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Ecological Building Constructions for a Sustainable Future

24.06.2022, Summer School in Vienna

Univ.Ass. DI Henriette Fischer

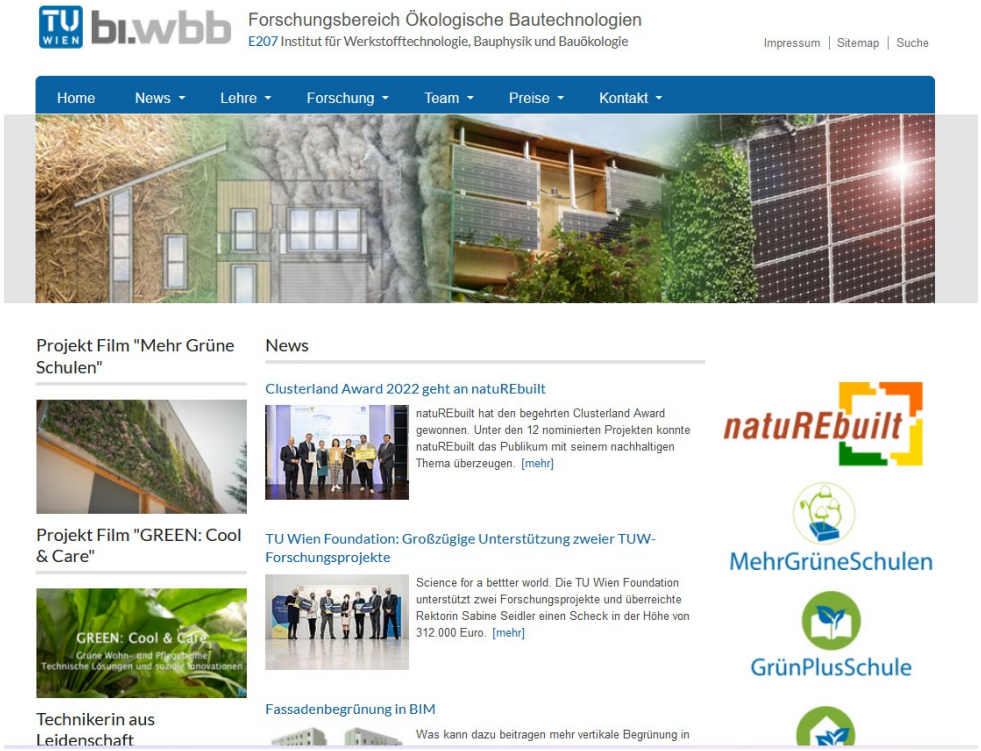
TECHNISCHE UNIVERSITÄT WIEN

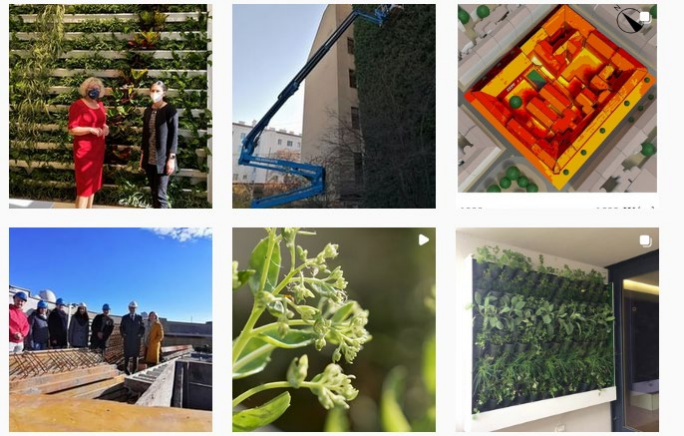
Research Unit „Ecological Building Technologies“

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

https://www.obt.tuwien.ac.at/home/

https://www.instagram.com/obt_tu_wien/

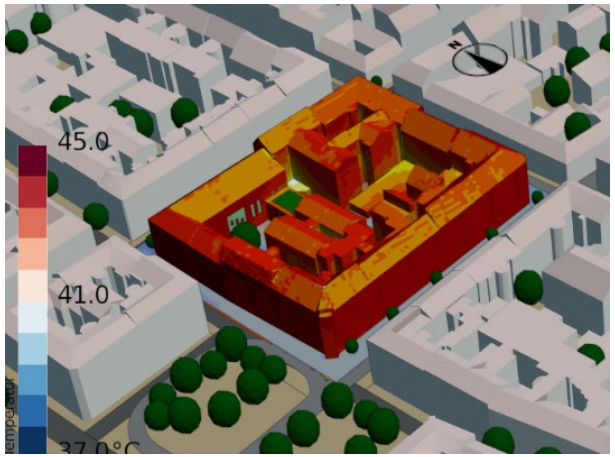




Research focuses

- 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



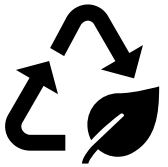
Goals

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

- **Sustainability:**

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

- **Ecology:**

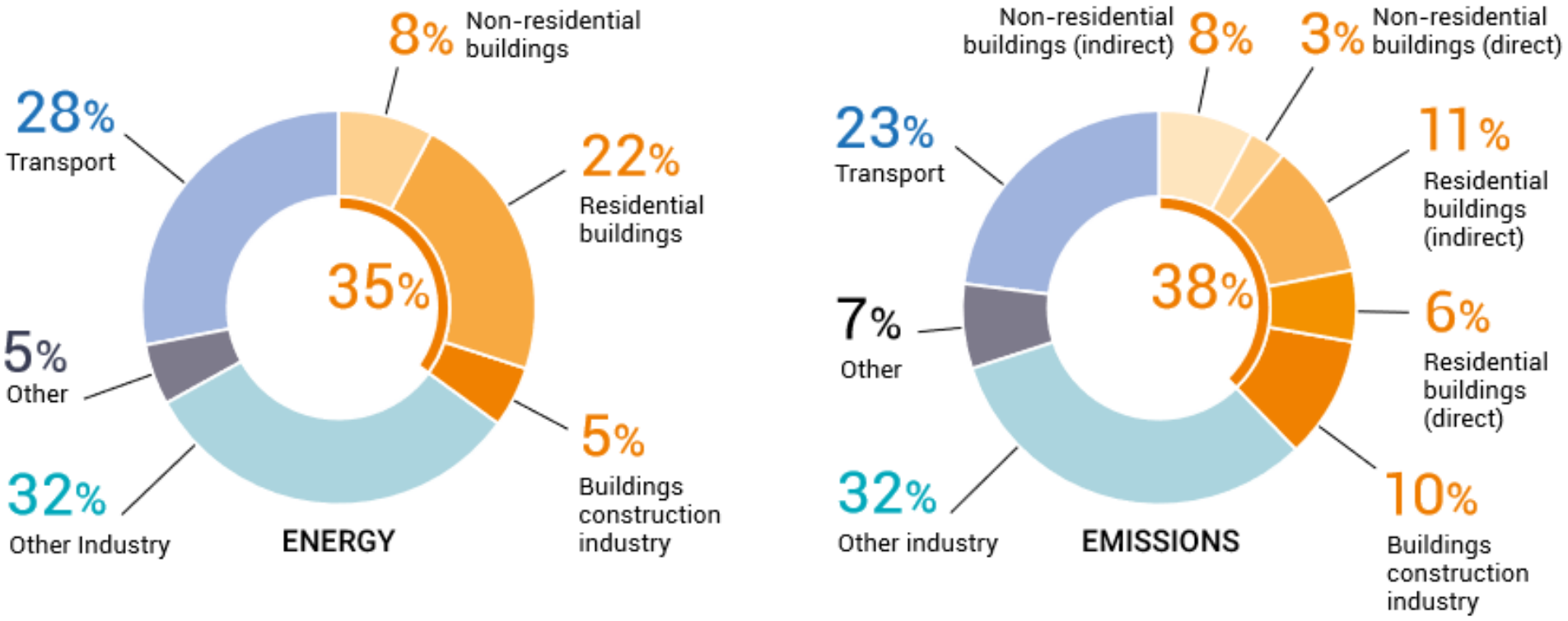
Ancient Greek “oikos”: house, household; “logos”: study of

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

- **Building ecology:**

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

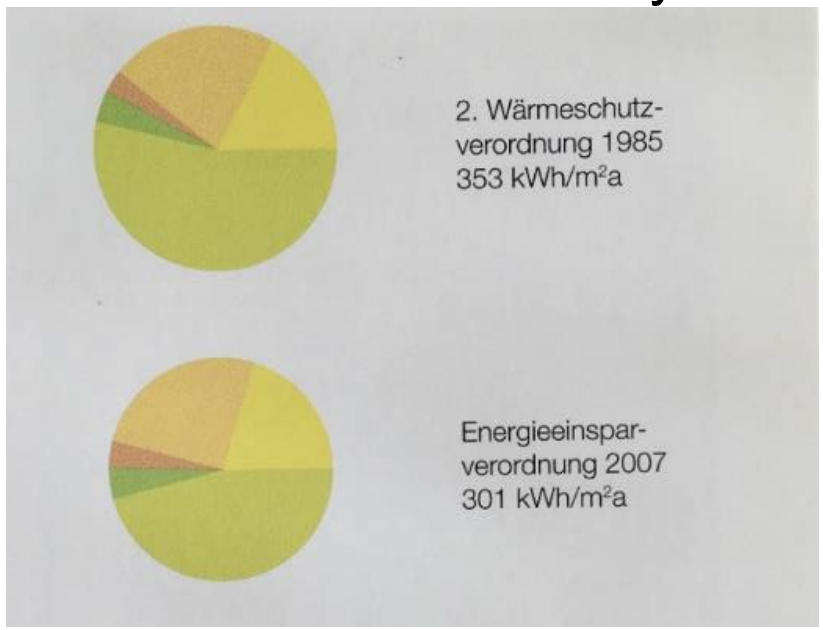
Global share of buildings and construction final energy and emissions (2019)

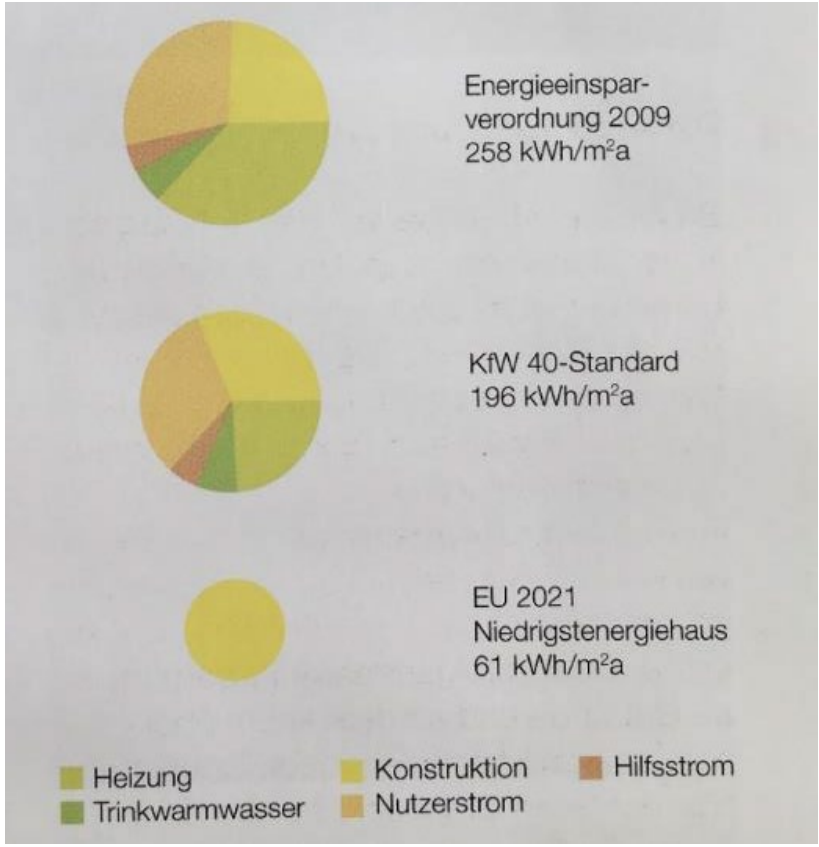


Source: 2020 Global Status Report for buildings and construction. United Nations Environment Programme,2020. https://globalabc.org/sites/default/files/inline-files/2020%20Buildings%20GSR_FULL%20REPORT.pdf (May 2022)

Primary energy demand

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



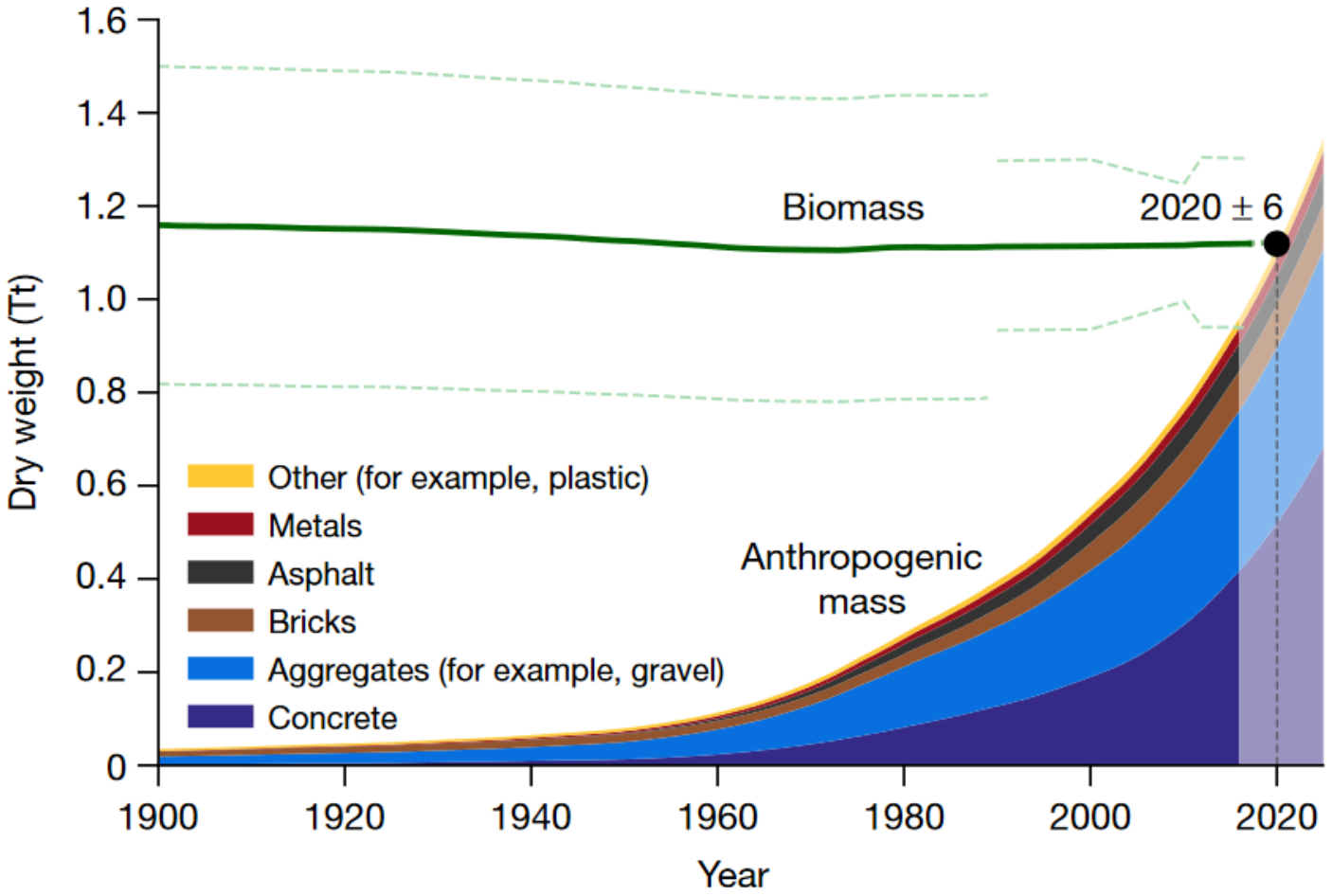


SOURCE: KHOULI, S. ET AL: NACHHALTIG KONSTRUIEREN: VOM TRAGWERKSENTWURF BIS ZUR MATERIALWAHL – GEBÄUDE ÖKOLOGISCH BILANZIEREN UND OPTIMIEREN (DETAIL GREEN BOOKS), 2014

Use of resources

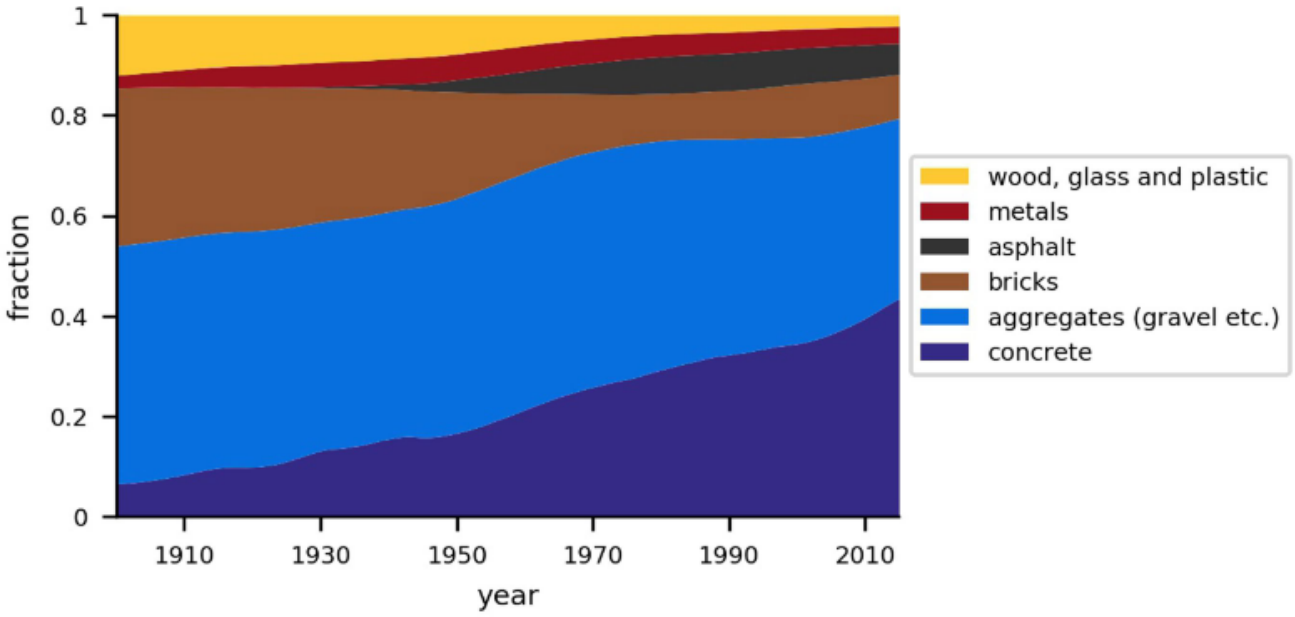
- 80% of all man-made things are made of concrete and mixed building materials
- 15 % consist of brick and asphalt
- 3 % consist of metal products
- 0,7 % of all man-made things are made of plastics

