Life Cycle Analysis of conservation vs. demolition and new construction

Using the example of a facade refurbishment

– A study by weberbrunner architekten zürich & berlin

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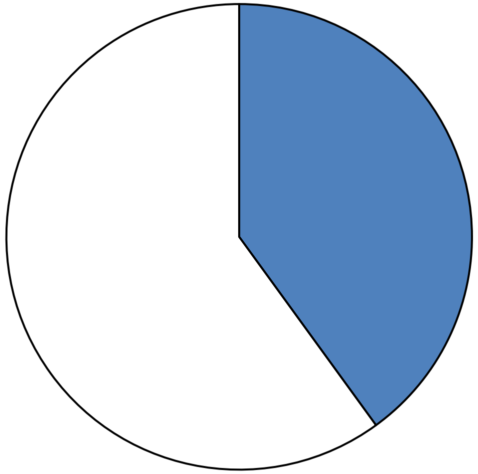
01 Current situation

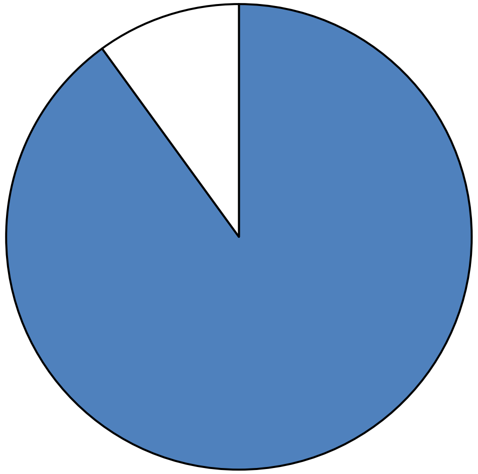
Environmental footprint of buildings in Germany

