TECHNISCHE UNIVERSITÄT WIEN

Ecological and resilient constructions for multi-storey buildings

16.06.2023, Summer School in Vienna

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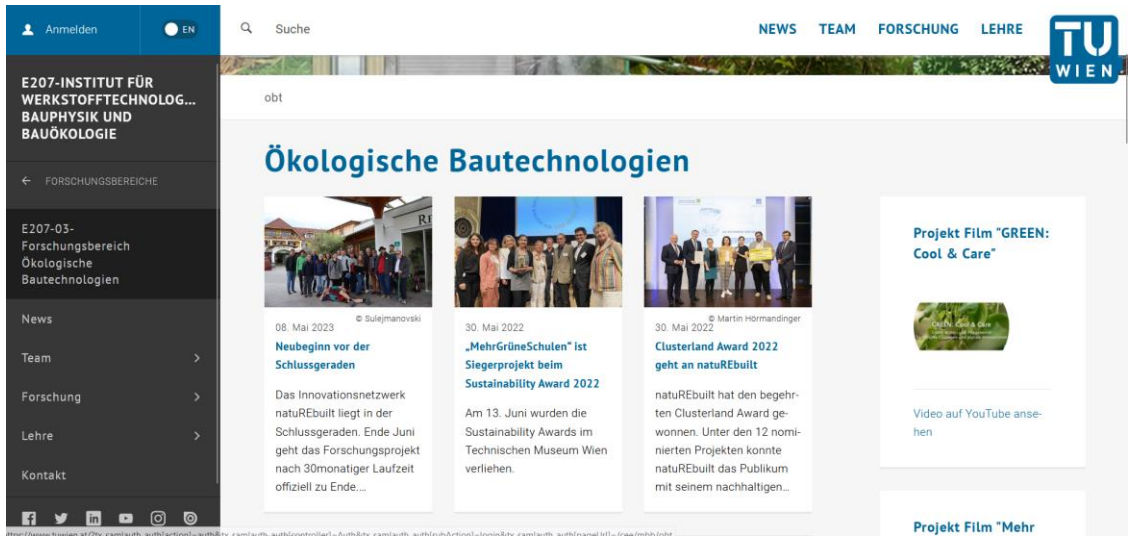
Research Unit „Ecological Building Technologies“

- Institute of Material Technology, Building Physics, and Building Ecology
- Faculty of Civil Engineering
- Head of Research Unit: Univ.Prof DI Dr. Azra Korjenic

Research Unit „Ecological Building Technologies“



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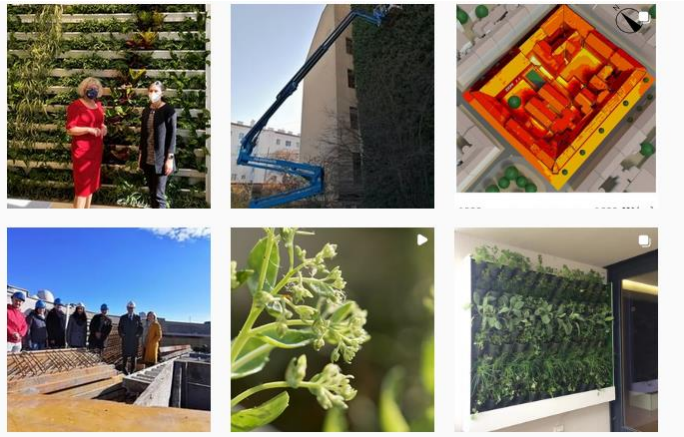
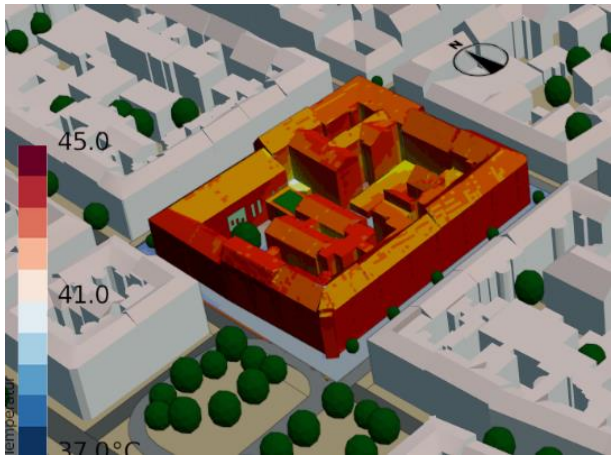


Research focuses

- Ecological building materials and constructions
- Building greening
- Smart and green cities

The aim is to increase the market share of ecological constructions - through reliable, scientifically based information



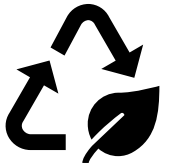
Goals

Interface between building physics and ecological technologies;

1. Health, Comfort

- Hygrothermal comfort
- Moisture protection, protection against mold, insects, ...
- Thermal insulation or protection against summer overheating

2. Resource efficiency, environmental protection



- Regional, recycable and renewable building materials
- considering the entire life cycle

Introduction to the topic

Building ecology

- **Ecology:**

Ancient Greek “oikos”: house, household; “logos”: study of

The study of the relationship between living organisms, including humans, and their physical environment (Wikipedia)

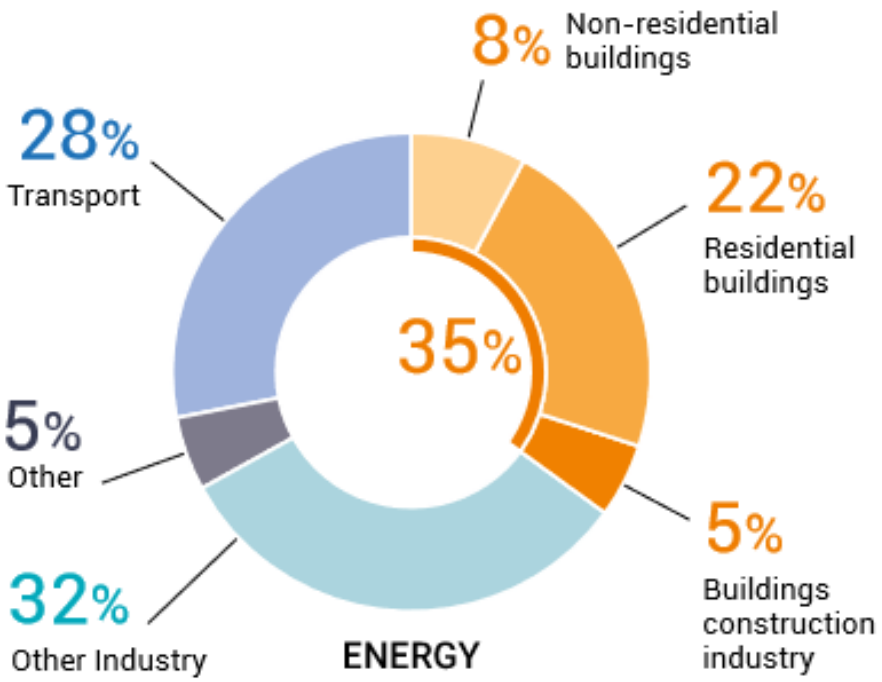
- **Sustainability:**

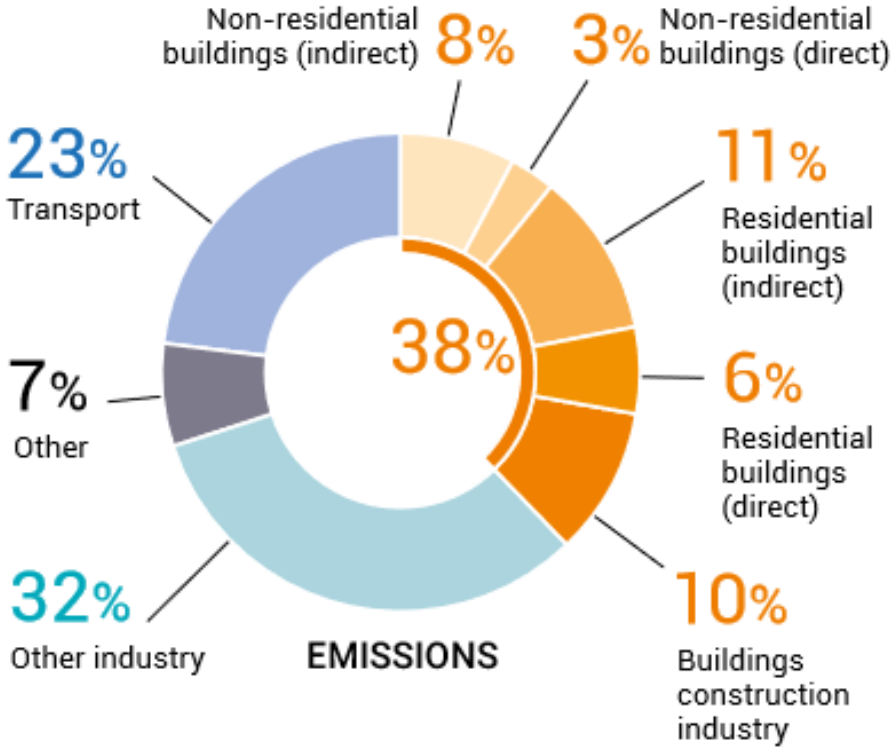
meeting the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland)

- **Building ecology:**

special attention is paid to ecological aspects in the design and construction of buildings

Global share of buildings and construction final energy and emissions (2019)

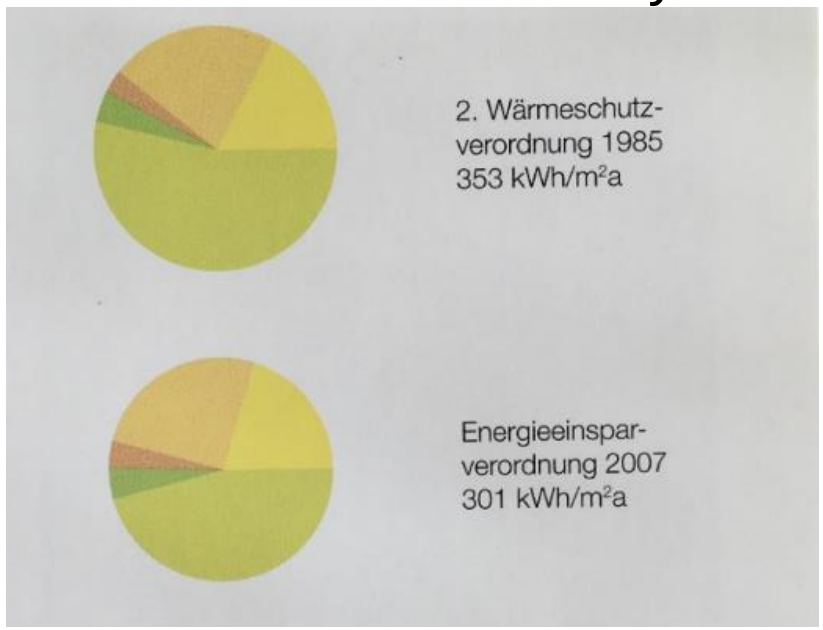


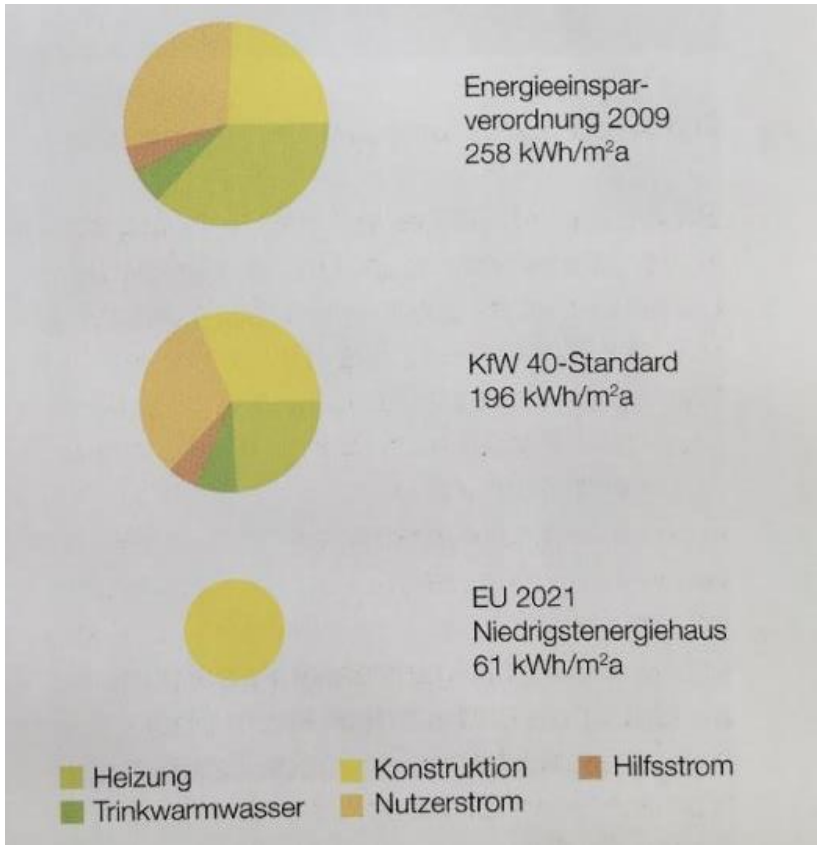


Source: 2020 Global Status Report for buildings and construction. United Nations Environment Programme,2020. https://globalabc.org/sites/default/files/inline-files/2020%20Buildings%20GSR_FULL%20REPORT.pdf (May 2022)