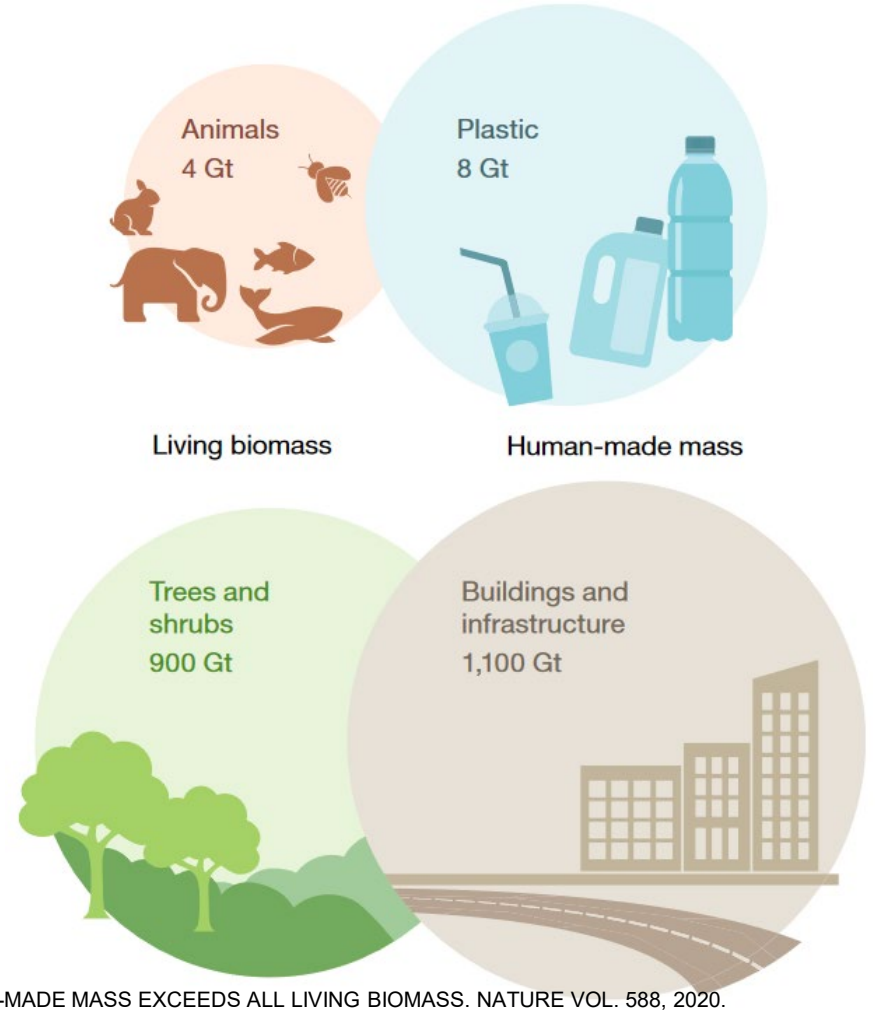
One of the most important trade raw material in the world: sand



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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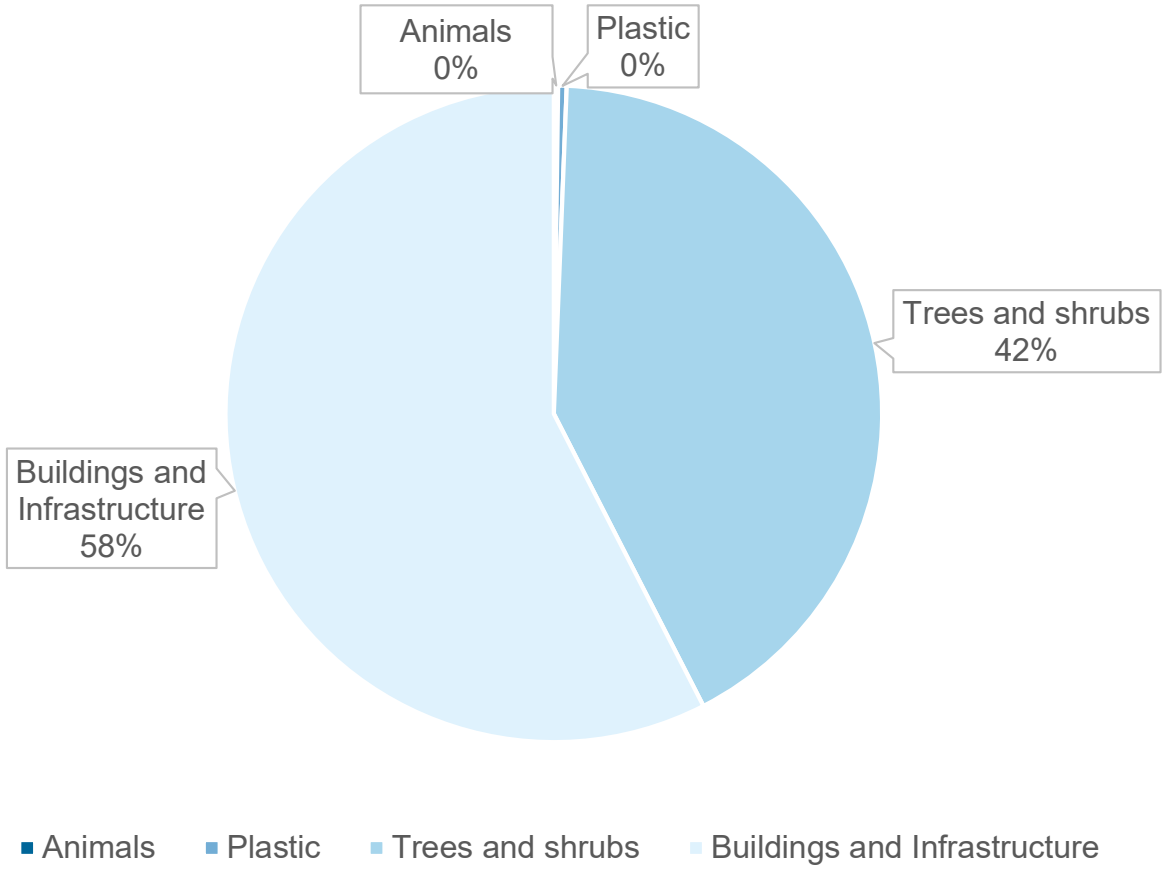
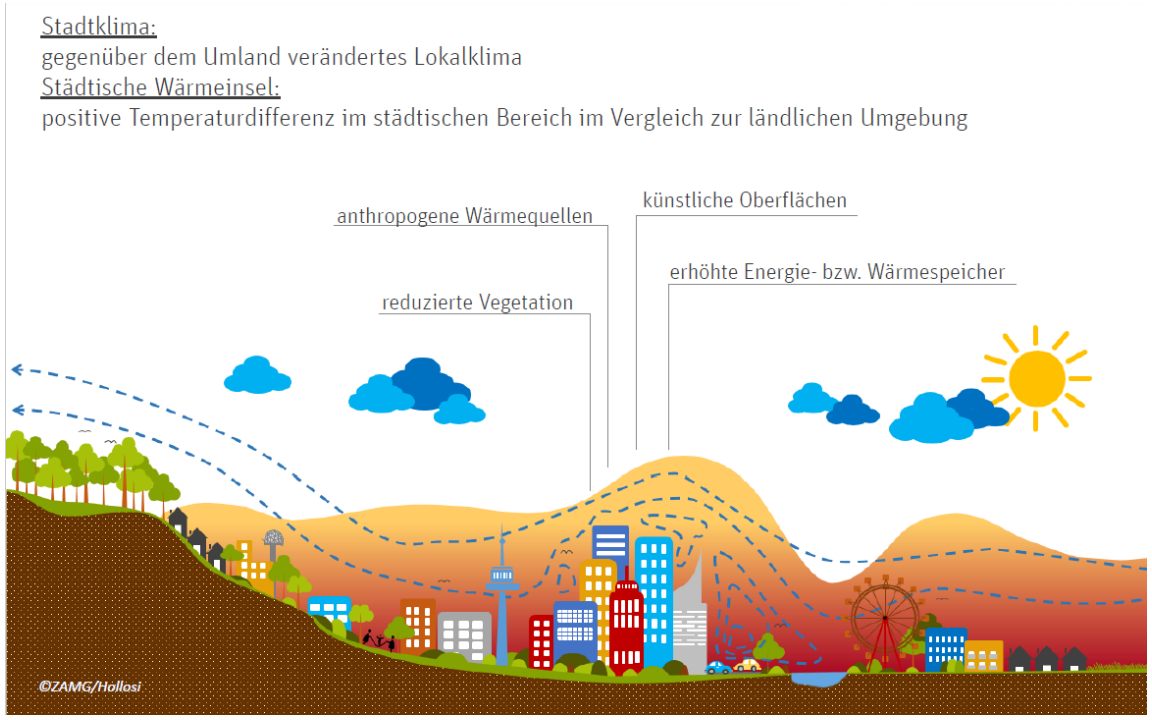
Human-made mass

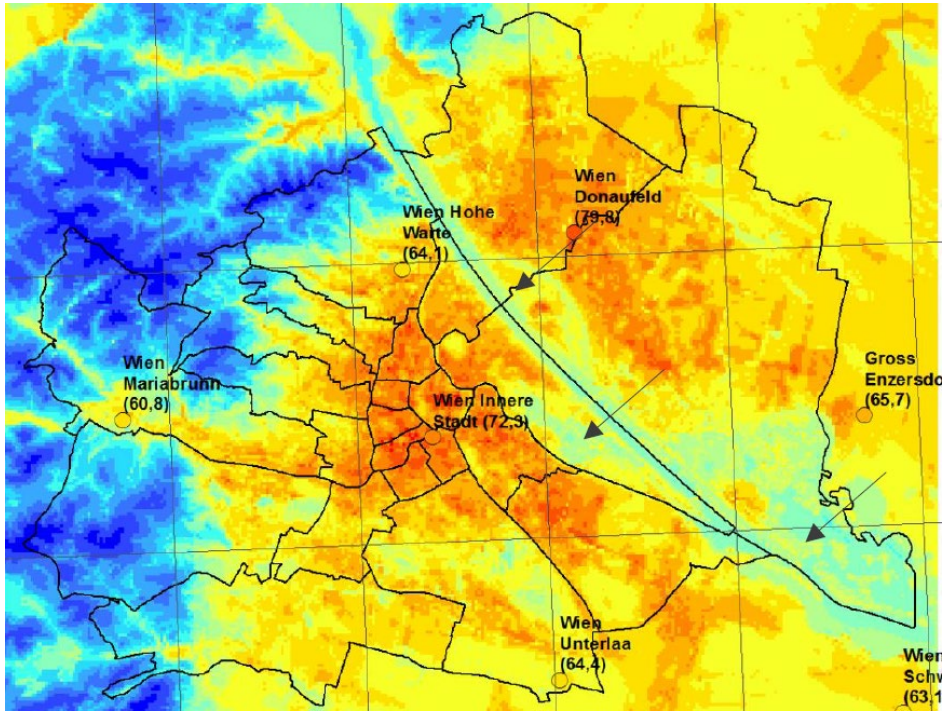


SOURCE: AUTHOR'S OWN GRAPH. DATA FROM: EMILY ELHACHAM, LIAD BEN-URI, JONATHAN GROZOVSKI, YINON M. BAR-ON & RON MILO: GLOBAL HUMAN-MADE MASS EXCEEDS ALL LIVING BIOMASS. NATURE VOL. 588, 2020.

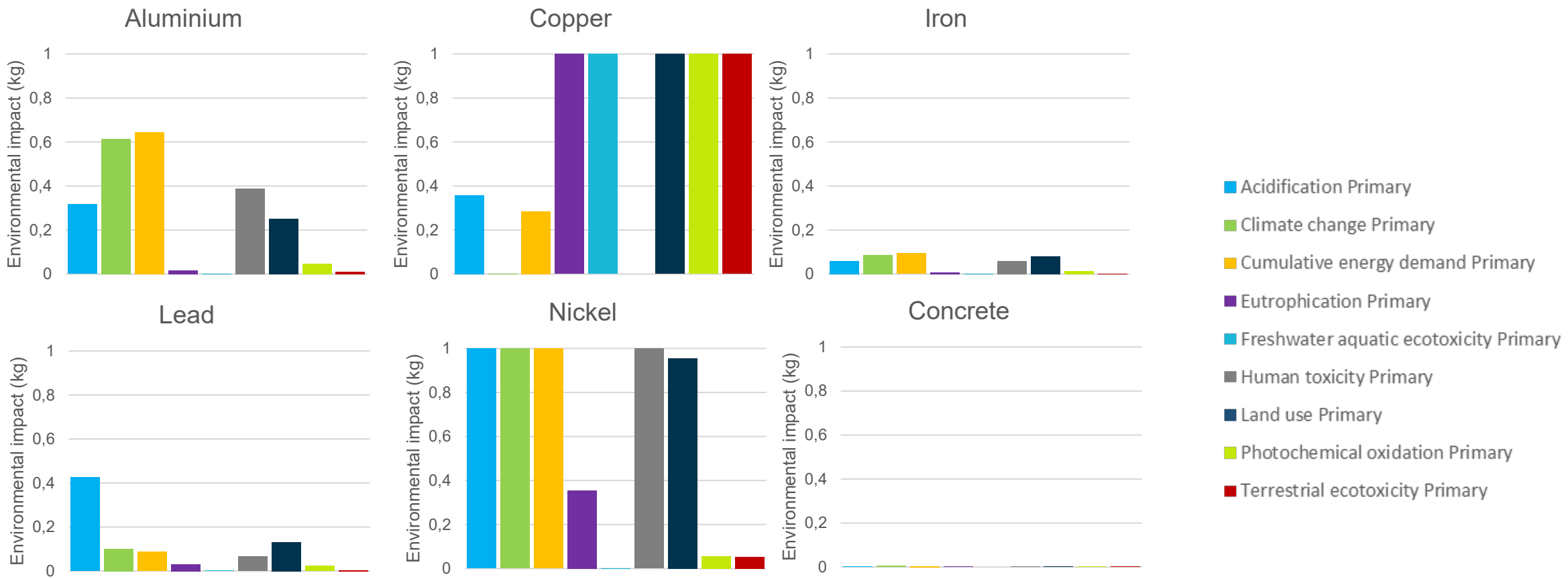
UHI Effect (Urban Heat Island)



SOURCE: ZAMG

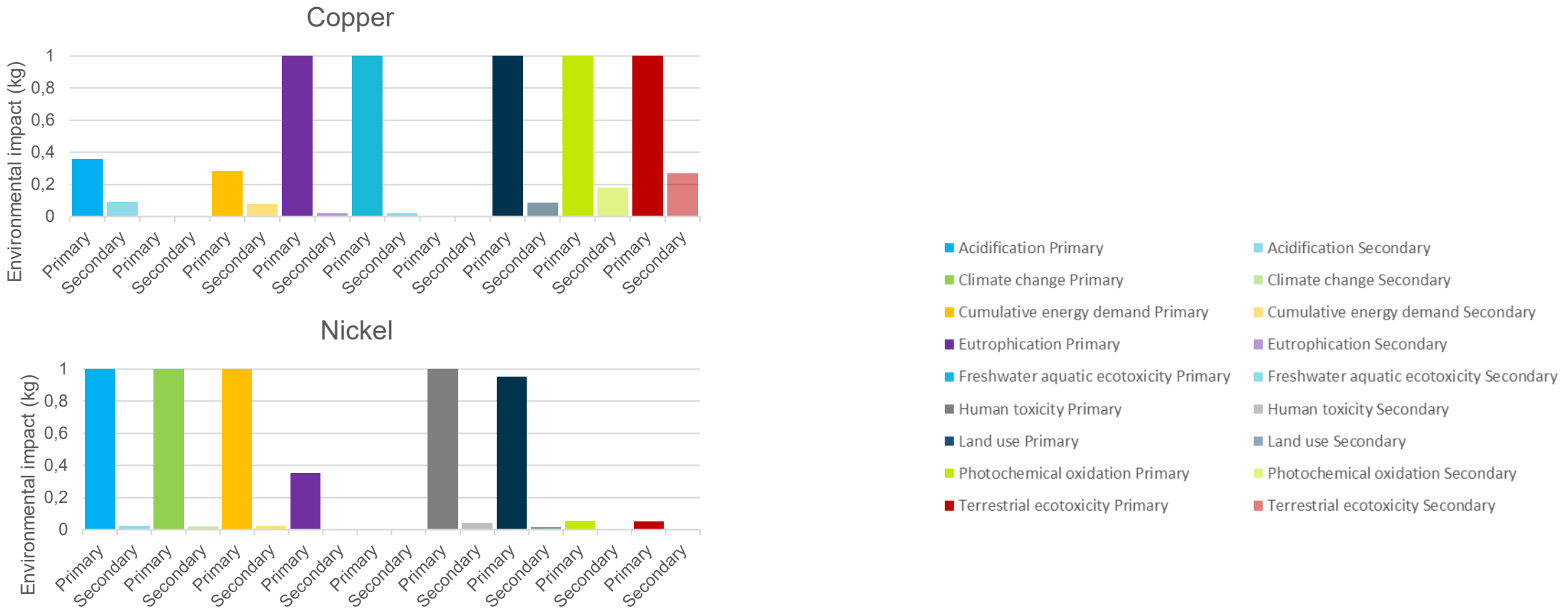


Environmental impact per kg per raw material



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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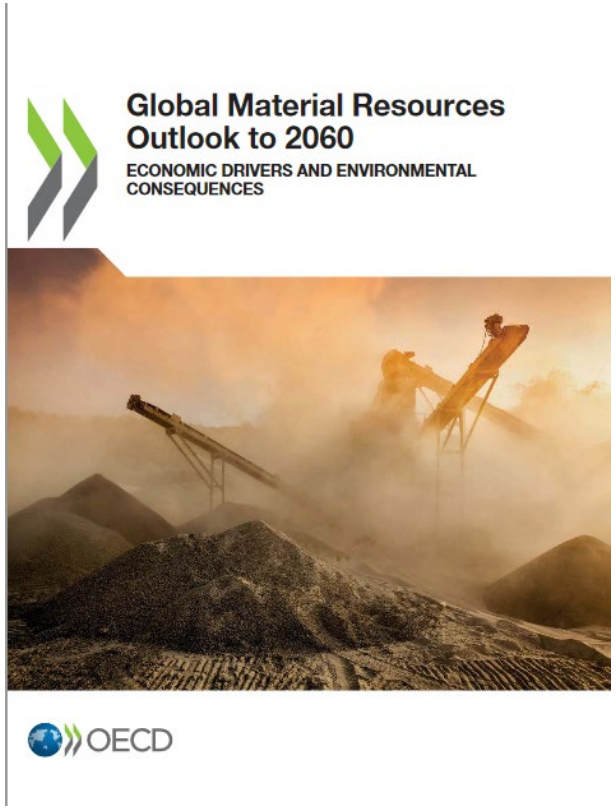
Global use of raw materials

According to the OECD, this will involve the following consumption of raw materials:

- Material consumption is expected to increase
- The largest share is sand, gravel and lime
- The volume of concrete use is so large that even relatively low per-kilogram emissions have a large impact: Concrete production will account for 12% of total GHG emissions in 2060, and metals production will account for 12%.
- Copper and nickel are the materials with the highest environmental impacts per kg (according to OECD calculation method)



SOURCE: 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)

