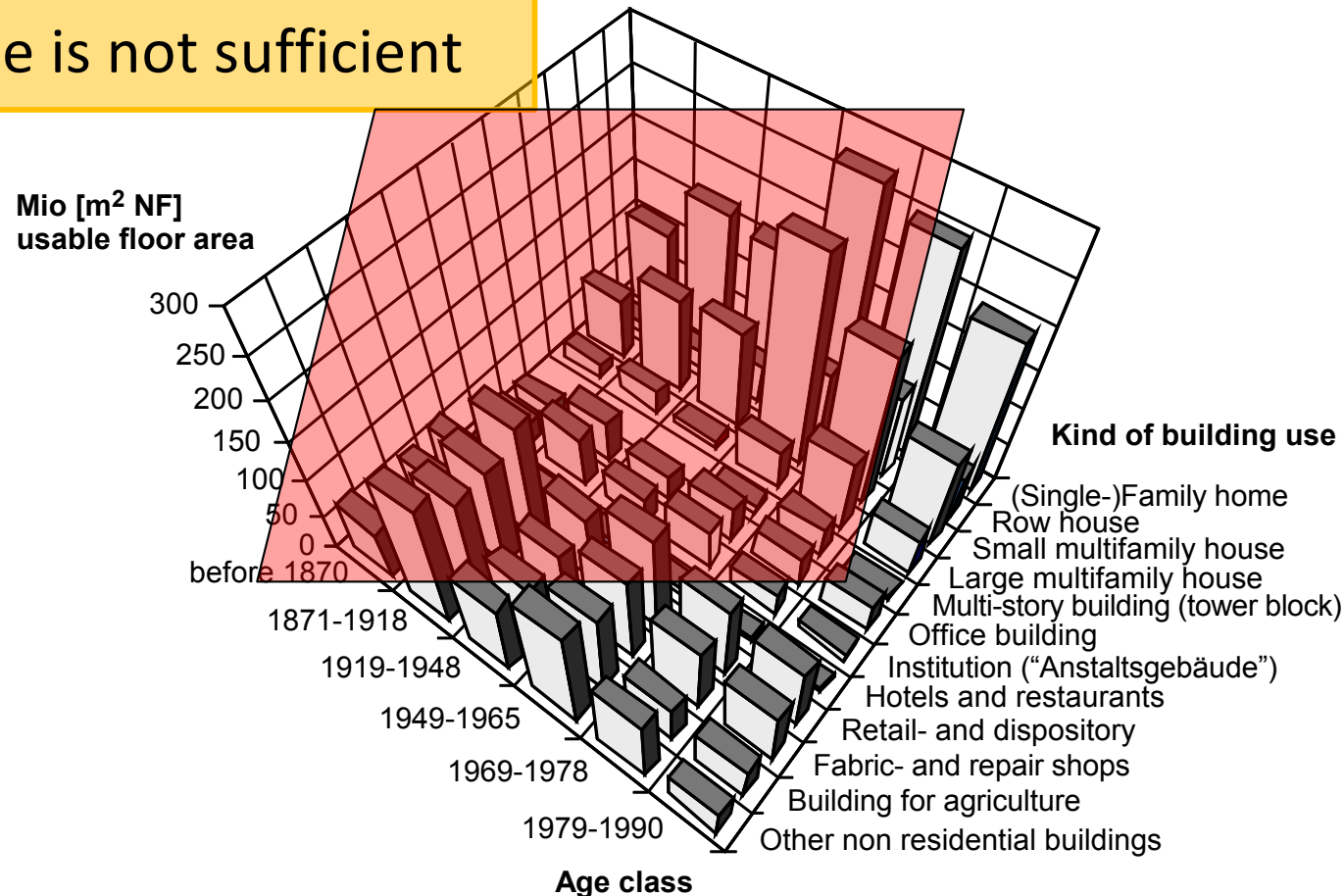
[EU Taxonomie - Anhang 2020] EU Taxonomie - Anhang: Verordnung (EU) 2020/852 des Europäischen Parlaments und des Rates vom 18. Juni 2020 über die Einrichtung eines Rahmens zur Erleichterung nachhaltiger Investitionen und zur Änderung der Verordnung (EU) 2019/2088 (Text von Bedeutung für den EWR), 2020, URL: [https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=PI\\_COM:C\(2021\)2800&from=EN](https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=PI_COM:C(2021)2800&from=EN) (letzter Aufruf: 10.11.2022)

# Building stock 12/1991 in Germany

## Mio. [m<sup>2</sup> NFA] (usable floor area)

[KÖHLER, N. 1999] Köhler, Niklaus; Hassler, Uta; Enquete Kommission „Schutz des Menschennachwuchses“ des 13. Deutschen Bundestages (Hrsg.): Stoffströme und Kosten in den Bereichen Bauen und Wohnen Berlin, Weidner Berg u.a.: Springer-Verlag 1999; ISBN 3-540-66073-9; Abb. 1, total 5,5 Billion m<sup>2</sup> NFA

► Building stock is old  
 ► Data base is not sufficient



► Variable Building age class

► Variable Building type

The simple questions are the best.





# The main questions

1. Which measures save the most CO<sub>2</sub> and meet the legal requirements?
2. How long will it take for our buildings to meet climate protection requirements??
3. What will be the cost to achieve the goals?
4. Which buildings might be at risk of being unprofitable in the future?
5. Are there any tools that can evaluate the LCC and LCA of a building in a single application efficiently in an early planning phase?

► Developing tool for calculating the economic efficiency, energy efficiency, and environmental impact of construction measures and buildings

The main requirements of a tool

Cheaper

Hollistic

Quick

Smart

Literature review *or easy handling*

2

# Requirements: Ecology (LCA) & Economy (LCC)



► incompatible opposites?

Source: Adobe



# (Used) Data base from Germany

## ▶ Areas

1. Reference buildings
  - Documentation Projekte
    - Areas DIN 277 (|B25), Number 4.139
    - Invest DIN 276 (|B26), Number 4.019
    - Trades DIN 276 (|B24), Number 321
  - Aggregierte (statistische) Auswertungen nach Bauwerkszuordnung (BWZ)
    - Areas DIN 277 (•B25), Number 34
    - Invest DIN 276 (•B26), Number 311
    - Operation DIN 18960 (•B46), Number 21
  - Benchmarks according to type of building(BWZ)
    - Areas DIN 277 (|C21), Number 454
    - Invest DIN 276 (|C22), Number 453

## ▶ Invests

2. Reference room programmes
  - Definition room programmes (|C12), Number 88
  - Documentation rooms
    - Definition (|C23), Number 830
    - Cost of rooms (|C24), Number 2.793

3. Life span
  - Datensätze (A3), Number 8.111 Number 9.577 data sets
  - Reference components
    - Components (|C51), Number 1.104
    - subcomponents (|C53), Number 3.246