Primary energy demand

Development of primary energy demand of residential buildings and its allocation to different uses in Germany

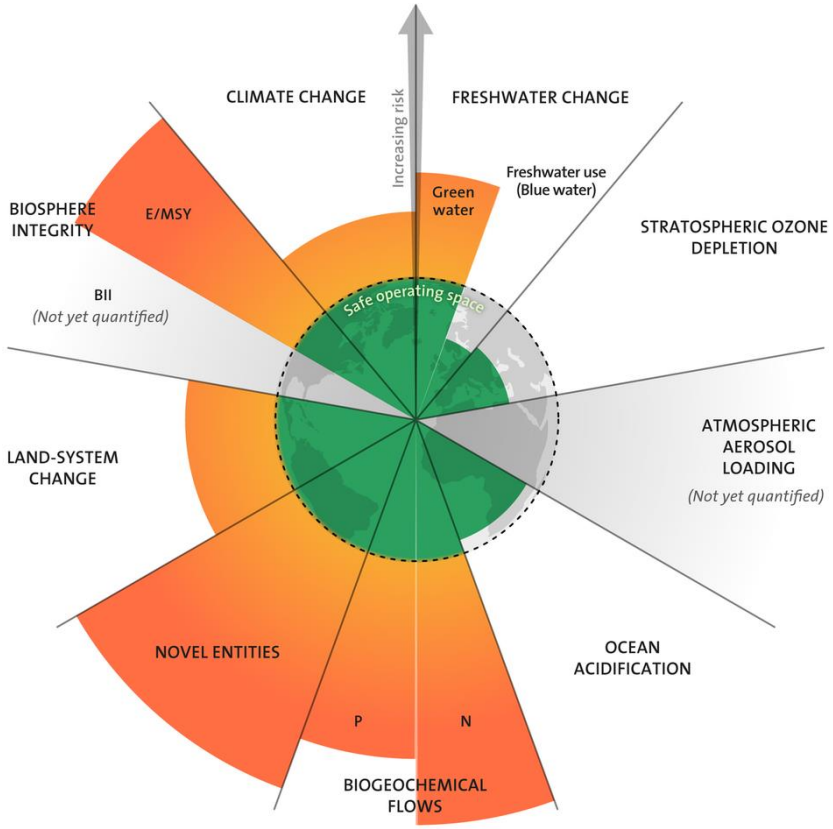




SOURCE: KHOULI, S. ET AL: NACHHALTIG KONSTRUIEREN: VOM TRAGWERKSENTWURF BIS ZUR MATERIALWAHL – GEBÄUDE ÖKOLOGISCH BILANZIEREN UND OPTIMIEREN (DETAIL GREEN BOOKS), 2014

Planetary boundaries

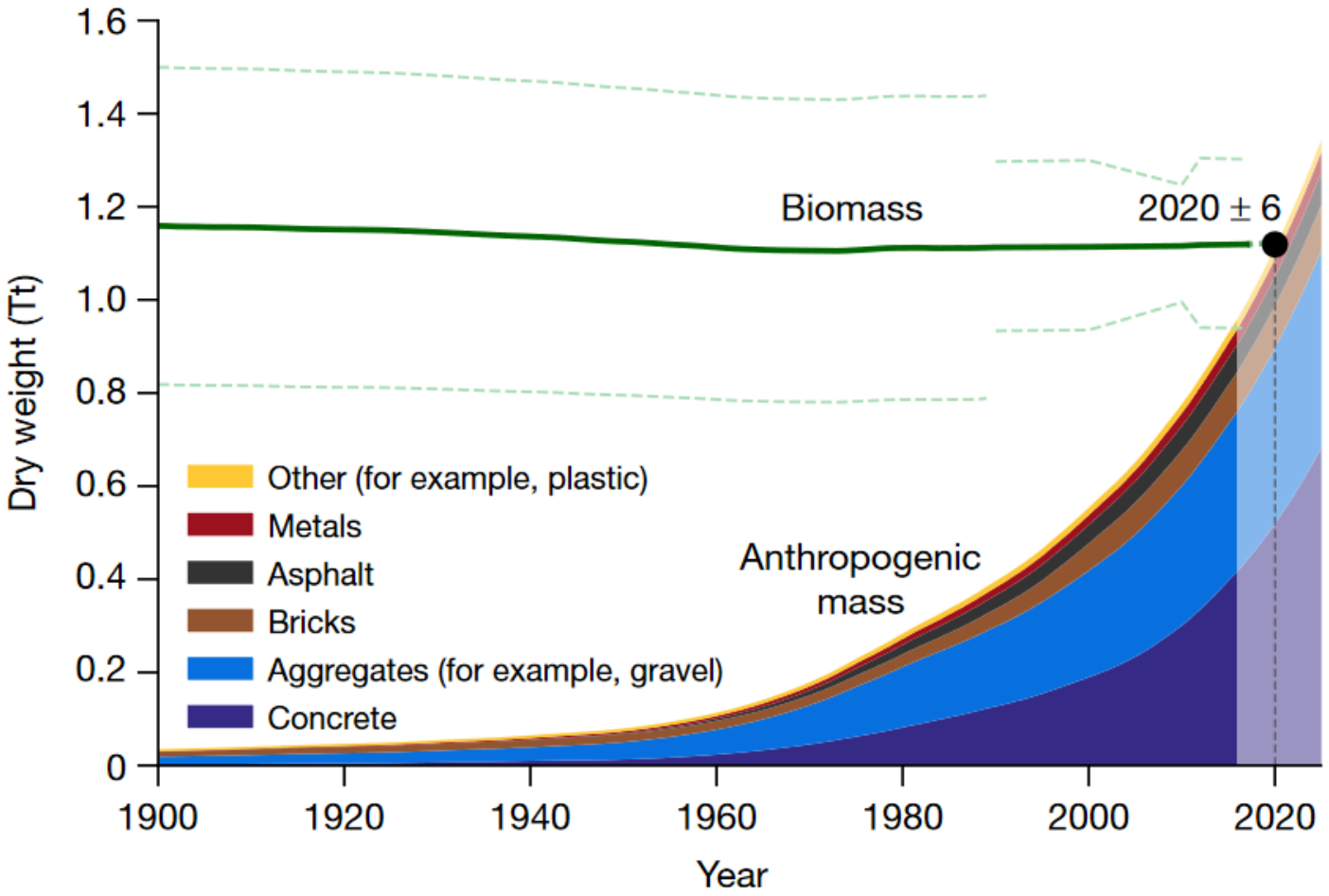
- A framework to describe limits to the impacts of human activities
- Beyond these limits: environment may not be able to self regulate anymore



Use of resources

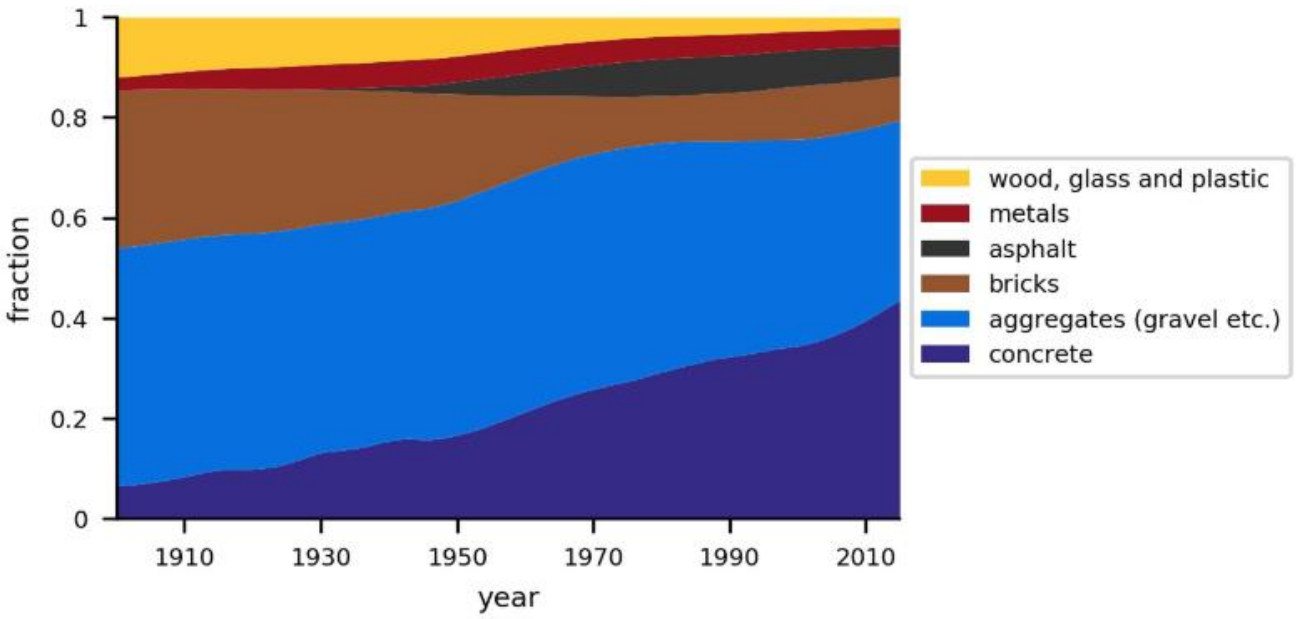
- 80% of all man-made things are made of concrete and mixed building materials
- 15 % consist of brick and asphalt
- 3 % consist of metal products
- 0,7 % of all man-made things are made of plastics

One of the most important trade raw material in the world: sand



SOURCE: EMILY ELHACHAM, LIAD BEN-URI, JONATHAN GROZOVSKI, YINON M. BAR-ON & RON MILO: GLOBAL HUMAN-MADE MASS EXCEEDS ALL LIVING BIOMASS. NATURE VOL. 588, 2020.