Sustainability and Ecology in the building industry

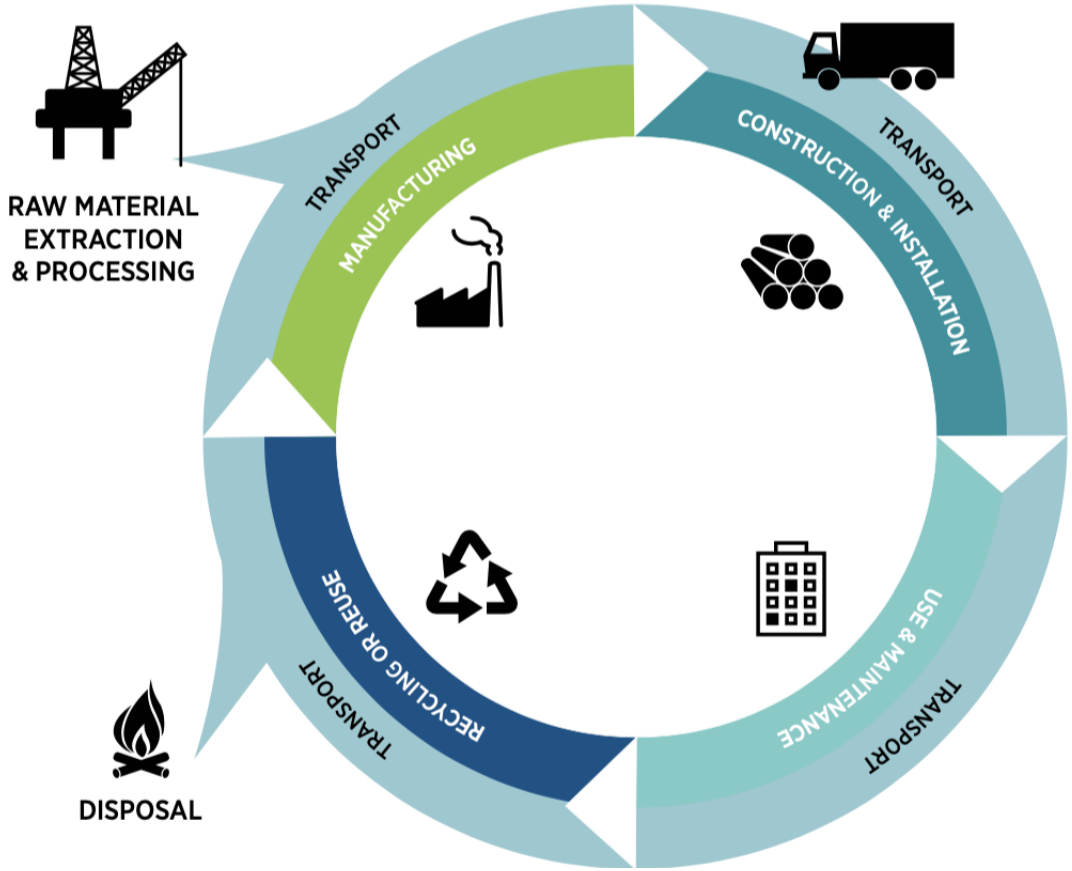
- Approx. 40% of CO_2 emissions are caused by the construction industry
- Approx. 36% of the total energy consumption is used for our buildings.
- Approx. 50% of waste is generated by the construction industry
- The average useful life of a house in the EU is 30-50 years

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

Ecological building materials

Ecological characteristics:

- No (minimal) finite / fossil base building materials.
- Low energy demand (from renewable sources) in production
- Low transport distances
- No harmful substances in the whole life cycle
- Energy optimized use (healthy indoor climate) - (from renewable sources)
- Recyclability / return to nature



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

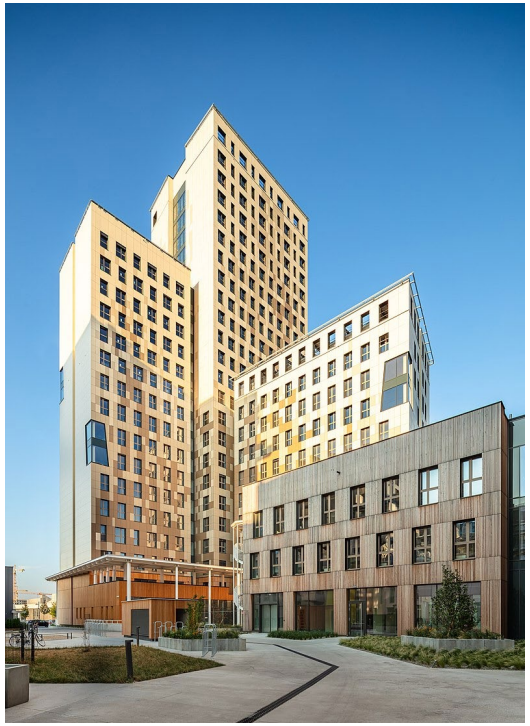
Ecological evaluation of building components

- 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

Building with wood

SOURCE: HTTPS://DE.WIKIPEDIA.ORG/WIKI/DATEI:MJ%C3%B8ST%C3%A5RNET.JPG (JUNE 2022)

Mjøstårnet is an 18-storey, 85.4 m high mixed-use building in Brumunddal, Norway.



SOURCE: HTTPS://DE.WIKIPEDIA.ORG/WIKI/HOHO_WIEN#/MEDIA/DATEI:HOHO_WIEN_HOFSEITE_HOTEL_UND_NEXT_AUGUST_2020_(C)DERFRITZ.JPG (JUNE 2022)

The HoHo Vienna is a high-rise building with 24 floors and 84 meters high.

SOURCE: HTTPS://WWW.UBM-DEVELOPMENT.COM/MAGAZIN/ASCENT-TOWER-MILWAUKEE/ (JUNE 2022)

Ascent MKE is a mass timber hybrid high-rise apartment building under construction in Milwaukee, Wisconsin. When completed, the 87 meter, 25-story high-rise will be the world's tallest mass timber structure.

CLT – Cross laminated timber

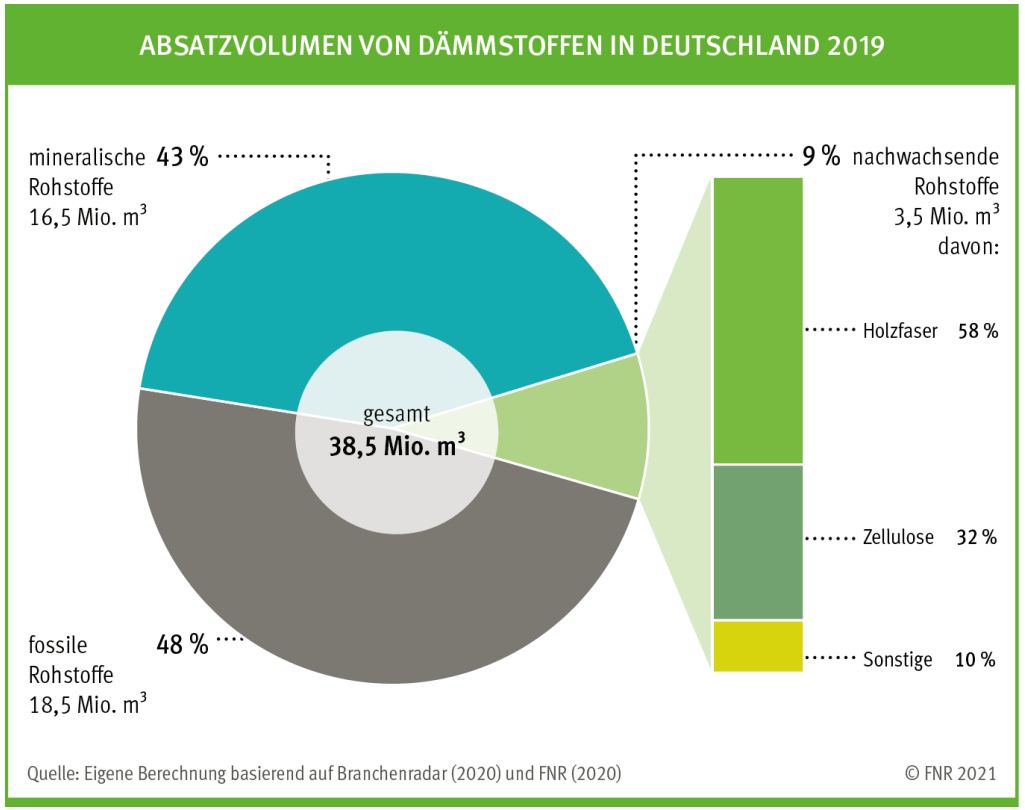
SOURCE: HTTPS://WWW.SCHNEIDER-HOLZ.COM/DE/PRODUKTE/HOLZ/BRETTSPERRHOLZ/CLT-DECKE/. (JUNE 2022)

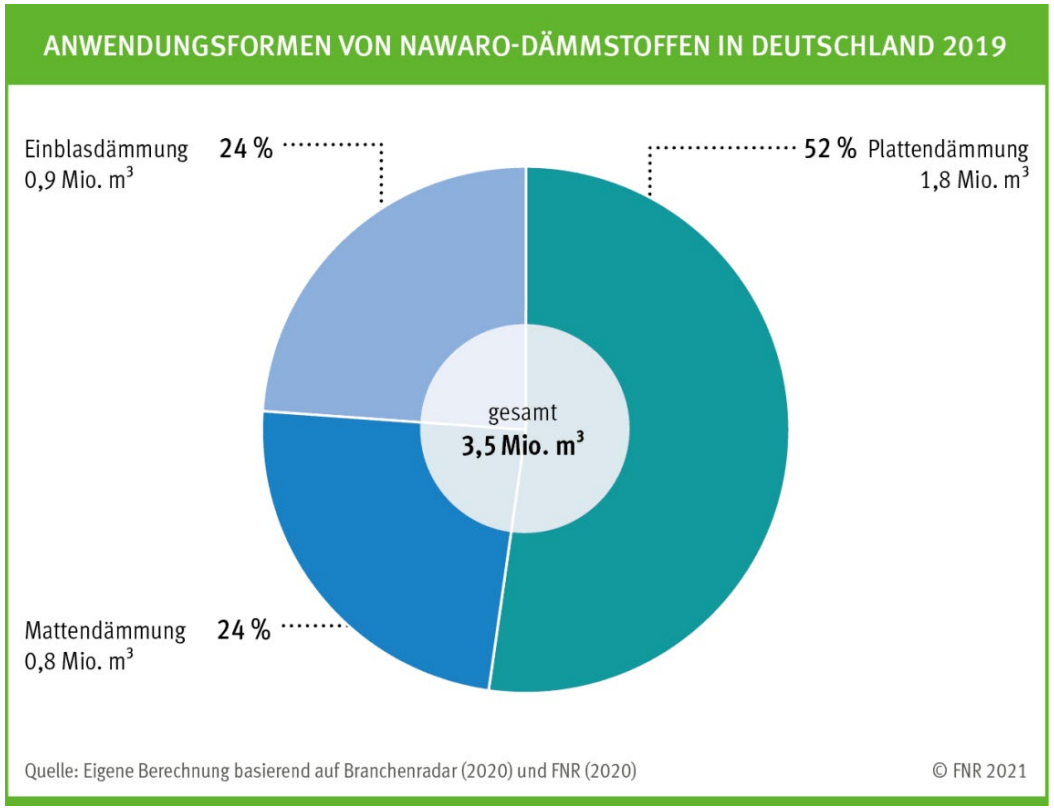
Building materials made of renewable raw materials

- High moisture absorption - can be beneficial in unfavorable moisture conditions.
- Partially higher heat storage capacity - can reduce attack of microorganisms and 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





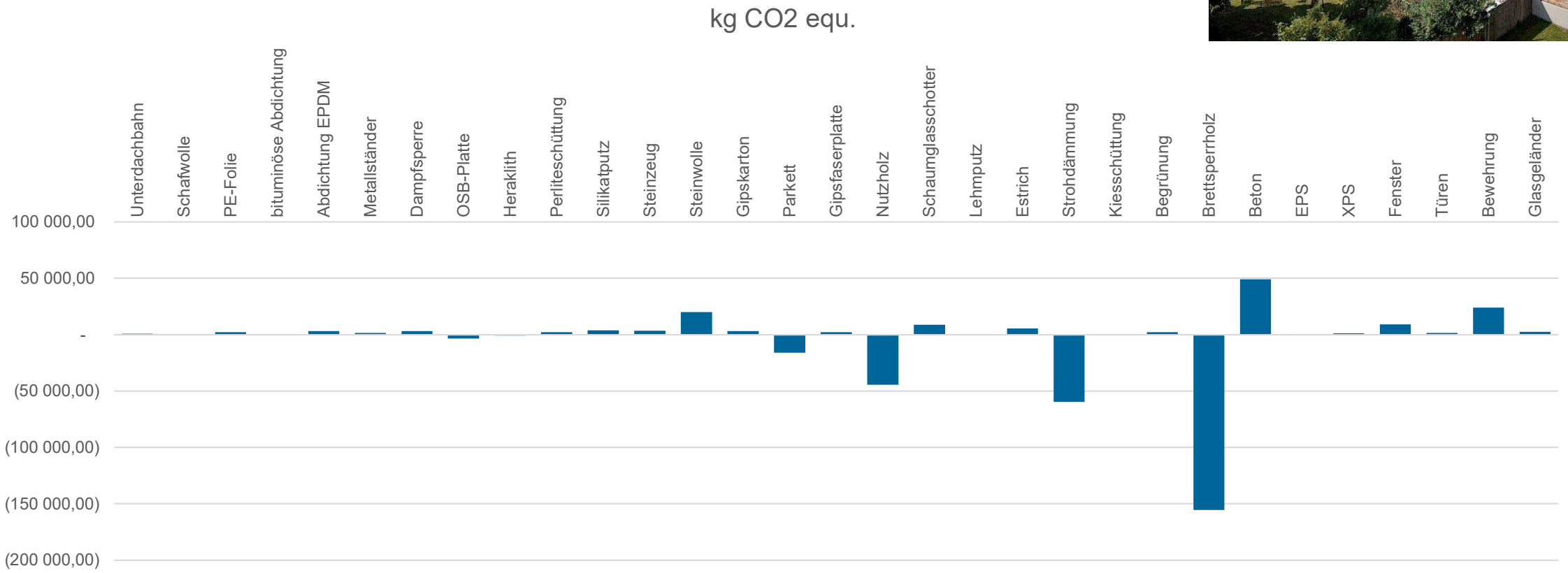
SOURCE: HTTPS://FNR.DE/MARKTANALYSE/MARKTANALYSE.PDF (MAY 2022)

Projects: Life cycle assement of a building

LCA

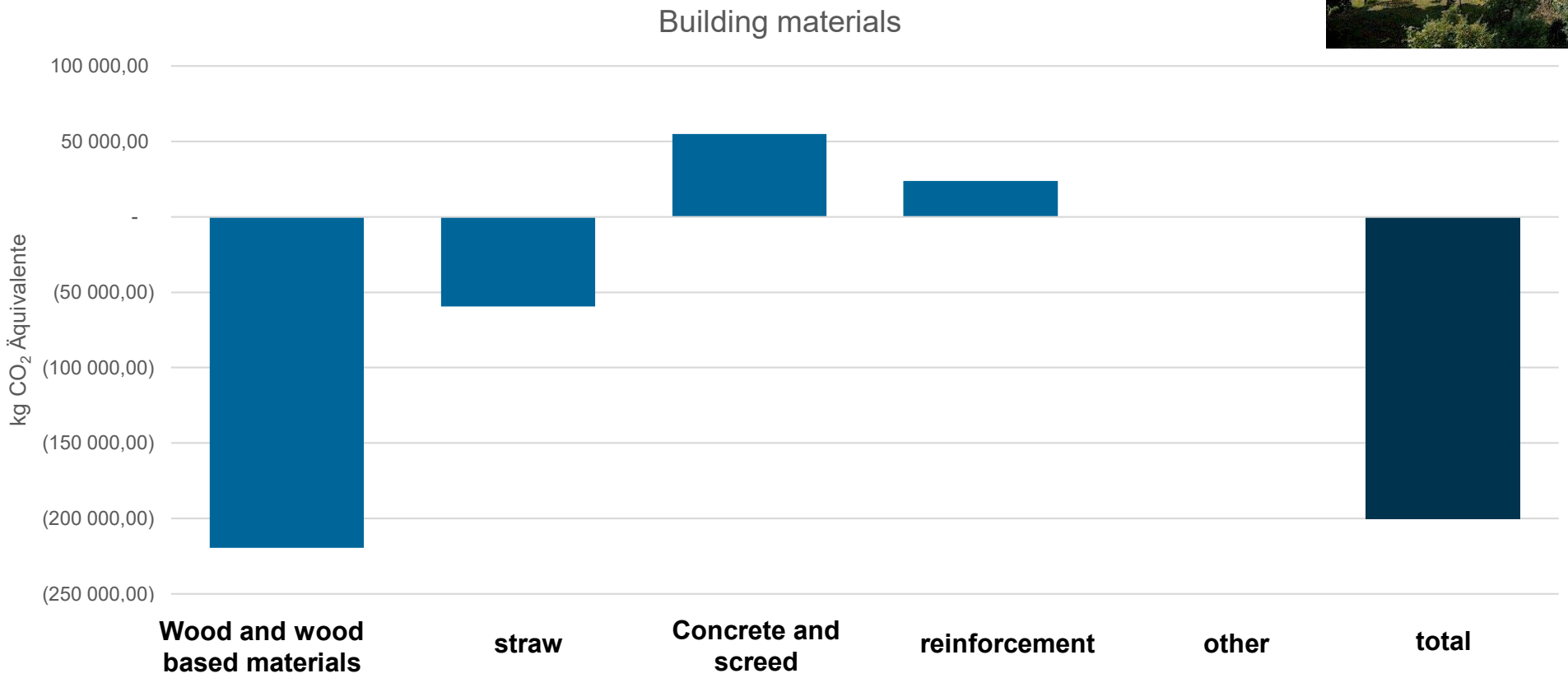
- Study: Ecological building components, FH Campus Wien
- Comparison of 2 wooden buildings: House of Learning (2018), 1236 m² and childcare center Maria Enzersdorf (2011), 3902 m²
- HdL: fully ecological; Mia: hybrid construction method
- Indicator: Global Warming Potential, framework of study: Production

Global Warming Potential HDL



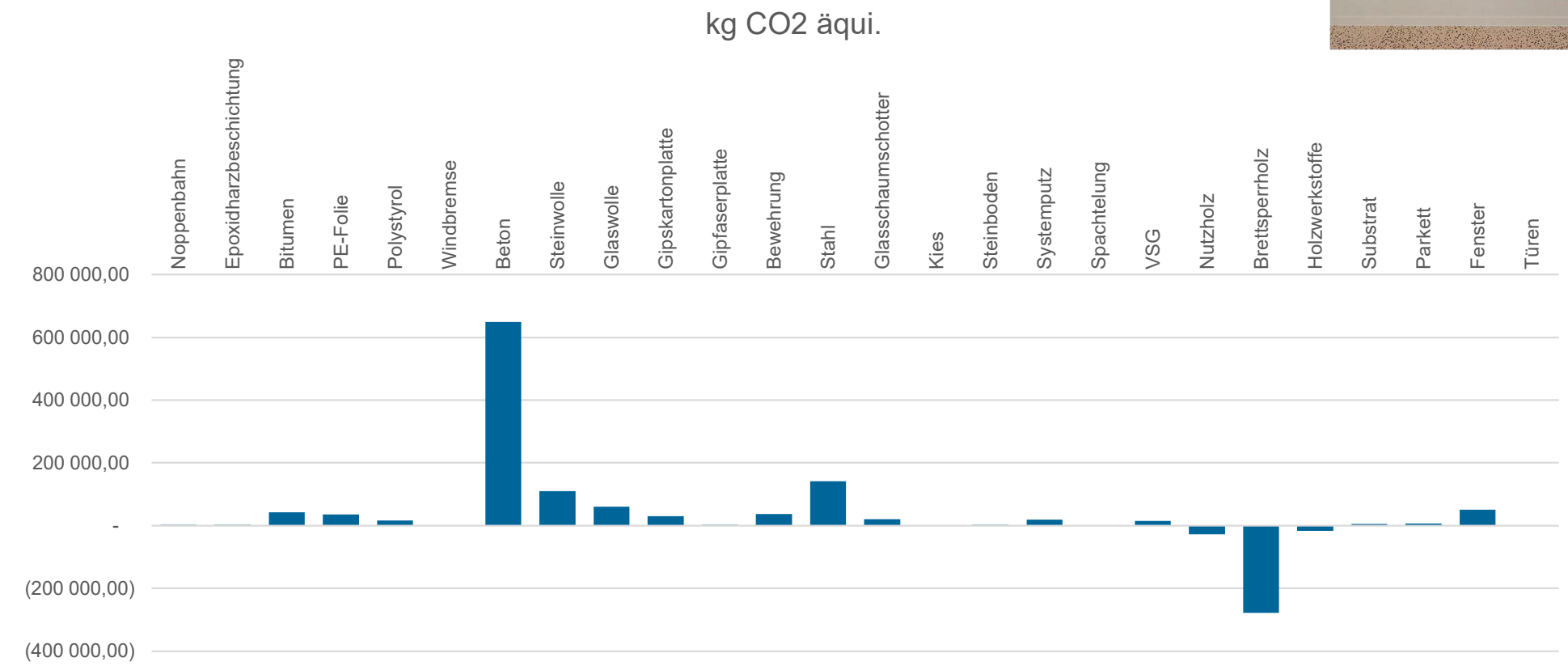
SOURCE: FISCHER, H.: ÖKOLOGISCHE BAUTEILAUFBAUTEN. ENDBERICHT, HOCHSCHULJUBILÄUMSSTIFTUNG STADT WIEN. 2019