4. Operation cost

5. Ecological

Stand: 23.9.2022 53.216 Data sets

## ▶ Life span

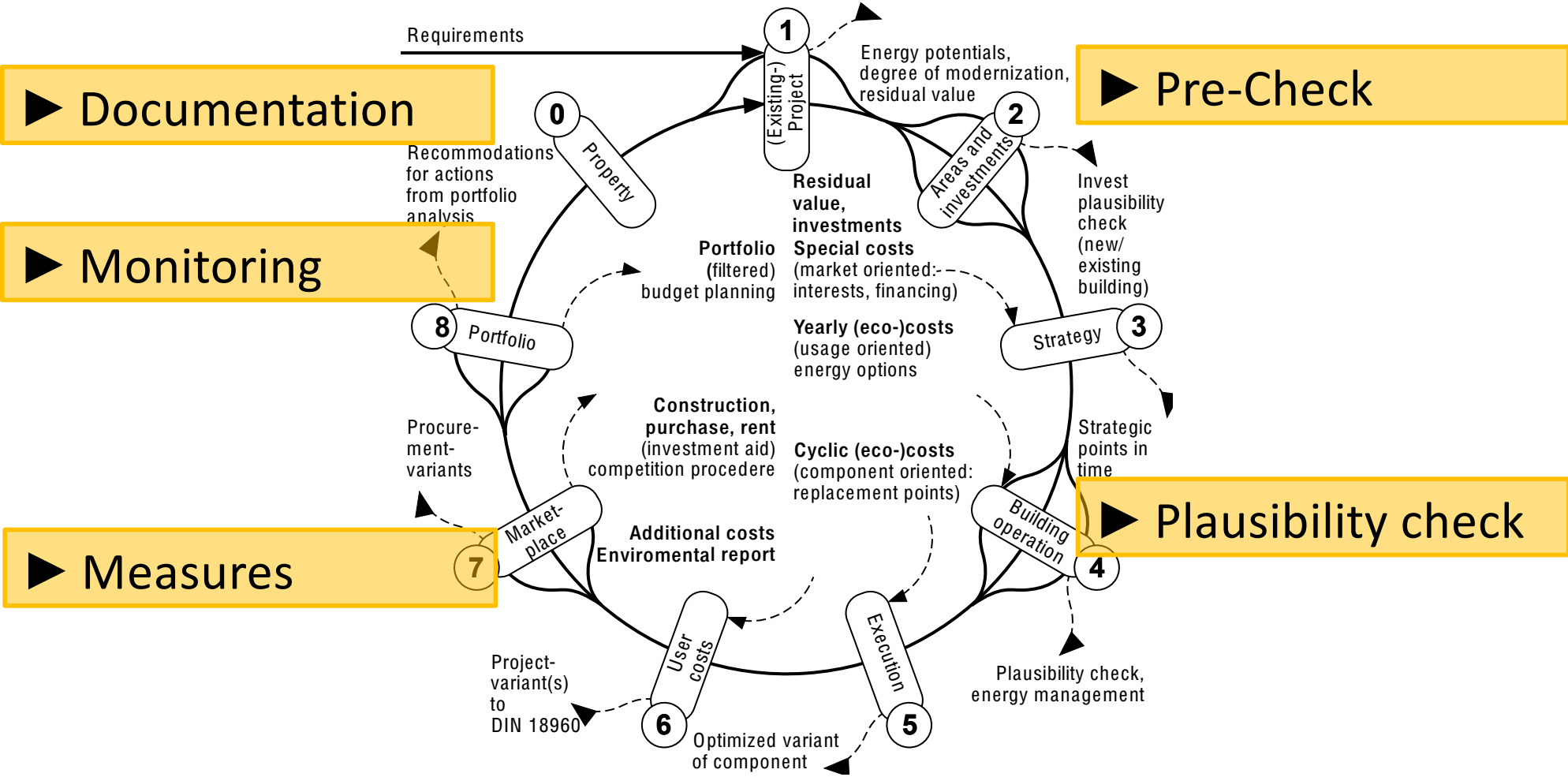
## ▶ Operation costs

LCA and LCA a use-cost-simulation  
(NUKOSI - Nutzen-Kosten-Simulation):  
*Case study*

3

# Hollistic

# tool in the life cycle





# Quick: You need 5 informations to start

► Size

► Building age class



► Type of buliding



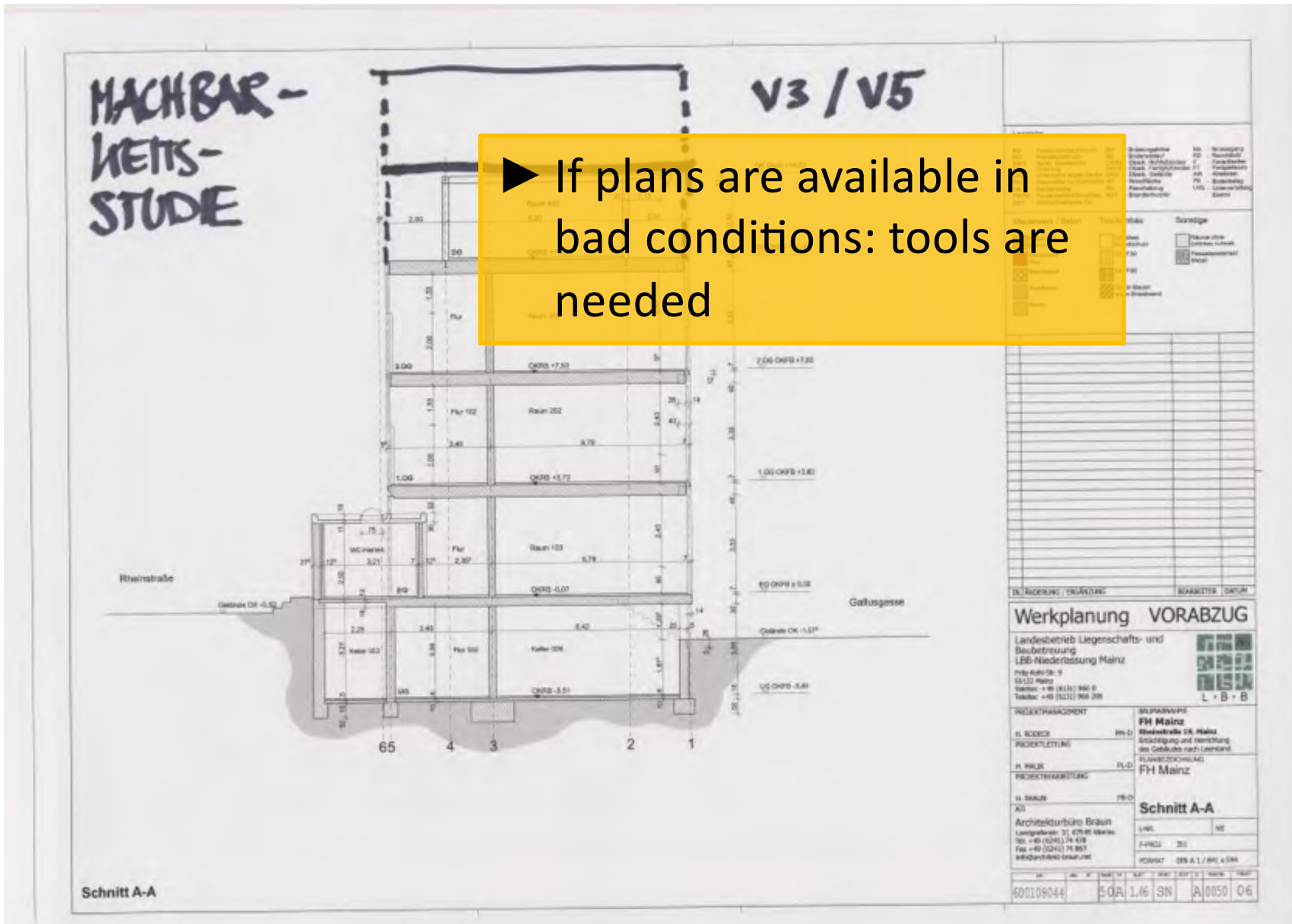
► Energy source



► Location

ifb.o.r.