CO_2 Emissions



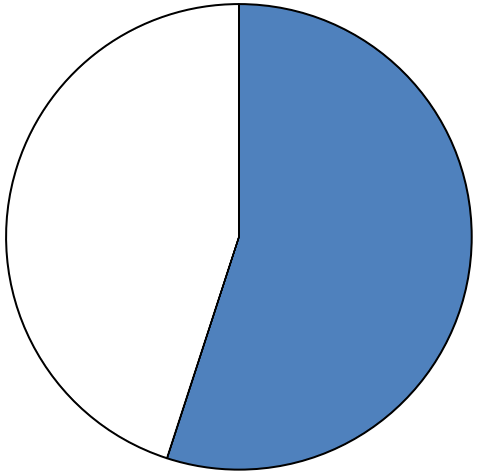
40%

Mineral Raw Material Consumption



90%

Waste Generation

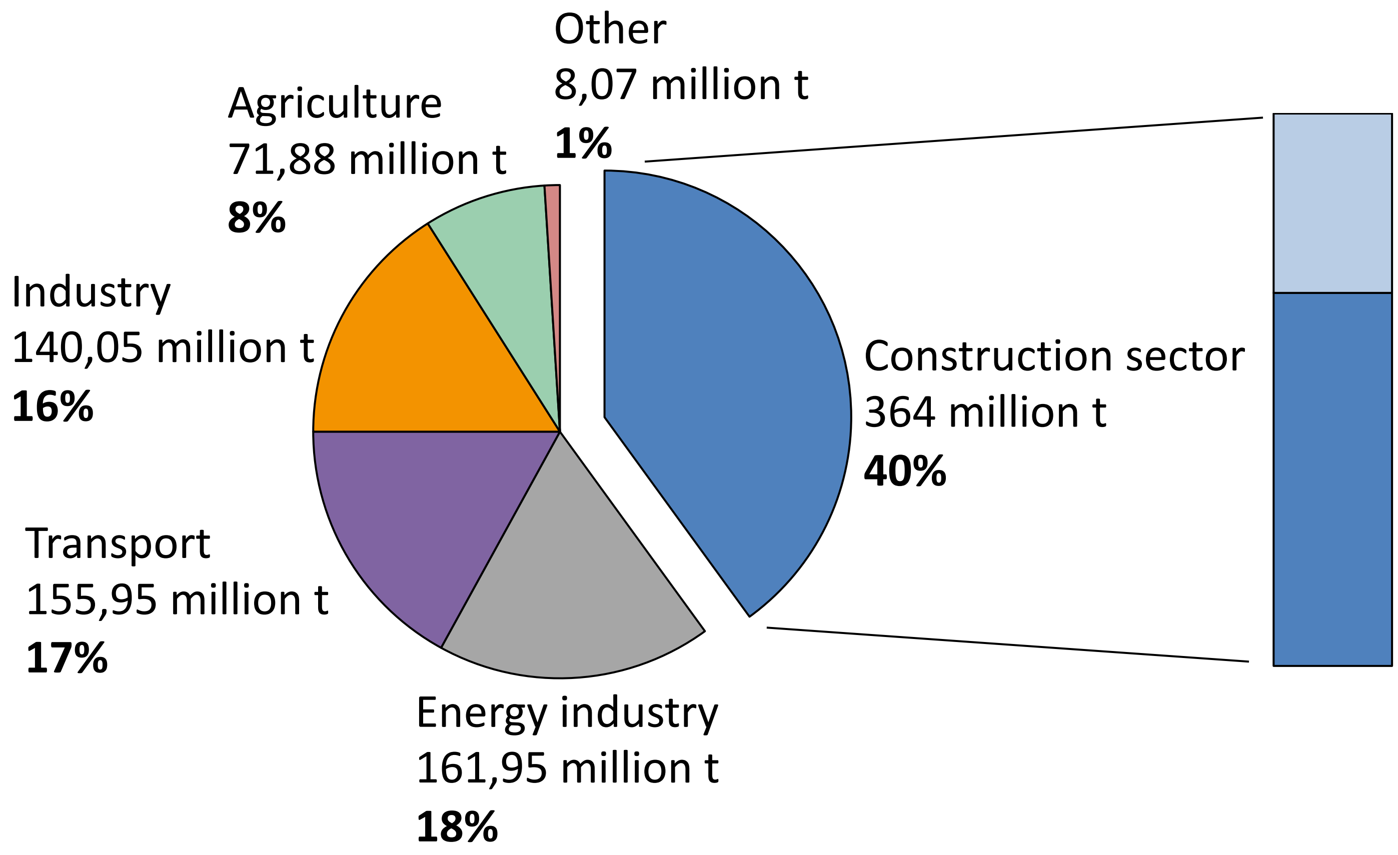


55%

CO_2 Emissions, Source: Umweltfußabdruck von Gebäuden in Deutschland, BBSR-Online-Publikation Nr. 17/2020
Mineral Raw Material Consumption, Source: F. Pichlmeier, Ressourceneffizienz im Bauwesen – von der Planung bis zum Bauwerk, VDI Zentrum Ressourceneffizienz GmbH, Mai 2019
Waste Generation, Source: Statistisches Bundesamt, Abfallbilanz, Wiesbaden, 2019

01 Current situation

CO_2 emissions in the construction sector



CO_2 emissions through field of action "Construction and use of buildings"

Buildings: 13%
(Direct emissions operating energy)
119 million t

Construction TOTAL: 27%
(Indirect emissions such as processes for building materials, provision of district heating, etc.)
245 million t
There of in : Energy industry 196 million t
Industry 40,95 million t
Agriculture 0,12 million t
Transport 4 million t
Other 3,93 million t

Source: Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen
Umweltfußabdruck von Gebäuden in Deutschland, Kurzstudie zu sektorübergreifenden Wirkungen des Handlungsfelds „Errichtung und Nutzung von Hochbauten“ auf Klima und Umwelt