Use of resources



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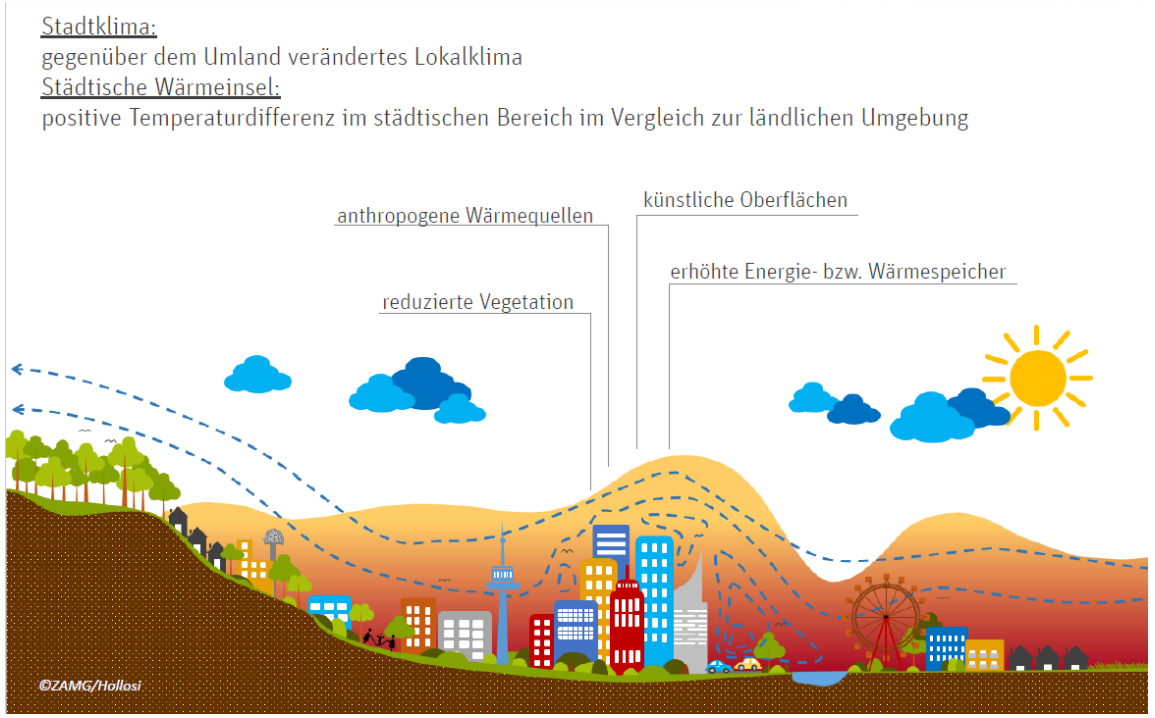
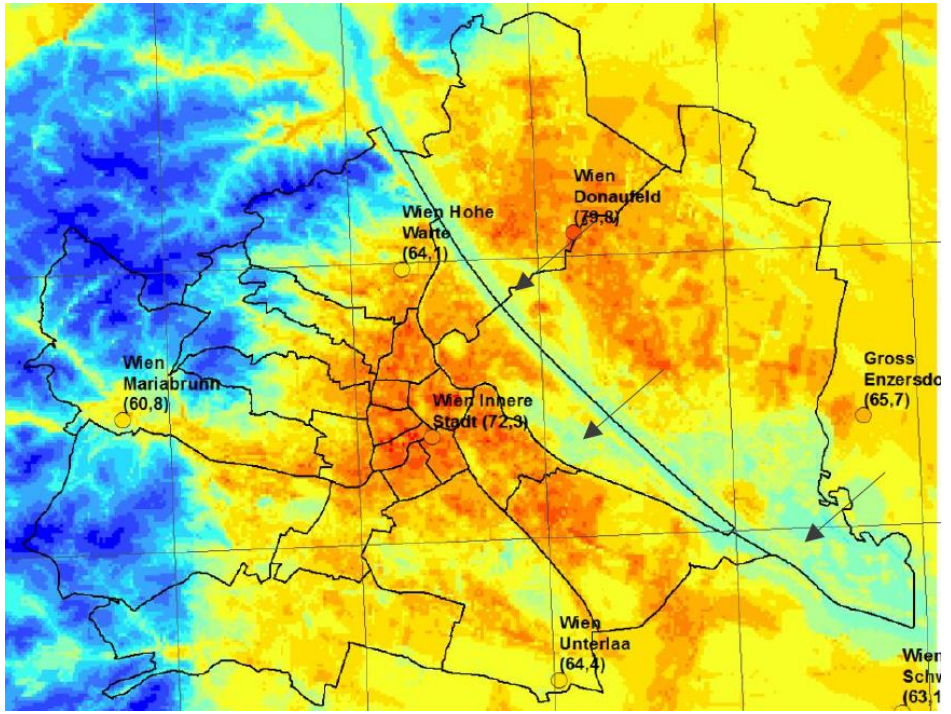
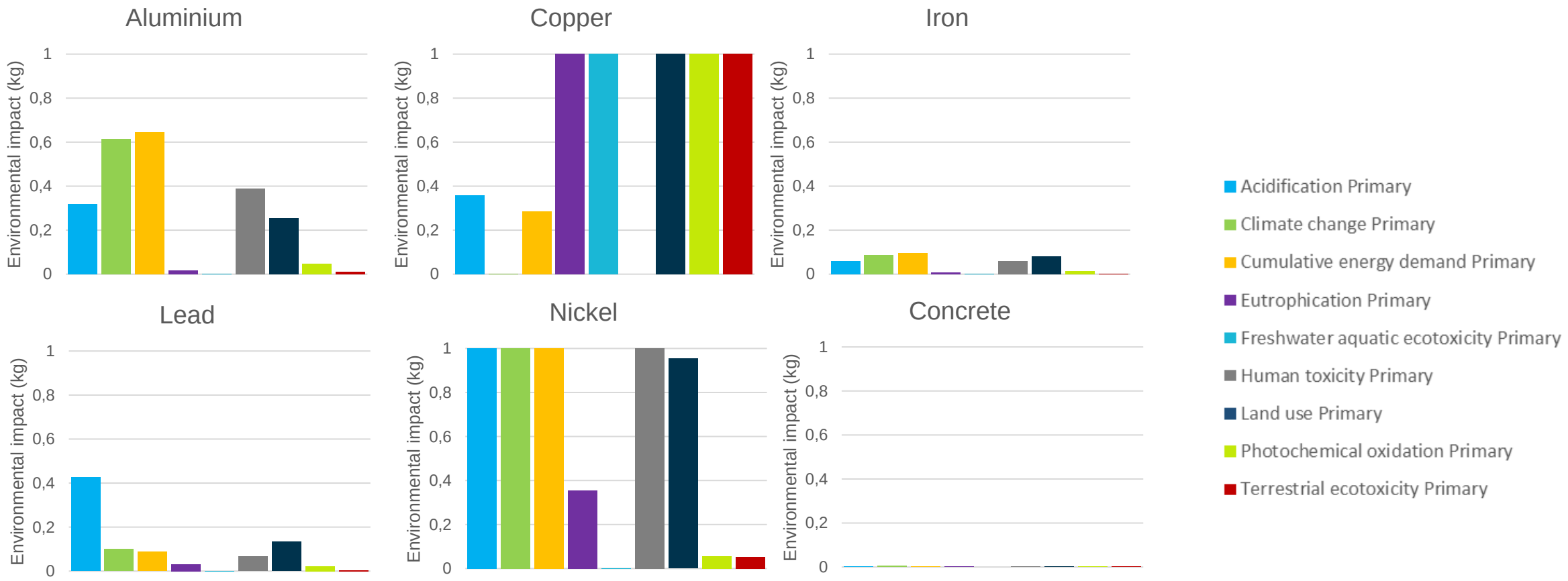
UHI Effect (Urban Heat Island)



SOURCE: ZAMG

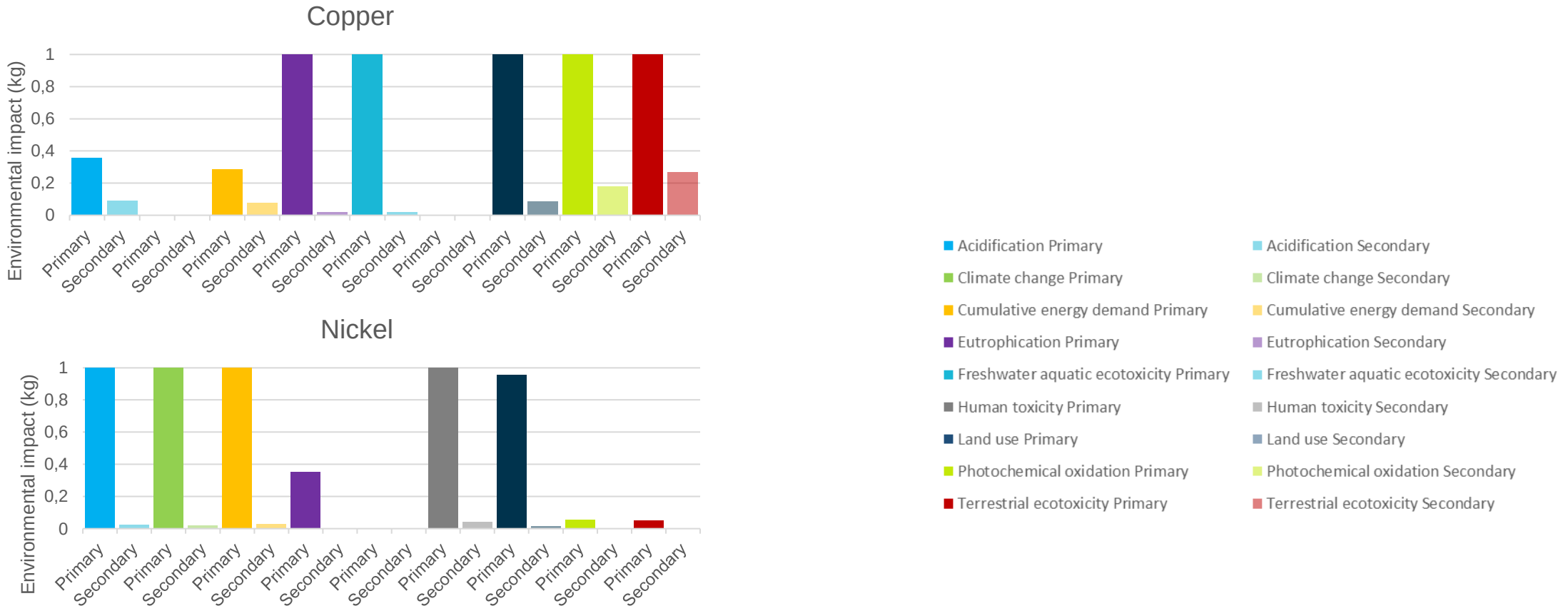


Environmental impact per kg per raw material



SOURCE: AUTHORS OWN GRAPH. DATA FROM: GLOBAL MATERIAL RESOURCES OUTLOOK TO 2060: ECONOMIC DRIVERS AND ENVIRONMENTAL CONSEQUENCES. OECD, 2019. HTTPS://READ.OECD-ILIBRARY.ORG/ENVIRONMENT/GLOBAL-MATERIAL-RESOURCES-OUTLOOK-TO-2060_9789264307452-EN#PAGE192 (MAY 2022)

Environmental impacts of secondary use



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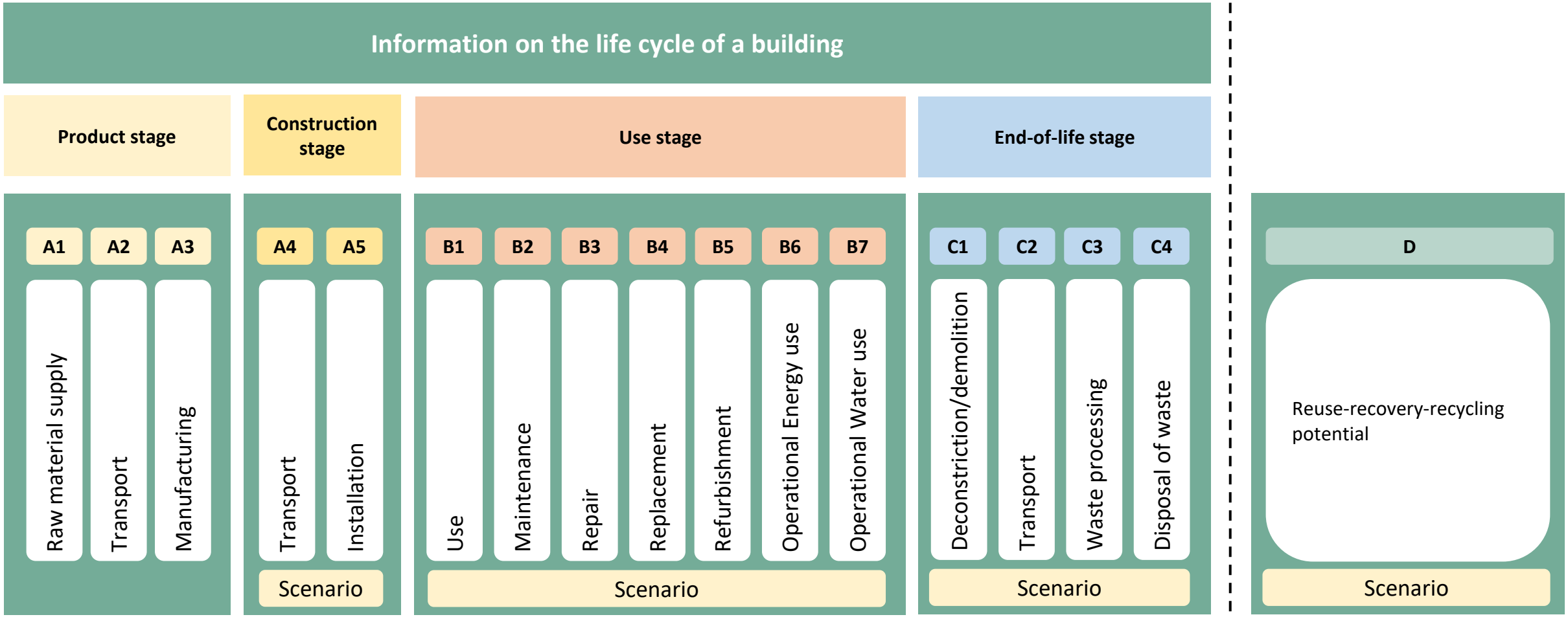
Ecological evaluation of building components

- Different stages (production, use, disposal, ..)
- Different indicators
- Main indicators:
  - GWP: Global Warming Potential (GHG)
  - PENRT: Primary energy non renewable, total
  - PERT: Primary energy renewable, total
  - AP: Acidification potential
  - EP: Eutrophication potential
  - POCP: Photochemical ozone creation potential
- Database is crucial

Ecological Evaluation



Sustainability and Ecology in the building industry

- Approx. 40% of CO_2 emissions are caused by the construction industry
- Approx. 36% of the total energy consumption is used for our buildings.
- Approx. 50% of waste is generated by the construction industry
- The average useful life of a house in the EU is 30-50 years

The construction industry is one of the main contributors to the enormous consumption of resources and energy !