# Size: Feasibility study



Hinweis: Zahlen und Texte sind lediglich zu Demonstration eingefügt und sind quantitativ und qualitativ anonymisiert.

Derzeit wird eine experimentelle Version von Google Earth ausgeführt.

Weitere Informationen Feedback geben

Rheinstraße 19  
Rheinstraße 19, 55116 ...  
50.00°N, 8.28°E

▶ No data available: size based on google earth

Rheinstraße 19

Google 100% GeoBasis-DE/BKG (©2009) 10 m Kamera: 199 m 49°59'50"N 8°16'40"E 83 m

The image shows a screenshot of the Google Earth interface. The main view is an aerial satellite image of a city street, identified as Rheinstraße 19. A yellow callout box with a play button icon and the text 'No data available: size based on google earth' is overlaid on the image. The interface includes a top navigation bar with 'Weitere Informationen' and 'Feedback geben', a search bar on the left, and a bottom status bar with 'Google 100% GeoBasis-DE/BKG (©2009)'. A scale bar shows 10 meters, and camera information indicates a height of 199 meters and coordinates of 49°59'50"N 8°16'40"E. A 3D/2D toggle and a globe icon are also visible in the bottom right corner.

Smart: it makes calculation cheaper

15-1e Component quantity of the building, overview

Nr. 12231 (24.02.2023 08:14): Anonymous Office (existing building): Office building (Existing) [10 trade] ID 1223120230224081413 (Existing).

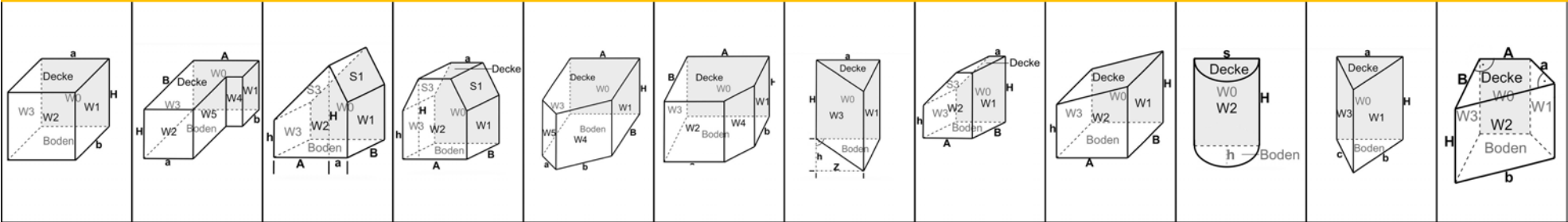
Projekt: Partial calculation project [12231] (359) High rise building Ground floor - 3rd

Modell: Quick energy statement

Teilberechnung Proj. [12231] (359) Hochhaus EG - 3.OG

02 L-orfen - A B a h H-1-Building

► Quantity of elements: just like Building Information Modelling (BIM), more simple, based on statistic or available data



Teilberechnung Proj. [12231] (362) Hochhaus 13. OG Treppenhaus

5 35 Trapezoid -a b h H-: Sloping building wall Actual (submodel): 3.630,31

Teilberechnung Proj. [12231] (5) Flachbau EG bis 2. OG

6 01 Cuboid -a b H-: Rectangle Actual (submodel): 316,75


Teilberechnung Proj. [12231] (6) Flachbau EG Endstück

# Potential of existing buildings

► Regulations valid in time of construction and today

Total Carbon footprint reduction potential (form)

Nr. 12231 (24.02.2023 08:14): Anonymous Office (existing building): Office Building (Existing) [10 trade] ID 1223120230224081413 (Existing).

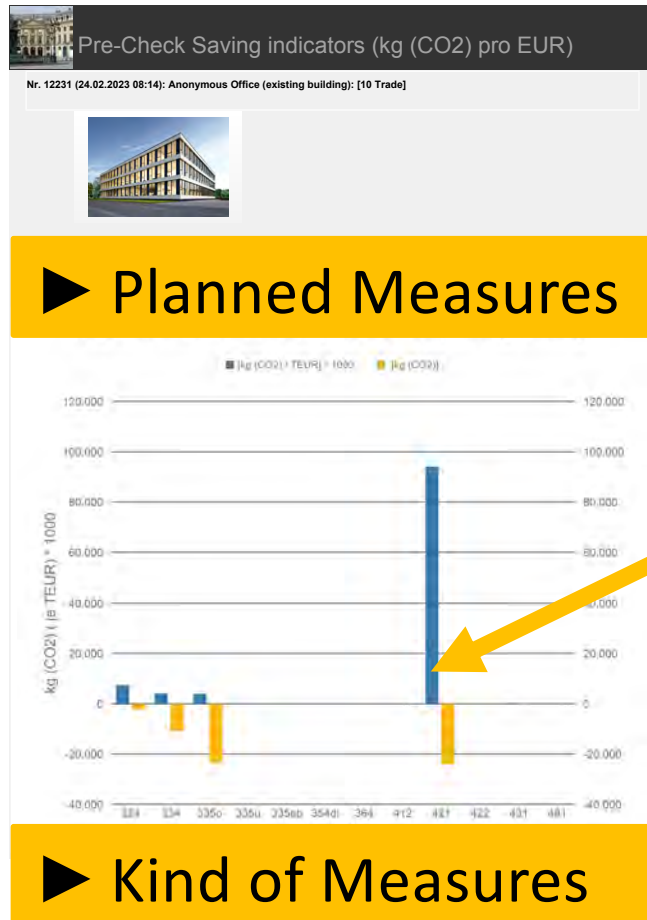


Energy standard:	1977 Wärmeschutzverordnung	2020 Gebäudeenergiegesetz (GEG)	Energy demand		Potential for execution		Investment	
	Actual / Potential	U-Value	Need	Reduction	U-Value	Need	Potential	
	Year of installation	[kWh/a]	[kWh/a]	[%]	[kWh/a]	[kWh/a]	[ (CO2)/a]	
<b>Low-investment measures</b>								
Solar profits:	1980		-67,672	0.05		-71,056	-3,384	-0.81
Hot water demand:	1980		16,640	0.05		15,808	-832	-0.20
Distribution losses:	1980		0	0.05		0	0	0.00
Internal profits:	1980		-7,577	0.05		-7,956	-379	-0.09
<b>Energetic measures</b>								
Ground floor plate:	1980	0.90	84,561		0.35	32,885	-51,676	-12.40
Windows:	1980	2.70	382,230		0.90	127,410	-254,820	-61.16
Walls against								
... outside (air):	1980	1.42	701,194		0.29	143,202	-557,992	-133.92
... soil:	1980	0.90	0		0.35	0	0	0.00
... other sidewalls:	1980	0.45	0		0.20	0	0	0.00
Basement ceiling:	1999		0			0	0	0.00
Roof:	1980	0.45	60,268		0.20	26,786	-33,482	-8.04
Ventilation system:	1980	0.00	4,881		0.90	488		
Window ventilation:			198,588			198,588		
Total ventilation:							-4,393	-1.05
<b>Energy demand:</b>			1,373,113			466,155	-906,958	
Heating efficiency:		* Efficiency			* Efficiency			
Heating renovation:	1980	0.75	457,704		1.11	-46,196	-593,779	-142.51
Including individual measures: pinned potential								
Energysource:	06 Erdgas				06 Erdgas			
Totals:			1,830,817			419,959	-1,500,737	
Korrektur Bedarf / Verbrauch:		0.0%						61.0%
								3,866,675
[kWh/a]			1,830,817			419,959	-1,500,737	
[kg CO2/kWh]	0.2400							
[... / GFAe]	7.50		243.14			55.77		