01 Current situation

CO_2 emissions of building materials

>10.000 kg CO_2e

10.000 kg CO_2e

1.000 kg CO_2e

100 kg CO_2e

10 kg CO_2e

0-10 kg CO_2e

Metallic

Mineral/ Synthetic

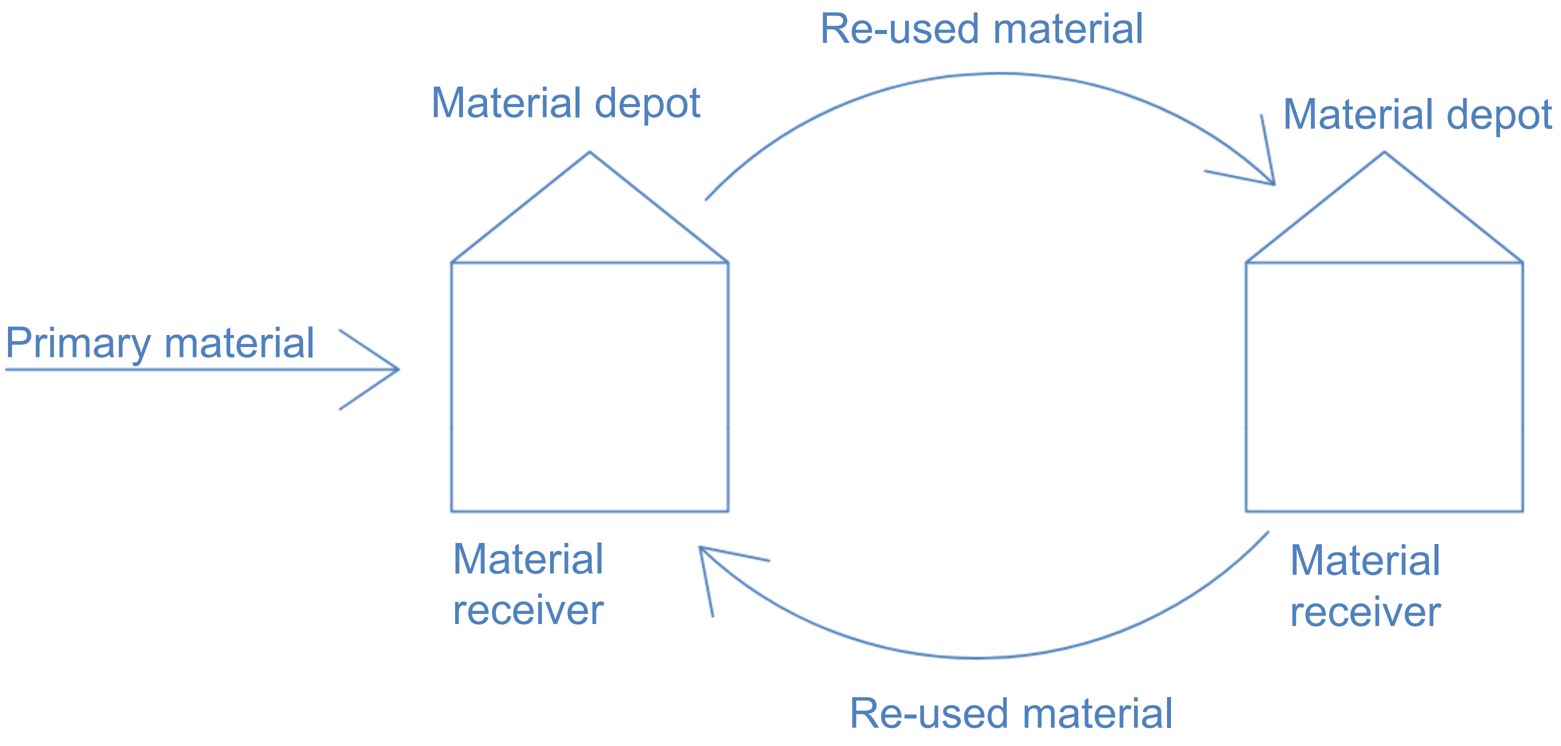
Bio-based/ organic

Materials that have high CO_2 emissions should be used as little as possible and should be kept in the material cycle as long as possible.

Source: https://materialpyramiden.dk/
* All CO_2 emissions in relation to modules A1-A3, per m^3 of material

01 Current situation

Explanation material cycle



Material depot:

- Buildings with deconstructible joints that can be recycled into the biotic cycle or separated by type.

Material receiver:

- Buildings constructed of re-used or recycled materials.

Today's building is tomorrow's material depot!

Source: weberbrunner architekten

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02 Introduction Life Cycle Analysis

Explanation LCA

- LCA = Life Cycle Analysis
- The aim of Life Cycle Analysis is to take a holistic view of buildings. The entire life cycle of materials, i.e. for production, operation, maintenance and deconstruction, can be considered in relation to 13 indicators
- Focus in this study is on the indicator Global Warming Potential (GWP)
- Separate designation of CO_2 storage for bio-based materials
- Component consideration without operating energy
- Observation period of building life of 50 years
- The eLCA is a tool for the LCA in Germany based on data sets from the ÖKOBAUDAT