Ecological building materials

Straw

Wood fiber

Sheep wool

perlite

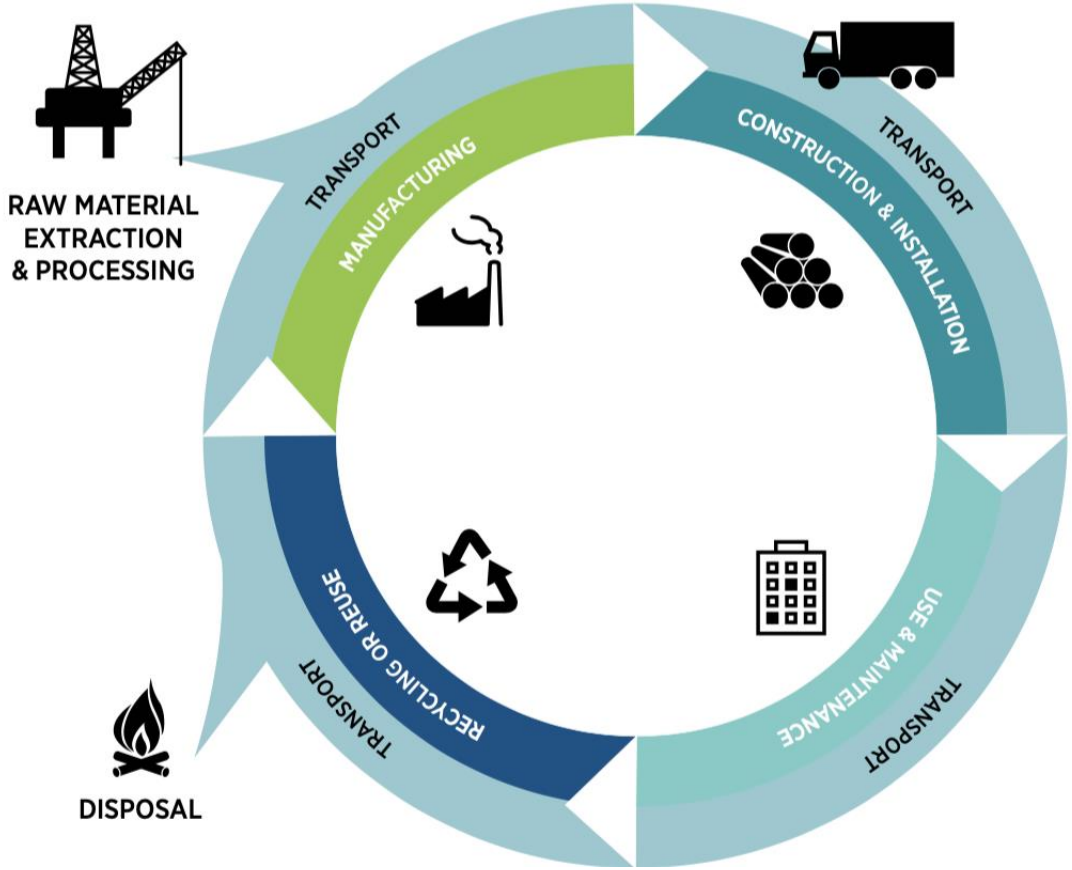
Clay board

Glass foam granulate

Ecological building materials

Ecological characteristics:

- No (minimal) finite / fossil base building materials. -> Renewable or already recycled materials
- Low energy demand (from renewable sources) in production
- Low transport distances/ regional
- No harmful substances in the whole life cycle
- Recyclability / return to nature



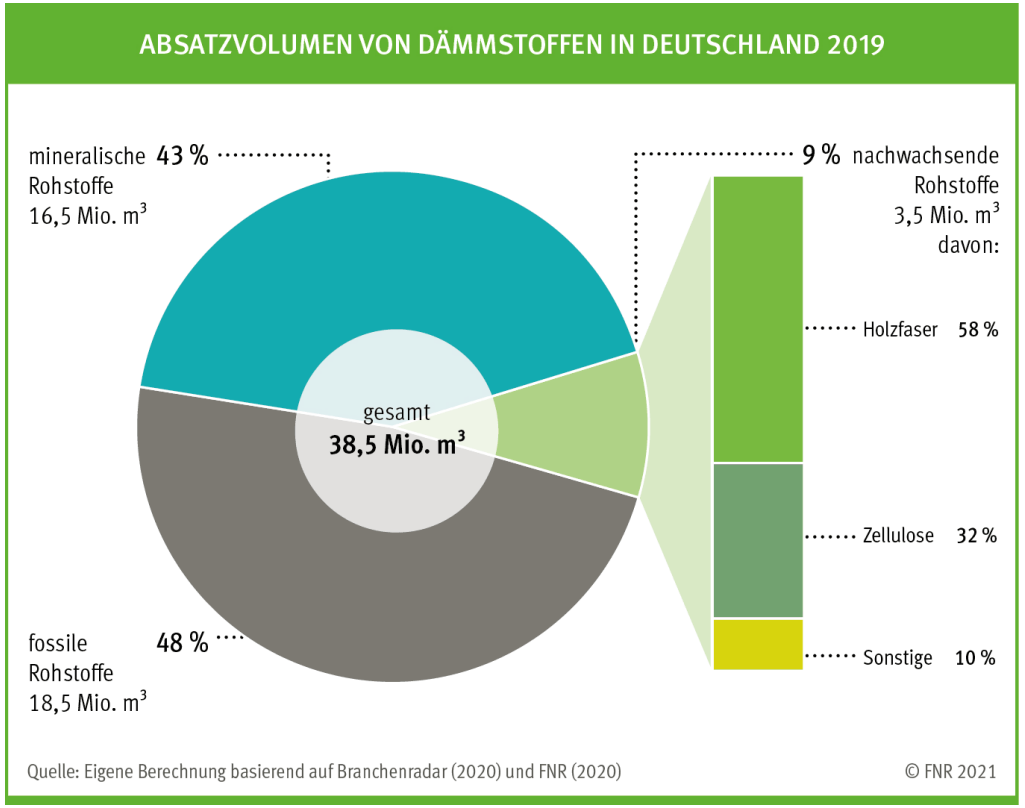
SOURCE OF PICTURE: HTTPS://BIOFILICO.COM/NEWS/HEALTHY-MATERIALS-BUILDING-INTERIORS-LIFE-CYCLE; (JUNE 2022)

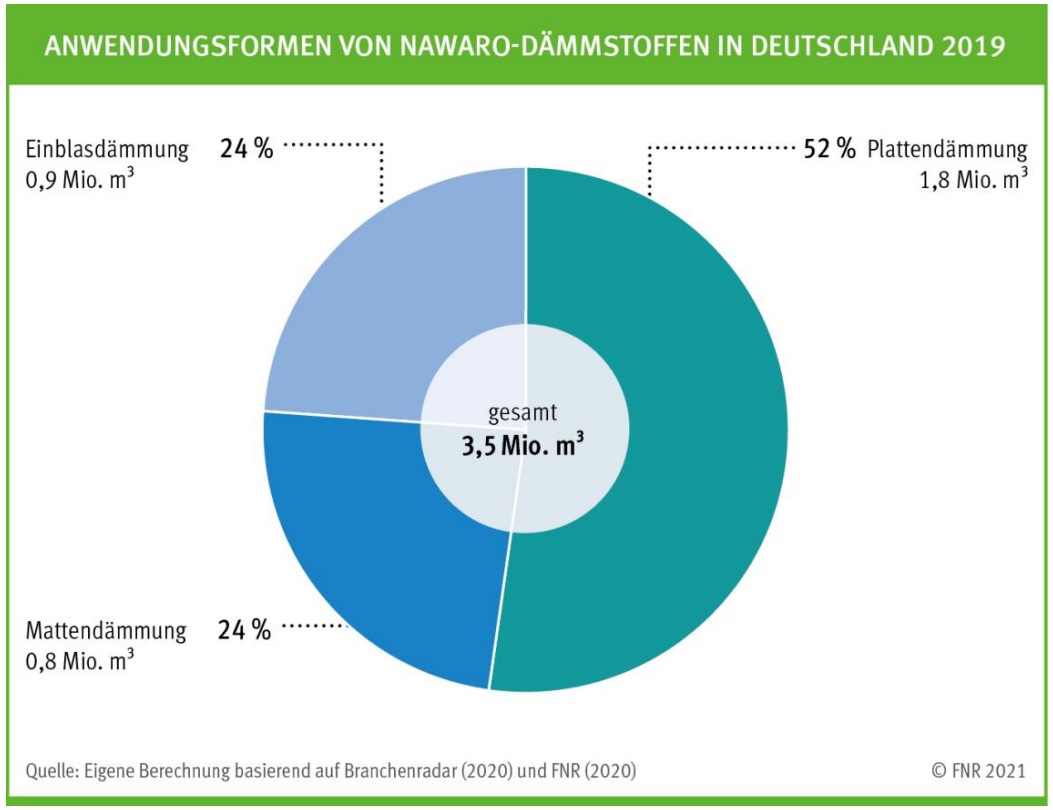
Building materials made of renewable raw materials

- High moisture absorption - can be beneficial in unfavorable moisture conditions.
- Partially higher heat storage capacity - can help against summer overheating
- Sheep wool binds pollutants
- Controllable fire behavior

SOURCE: HTTPS://FNR.DE/MARKTANALYSE/MARKTANALYSE.PDF (MAY 2022)

Insulation made of bio-based materials



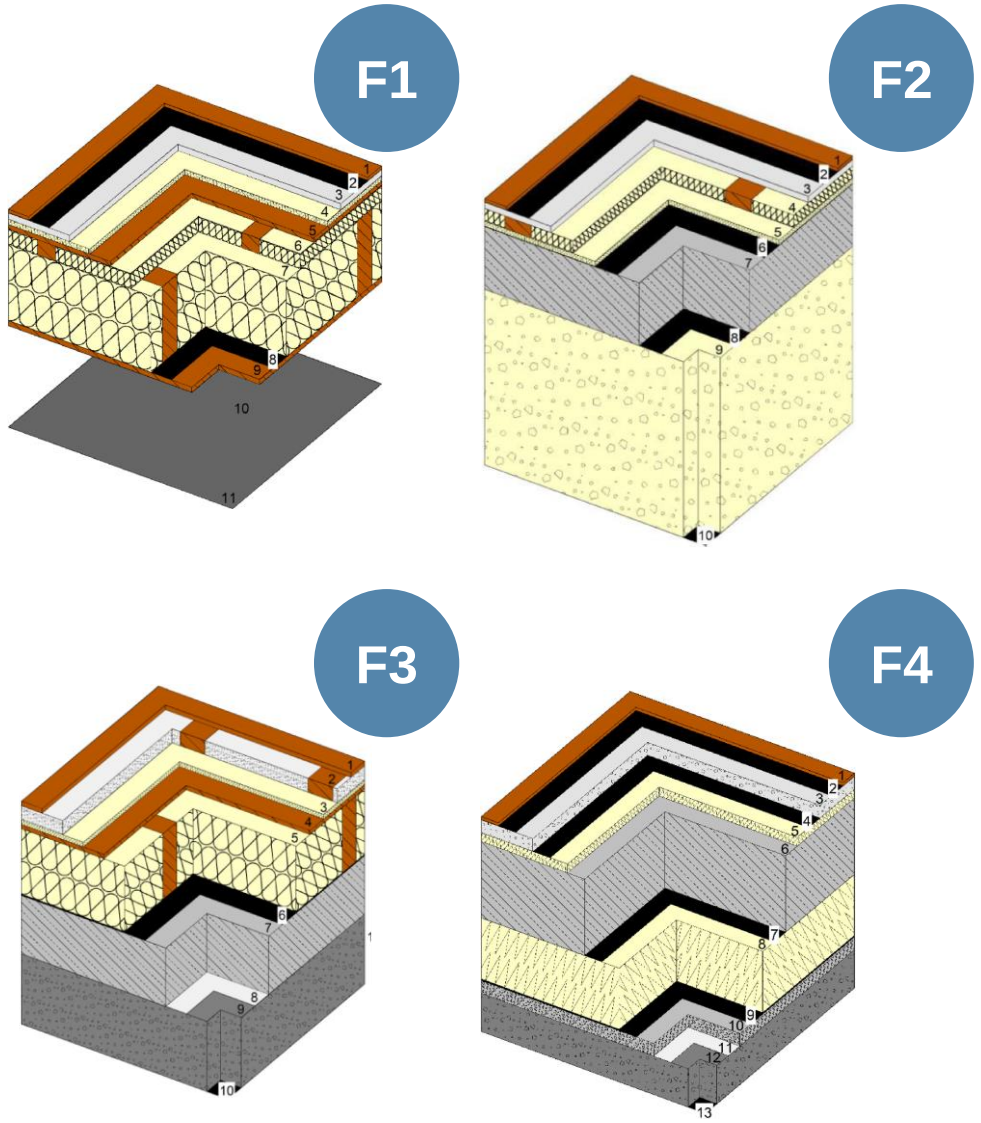


SOURCE: HTTPS://FNR.DE/MARKTANALYSE/MARKTANALYSE.PDF (MAY 2022)

Projects: Life cycle assement of different floor constructions

Ground floor constructions

- **F1:** „ventilated floor with screw foundations, 2 versions: Cement-bound panel or wooden panel
- **F2:** Reinforced concrete slab with glass foam granulate; 2 versions: Normal concrete with EPDM or waterproof concrete
- **F3:** Ecological interior insulation with strip foundations
- **F4:** Standard construction with reinforced concrete slab and XPS



QUELLE: FISCHER ET AL: ECOLOGICAL COMPARISON OF HYGROTHERMALLY SAFE FLOOR CONSTRUCTIONS BASED ON RENEWABLE RAW MATERIALS FOR MULTI-STOREY BUILDINGS. JOURNAL OF BUILDING ENGINEERING 57, 104899. 2022.

Ground floor constructions

- Different foundations:
  - Screw foundations
  - Strip foundations
  - Slab foundation

Screw foundations

- Point foundations for up to three-storey buildings in timber and steel construction.
- With support grid they also function as strip foundations
- Size: 50 to 300 cm, maximum load capacity at 10t per screw foundation
- Ecological advantages: Ecosystem in the soil is only minimally disturbed

QUELLE: HILLEBRANDT ET AL: ATLAS RECYCLING. GEBÄUDE ALS MATERIALRESSOURCE. DETAIL ATLAS, 2018.