► Energy potential

► Cost of measures

# Optimisation Potential Saving indicators



# Calculating User costs of 1 building

## ► Full cost accounting

Form E 3.5 LCC, CO2-flow

User costs of buildings of DIN 18960:2020-11

User cost group (UCG) 100 Capital costs	€/m² GFA a. yr.	€/a, Ø yr. (static)	€/50 years (Cash values)	
110	Borrowed capital			
120	Equity capital			
130	Depreciation			
180	Capital costs, other			
<b>Capital costs (Total 110 - 190)</b>				
User cost group (UCG) 200 Object management costs	€/m² GFA a. yr.	€/a, Ø yr. (static)	€/50 years (Cash values)	
210	Own personnel costs	11.47	114.748	4.572.175
220	Own material costs			
230	External services			
290	Object management costs, other			
<b>Object management costs (Total 210 - 290)</b>				
User cost group (UCG) 300 Operating costs (incl. tax)	€/m² GFA a. yr.	€/a, Ø a/yr. (statisch / static)	€/50 years (Cash values)	
310	Supply	16.29	162.910	6.491.224
311	Water			
312	Oil	0.11	1.099	43.775
313	Gas			
314	Cond. fuels			
315	District heating			
318	Electricity	7.60	76.018	3.028.969
317	Technical media			
319	Supply, other			
320	Disposal	1.40	13.975	556.827
321	Wastewater	0.22	2.175	86.050
322	Waste	1.18	11.800	470.178
323	Disposal, other			
330	Cleaning and care of buildings	6.88	69.764	2.779.790
331	Maintenance cleaning	0.37	3.694	145.897
332	Glass cleaning	0.34	3.433	136.779
333	Facade cleaning	0.26	2.638	105.114
334	Cleaning of technical installations			
339	Cleaning and care of buildings, other			
340	Cleaning and care of outdoor facilities	0.87	8.679	338.132
350	Operation, inspection and maintenance	18.66	186.563	7.434.970
361	Operation of technical installations	4.52	45.225	1.802.050
352	Inspection and maintenance of structures	0.43	4.291	170.984
353	Inspection and maintenance of technical installations	3.17	31.685	1.241.684
354	Inspection and maintenance of outdoor facilities			
355	Inspection and maintenance of furnishings, works of art	0.71	7.110	283.309
356	Maintenance of technical structures	0.75	7.510	299.223
357	Maintenance of technical installations	6.59	65.919	2.604.615
358	Maintenance of outdoor facilities	2.49	24.921	992.096
359	Operations, inspection and maintenance, other			
360	Security and surveillance services	1.51	15.105	601.883
370	Stability charges and contributions			
390	Operating costs, other			
<b>Operating costs (Total 310 - 390)</b>				
User cost group (UCG) 400 Repair costs (incl. tax)	€/m² GFA a. yr.	€/a, Ø yr. (static)	€/50 years (Cash values)	
410	Structural repair	33.02	330.209	13.823.368
420	Repair of technical installations	26.56	265.572	11.036.813
430	Repair of outdoor facilities	9.77	97.709	3.907.052
440	Repair of furnishings and works of art	0.33	3.281	130.749
490	Repair costs, other			
<b>Repair costs (Summe / Total 410 - 490)</b>				
User cost group (UCG) 100 - 400	€/m² GFA a. yr.	€/a, Ø yr. (static)	€/50 years (Cash values)	
<b>User costs (Total NKG 100 - 400)</b>				
<b>Total LZK / LCC (Investments and User)</b>				
<b>Annuity LZK / LCC</b>				
<b>Annuity [LZK / m² BGF] / [LCC / m² GFA]</b>				
<b>Greenhousepotential (GHP) (CO2-Äquivalent [kg abs.])</b>				
<b>GHP (CO2-Äquivalent [kg/m²])</b>				

Basic of Investment (DIN 278): KG 100-800 02 Invest (Bedarfswert, [19])

► Costs of energy consumption (heating, electricity)

► Detailed cost of repair measures

► Investments in measures

# Calculating environmental balance of 1 building

Environmental report (Scopes according to GHG-  
 Nr. 12231 (24.02.2023 08:55): Anonymous Office (New building): Office Building (New) [10 trade] ID  
 1223120230224085519 (new).

**Formation of the key figures of unit...**  
 [m<sup>2</sup> (BGFa)] 6.964

**Calculation of CO2 consumption based on:**  
 06 Erdgas  
 01 Regenerativen (Berücksichtigung Bauende / Nutzungsdauer) Anteil berücksichtigte

**Water consumption (according to table [15] (selected))**

Water	[m3]	Surface area		Water consumption	
		[m <sup>2</sup> (unit)]	total	year [a] und	[m <sup>3</sup> (unit)]
		6.964	69.615	1.392.30	0.20

**Energy balance ((kWh) (selected))**

[15] Energy balance (heat)	[kWh]	Total (total service)	
		Jahr	[m <sup>2</sup> (unit)]
Energy balance (electricity)	12.890.827	257.817	37.02
<b>Total energy</b>	<b>28.208.886</b>	<b>564.178</b>	<b>81.01</b>

**CO2 equivalent (selected)**

Table	Description	[kg (CO2)] in year 0		[kg (CO2)], including year 0	
		total	[m <sup>2</sup> (unit)]	total	year [a] und
				50	
+ [49.1	Energy source (heat)	0,00	0,240	3.670,000	73,527
+ [49.2	Energy source (electricity)	0,00	0,160	2.094,400	41,988
= [49	<b>Energy source</b>	<b>0,00</b>	<b>0,400</b>	<b>5,775,734</b>	<b>115,515</b>
+ [59	Residual CO2 (e.g. in case of demolition)	2,049,794			
+ [59	Embodied energy (material, components)	3,269,316	469,43	0,240	
= [59	<b>Materials (embodied carbon)</b>	<b>5,319,110</b>	<b>763,75</b>	<b>6,738,339</b>	<b>134,767</b>
= [69	<b>Total</b>	<b>5,319,110</b>	<b>763,75</b>	<b>12,514,073</b>	<b>250,281</b>