Global Warming Potential HDL



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

Global Warming Potential MIA



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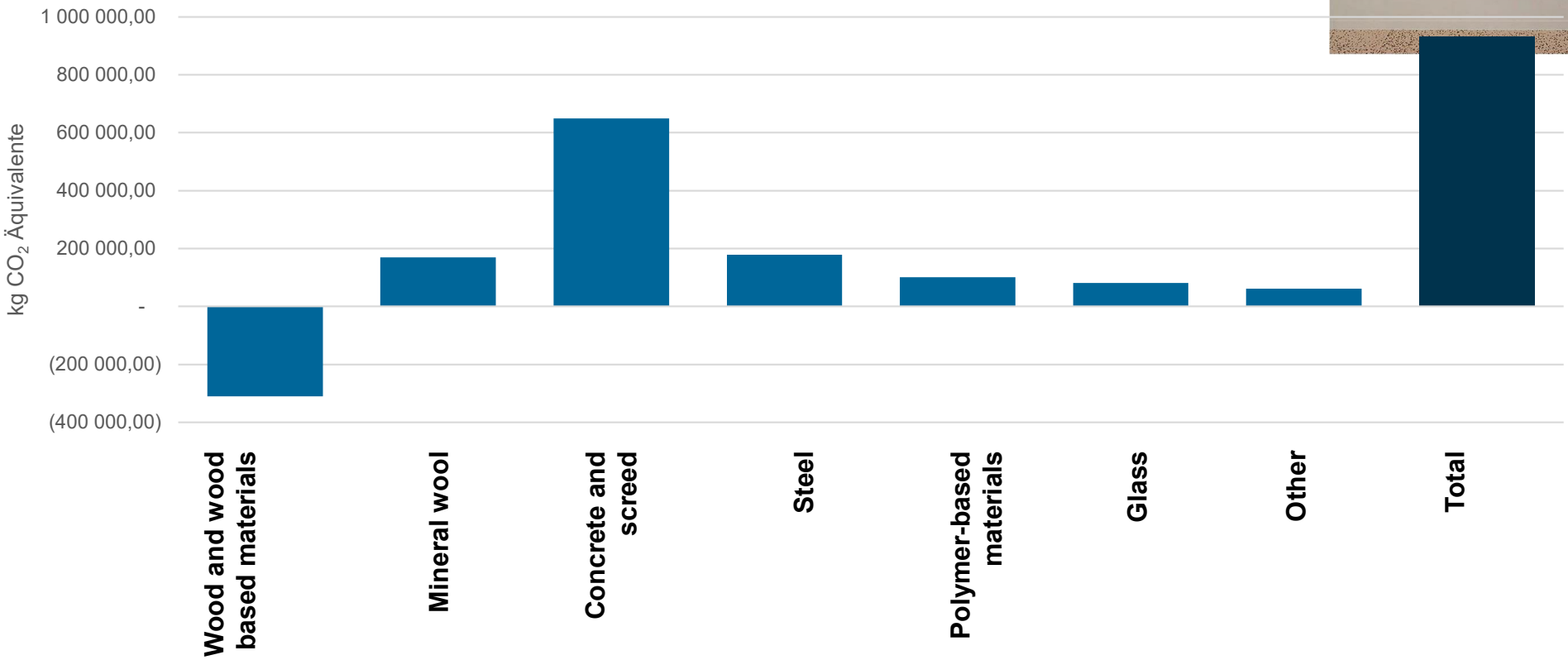
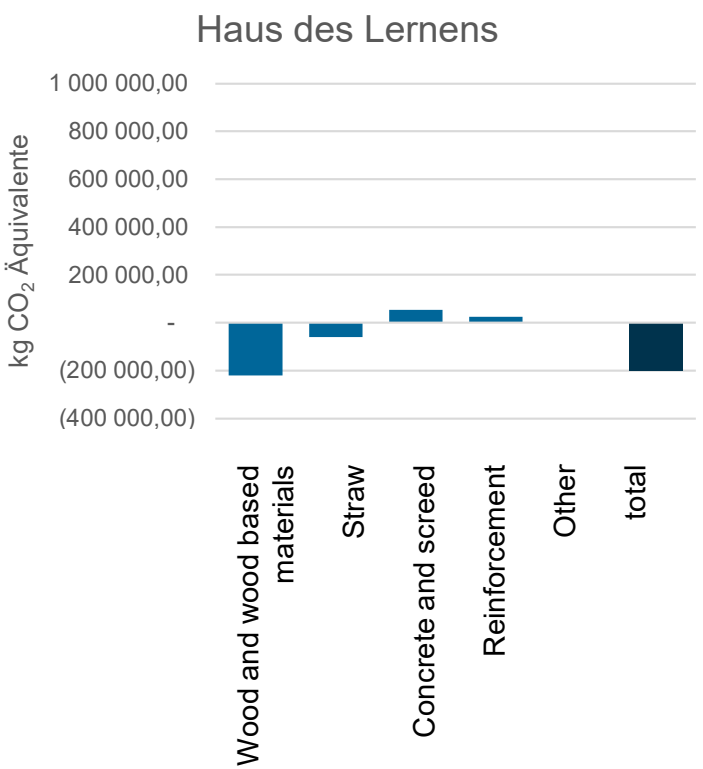
Global Warming Potential HDL

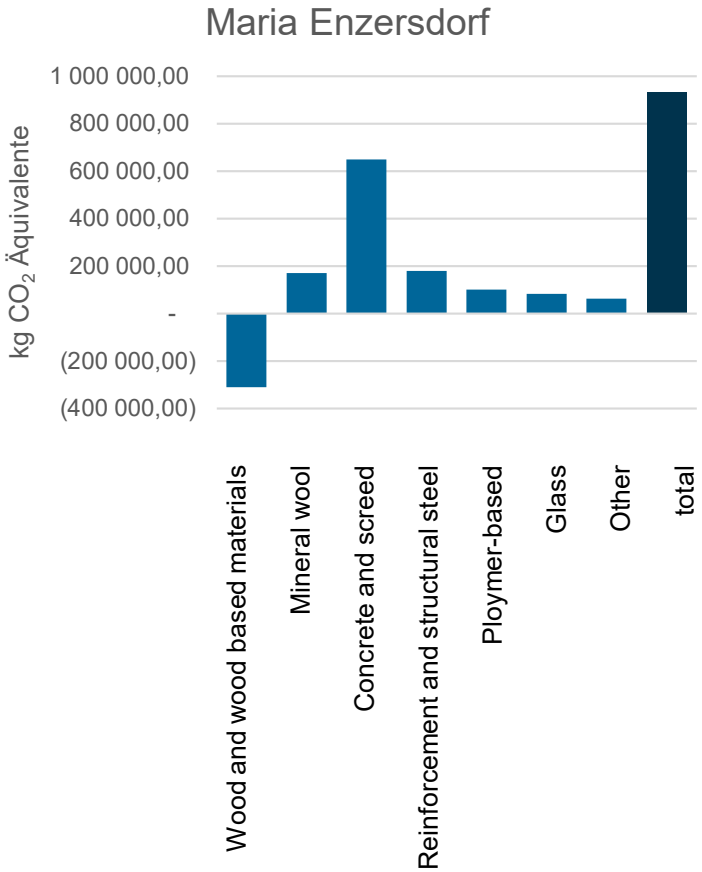


SOURCE: FISCHER, H.: ÖKOLOGISCHE BAUTEILAUFBAUTEN. ENDBERICHT, HOCHSCHULJUBILÄUMSSTIFTUNG STADT WIEN. 2019

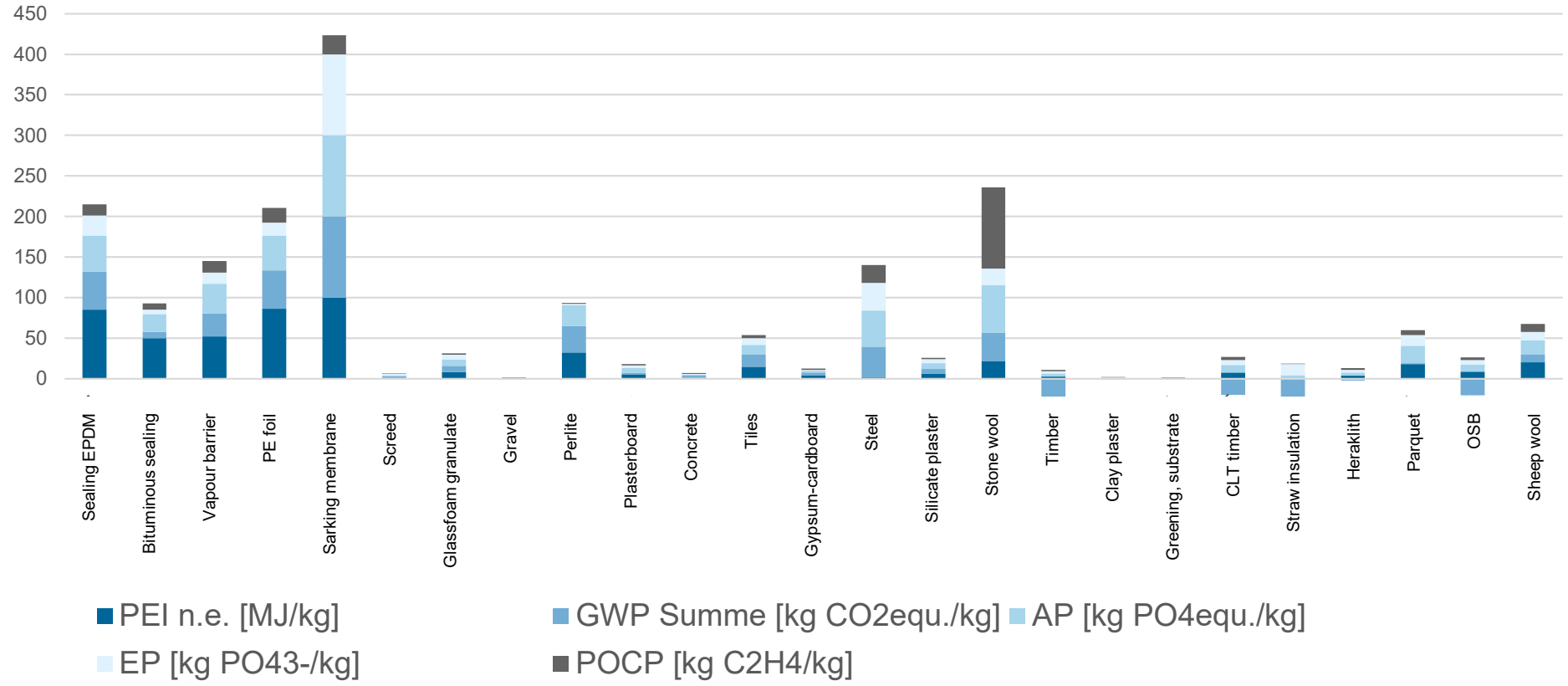
Comparison GWP

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

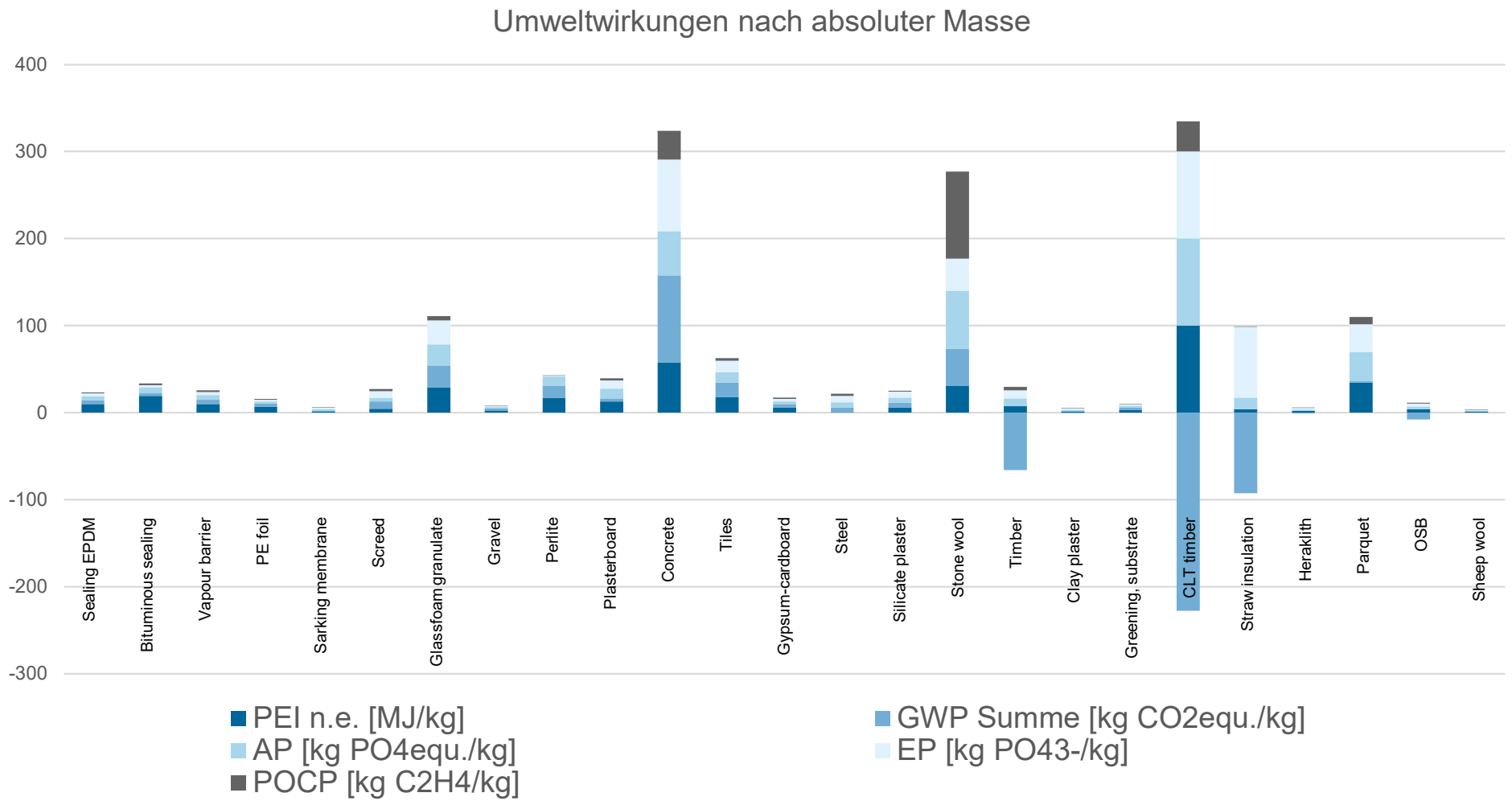




Environmental impacts HDL relative



Environmental impacts HDL absolute



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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: NatuREbuilt

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natuREbuilt

Innovationsnetzwerk für regenerative, rezyklierbare, regionale und resiliente Komponenten im Hochbau

- Team of 19 partners
- Most of them are companies, which have a lot of experience with ecological buildings
- Workshops to share experience, knowledge, information,…
- Experimental studies, simulations, design of new constructions

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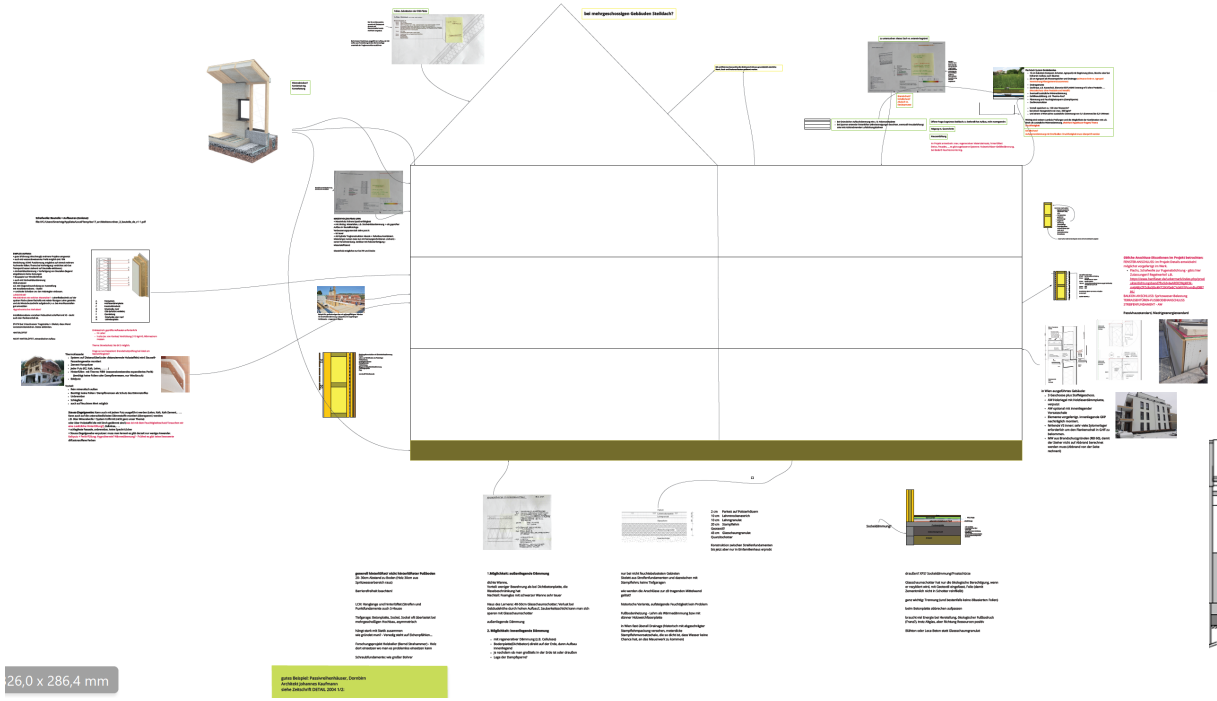
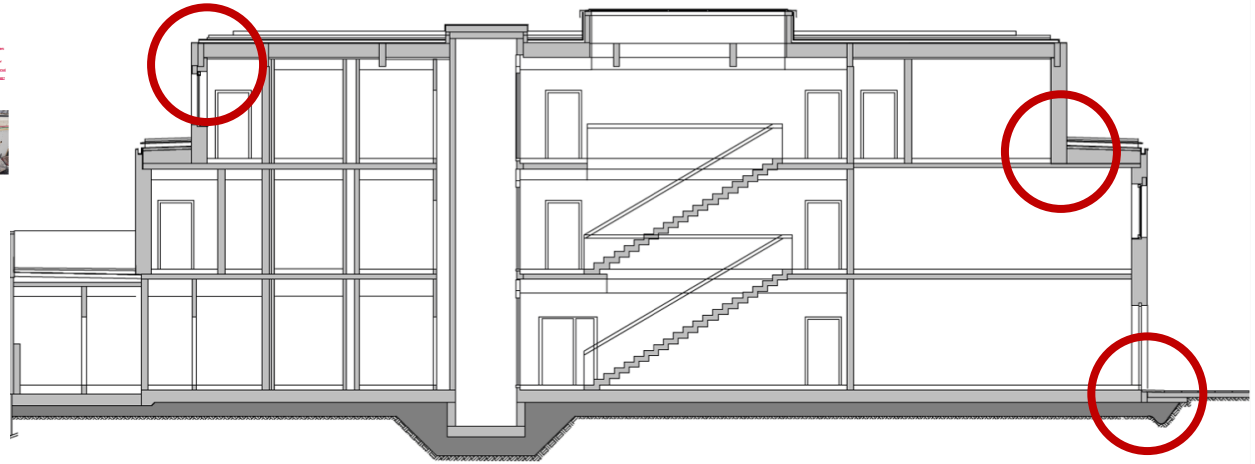
natuREbuilt