Ecological evaluation

- Various databases: :
  - baubook (ecoinvent, production phase)
  - Ökobaudat (GaBi, all phases)

- Calculation methods
  - GWP – ökobaudat
  - Ökoindex OI3 - baubook
  - Disposal indicator - baubook
  - All existing indicators – ökobaudat – own representation

Oekoindex 3 – OI3

- Includes the indicators GWP, AP, PENRT
- Used in Building certifications such as klimaaktiv, TQB, ...
- Sometimes linked to housing subsidies
- $\Delta OI3 = 1/3\ OI_{GWP} + 1/3\ OI_{AP} + 1/3\ OI_{PENRT}$

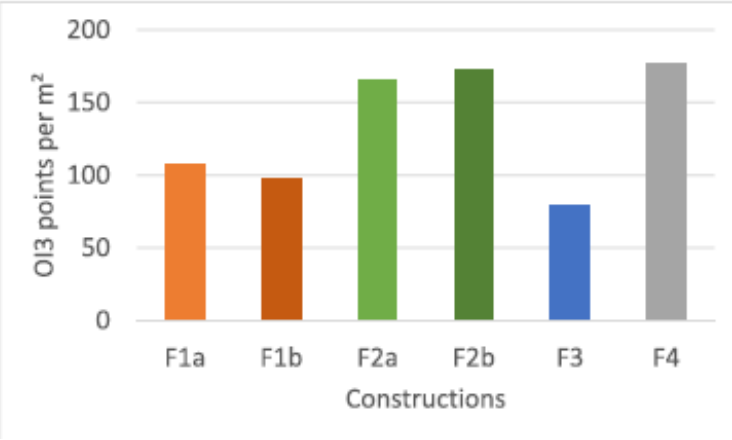
HTTPS://WWW.IBO.AT/MATERIALOEKOLOGIE/LEBENSZYKLUSANALYSEN/OEKOINDEX OI3/

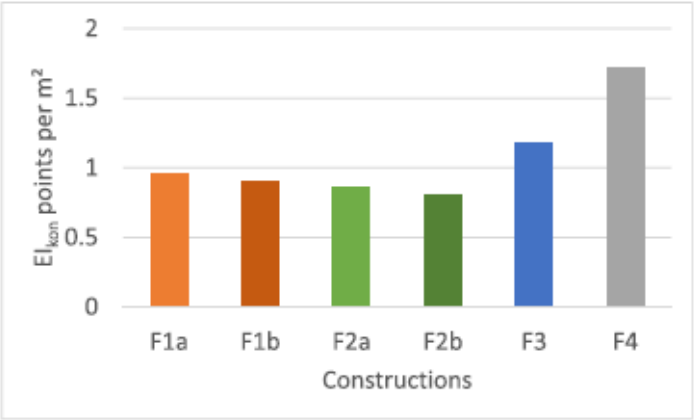
Ecological evaluation

GWP; Module A,C,D

- F1 with wooden panel

Ecological evaluation





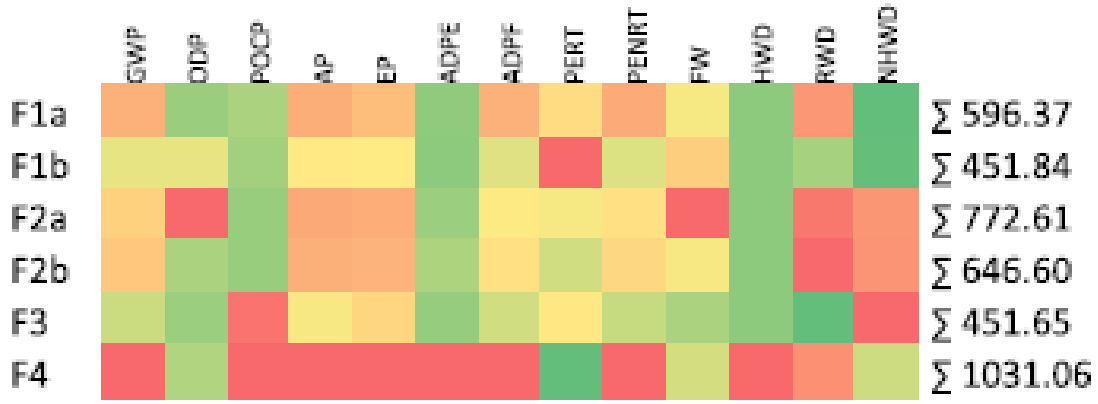
OI3; Module A

- F3

Disposal Indicator

- F2b

Ecological evaluation



All existing indicators and modules (A,B,C,D)

- F1 with wooden panel and F3 nearly equivalent

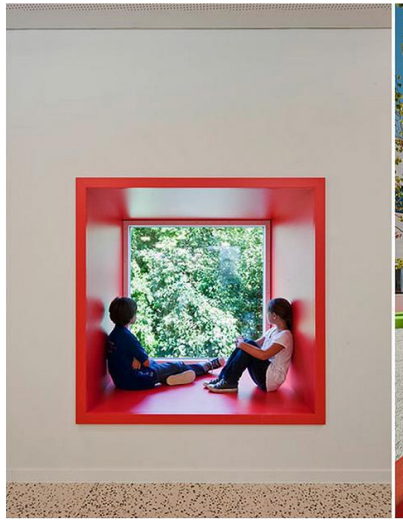
Conclusion

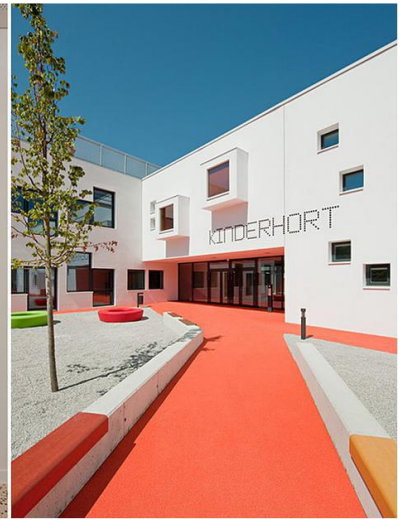
- Different results depending on indicator choice and system boundaries
- If only the GWP is considered, 82% per m² can be saved by the choice of floor construction;
- if several indicators are considered, approx. 50% can be saved
- All variants are strongly influenced by the choice of foundation

Projects: Carbon footprint of a whole building

LCA

- Study: Ecological building components, FH Campus Wien
- Comparison of a wooden and a hybrid building
- Architects: MAGK Architects
- HdL: fully ecological; Mia: hybrid construction method
- Indicator: Global Warming Potential, framework of study: Production