Source: oekobaudat.de

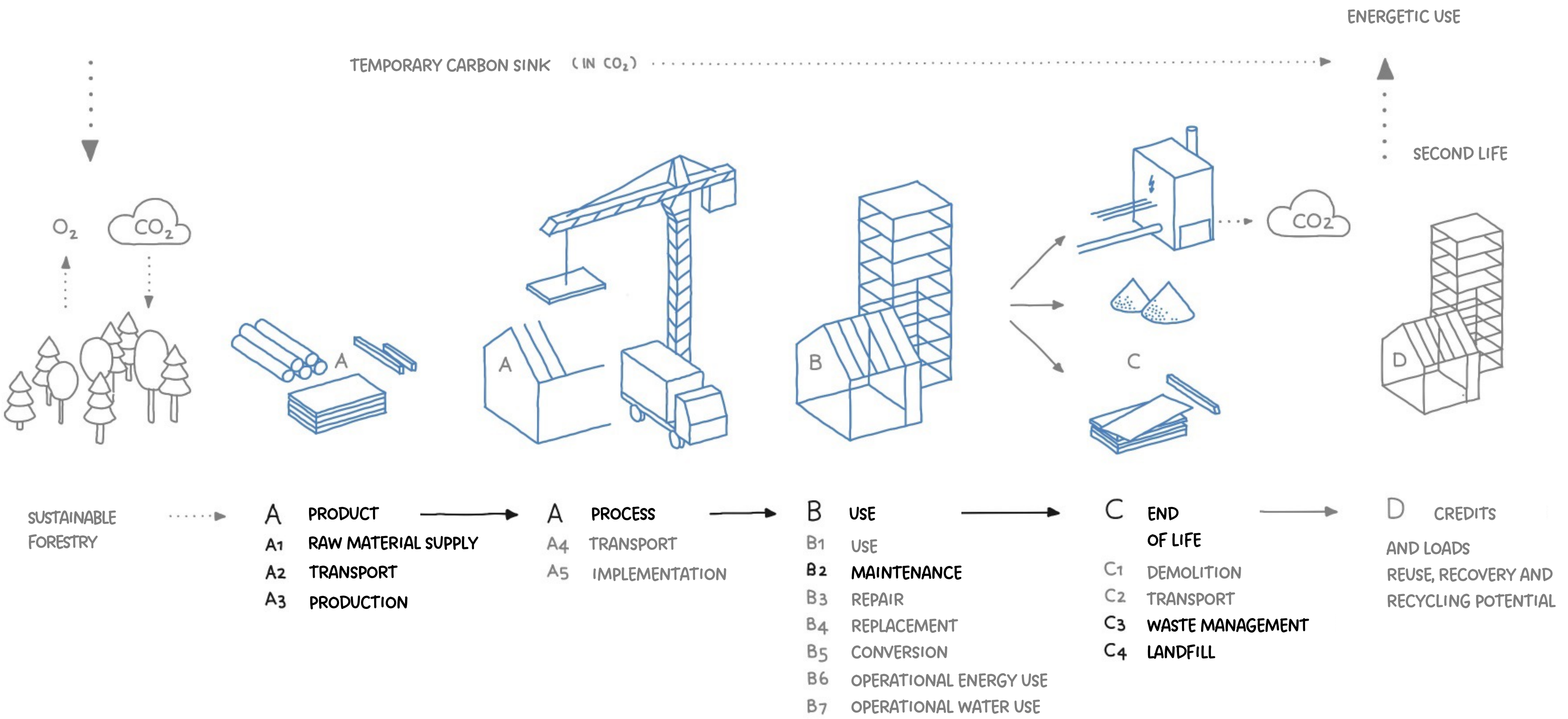
02 Introduction Life Cycle Analysis

Explanation indicators

GWP: Global Warming Potential, equivalent to greenhouse gas emissions
ODP: stratospheric ozone depletion potential
POCP: Potential for tropospheric ozone formation
AP: Acidification potential
EP: Eutrophication potential
PE Total: Total primary energy input
PENRT: Total input of non-renewable primary energy
PENRM: Input of non-renewable primary energy sources used as raw materials (material use)
PENRE: Input of non-renewable primary energy sources without the non-renewable primary energy sources used as raw material
PERM: Input of renewable primary energy sources used as raw materials (material use)
PERE: Input of renewable primary energy sources without the renewable primary energy sources used as raw material
ADP elem.: potential for abiotic resource extraction - elements for non-fossil resources
ADP fossil: Potential for abiotic resource depletion - fossil fuels.

02 Introduction Life Cycle Analysis

Explanation Modules



Lebenszyklus eines Gebäudes nach DIN EN 15978 und DIN EN 15804, Source: S. Djahanschah et al., DBU Bauband 4, Wohnquartier in Holz

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Building profile:

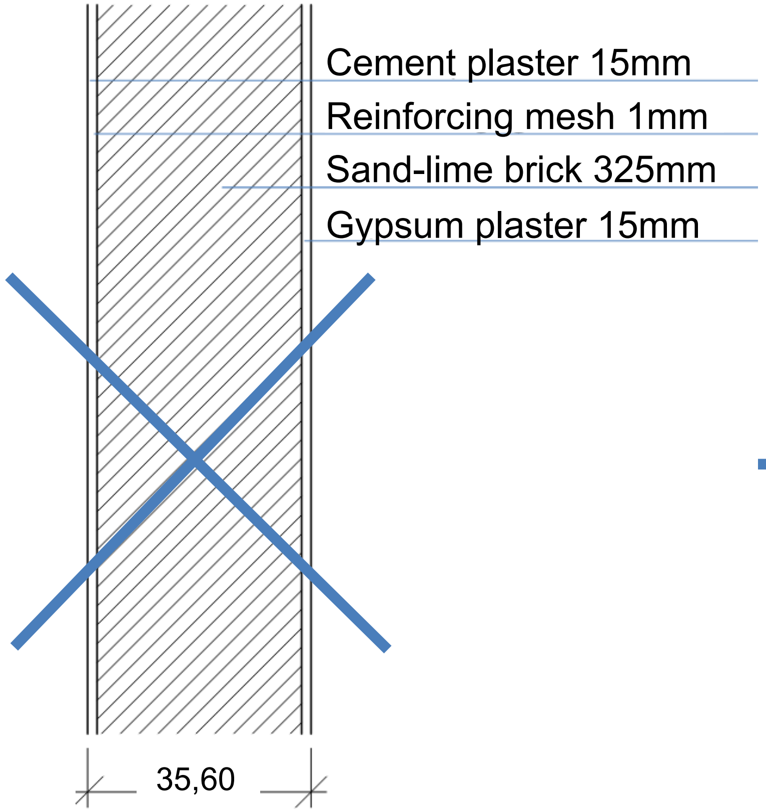
- Brickwork construction of sand-lime brick, uninsulated
- Flat roof made of reinforced concrete and 18cm EPS insulation
- Gross floor area: 12,600 m^2
- Facade area: 7.150 m^2
- 9 stories (building class 5), fire protection REI 90
- U-value to be achieved during refurbishment: < 0.20 W/(m²K) (EH-55 standard)
- U-value to be achieved for new replacement construction: < 0.15 W/(m²K) (EH-40 standard, as future-oriented standard for new buildings)

03 Life Cycle Analysis of conservation vs. demolition

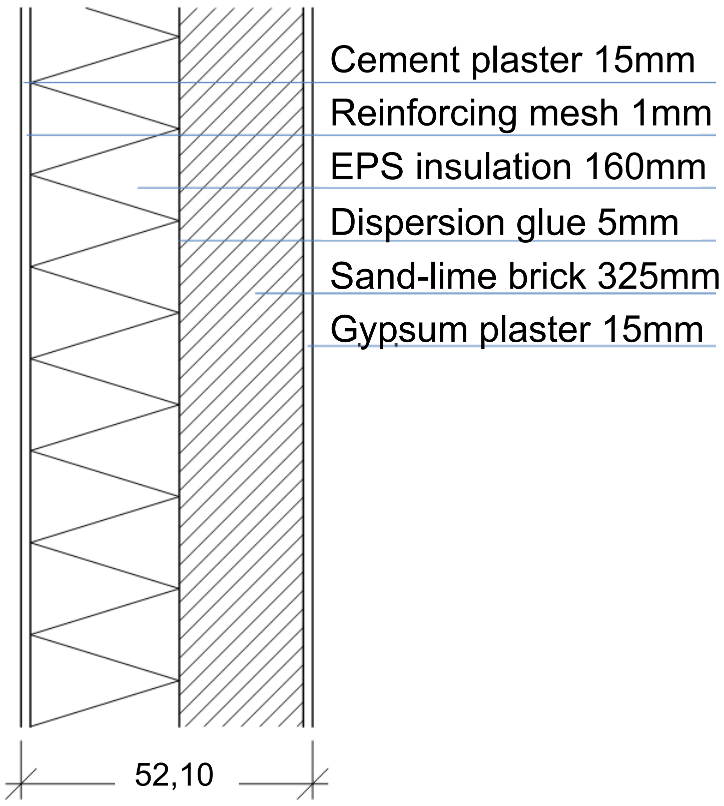
– Using the example of a facade refurbishment