Goals:

- create an overview of safe, ecological constructions
- develop new, ecological, building-physically safe constructions through tests in the laboratory, on the test bench, in situ and through simulations
- digitize validated data collected and generated in the project in a BIM-compatible way
- create a planning toolkit for ecological constructions

natuREbuilt





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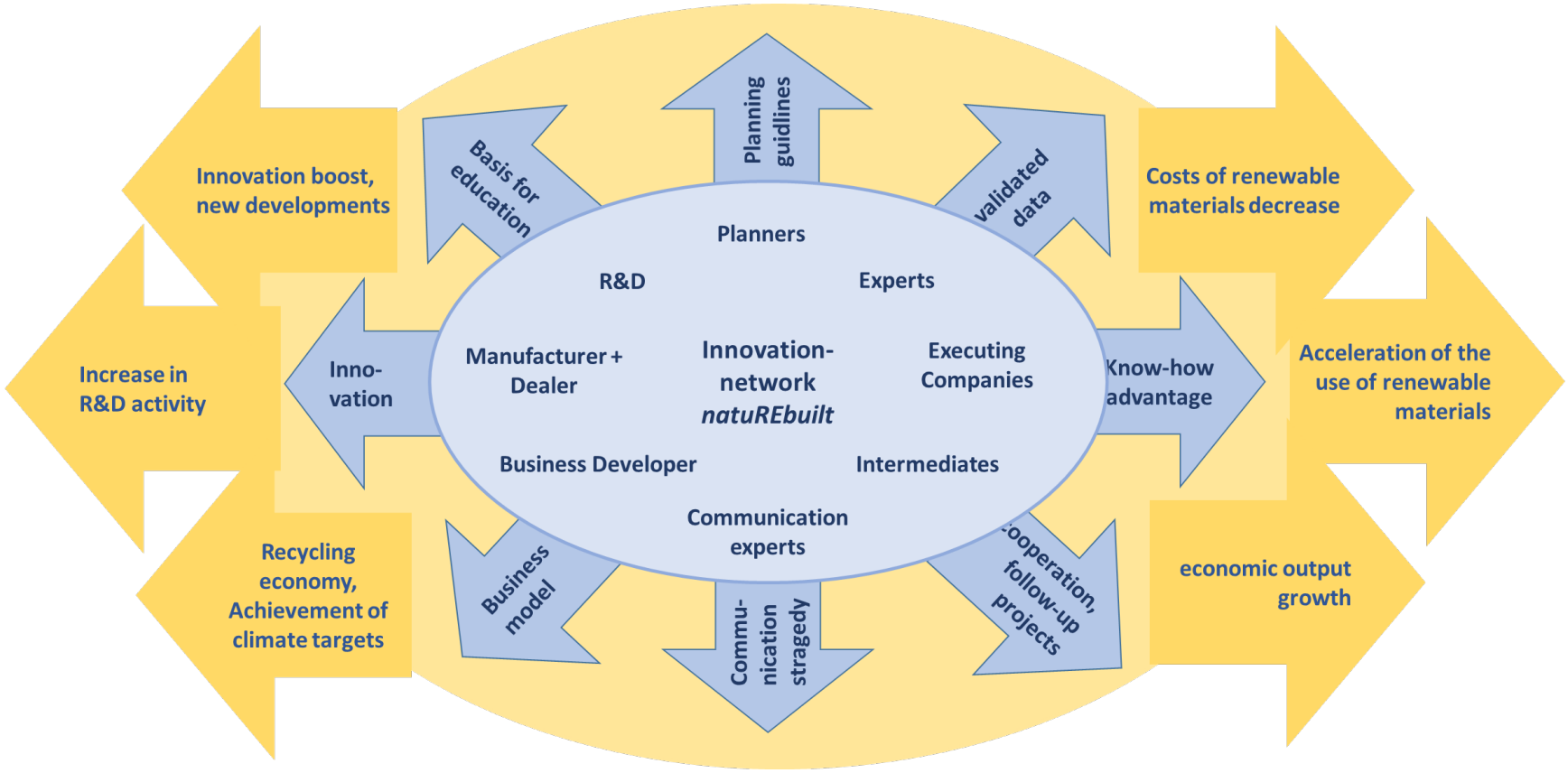


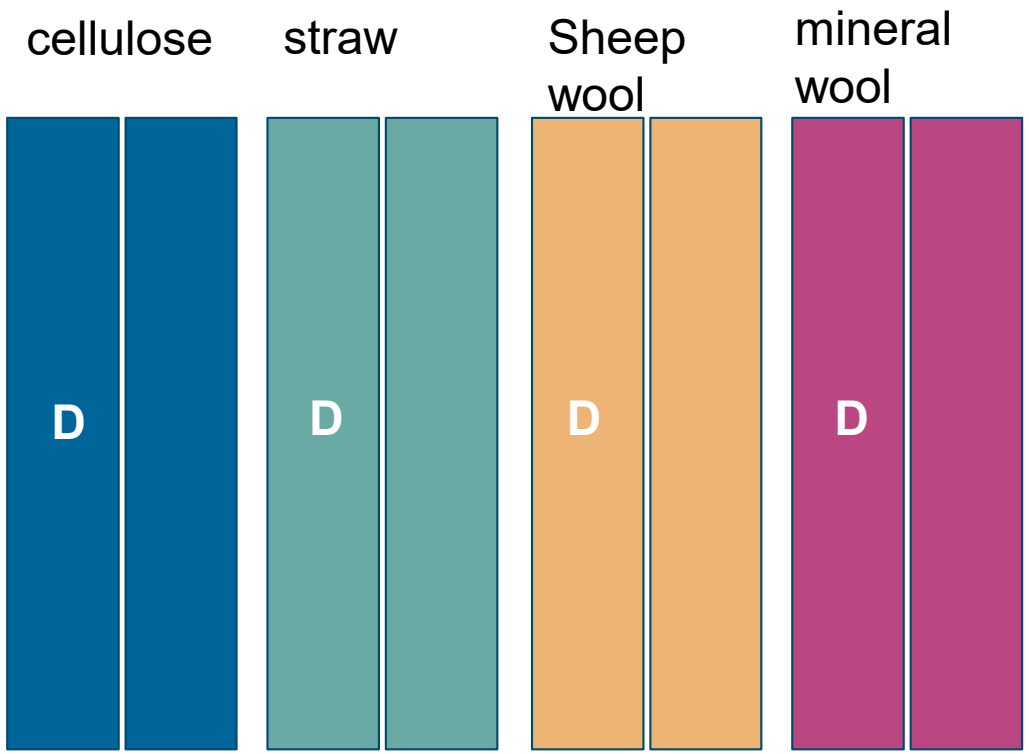
Test rig

- Location: Arsenal, 1030 Vienna
- Mounted on a slewing ring
- Single-storey, on one quarter two-storey
- Wood structure as a base
- Exchangeable modules (wall, flat roof)
- Installation of different constructions:
  - Stress test of different bio-based insolations
  - Durability of fleece coated with clay as a vapour barrier
  - Thermal properties of straw insulation

Test rig: Stress test of bio-based insulations

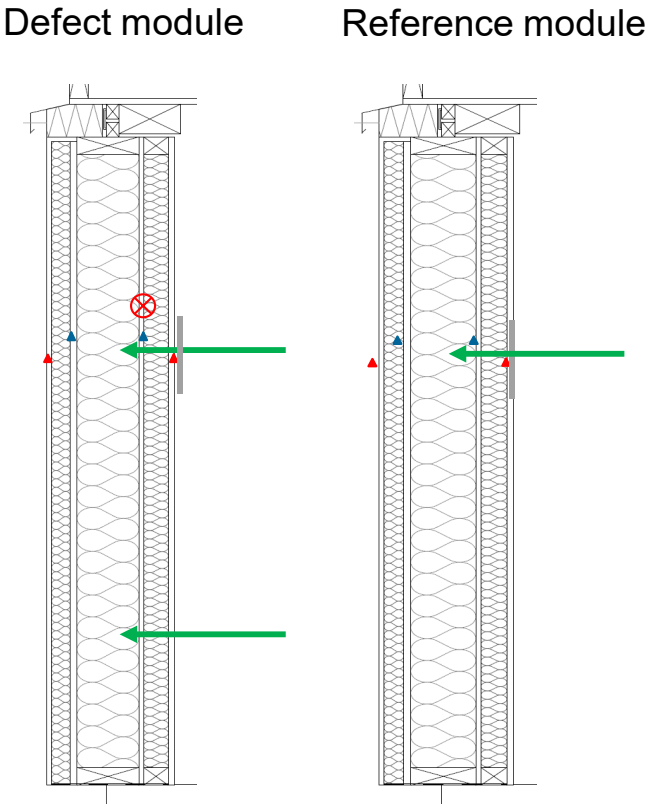
- Stress test of bio-based constructions
- Insulation made of different bio-based materials (cellulose, straw, sheep wool, mineral wool as reference)
- Intentionally imperfections in the constructions
- Defect module compared with a reference module

Test rig: Stress test of bio-based insulations



Test rig: Stress test of bio-based insulations

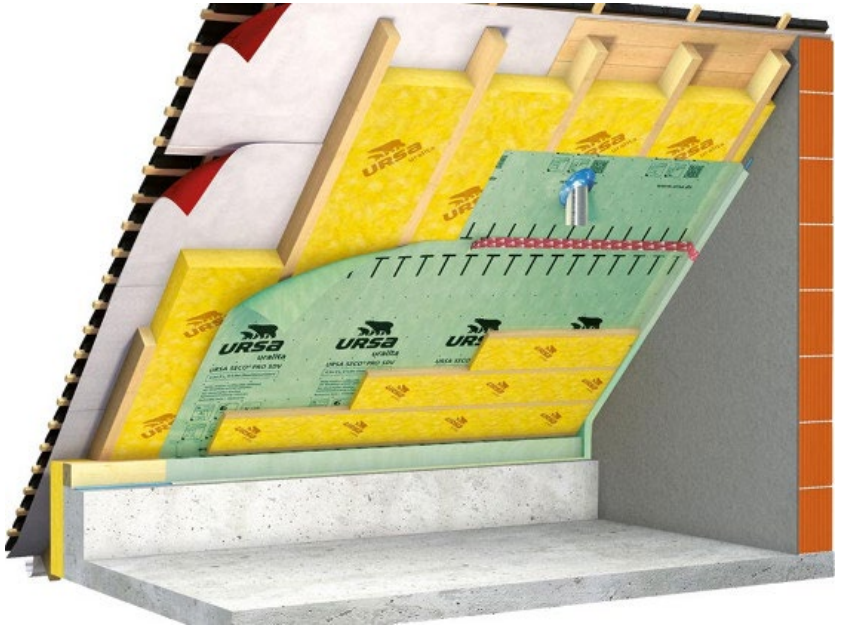
temperature
temperature/moisture
Wood moisture
Heat measuring foil
defect



- First heating period measured and evaluated: so far no significant differences between reference and defect module
- Further procedure: Further measurement/evaluation, Adjustment of different climatic conditions, generation of additional defects

Durability of fleece coated with clay

- Timber frame construction is usually installed with a vapour barrier and sometimes air barrier (ventilated façade), which are usually made of polymers
- Can the clay fleece be used instead of the vapour barrier?
- Measurement of temperature and humidity in the building component in order to draw conclusions about the building's physical functionality



SOURCE PICTURE: HTTPS://WWW.ENERGIE-FACHBERATER.DE/DAEMMUNG/WAS-IST-EIGENTLICH-EINE-FEUCHTEVARIABLE-DAMPFBREMSE.PHP (JUNE 2022)

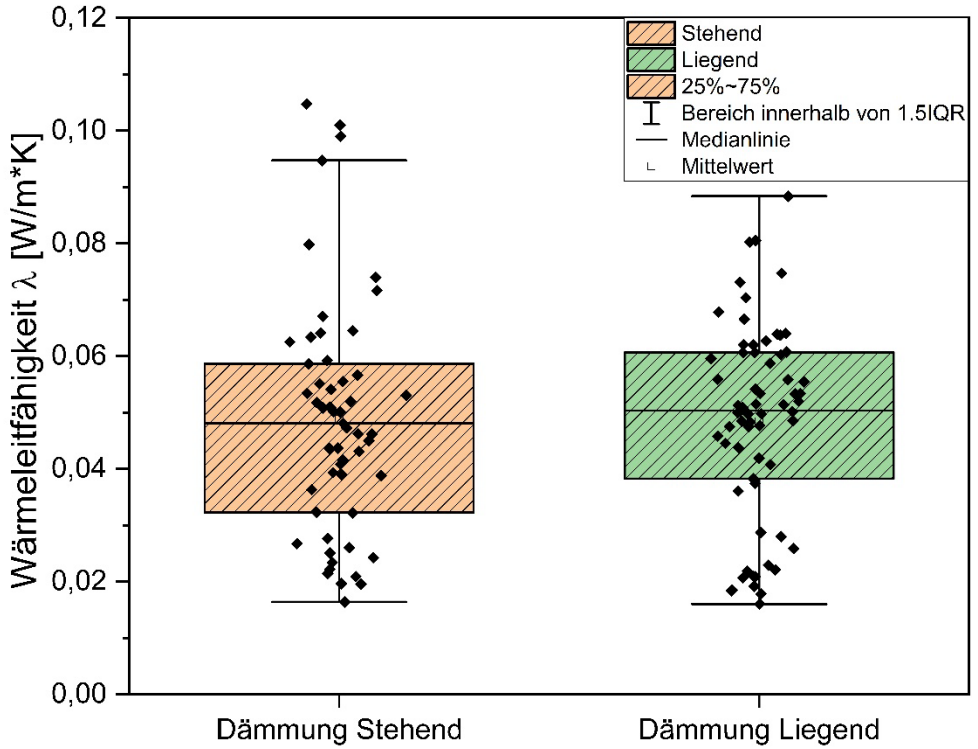
SOURCE: PAUL PICHLER, 2022. MASTER THESIS IN PROGRESS.

Thermal insulation properties of straw

- it is investigated whether the thermal conductivity is different depending on whether the straw is blown in horizontally or vertically
- State of the art: only vertically, because of the assumption that the thermal conductivity is better (and the insulation worse) when the straw fibers are parallel to the heat flow

Thermal insulation properties of straw

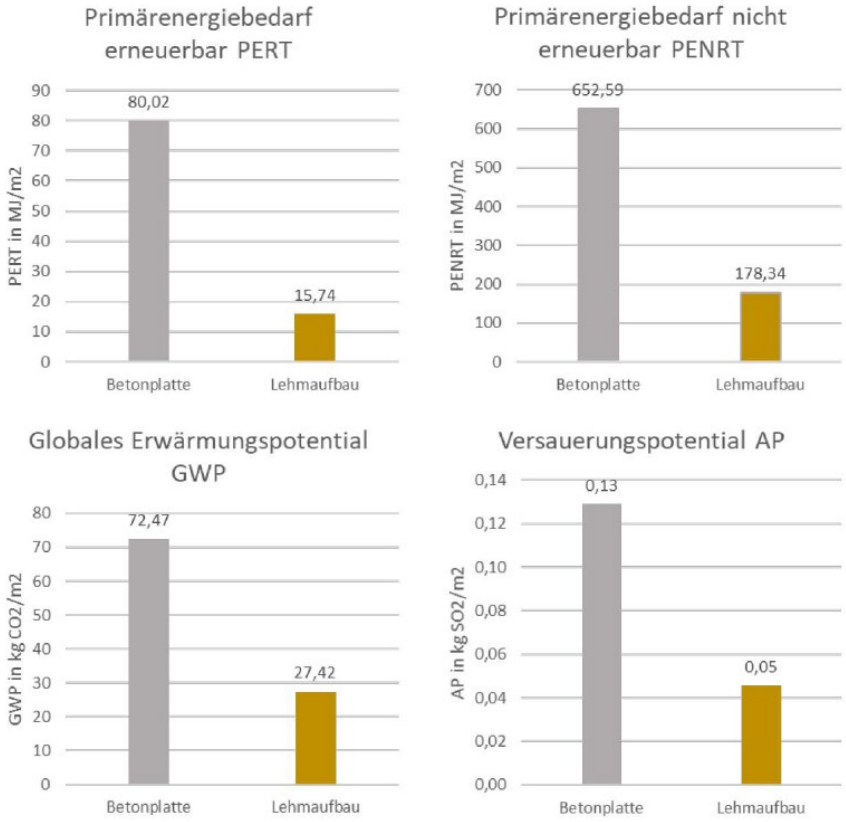
- No significant difference
- Difference within the error tolerance of the measurement accurancy
- similar to the data that can be found in the literature



Projects: Floor construction made of clay

Clay

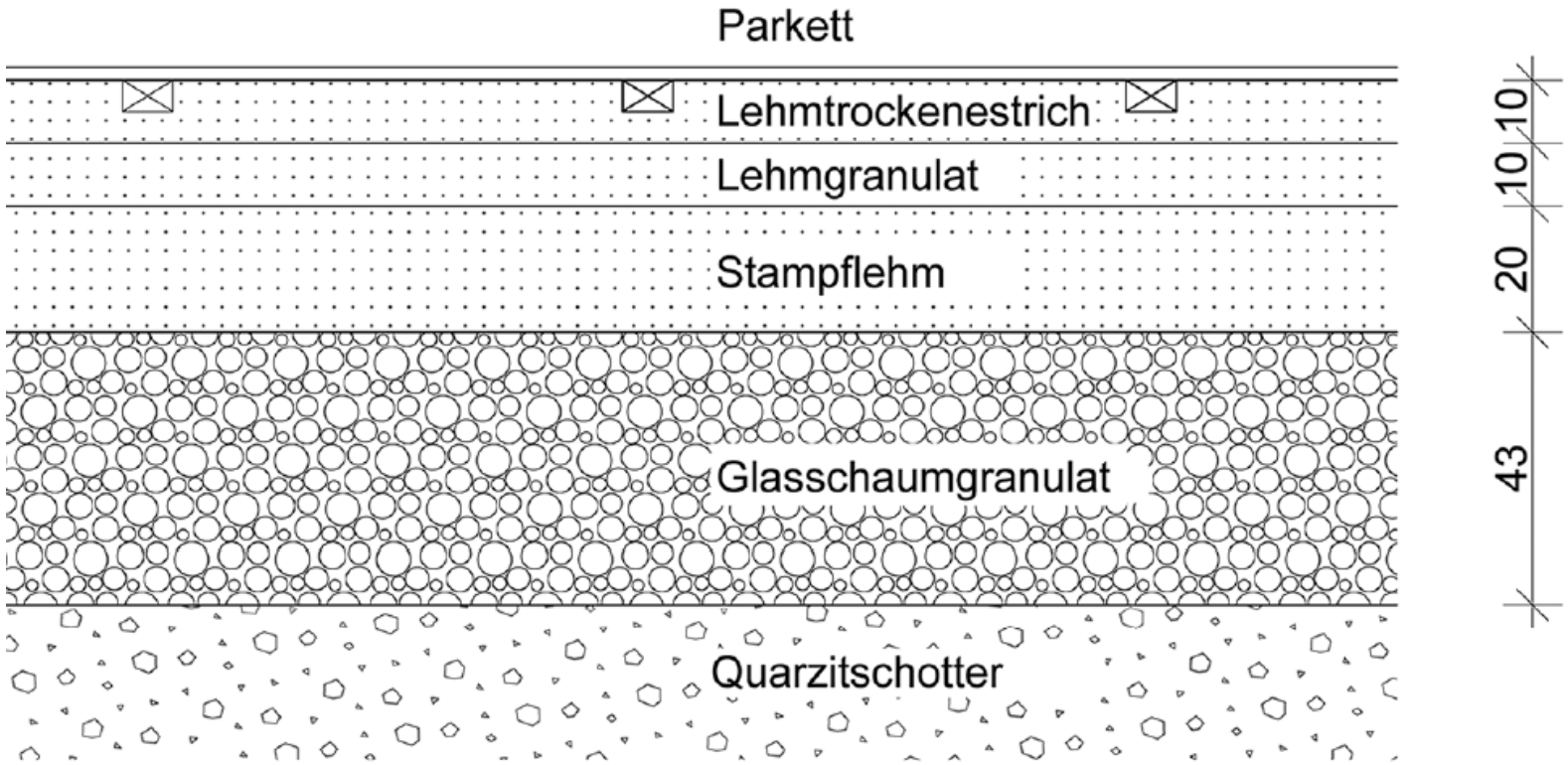
- Good hygrothermal properties
- Improves indoor climate
- Free from chemical additives, toxins, ...
- Harmless in processing
- Regionally available
- Recyclable
- No bonding of layers
- No waterproofing/no fossil building materials necessary