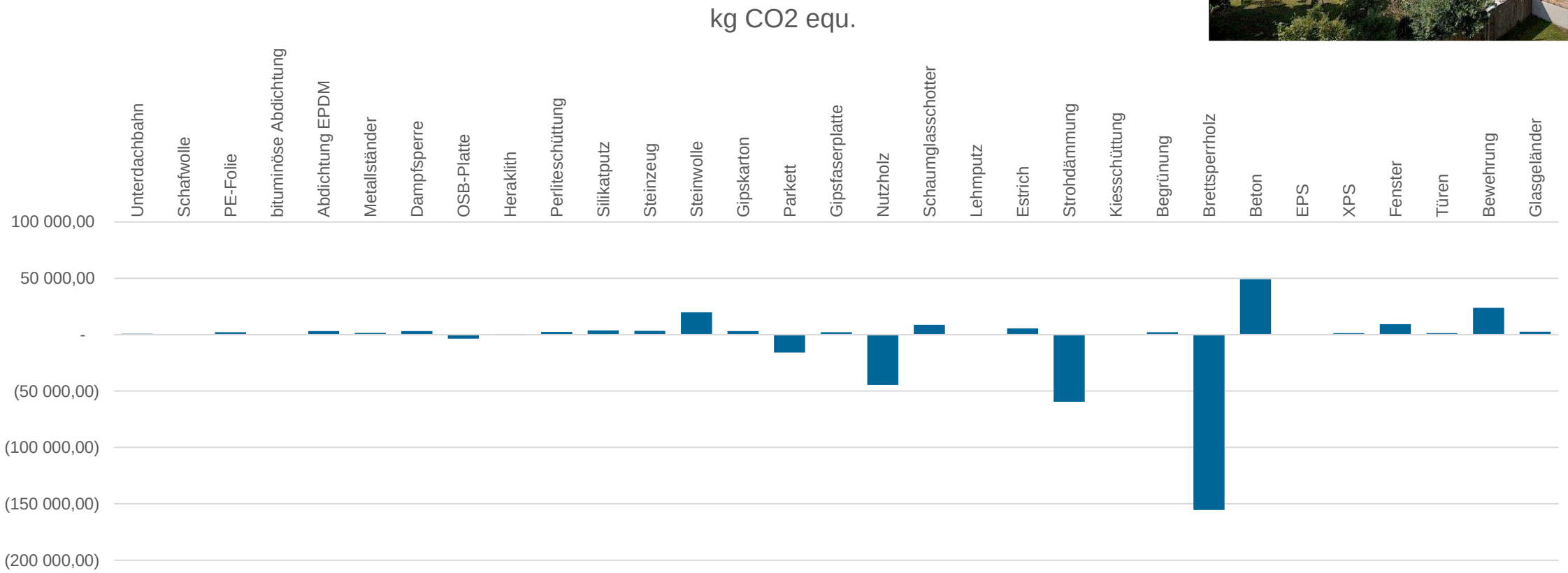


House of Learning



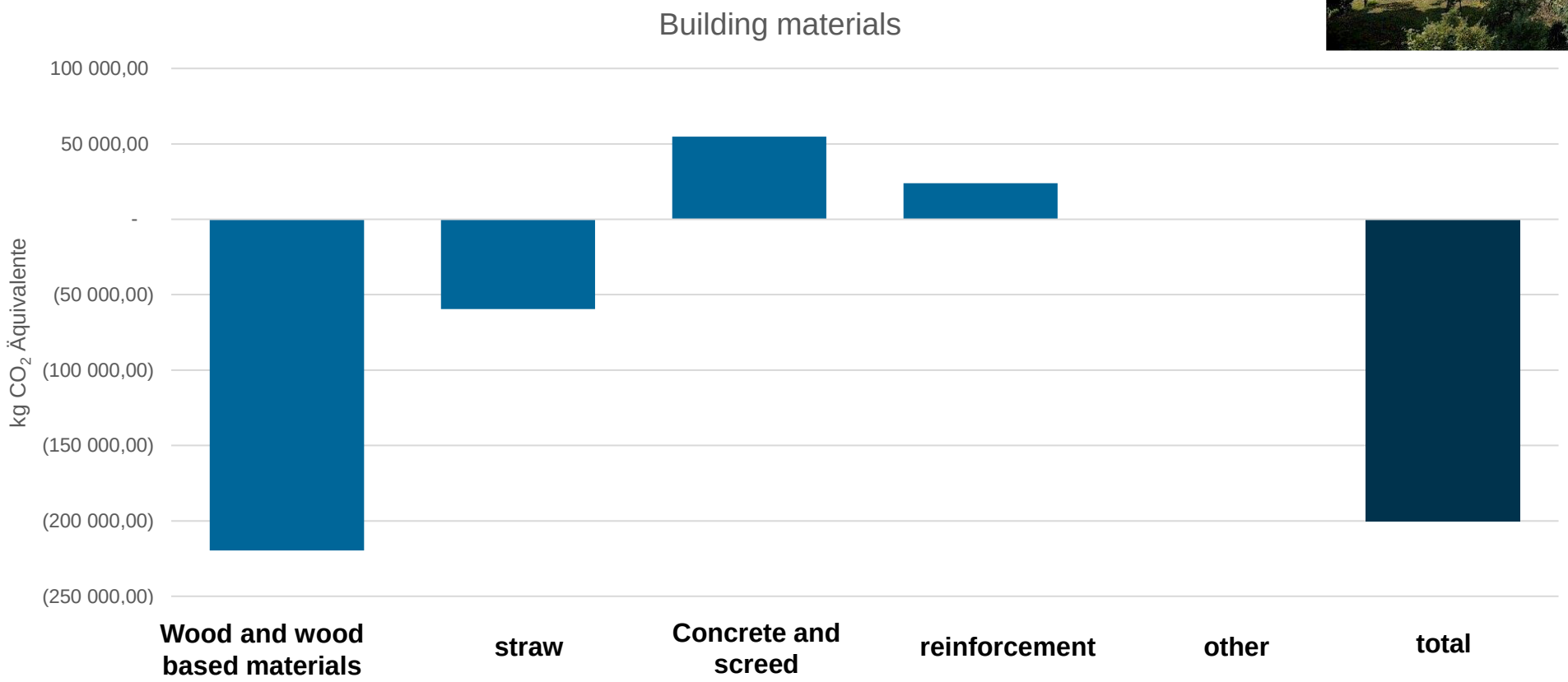

HTTPS://WWW.MAGK.AT/HDL

Global Warming Potential HDL



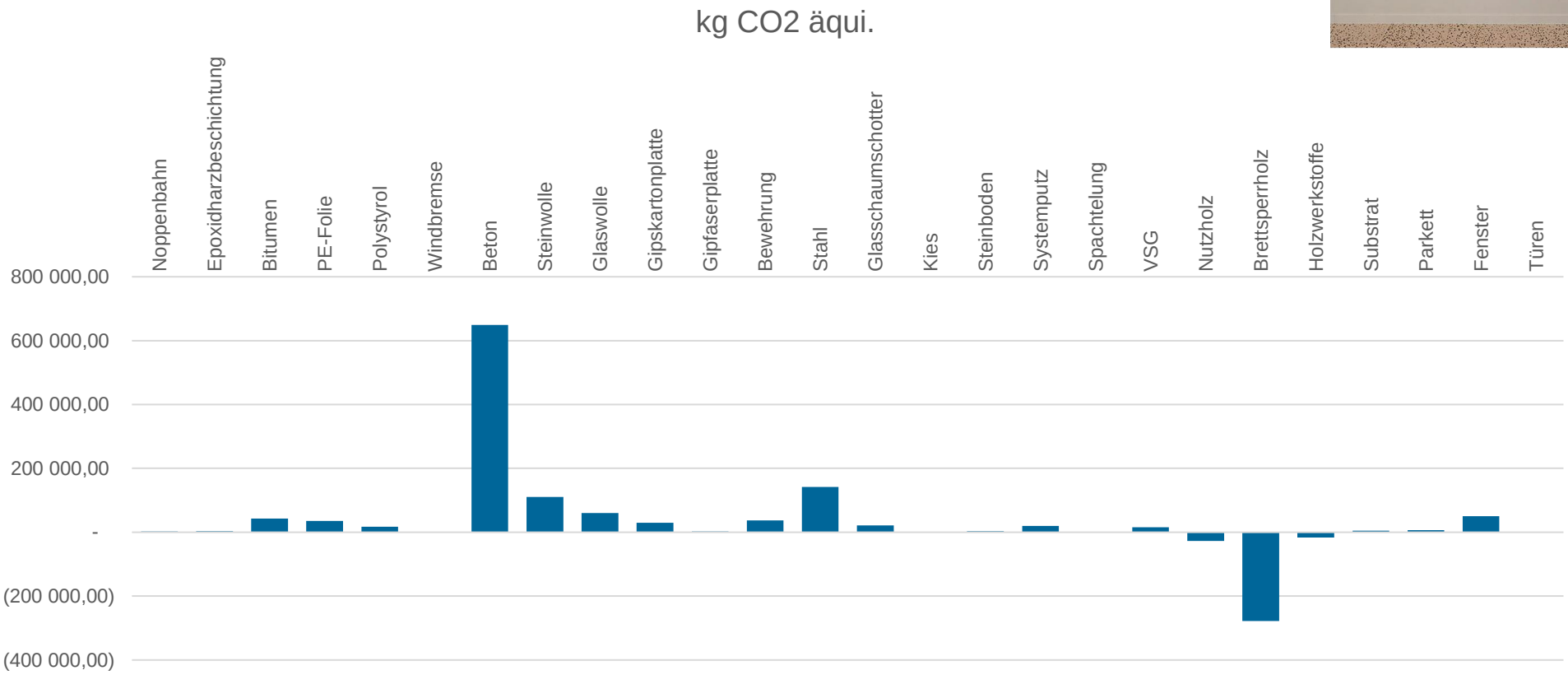
SOURCE: FISCHER, H.: ÖKOLOGISCHE BAUTEILAUFBAUTEN. ENDBERICHT, HOCHSCHULJUBILÄUMSSTIFTUNG STADT WIEN. 2019

Global Warming Potential HDL



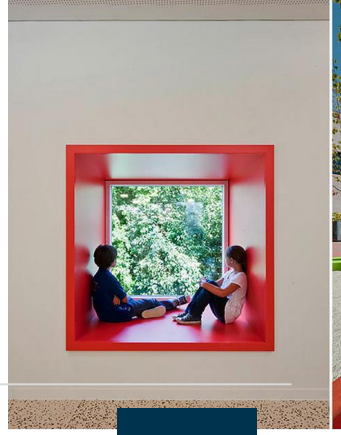
SOURCE: FISCHER, H.: ÖKOLOGISCHE BAUTEILAUFBAUTEN. ENDBERICHT, HOCHSCHULJUBILÄUMSSTIFTUNG STADT WIEN. 2019