Scenario 1:

Demolition existing facade



New construction conventional facade
Sand-lime brick + Composite thermal insulation



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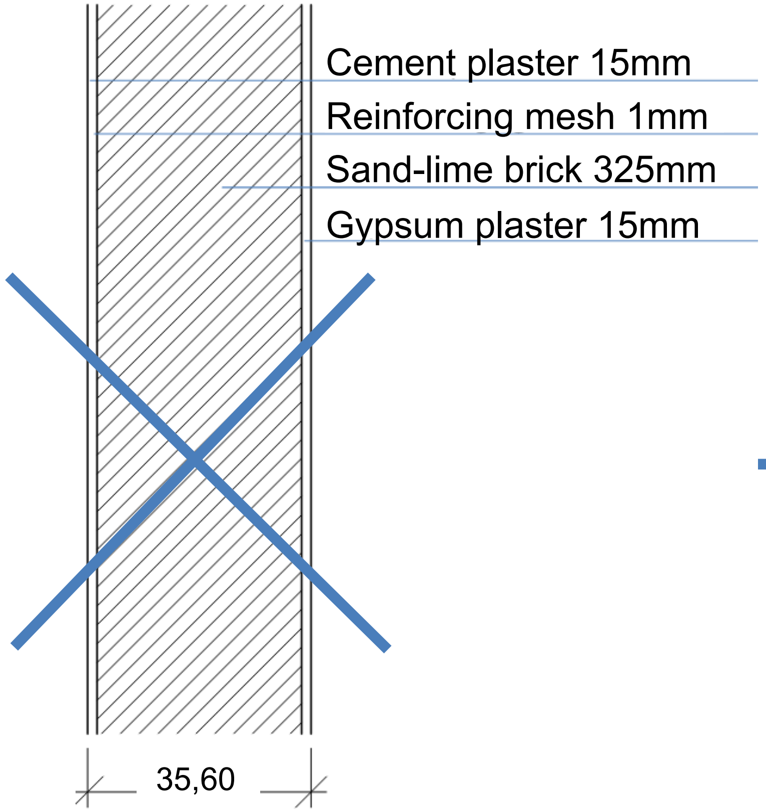
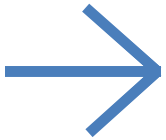
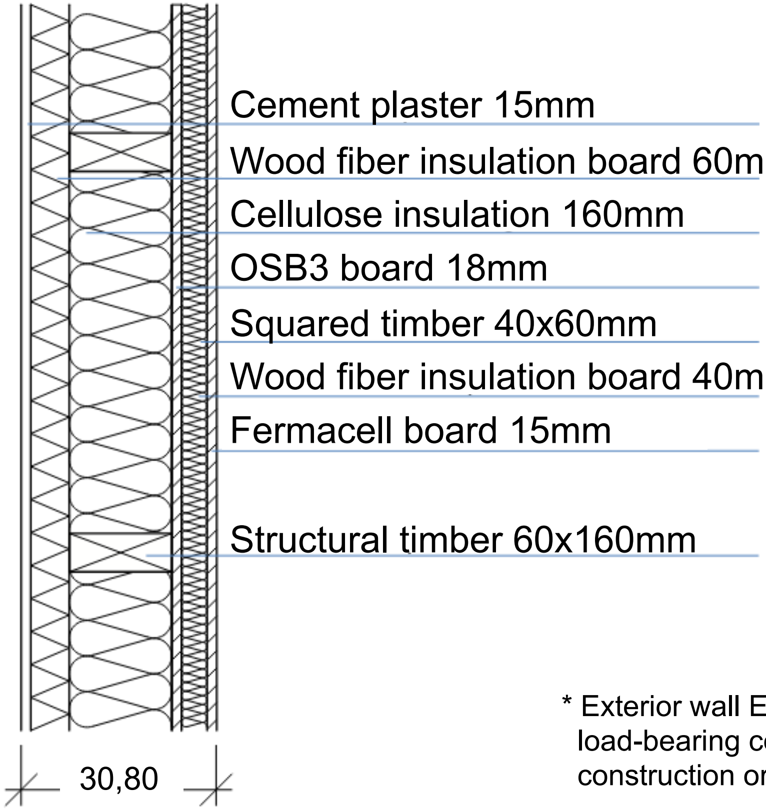
Scenario 2:

Demolition existing facade





New building ecological facade
Timber frame construction + cellulose blow-in insulation *