**CO2 material (according to table [59] (selected))**

Primary energy	[MJ]	Resource in year 0		Surface		Resource consumption	
		total	[m <sup>2</sup> (unit)]	total	year [a] und	[m <sup>2</sup> (unit)]	
Renewable	5,648,804	811,09		8,100,982	162,020		
Renewable (energy)	6,309,684	905,98		9,048,753		25,99	
Renewable (material)	-687,039	-98,65			-19,706	-2,83	
Non renewable	32,066,690	4,604,32		45,987,020	919,740	132,06	
Non renewable (energy)	29,286,805	4,150,00		42,000,371	840,007	120,61	
Non renewable (material)	2,779,885	348,75		3,483,258	69,665	10,00	
Use of freshwater resources	10,340	0,00			0	0,00	
<b>Potentials (equivalence)</b>							
Greenhouse (CO2)	[kg CO2 eq]	3,269,316	469,43	4,688,544	93,771	13,46	
Ozone layer depletion (CFC11)	[kg CFC-11 eq]	0	0,00	0	0	0,00	
Acidification (SO2)	[mol H+ eq]	7,509	1,08	10,769	215	0,03	
Overfertilization (P)	[mol N eq]	927	0,13	1,330	27	0,00	
Abiotic resource consumption (Sb)	[kg Sb eq]	279	0,04	400	8	0,00	
Summersmog (Ethen)	[Kg NMVOC eq]	1,659	0,24	2,379	48	0,01	
<b>CO2 start balance (Project)</b>		<b>3,269,316</b>	<b>5,319,110</b>	<b>763,75</b>	<b>50</b>	<b>1,974,810</b>	<b>294,32</b>

▶ Total energy consumption

▶ Carbon footprint for demolition

▶ Primary energy, potentials



# Variations of measures (many buildings)

▶ Existing

▶ Modernisation

▶ New

▶ Floor space

▶ Investment

▶ User costs

▶ Environmental impacts

Anonymous Office (existing building)  
|79-R792e Variant overview

Areas and volumes in building construction		Existing		Existing +		Modernization		Modernization +		New	
DIN 277-1:2016-01 Areas in building construction		[m <sup>2</sup> ] total	%	[m <sup>2</sup> ] total	%	[m <sup>2</sup> ] total	%	[m <sup>2</sup> ] total	%	[m <sup>2</sup> ] total	%
<b>NUF</b>	<b>Primary area</b>	6,388	63,9%	6,388	63,9%	6,388	63,9%	6,388	63,9%	6,028	60,5%
+	TF Technical area	434	4,3%	434	4,3%	434	4,3%	434	4,3%	409	4,1%
+	VF Circulation area	2,313	23,1%	2,313	23,1%	2,313	23,1%	2,313	23,1%	2,182	21,9%
=	<b>NRF Net room area</b>	9,134	91,3%	9,134	91,3%	9,134	91,3%	9,134	91,3%	8,620	86,6%
-	KGF Construction floor area	866	8,7%	866	8,7%	866	8,7%	866	8,7%	1,339	13,4%
=	<b>BGF Gross floor area</b>	10,000	100,0%	10,000	100,0%	10,000	100,0%	10,000	100,0%	9,959	100,0%
	BRI Gross volume / BRI to BGF	34,900	3,49	34,900	3,49	34,900	3,49	34,900	3,49	34,755	3,49

Building costs (incl. tax.)		KG 100-800		02 Invest (Demand,  19)		02 Invest (Demand,  19)		02 Invest (Demand,  19)		02 Invest (Demand,  19)		04 Invest (New,  29)	
DIN 276:2018-12 Cost group (CG)		[EUR]	... / [m <sup>2</sup> (BGF)]	[EUR]	... / [m <sup>2</sup> (BGF)]	[EUR]	... / [m <sup>2</sup> (BGF)]	[EUR]	... / [m <sup>2</sup> (BGF)]	[EUR]	... / [m <sup>2</sup> (BGF)]	[EUR]	... / [m <sup>2</sup> (BGF)]
200	Clearance and development	1,170,894	117.09	1,170,894	117.09	0	0.00	0	0.00	2,323,203	233.29		
300	Structure – Construction works	10,681,967	1,068.20	10,681,967	1,068.20	4,256,681	425.67	4,256,681	425.67	17,661,982	1,773.56		
400	Structure – Technical systems	4,814,959	481.50	4,814,959	481.50	2,077,451	207.75	2,077,451	207.75	7,961,241	799.44		
	<b>BWK (300-400) Construction costs</b>	15,496,925	1,549.69	15,496,925	1,549.69	6,334,132	633.41	6,334,132	633.41	25,623,223	2,573.00		
500	External works and open spaces	2,237,319	223.73	2,237,319	223.73	0	0.00	0	0.00	4,439,126	445.76		
619	General furnishings / furniture, other	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00		
700	Incidental building costs	2,765,517	276.55	2,765,517	276.55	808,072	80.81	808,072	80.81	5,735,874	575.98		
	<b>GWK (200-700) Total construction costs</b>	22,401,943	2,240.19	22,401,943	2,240.19	7,142,204	714.22	7,142,204	714.22	39,572,392	3,973.73		