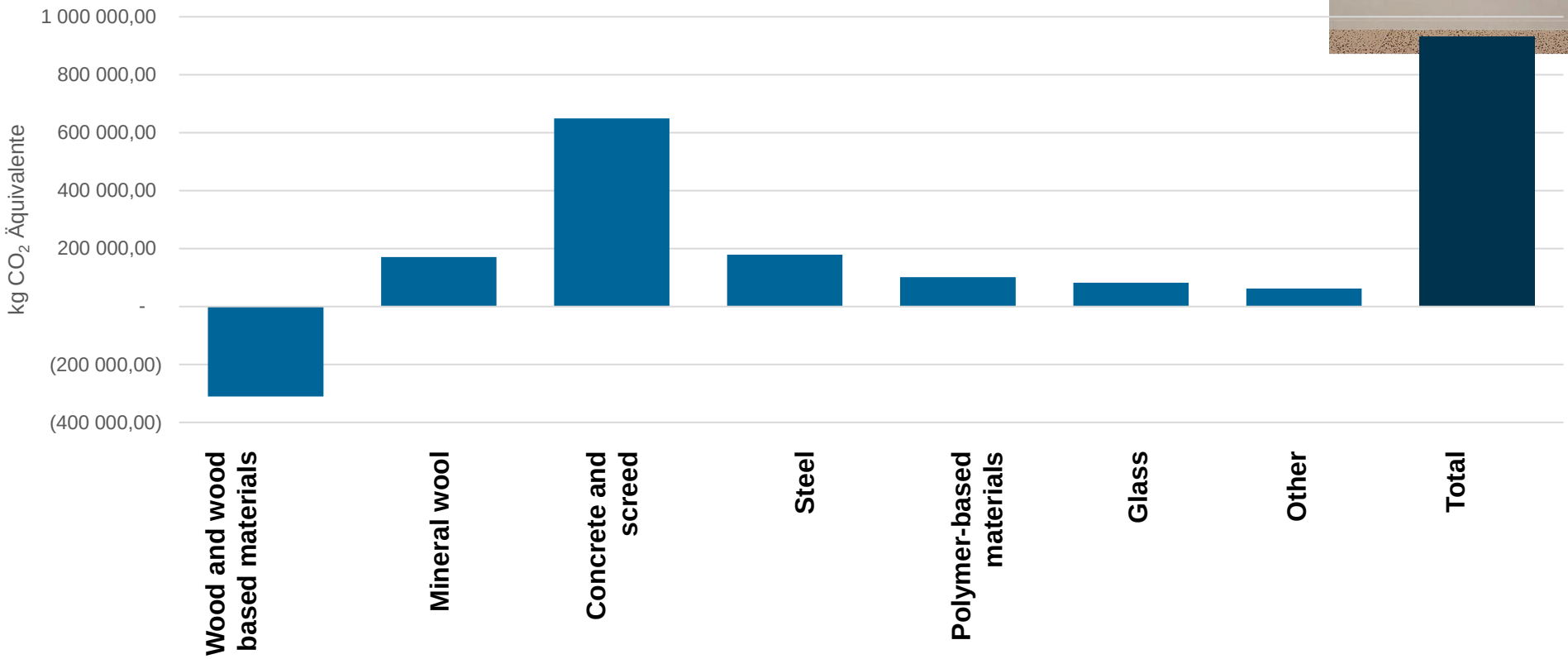
Global Warming Potential MIA



SOURCE: FISCHER, H.: ÖKOLOGISCHE BAUTEILAUFBAUTEN. ENDBERICHT, HOCHSCHULJUBILÄUMSSTIFTUNG STADT WIEN. 2019

Global Warming Potential HDL

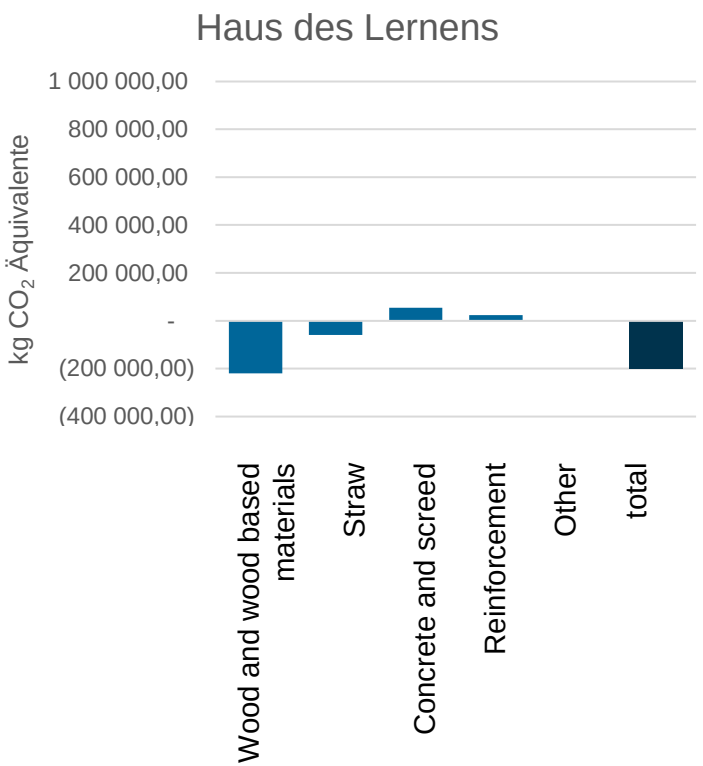


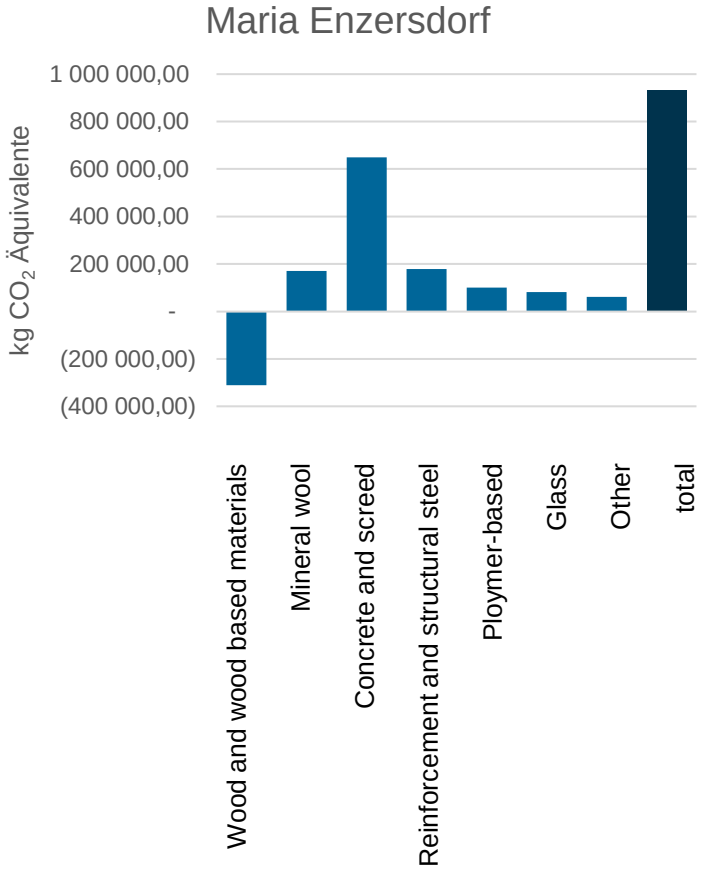


SOURCE: FISCHER, H.: ÖKOLOGISCHE BAUTEILAUFBAUTEN. ENDBERICHT, HOCHSCHULJUBILÄUMSSTIFTUNG STADT WIEN. 2019

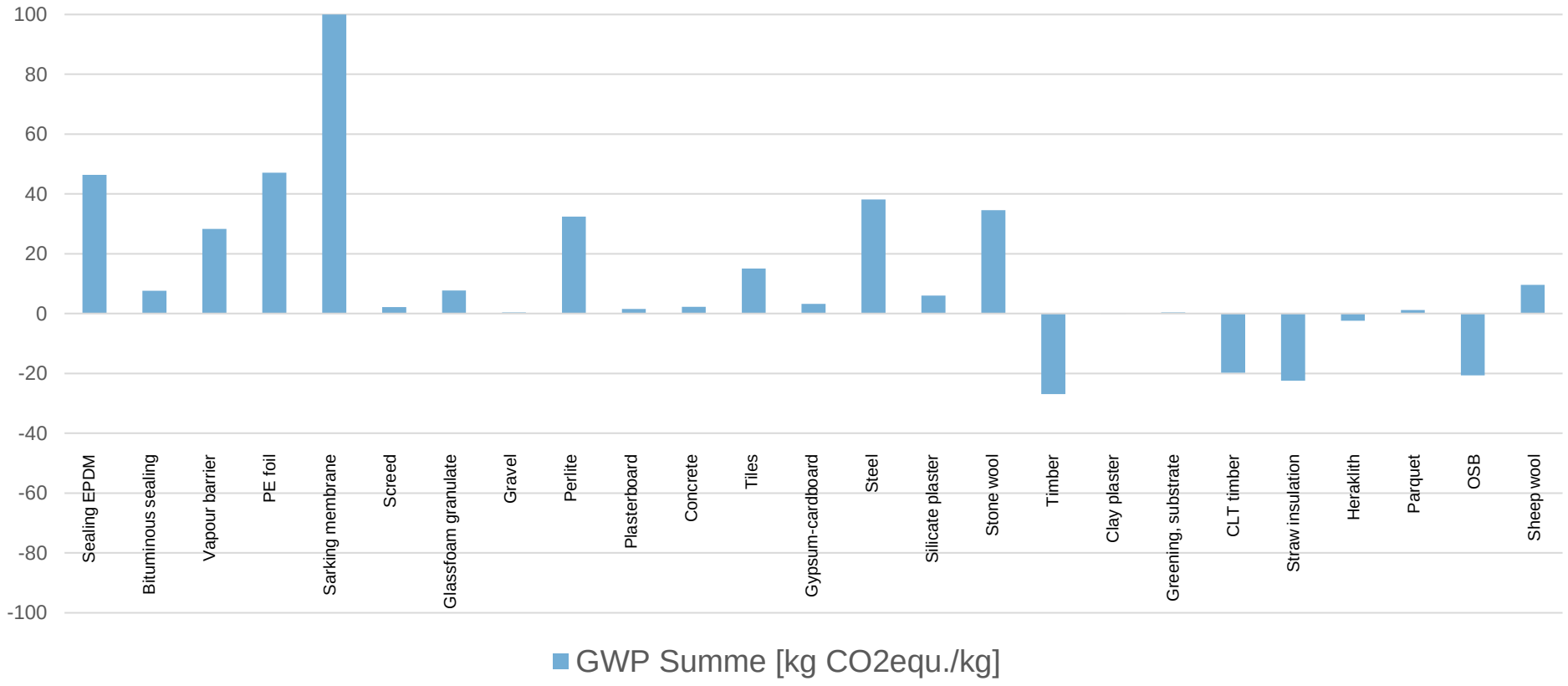
Comparison GWP

- Difference in total: approx. 1 100 t CO_2 eq.
- Difference per m²: approx. 140 t CO_2 eq.
- 5 million km with a mid-range gasoline engine (134 times around the world)
- 1 100 times flying from Frankfurt to Lisbon and back

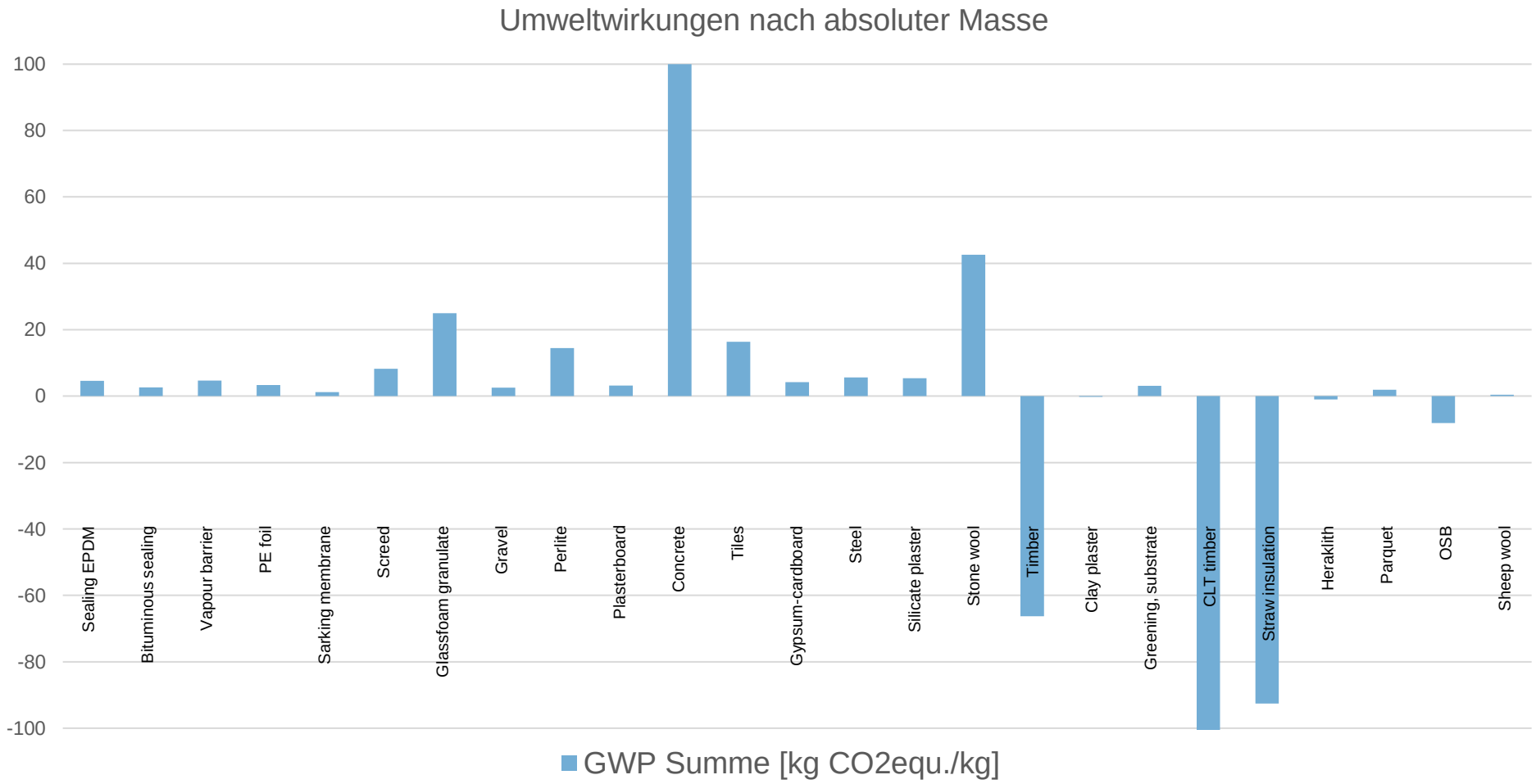




GWP relative HDL



GWP absolute HDL



Results

- absolute numbers are crucial
- Structural system is decisive for global warming impact
- Despite highly ecological construction method: Foundation is responsible for a big impact – there is a big optimization potential
- one-dimensionality
- Improvement in global warming potential is not necessarily related to an improvement in all indicator values
- Ecological assessment should be based on protection goals

Projects: Ecological Potential of Building Components in Multi-Storey Residential Construction

Comparative case study

- Comparison of two realised residential buildings in Vienna, 1220: reinforced concrete and wooden building.
- Two life cycle assessments:
  - A1-A4, B4, B6, C1-C6
  - A1-A3
- Building elements that are identical were excluded (balconies, windows, foundation slabs, basement).

FISCHER, H.; AICHHOLZER, M.; KORJENIC, A. ECOLOGICAL POTENTIAL OF BUILDING COMPONENTS IN MULTI-STOREY RESIDENTIAL CONSTRUCTION: A COMPARATIVE CASE STUDY BETWEEN AN EXISTING CONCRETE AND A TIMBER BUILDING IN AUSTRIA. SUSTAINABILITY 2023, 15, 6349.

Functional equivalent

- Useful floor space: 1143 m^2;
- A/V: 0.42 1/m; Average
- U-value: 0.3 W/m^2K;
- Hot water demand: 13 kWh/m^2a;
- Heating demand: 58 kWh/m^2a;
- Electricity demand: 16 kWh/m^2a;
- Heating demand: 30 kWh/m^2a.

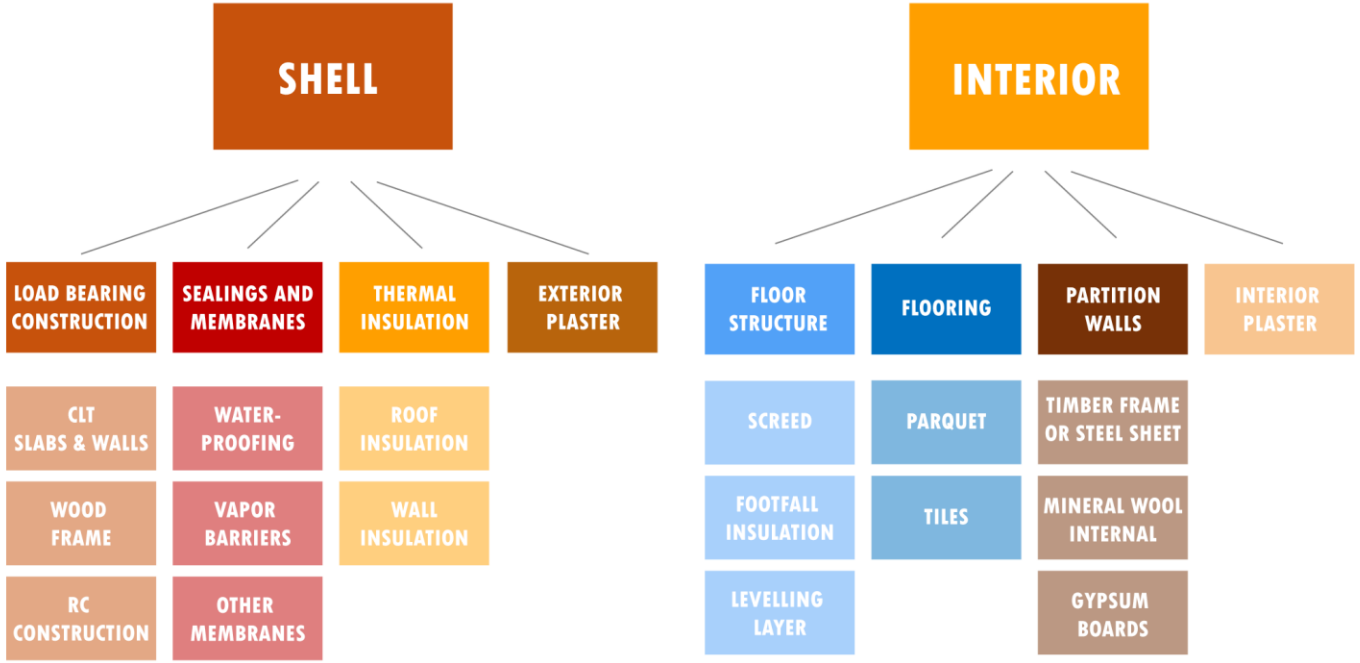
FISCHER, H.; AICHHOLZER, M.; KORJENIC, A. ECOLOGICAL POTENTIAL OF BUILDING COMPONENTS IN MULTI-STOREY RESIDENTIAL CONSTRUCTION: A COMPARATIVE CASE STUDY BETWEEN AN EXISTING CONCRETE AND A TIMBER BUILDING IN AUSTRIA. SUSTAINABILITY 2023, 15, 6349.

Indicators

- GWP: Global warming potential kg CO_2 eq.
- PERT: Primary energy, renewable, total MJ
- PENRT: Primary energy, non-renewable, total MJ
- ODP: Ozone depletion potential kg CFC-11
- AP: Acidification potential kg SO_2 eq.
- EP: Eutrophication potential kg PO_4^{3-}
- POCP: Photochemical ozone creation potential kg C_2H_4

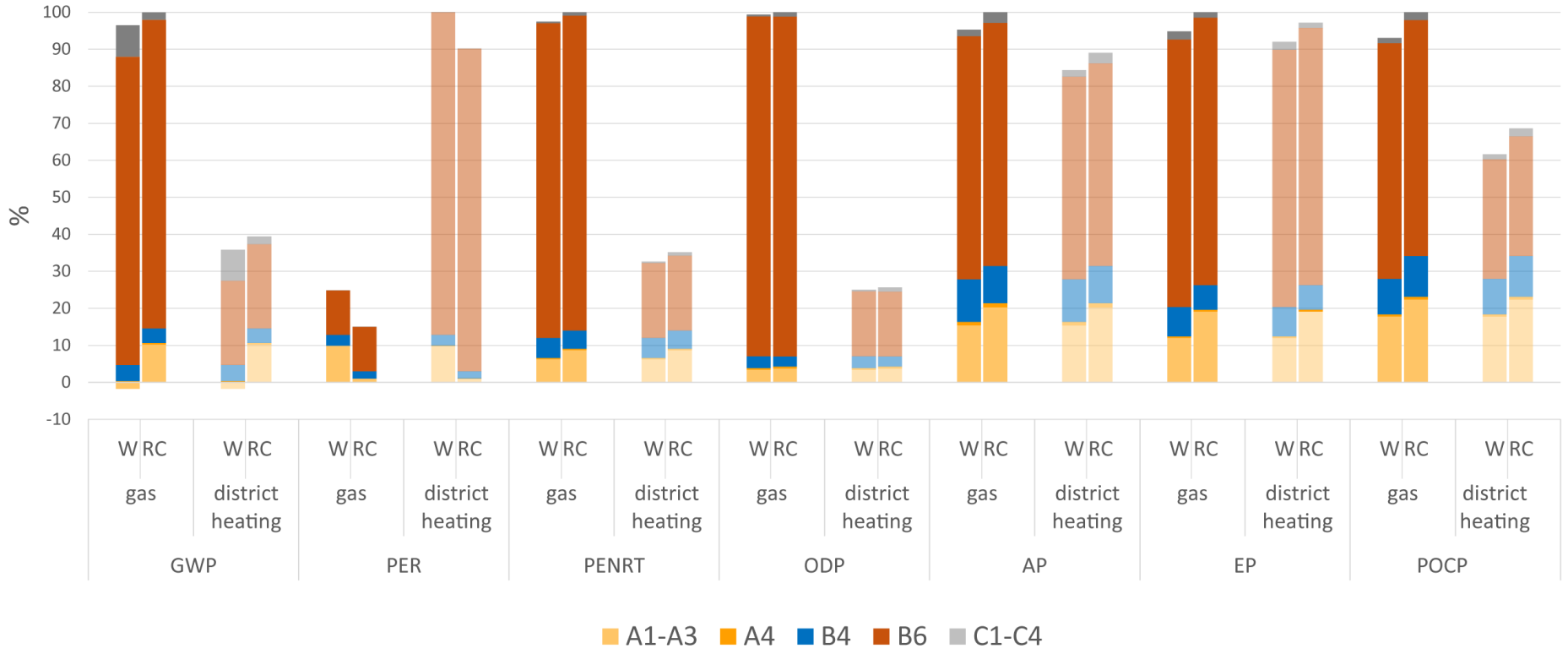
FISCHER, H.; AICHHOLZER, M.; KORJENIC, A. ECOLOGICAL POTENTIAL OF BUILDING COMPONENTS IN MULTI-STOREY RESIDENTIAL CONSTRUCTION: A COMPARATIVE CASE STUDY BETWEEN AN EXISTING CONCRETE AND A TIMBER BUILDING IN AUSTRIA. SUSTAINABILITY 2023, 15, 6349.