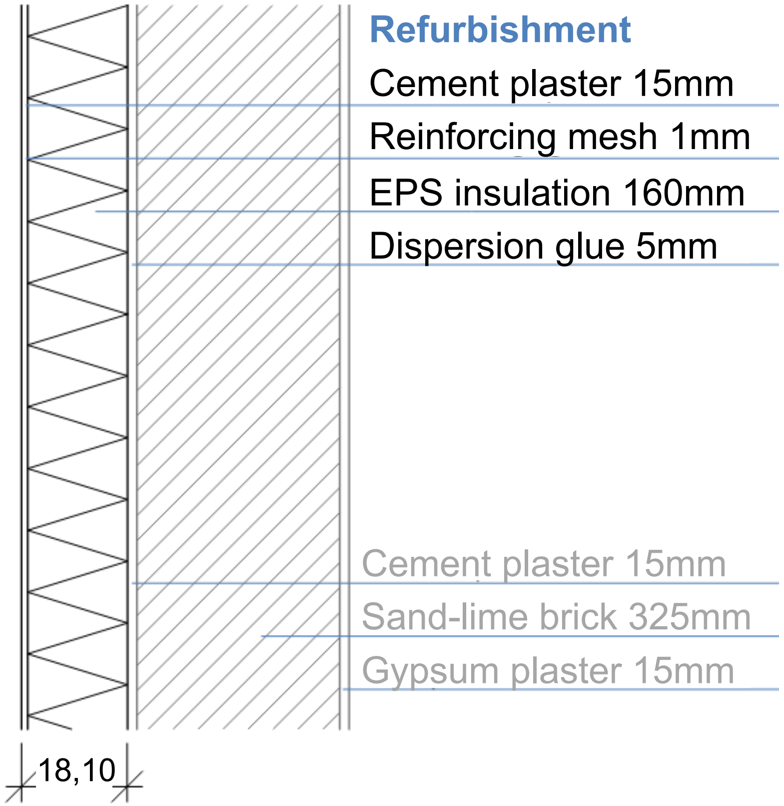
* Exterior wall EI30, non-load-bearing
load-bearing construction is made by bulkhead construction or column-beam construction

03 Life Cycle Analysis of conservation vs. demolition

– Using the example of a facade refurbishment

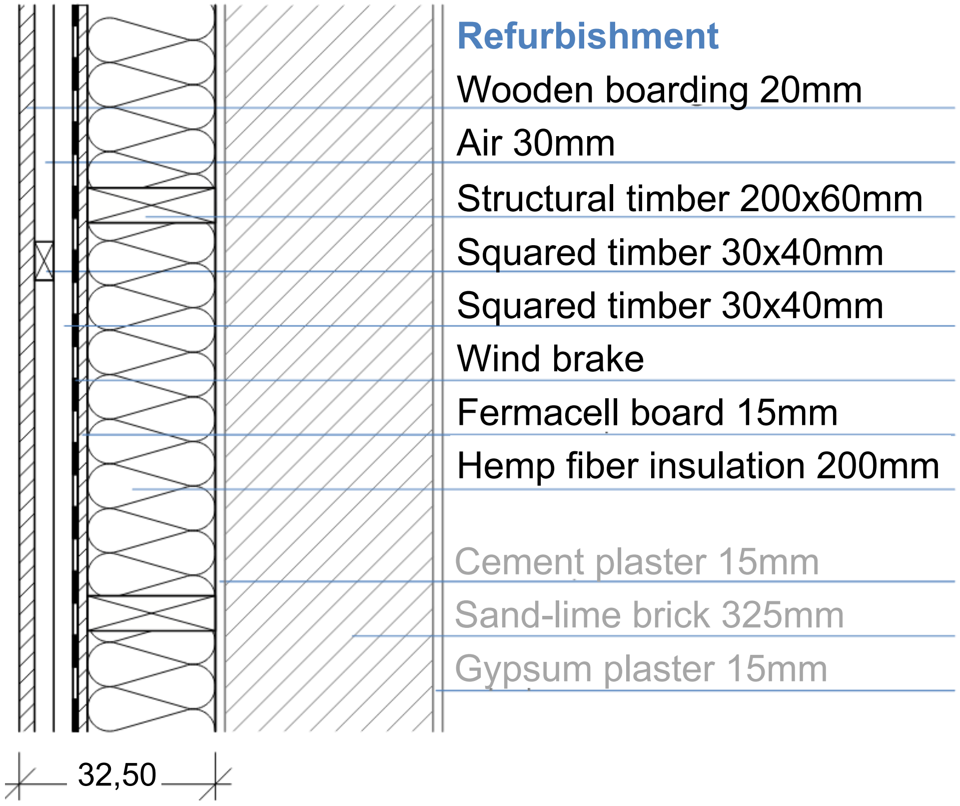
Scenario 3:

Conventional facade refurbishment
EPS insulation + plaster



Scenario 4:

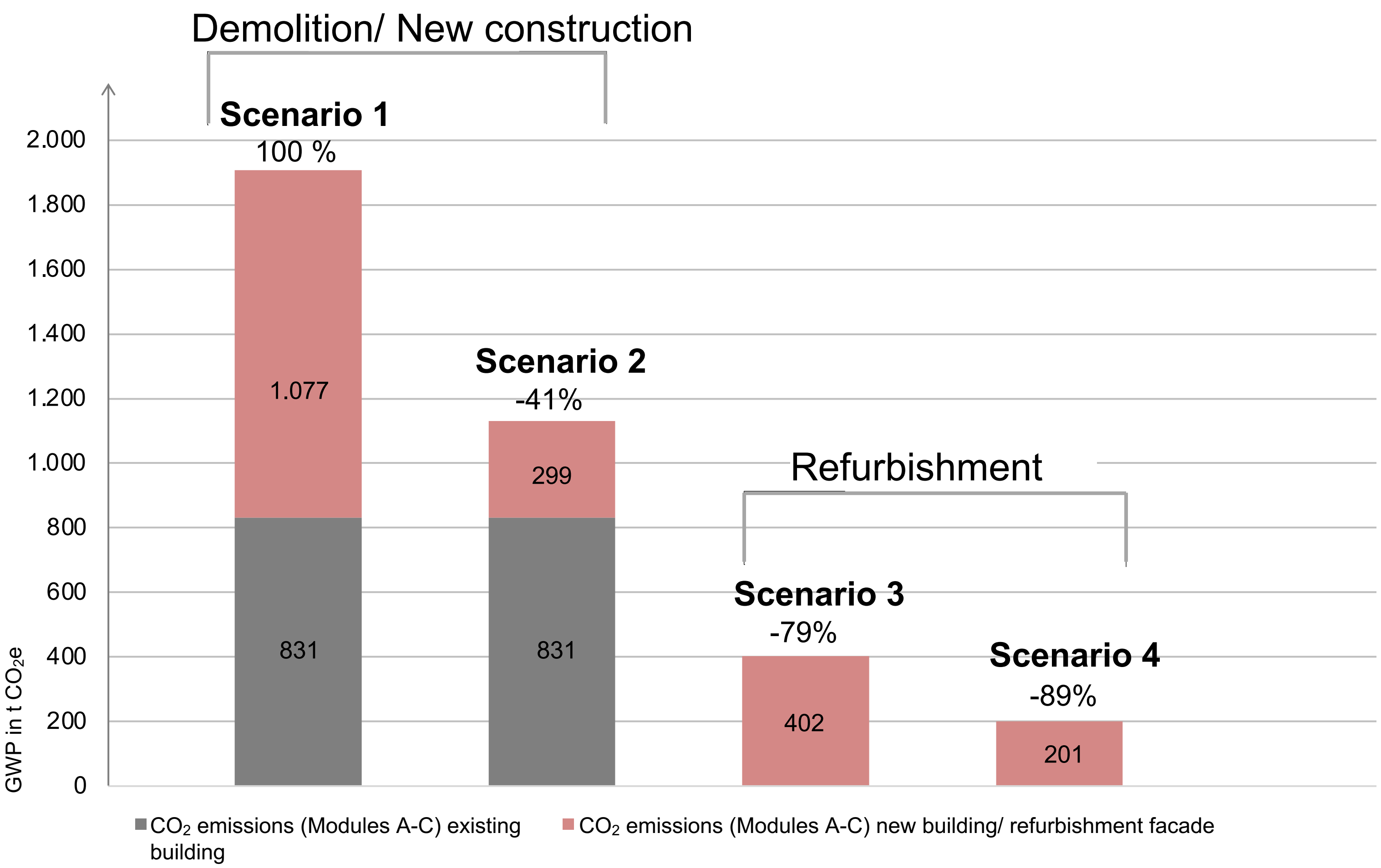
Ecological facade refurbishment
Timber frame construction + hemp fiber insulation