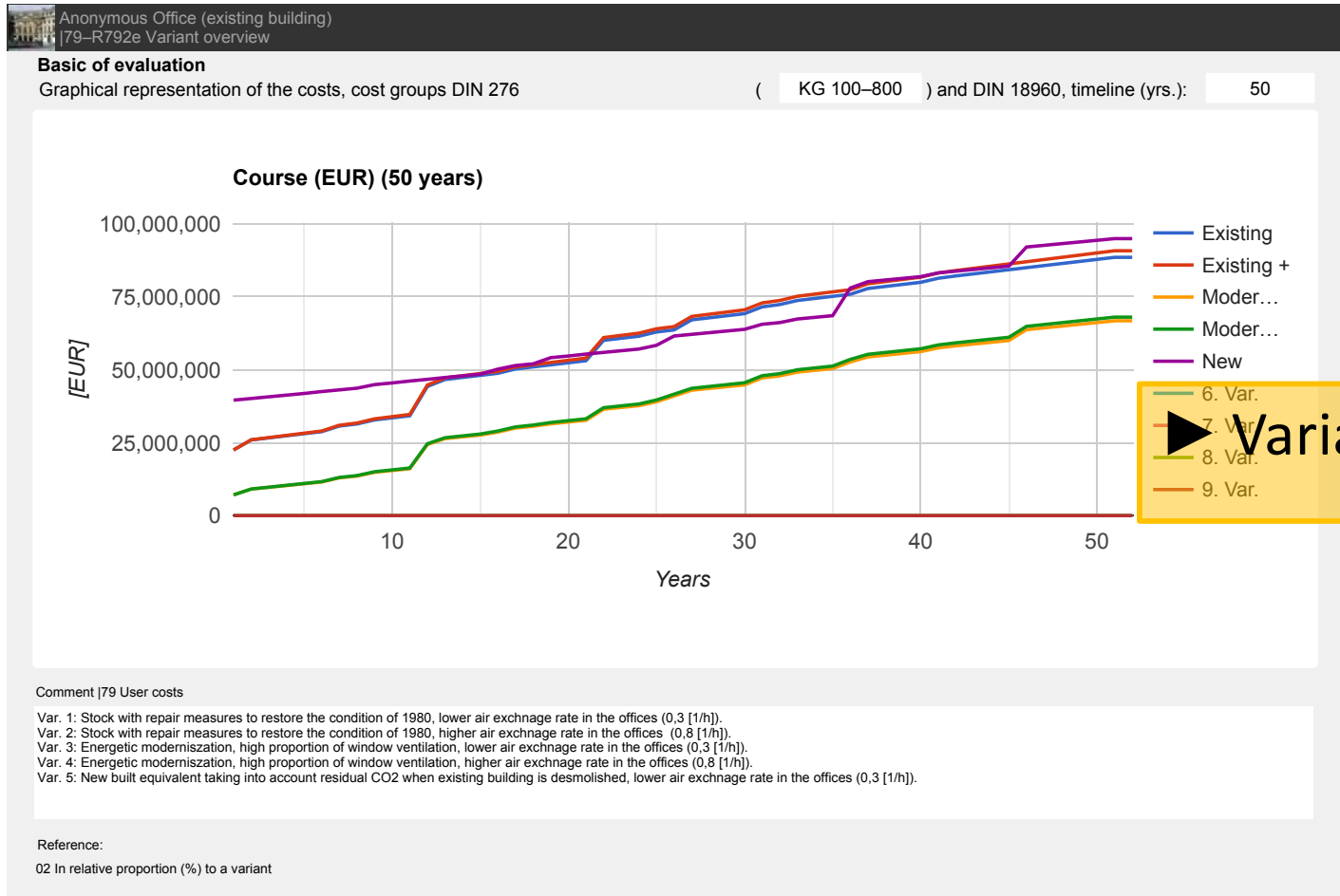
  

User costs of buildings (incl. tax.)		KG 100-800		02 Invest (Demand,  19)		02 Invest (Demand,  19)		02 Invest (Demand,  19)		02 Invest (Demand,  19)		04 Invest (New,  29)	
DIN 18960:2020-11 Cost group (CG)		[EUR / a]	... / [m <sup>2</sup> (BGF)]	[EUR / a]	... / [m <sup>2</sup> (BGF)]	[EUR / a]	... / [m <sup>2</sup> (BGF)]	[EUR / a]	... / [m <sup>2</sup> (BGF)]	[EUR / a]	... / [m <sup>2</sup> (BGF)]	[EUR / a]	... / [m <sup>2</sup> (BGF)]
100	Capital costs	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
200	Object management costs	114,748	11.47	114,748	11.47	111,148	11.11	111,148	11.11	100,830	10.13		
300	Operating costs	455,026	45.50	482,009	48.20	398,096	39.81	413,252	41.33	381,489	38.31		
400	Repair costs	676,762	67.68	676,762	67.68	649,672	64.97	649,672	64.97	597,716	60.02		
	<b>100-400 User costs of buildings</b>	1,246,536	124.65	1,273,519	127.35	1,158,916	115.89	1,174,072	117.41	1,080,036	108.45		

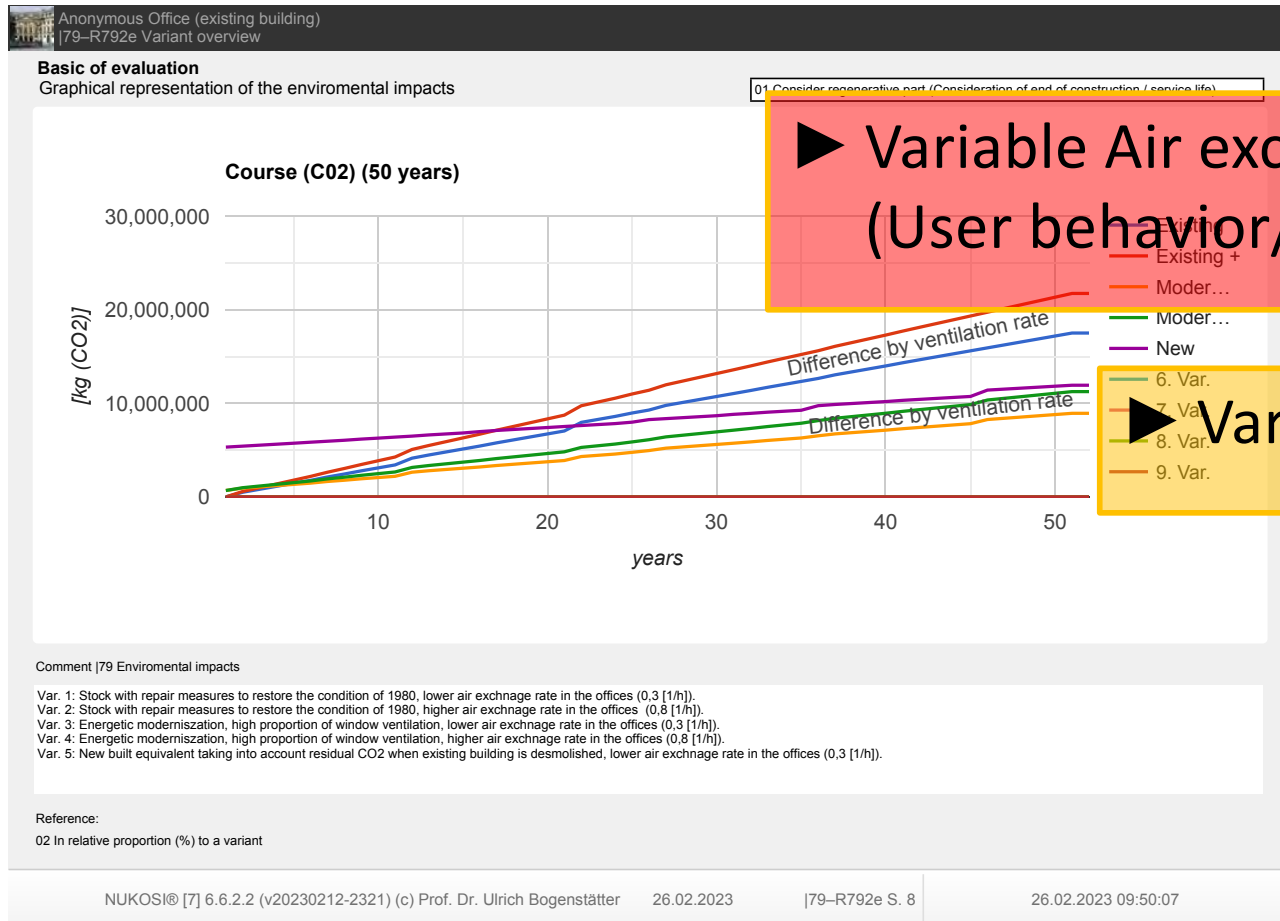
  

Environment impact		Starting balance [kg (CO <sub>2</sub> )]		3.431.995 [m <sup>2</sup> (BGF)]		3.431.995 [m <sup>2</sup> (BGF)]		3.431.995 [m <sup>2</sup> (BGF)]		3.431.995 [m <sup>2</sup> (BGF)]		5.319.110 [m <sup>2</sup> (BGF)]	
...	Energy consumption [kWh / a]	1.615.824	162	2.035.276	204	704.670	70	934.843	93	564.178	81		
...	CO <sub>2</sub> emission [kg (CO <sub>2</sub> ) 50a]	20.118.829	2.012	25.140.335	2.514	9.809.029	981	12.559.194	1.256	12.514.073	1.797		