Building components



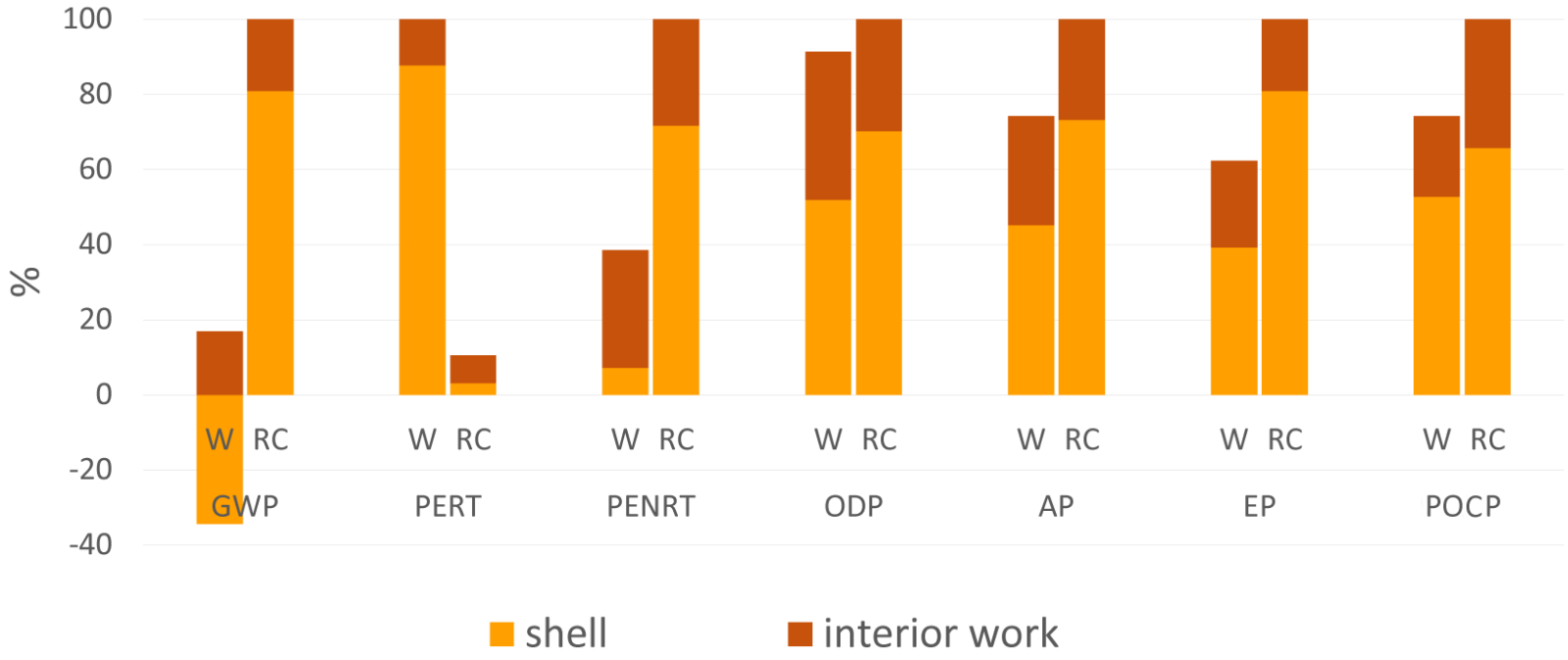
FISCHER, H.; AICHHOLZER, M.; KORJENIC, A. ECOLOGICAL POTENTIAL OF BUILDING COMPONENTS IN MULTI-STOREY RESIDENTIAL CONSTRUCTION: A COMPARATIVE CASE STUDY BETWEEN AN EXISTING CONCRETE AND A TIMBER BUILDING IN AUSTRIA. SUSTAINABILITY 2023, 15, 6349.

Modules A-C, comparison district heating and gas

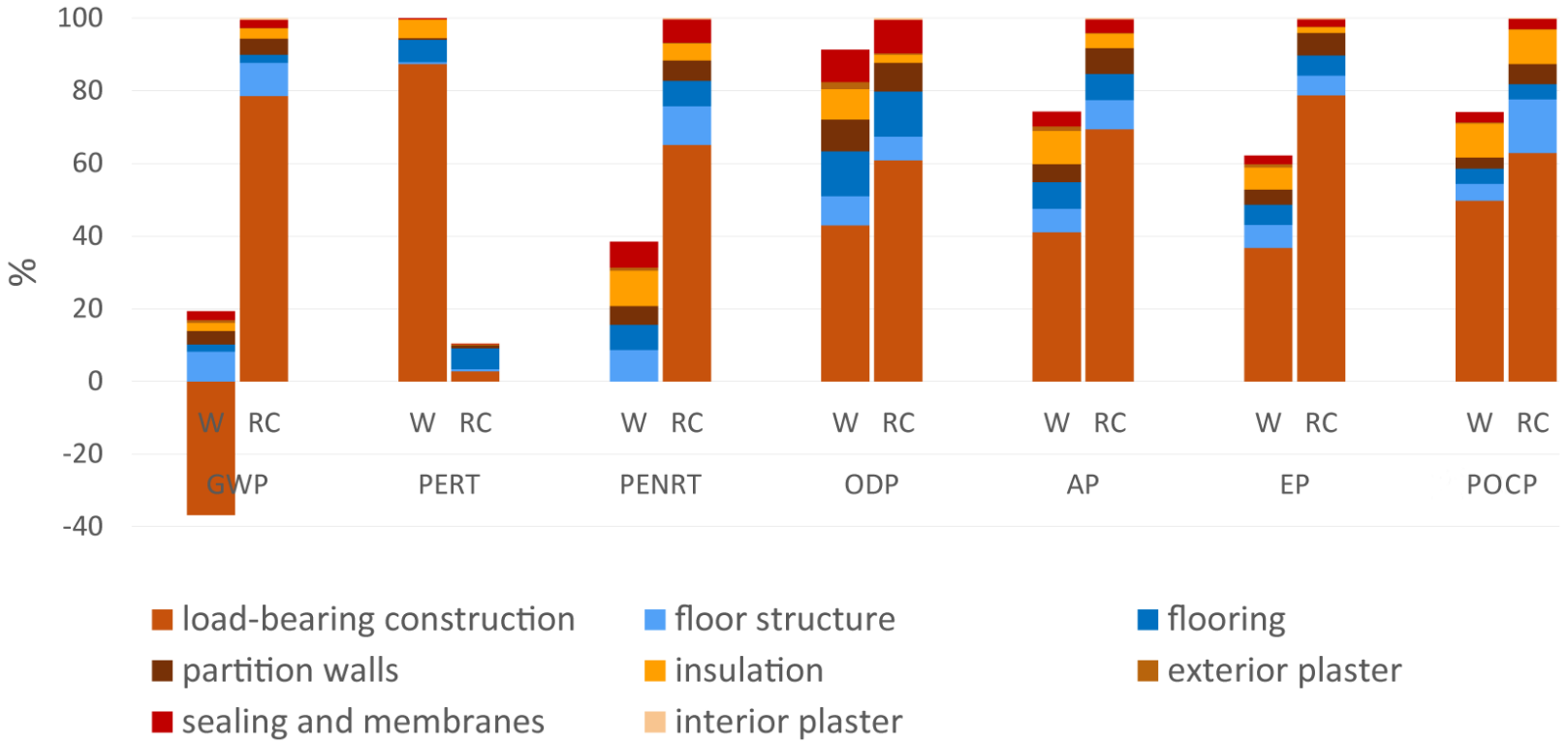


A1-A3: Herstellung
A4: Transport
B4: Austausch
B6: Nutzung
C1-C4: Entsorgung

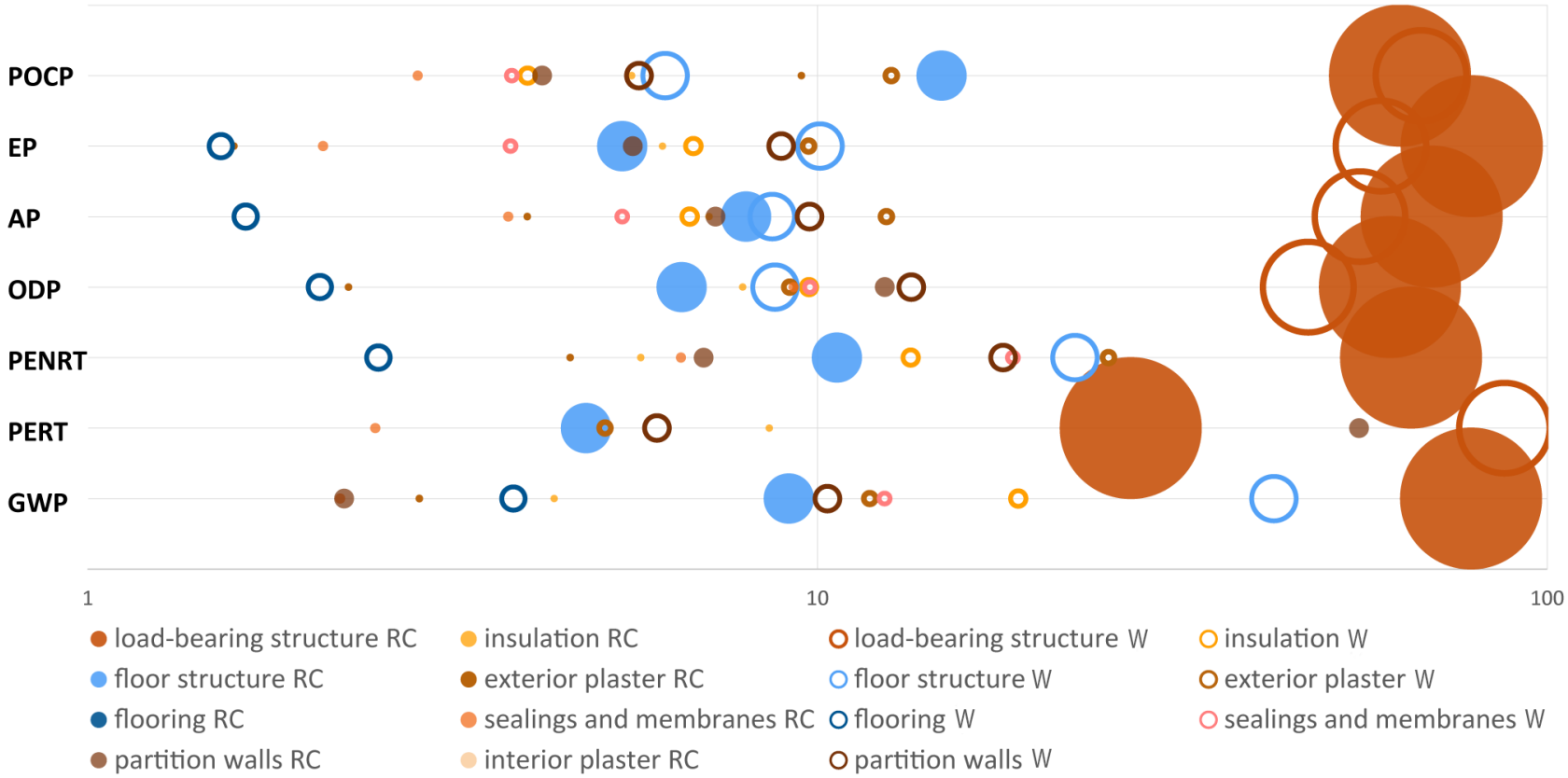
Ecological assessment of the production phase



Ecological assessment of the production phase



Ecological assessment of the production phase



Conclusion

- Use phase most influential, unless heat, energy, etc. are provided in a renewable and efficient way.
- Load-bearing construction responsible for the greatest impact in both buildings
- After that: Floor constructions (multi-storey!)
- Rule of thumb: Mass

Thank you! ☺