SOURCE: FISCHER, H. ET AL: **UNTERSUCHUNG DER HYGROTHERMISCHEN EIGENSCHAFTEN EINES ÖKOLOGISCHEN BODENAUFBAUS AUS LEHM. BAUPHYSIK VOL.42, ISSUE 3, S.116-123**

Floor construction based on clay

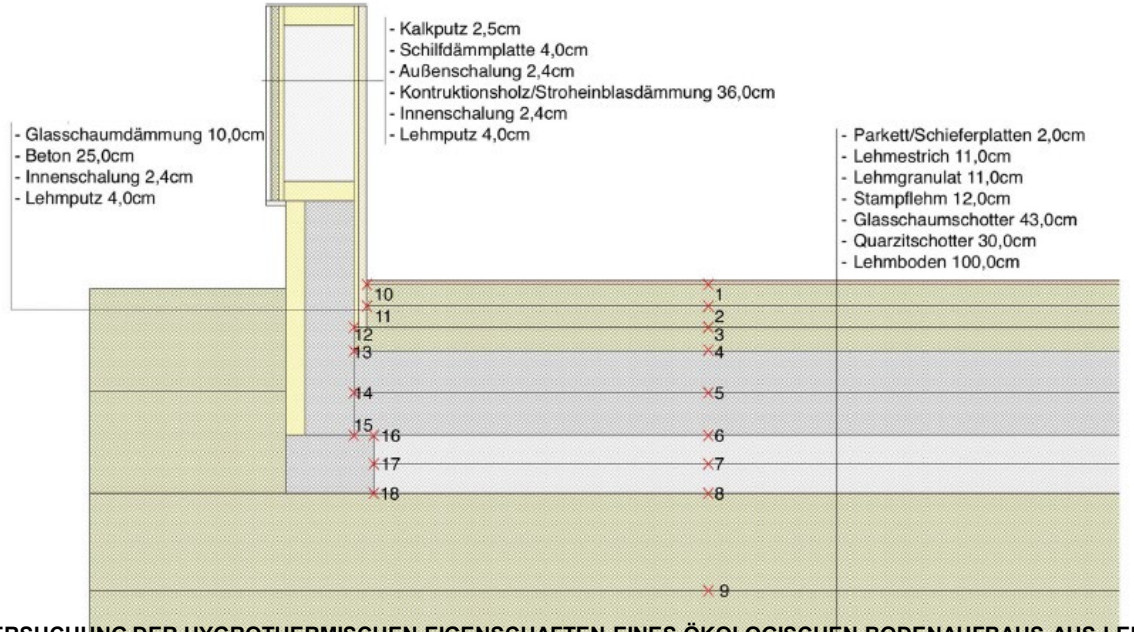
- Single family house
- Controlled residential ventilation and radon drainage
- Strip foundations
- Without waterproofing



SOURCE: FISCHER, H. ET AL: **UNTERSUCHUNG DER HYGROTHERMISCHEN EIGENSCHAFTEN EINES ÖKOLOGISCHEN BODENAUFBAUS AUS LEHM. BAUPHYSIK VOL.42, ISSUE 3, S.116-123**

Floor construction based on clay

- Simulations with different floor coverings in WUFI 2D - hygrothermal functionality
- Simulation of the building in WUFI Plus - hygrothermal comfort
- Floor structure in-situ equipped with humidity and temperature sensors



SOURCE: FISCHER, H. ET AL: **UNTERSUCHUNG DER HYGROTHERMISCHEN EIGENSCHAFTEN EINES ÖKOLOGISCHEN BODENAUFBAUS AUS LEHM. BAUPHYSIK VOL.42, ISSUE 3, S.116-123**

Floor construction based on clay

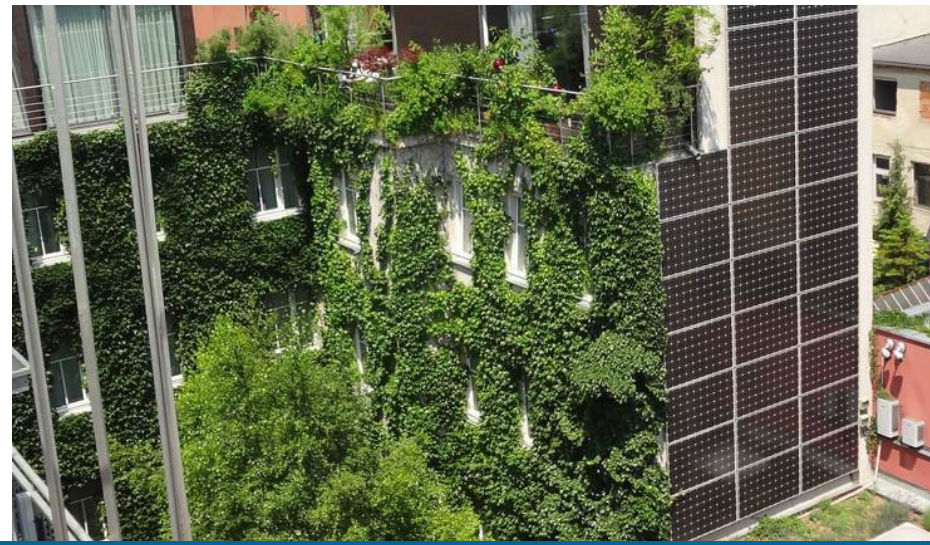
- Structure is hygrothermally functional
- Correct planning and execution of the connection to the outer wall is important
- Hygrothermal comfort is higher in winter

SOURCE: FISCHER, H. ET AL: **UNTERSUCHUNG DER HYGROTHERMISCHEN EIGENSCHAFTEN EINES ÖKOLOGISCHEN BODENAUFBAUS AUS LEHM. BAUPHYSIK VOL.42, ISSUE 3, S.116-123**

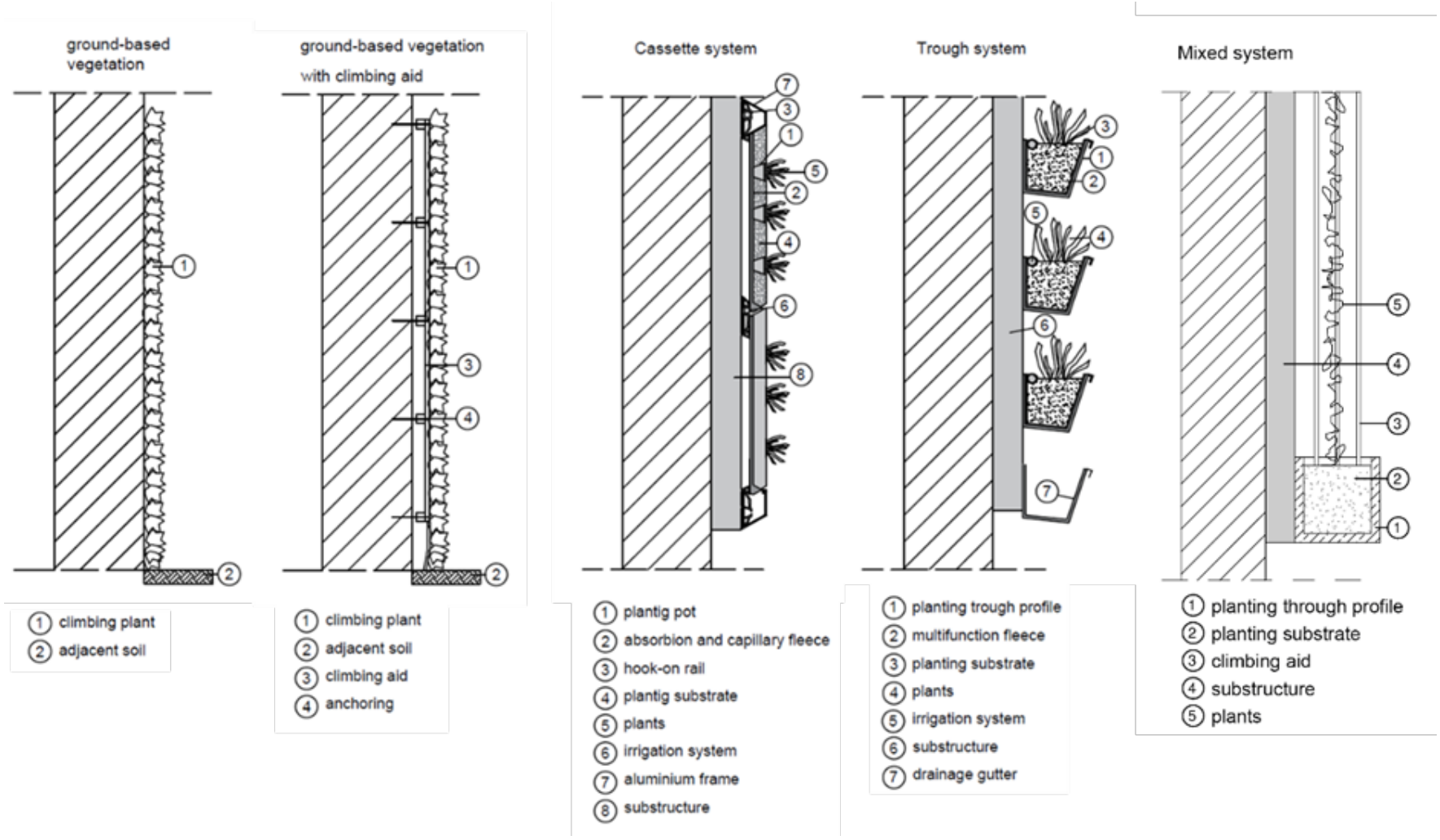
Projects: Building greening

Building greening

- Reduce the energy demand for heating and cooling
- Reduce the amount of CO_2
- Reduce noise
- Binds dust
- Increases air quality
- Positive effects on the microclimate, night cooling
- Reduction of small-scale flooding
- …



Building greening: systems



Ecological comparison of greening systems

- Lightweight systems are usually more environmentally friendly
- Environmentally harmful substances should be avoided. (polymer!)
- As far as possible, the light requirements of plants should be met naturally.
- Metals (aluminum) should be processed in such a way that recycling can be carried out as easily as possible.

Grünwand (innen)	PEI nicht erneuerbar in kWh/m²	PEI erneuerbar in kWh/m²	CO_2 in kg/m²	SO_2 in kg/m²
Herstellung (A1 ÷ A3)	556,18	161,51	138,47	0,58
Ersatz (B4)	614,47	200,65	139,40	0,60
Entsorgung/Recycling (C4/D)	-807,83	-239,41	-202,12	-0,92
Graue Energie = + +	362,82	122,76	75,74	0,26

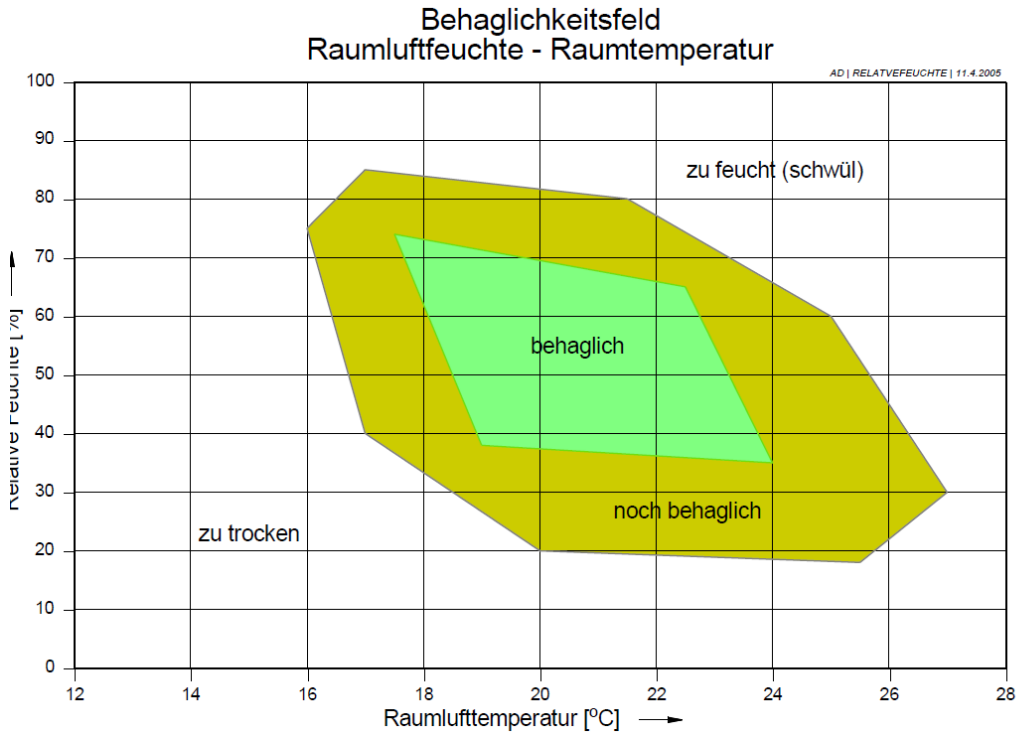
Florawall (innen)	PEI nicht erneuerbar in kWh/m²	PEI erneuerbar in kWh/m²	CO_2 in kg/m²	SO_2 in kg/m²
Herstellung (A1 ÷ A3)	426,85	47,48	72,61	0,28
Ersatz (B4)	2135,49	109,77	285,39	1,02
Entsorgung/Recycling (C4/D)	-802,60	-135,26	42,20	-0,35
Graue Energie = + +	1759,74	21,99	400,21	0,95

Optigrün (außen)	PEI nicht erneuerbar in kWh/m²	PEI erneuerbar in kWh/m²	CO_2 in kg/m²	SO_2 in kg/m²
Herstellung (A1 ÷ A3)	916,02	232,58	241,81	0,99
Ersatz (B4)	945,17	233,68	244,82	1,00
Entsorgung/Recycling (C4/D)	-1266,94	-365,15	-332,64	-1,44
Graue Energie = + +	594,25	101,11	153,99	0,55

Gründwand (außen)	PEI nicht erneuerbar in kWh/m²	PEI erneuerbar in kWh/m²	CO_2 in kg/m²	SO_2 in kg/m²
Herstellung (A1 ÷ A3)	479,37	130,03	121,84	0,50
Ersatz (B4)	538,39	131,96	129,76	0,52
Entsorgung/Recycling (C4/D)	-724,72	-211,53	-177,54	-0,82
Graue Energie = + +	293,04	50,46	74,07	0,21

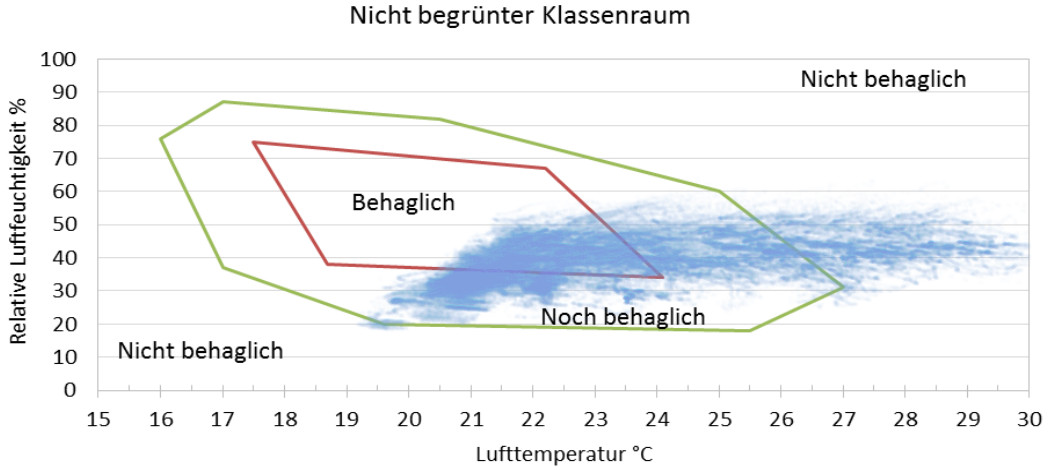
Definition of comfort

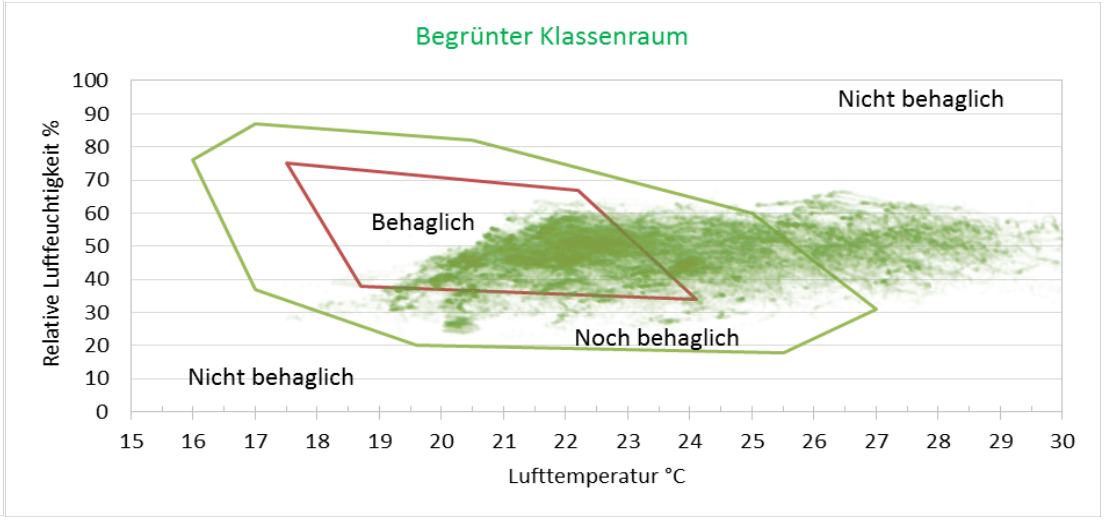
- Comfort field according to Frank
- No consideration of clothing or activity
- Non air conditioned rooms