# The economical solution



# The ecological solution



# Analysis (Var. 3 Modernisation)

## ▶ Variable Air exchange rate

<p><b>Var. 3</b></p> <p>Areas in building construction. Please refer to Var. 1.</p> <p>User cost of buildings. Standard: BWZ (Use of the building) 1300 (administrative building) Assumption: Only energetic measures for today's standard.</p> <p>User cost of buildings. Lower energy costs than Var. 1, Var. 2 and Var. 4, more expensive than Var. 5. User Cost Rank 3.</p> <p>Environmental impact. Unusually high energy consumption according to the energy performance certificate, can be much lower with lower air exchange rates with mechanical ventilation.</p> <p>Energy consumption Rank 1. CO2 emissions Rank 1.</p> <p><b>Total Mark 1,7</b></p>		<table border="1"> <tr> <td data-bbox="1464 304 1594 608"> <p><b>Var. 1</b></p> <p>Areas in building construction. Gross floor area (GFA) according to as-built plans. Construction floor area (KGF) is relatively low and not plausible.</p> <p>Standard: BWZ (Use of the building) 1300 (administrative building). Assumption: production of new building condition 1980.</p> <p>User cost of buildings. High energy costs, cheaper than Var. 2.</p> <p>Environmental impact. Unusually high energy consumption according to the energy performance certificate, may be lower with lower air exchange rates with window ventilation.</p> <p>CO2 emissions Rank 4.</p> <p><b>Total Mark 4</b></p> </td> <td data-bbox="1594 304 2119 608"> <p>▶ Energetic measures</p> </td> </tr> <tr> <td data-bbox="1464 608 1594 746"> <p><b>Var. 2</b></p> <p>Areas in building construction. Please refer to Var. 1.</p> <p>User cost of buildings. Highest energy costs of all variations.</p> </td> <td data-bbox="1594 608 2119 746"> <p>▶ Lower user costs</p> </td> </tr> <tr> <td data-bbox="1464 746 1594 895"> <p><b>Var. 3</b></p> <p>Areas in building construction. Please refer to Var. 1.</p> <p>User cost of buildings. Lower energy costs than Var. 1, Var. 2 and Var. 4, more expensive than Var. 5. User Cost Rank 3.</p> <p>Environmental impact. Unusually high energy consumption according to the energy performance certificate, can be much lower with lower air exchange rates with mechanical ventilation.</p> <p>Energy consumption Rank 1. CO2 emissions Rank 1.</p> <p><b>Total Mark 1,7</b></p> </td> <td data-bbox="1594 746 2119 895"> <p>▶ Lower energy consumption and CO2 emissions</p> </td> </tr> <tr> <td data-bbox="1464 895 1594 1284"> <p><b>Var. 4</b></p> <p>Areas in building construction. Please refer to Var. 1.</p> <p>Construction costs. Please refer to Var. 3.</p> </td> <td data-bbox="1594 895 2119 1284"></td> </tr> </table>	<p><b>Var. 1</b></p> <p>Areas in building construction. Gross floor area (GFA) according to as-built plans. Construction floor area (KGF) is relatively low and not plausible.</p> <p>Standard: BWZ (Use of the building) 1300 (administrative building). Assumption: production of new building condition 1980.</p> <p>User cost of buildings. High energy costs, cheaper than Var. 2.</p> <p>Environmental impact. Unusually high energy consumption according to the energy performance certificate, may be lower with lower air exchange rates with window ventilation.</p> <p>CO2 emissions Rank 4.</p> <p><b>Total Mark 4</b></p>	<p>▶ Energetic measures</p>	<p><b>Var. 2</b></p> <p>Areas in building construction. Please refer to Var. 1.</p> <p>User cost of buildings. Highest energy costs of all variations.</p>	<p>▶ Lower user costs</p>	<p><b>Var. 3</b></p> <p>Areas in building construction. Please refer to Var. 1.</p> <p>User cost of buildings. Lower energy costs than Var. 1, Var. 2 and Var. 4, more expensive than Var. 5. User Cost Rank 3.</p> <p>Environmental impact. Unusually high energy consumption according to the energy performance certificate, can be much lower with lower air exchange rates with mechanical ventilation.</p> <p>Energy consumption Rank 1. CO2 emissions Rank 1.</p> <p><b>Total Mark 1,7</b></p>	<p>▶ Lower energy consumption and CO2 emissions</p>	<p><b>Var. 4</b></p> <p>Areas in building construction. Please refer to Var. 1.</p> <p>Construction costs. Please refer to Var. 3.</p>	
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# Ranking of measures

► Investment

► Ranking

► Heating

► 1st choice

► Isolation  
ground floor  
plate

► 2nd choice

► facade

► 3rd choice

<i>Investment for energetic measures (solutions)</i>	<i>Ranking LCC and LCA per square meter</i>
<p>1. Modernization of the heating system. The calculation of the costs of the construction elements shows significant deviations from the BWZ 1300 and must be examined in more detail depending on the type of heating installation. The cost calculation for the building components of approx. EUR 82,610</p>	<p>1<sup>st</sup>: Renovation of the heating system Investment in the heating system is the most effective measure (kg (CO2) / EUR (investment)).</p>
<p>2. Isolation of the ground floor plate The cost calculation for the building components of approx. EUR 98,103</p>	<p>2<sup>nd</sup> : Isolation of the ground floor plate The options of isolation of the ceiling between the underground car park and offices should be investigated.</p>
<p>3. Installation of an air ventilation system Due to the importance of the air change rate, the concept must be examined in regard to a mechanical ventilation possibility or the influence of the use. The cost calculation for the building components of approx. EUR 358,315</p>	<p>Out of range: Air ventilation system is not installed yet, therefore possibilities has to be proven: The technical possibilities of installing an air ventilation system with heat recovery should be investigated for retrofit during operation.</p>
<p>1. Substitution of the windows The cost calculation for the building components of approx. EUR 916,000 is therefore in the range from an average to a higher technical standard.</p>	<p>4<sup>th</sup> : Renew of windows should be done under consideration if a mechanical ventilation concept.</p>
<p>2. Substitution of the façade The values tend to be too high due to the high proportion of window surfaces. The cost calculation for the building of approx. EUR 2,060,000 is therefore in the range of medium to higher technical standard.</p>	<p>3<sup>rd</sup> : Façade (more potential to save CO2)</p>

# Main findings

1. Benchmarks does not help.
2. Disassemble into component is needed.
3. Building data is bad, easy tools are needed in a early design phase.
4. We have enough data.
5. Ecology (LCA) and economy (LCC) are not incompatible opposites.
6. Simulation is needing to find the most important variables.
7. The basic of decisions for actions can be made quickly for a huge portfolio.