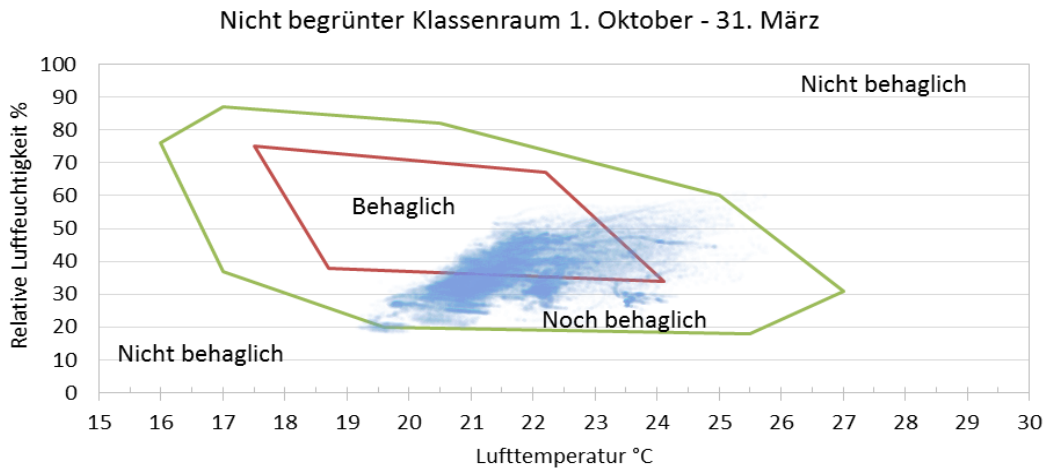


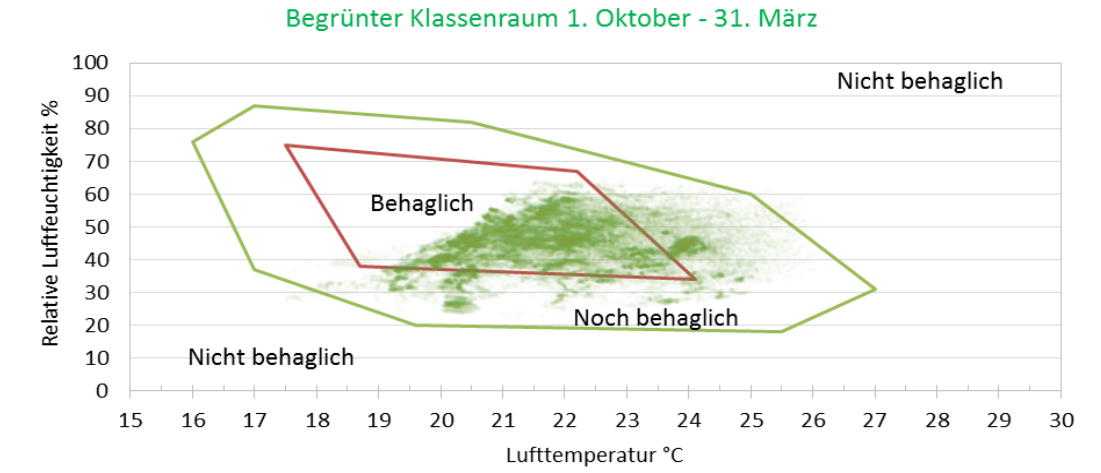
DENTEL, A., DIETRICH, U., THERMISCHE BEHAGLICHKEIT – KOMFORT IN GEBÄUDEN

Hygrothermal Comfort of green and non-green classrooms

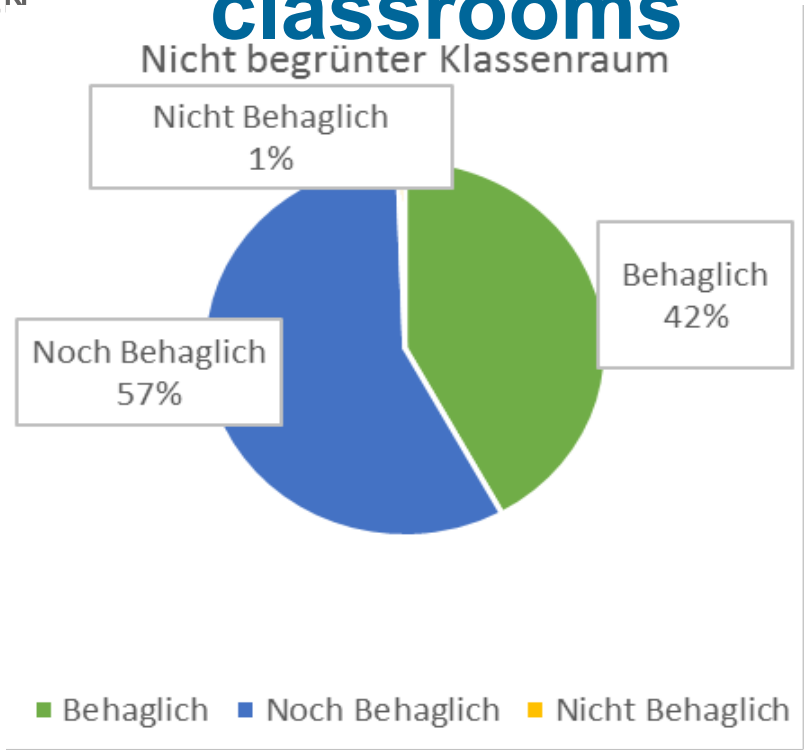


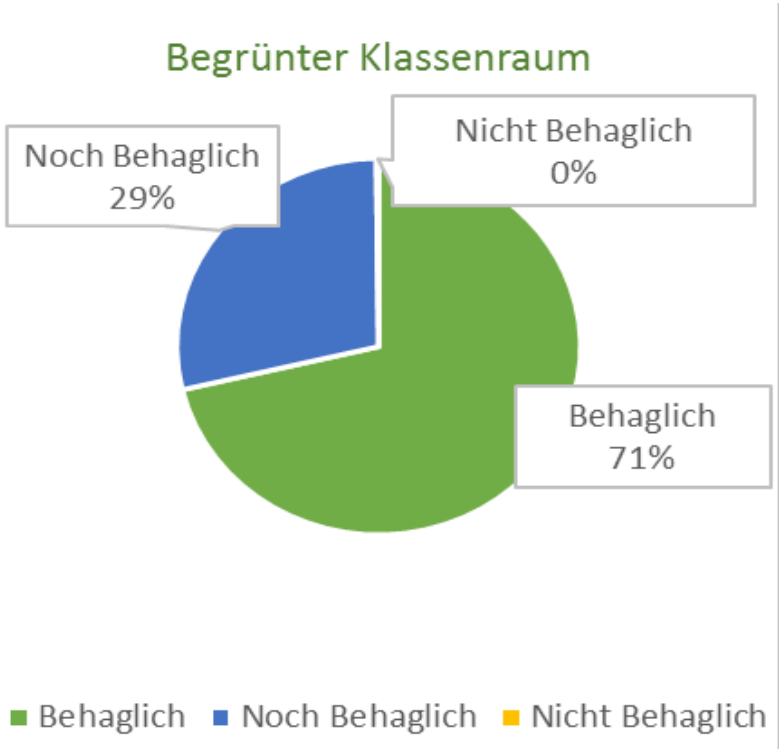






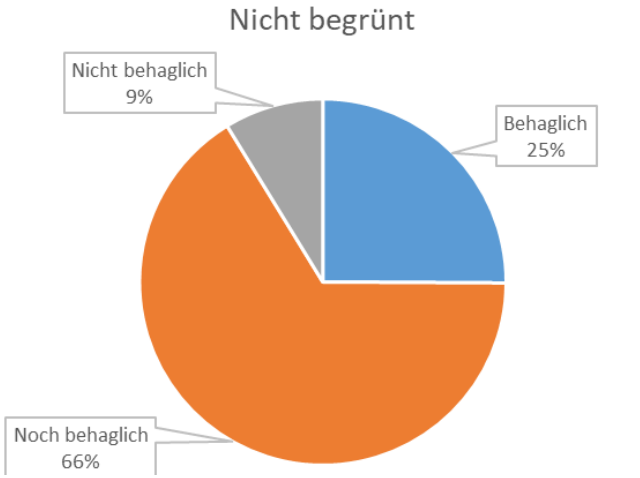
Hygrothermal Comfort of green and non-green classrooms

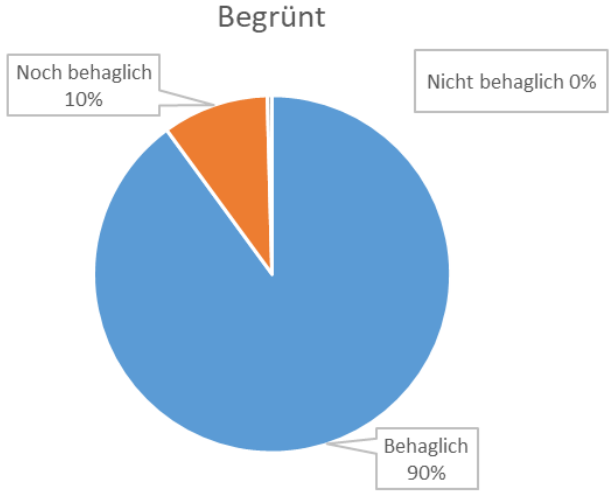




The hygrothermal indoor climate is improved due to indoor greening. The air humidity is increased due to the indoor greening, nevertheless, no increased mold spore load is to be feared with sensible dimensioning of the greening. Mold spore measurements were carried out by IBO Innenraumanalytik OG.

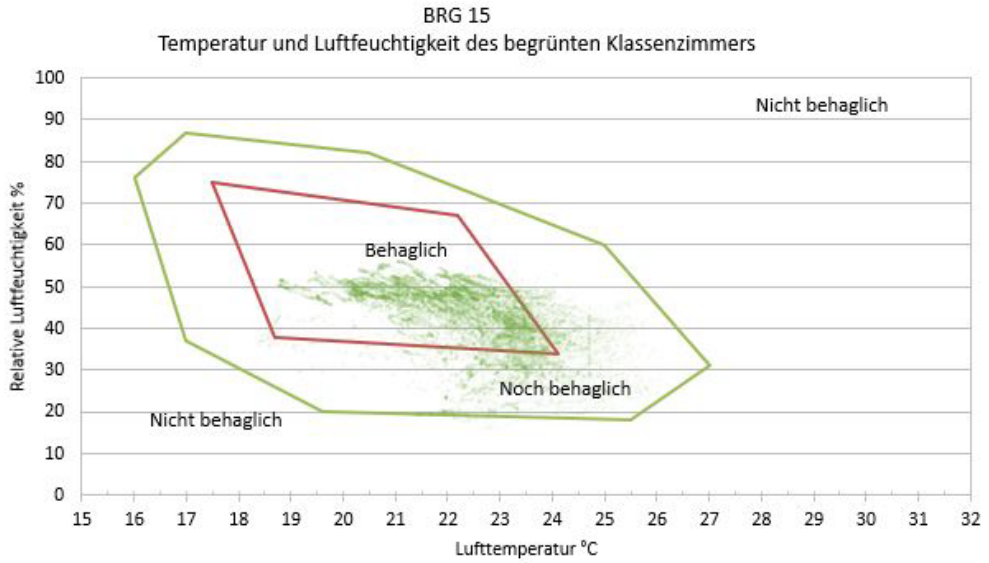
Hygrothermal Comfort of green and non-green classrooms

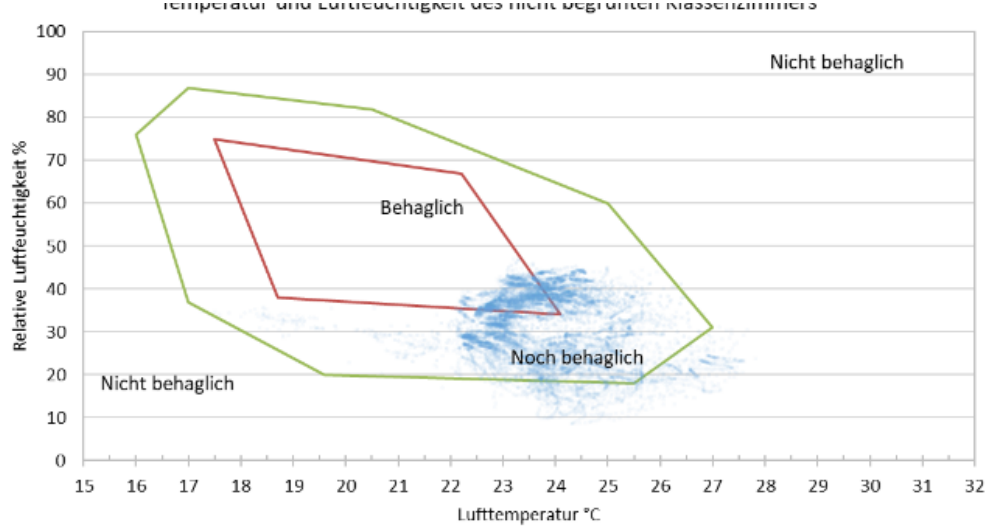




www.gruenezukunftschulen.at

1. Oktober bis 31. März





TECHNISCHE UNIVERSITÄT WIEN

MehrGrüneSchulen

- Cooperation with a school, which focus lies on building technology
- Developing Low Cost greening systems
- Workshops with students
- Realisation of greening systems
- online database with greening options and costs, technical implementation, construction instructions









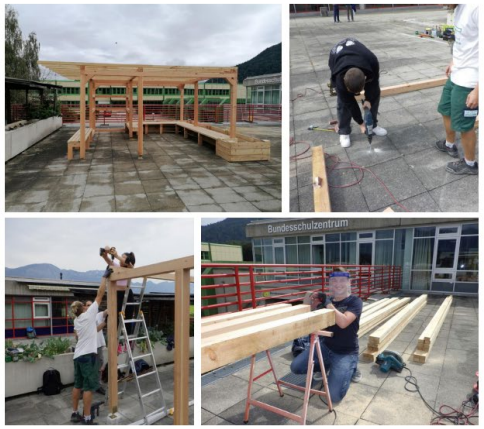
MehrGrüneSchulen

powered by klima+ energie fonds

FFG

Do-It-Yourself Bauanleitung Außenraumbegrünung

Green Classroom



MehrGrüneSchulen
Finanzierungsmodelle für grüne Infrastruktur an Schulen

Die Bauanleitung wurde in Zusammenarbeit erstellt von:

Schüler*innen des Camillo Sitte Bautechnikums:
Daribor Ilic, Ermin Korjenic, Celine Al Bayati, Mehmet Kocaman
Beteiligter Betreuer: Dipl.-Ing. Marco Fiedler

Schüler*innen der HBLFA Gartenbau Schönbrunn:
Nina Weissenberger, Veronika Schmidt, Alina Ondrovic
Beteiligte Betreuerin: Dipl.-Ing. Elisabeth Kuligowski

Workshop-Umsetzung: Schüler*innen der HAK Wörgl, angeleitet von Dipl.-Ing. Ralf Dopheide

TU Wien - Forschungsbereich Ökologische Bautechnologien:
Univ. Prof. Dipl.-Ing. Dr. techn. Azra Korjenic, Florian Teichmann, Dipl.-Ing. Ines Kirchengast, Tarja Salonen BSc, Abdulah Sulejmanovski, Werner Wimmer

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Do-It-Yourself Bauanleitung Außenraumbegrünung

T-Bench

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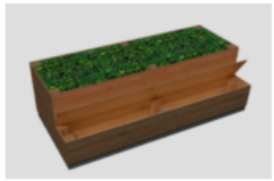
Systeme Innenraumbegrünung	Beispielhafte Abbildung	Geschätzte Herstellungskosten	Pflege und Wartung	DL
The Vessel (Hochbeet mit Sitzbank und Stauraum) Entwurf		ca. 860 € pro Stk. (exkl. Pflanzen, inkl. Hochbeeterde)	Mind. 2x pro Woche zu kontrollieren: Sehen die Blätter gesund aus, sind sie gelb oder welk? Ist das Substrat ausgewogen feucht oder zu feucht/trocken?	
Begrünter Brunnen (Hochbeet mit Wasserstelle und Solar-Springbrunnen) Entwurf		ca. 1.050 € pro Stk. (exkl. Pflanzen und Substrat)	Zusätzliche Kontrolle beim Begrünten Brunnen: Ist der Wasserstand im Becken hoch genug, ist die Pumpe frei und in Betrieb?	
T-Bench (2-seitige Sitzbank mit begrünter Überdachung) Entwurf		ca. 800 € pro Stk. (exkl. Pflanzen und Substrat)		
Green Trio (dreiseitig um einen Baum angeordnete „Hollywood-Schaukeln" mit Begrünung durch Kletterpflanzen) Entwurf		ca. 2.000 € pro Stk. (exkl. Pflanzen und Substrat)		
The Green Classroom (begrünbare und modular erweiterbare Pergola) Entwurf		ca. 1.100 € pro Stk. (exkl. Pflanzen und Substrat)		
Place Evergreen (begrünte Pergola mit hexagonalem Grundriss; optional als Spielgerät gestaltbar) Entwurf		ca. 1.200 € bis 2.000 € pro Stk. (je nach Ausstattung)		

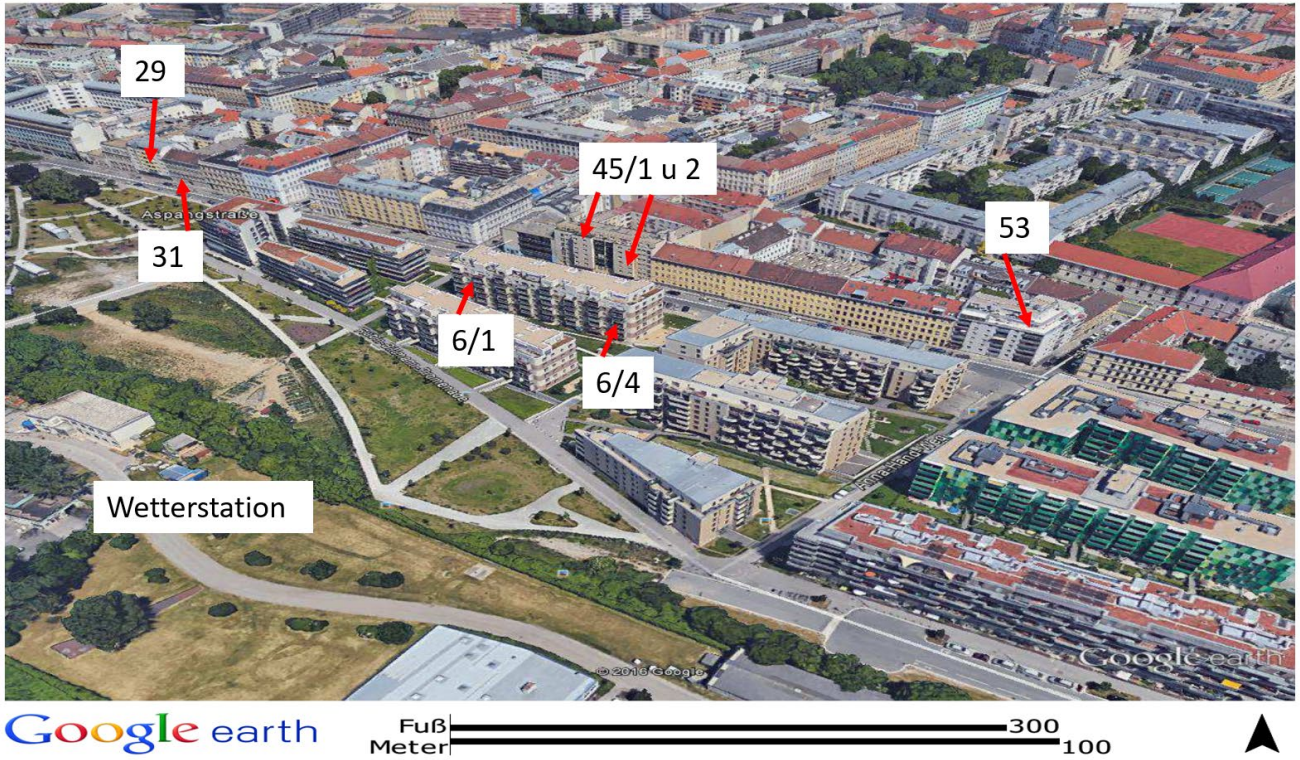
TECHNISCHE UNIVERSITÄT WIEN

MehrGrüneSchulen

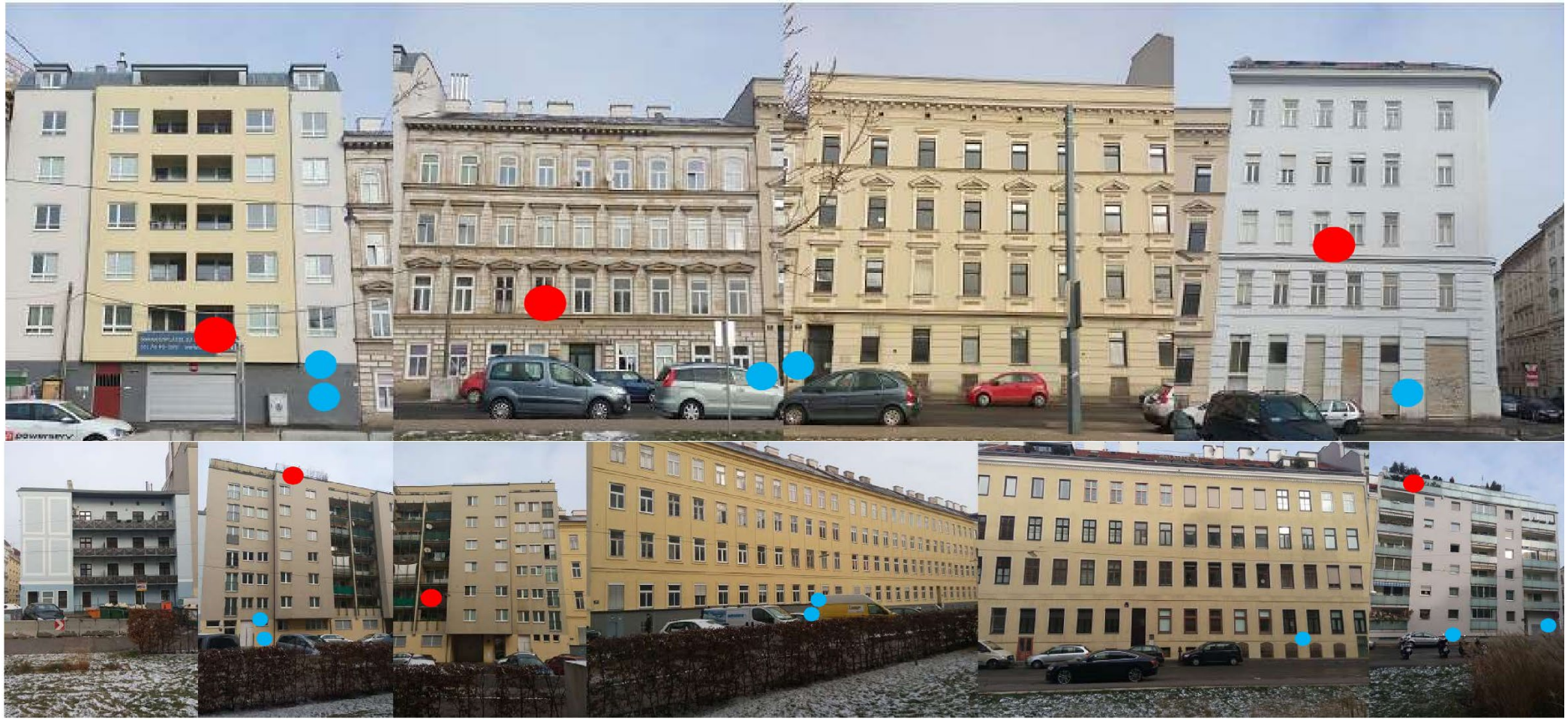
Projektfilm: https://www.youtube.com/watch?v=O-XVXL0jHWk

Projects: Greening Aspern

Greening Aspang

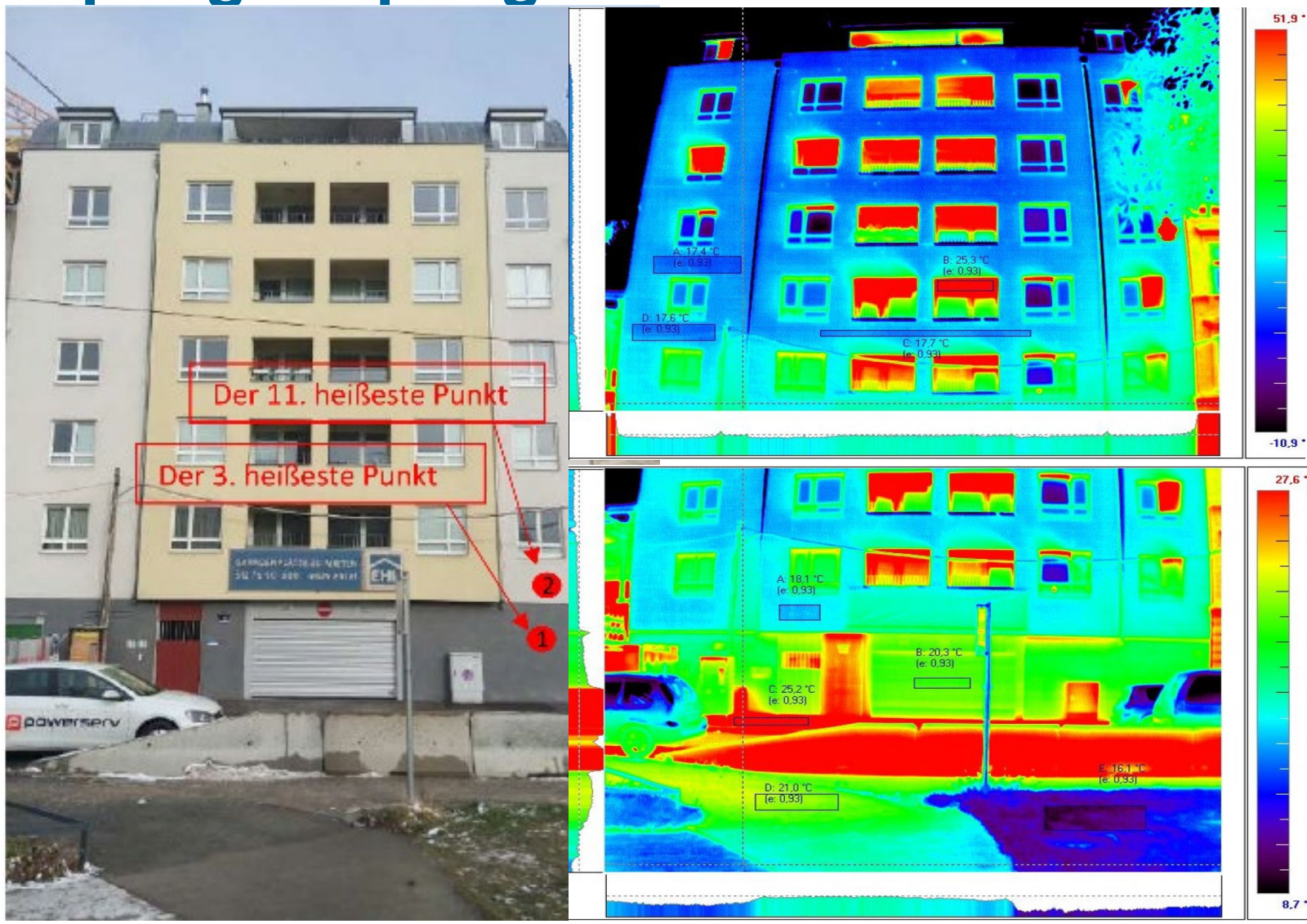


Greening Aspang



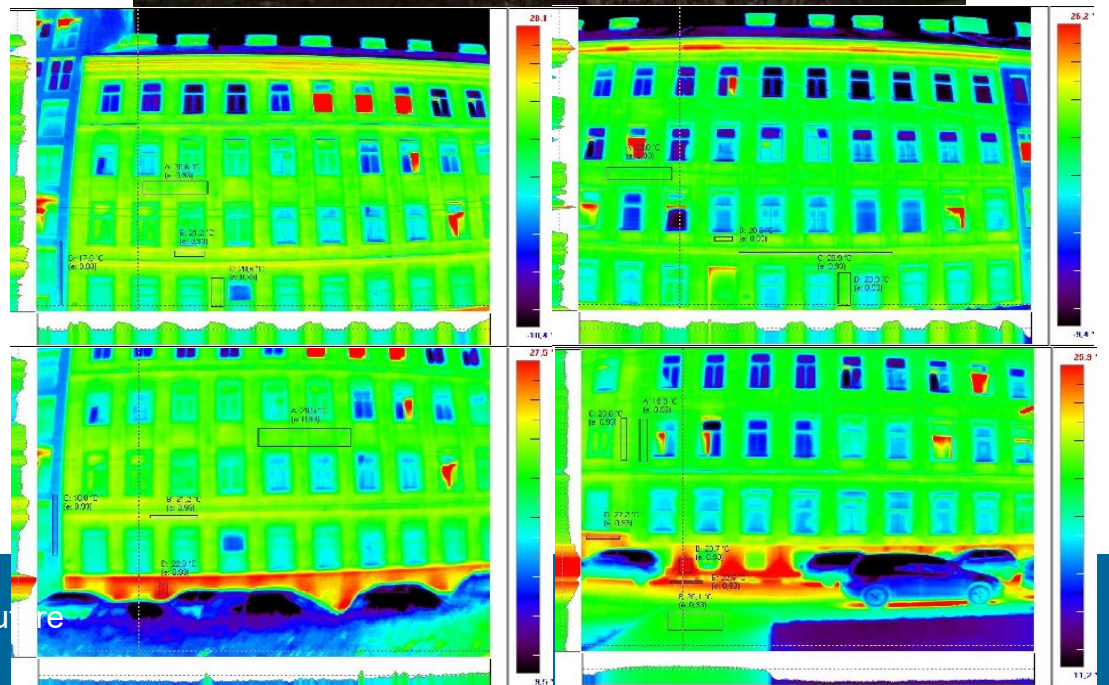
Greening Aspang: Aspangstraße 19

- Construction: reinforced concrete / brick
- Facade: 8cm thermal insulation composite system
- color: light/grey
- Base color: dark/black



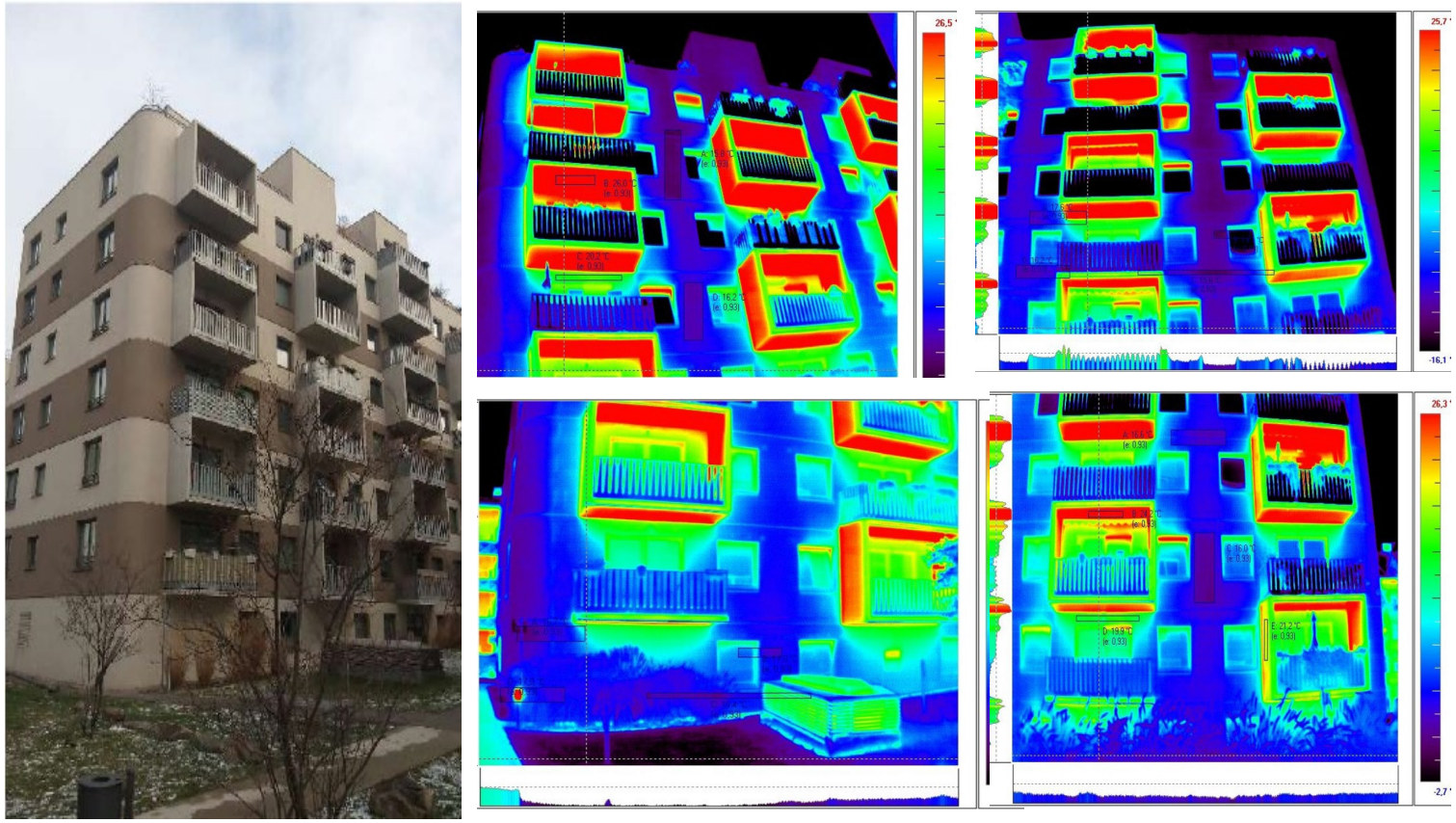
Greening Aspang: Aspangstraße 47-49

- Construction: solid brick
- Facade: plastered
- Color: medium/yellow
- Base color: dark/grey

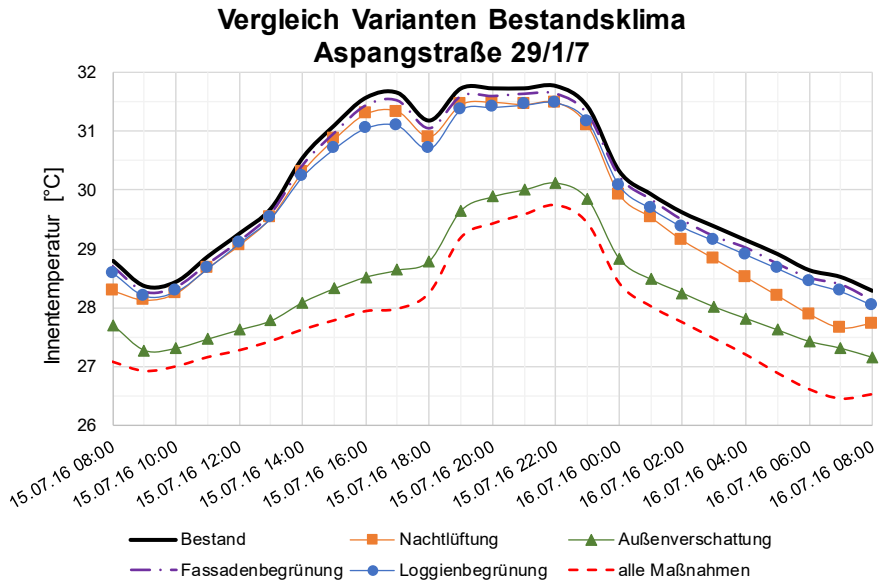


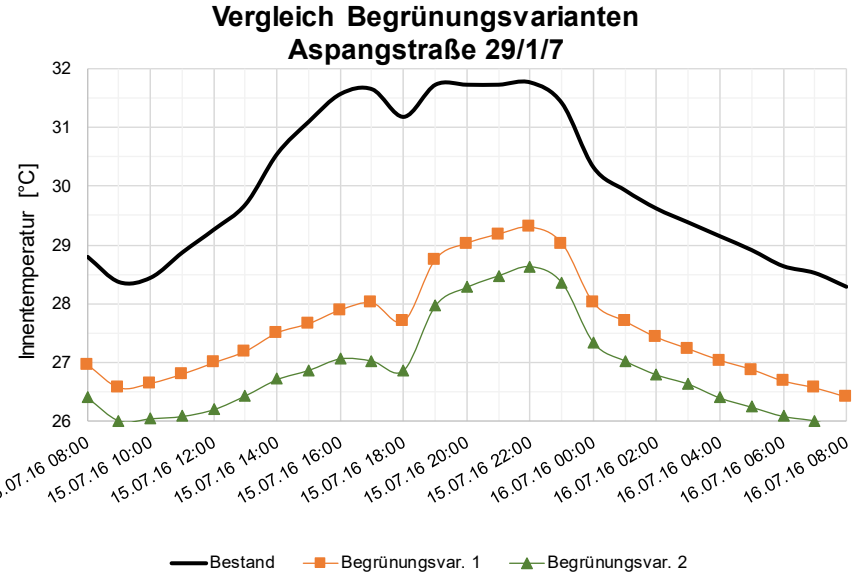
Greening Aspang: Aspangstraße 6 (passive house)

- Year of construction: 2012
- Construction: reinforced concrete
- Facade: 30cm thermal insulation composite system
- Color: bright and dark brown



Greening Aspang: Aspangstraße 29

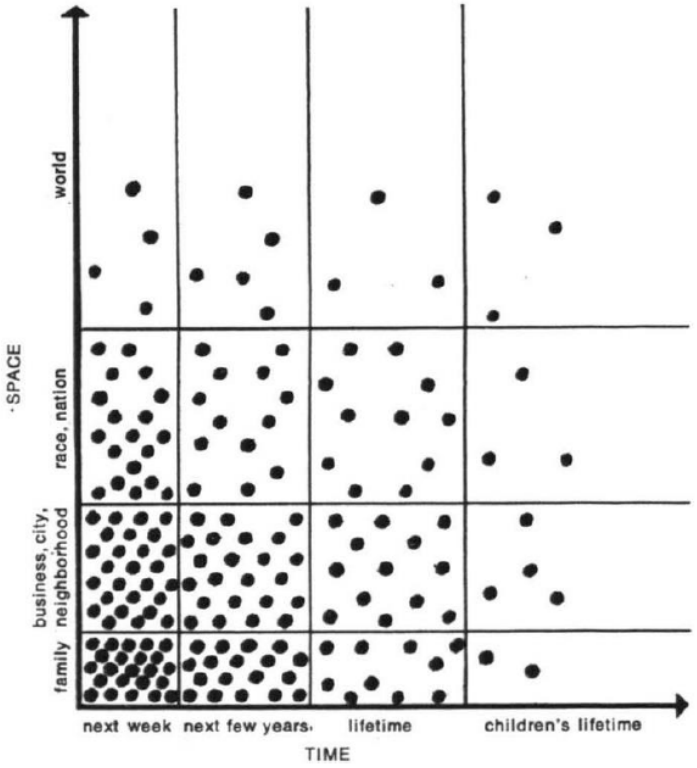




- The improvement through structural and microclimatic interventions is greater the worse the existing building is
- The most effective structural measure is external shading
- Combination of exterior shading and microclimatic actions would achieve comfort range

Conclusion

- No building or using and renovating older building stock is the most ecological way
- Use of secondary raw materials, choose materials with low energy and emission profiles (bio-based and recycled materials)
- Question the method and the indicators
- Trees store CO_2 and are air conditioners
- ecology must not be the only criterion, use materials with additional benefits
- think of the future!



Thank you! ☺