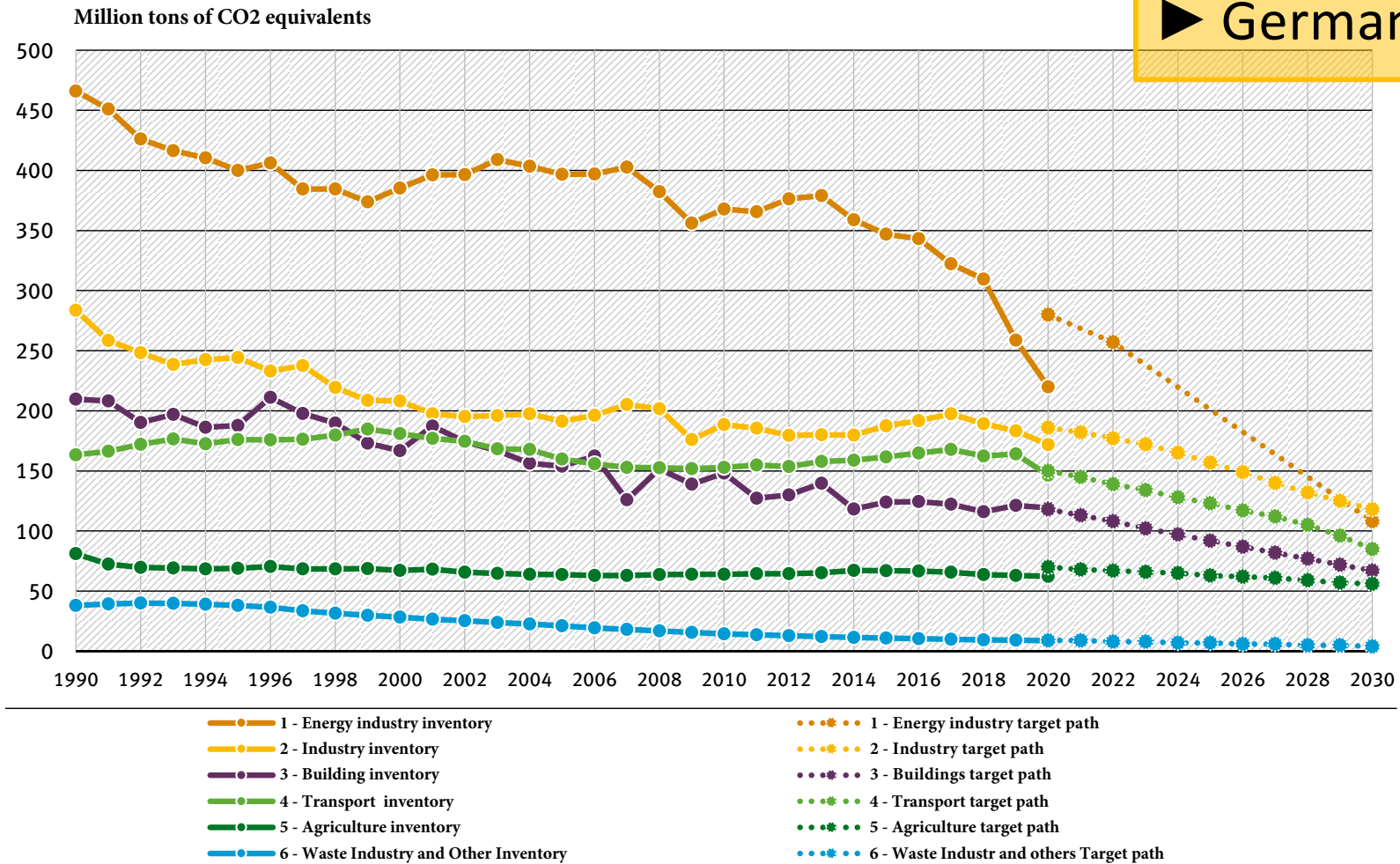
We can make the world a little bit better.

# Conclusion *and future works*

4

# Remember: that is the target

Development and target achievement of greenhouse gas emissions in Germany as defined by the sectors of the German Federal Climate Protection Act\*.

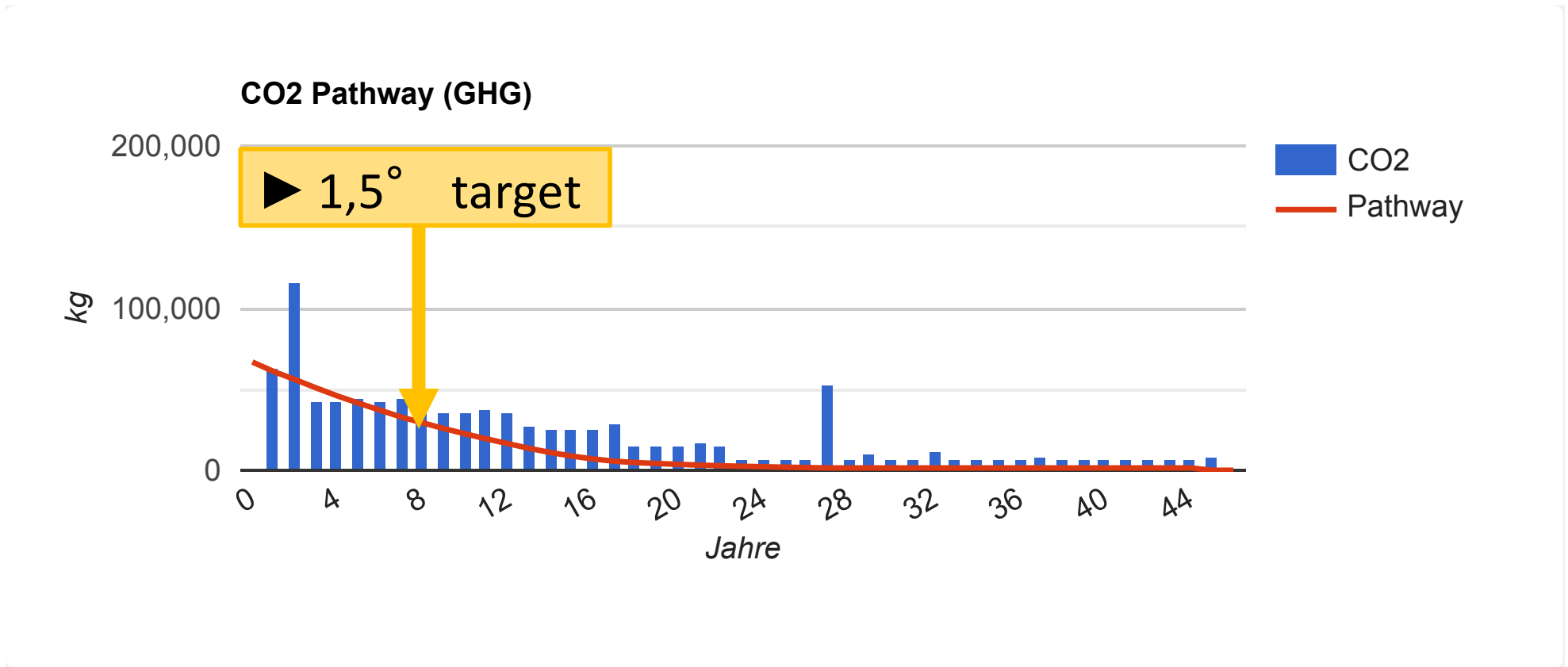


\* The breakdown of emissions differs from UN reporting, total emissions are identical

Source EM data 1990-2019: Federal Environment Agency, German Greenhouse Gas Inventory 1990-2019, final status as of 04/15/2021 Source previous year's estimate (VJS) for 2020: Federal Environment Agency, Press Release 07/2021, as of 03/15/2021 Source Targets 2020 & 2030: Amendment to the Federal KSG as of 05/12/2021.



# Path to the 1,5° target



# Automatic calculation



Quelle: [SCHÖNEICH, N. Capital 8-2012] Schöneich, Nicolas: Propellerazzi: Drohnen. Ein Smartphone, ein gutes Auge und eine ruhige Hand - mehr braucht es nicht mehr, um in den Klub der Hobbyspäter einzutreten, in: Capital; (2012), Nr. 8, S. 140.



# Questions?

Prof. Dr. ULRICH BOGENSTÄTTER

Dr. Rabih SLIM

London, 14.07.2023

[www.hs-mainz.de](http://www.hs-mainz.de), [www.ifbor.com](http://www.ifbor.com)