03 Life Cycle Analysis of conservation vs. demolition

Global Warming Potential (GWP) absolute

Observation period: 50 years

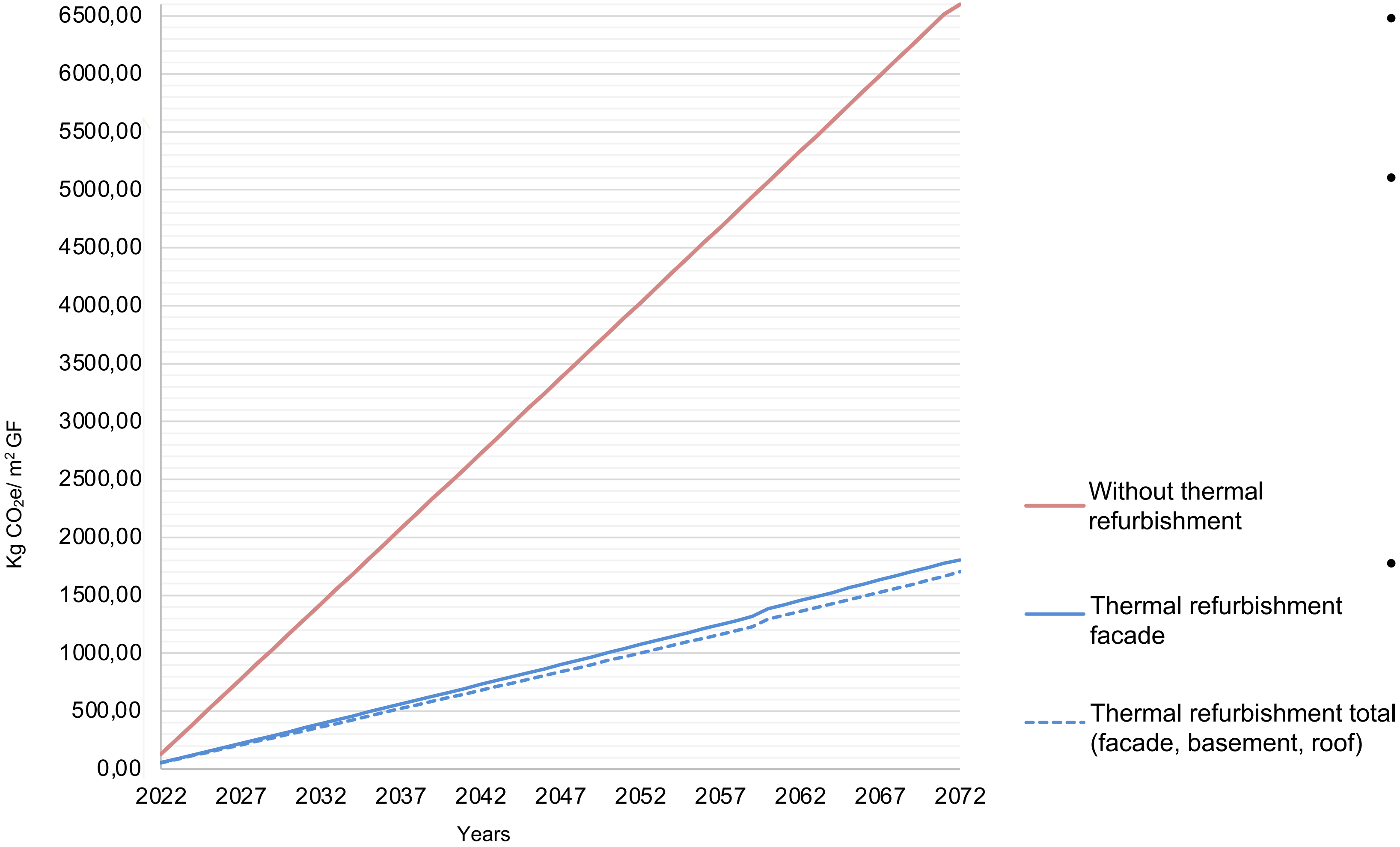


Taking into account the CO_2 emissions of the existing building, a facade refurbishment saves between 79 and 89% of CO_2 emissions compared to the conventional facade demolition/new facade construction scenario.

Conclusion: The scenario of building demolition and replacement should only be approved in exceptional cases. Life cycle assessment should be mandatory for such decisions in the future.

03 Life Cycle Analysis of conservation vs. demolition

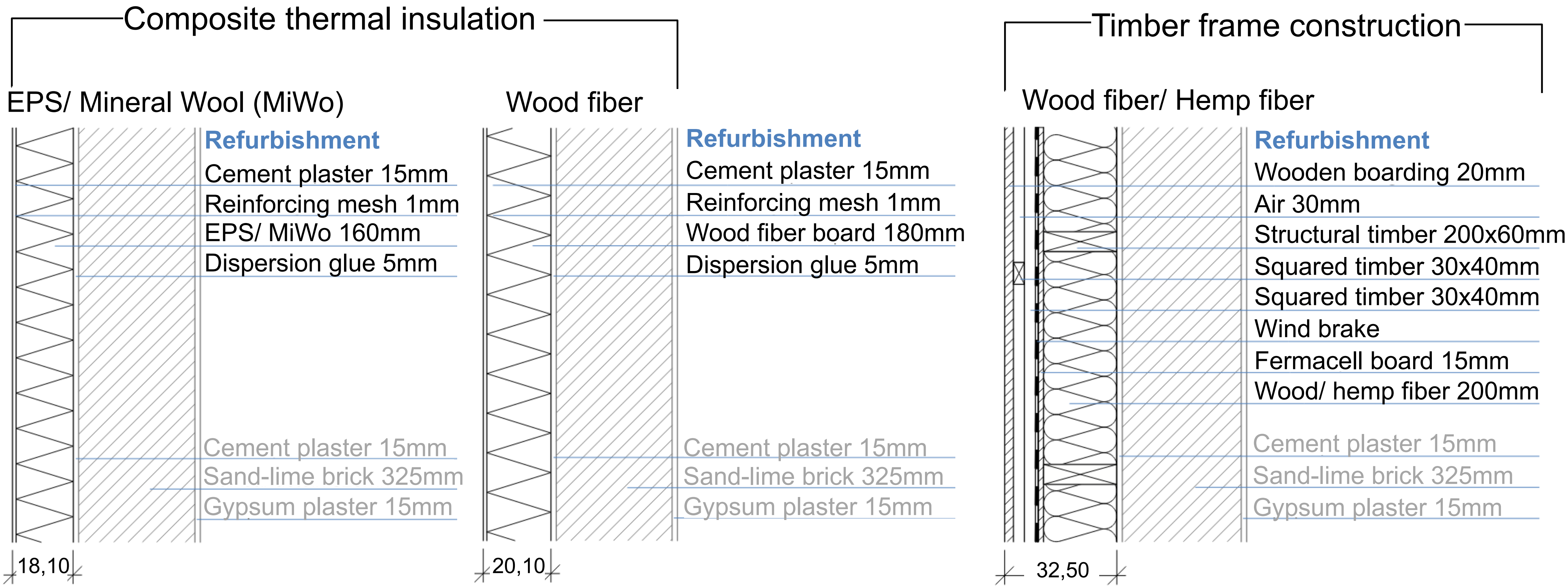
Cumulative emissions Construction and operating energy (modules A-C)



- Looking at the cumulative emissions of the building, it is clear that retrofitting is inevitable.
- The insulation of the facade accounts for the largest share, as it is uninsulated in the existing building and has a large surface area. Over the entire life cycle, it generates huge potential savings in terms of the building's CO_2 emissions. A U-value of 0.20 W/(m²K) was considered for the renovated facade.
- The roof is already insulated with 18 cm EPS insulation. Therefore, the difference between “refurbishment facade" and “refurbishment total" is very small.

03 Life Cycle Analysis of conservation vs. demolition

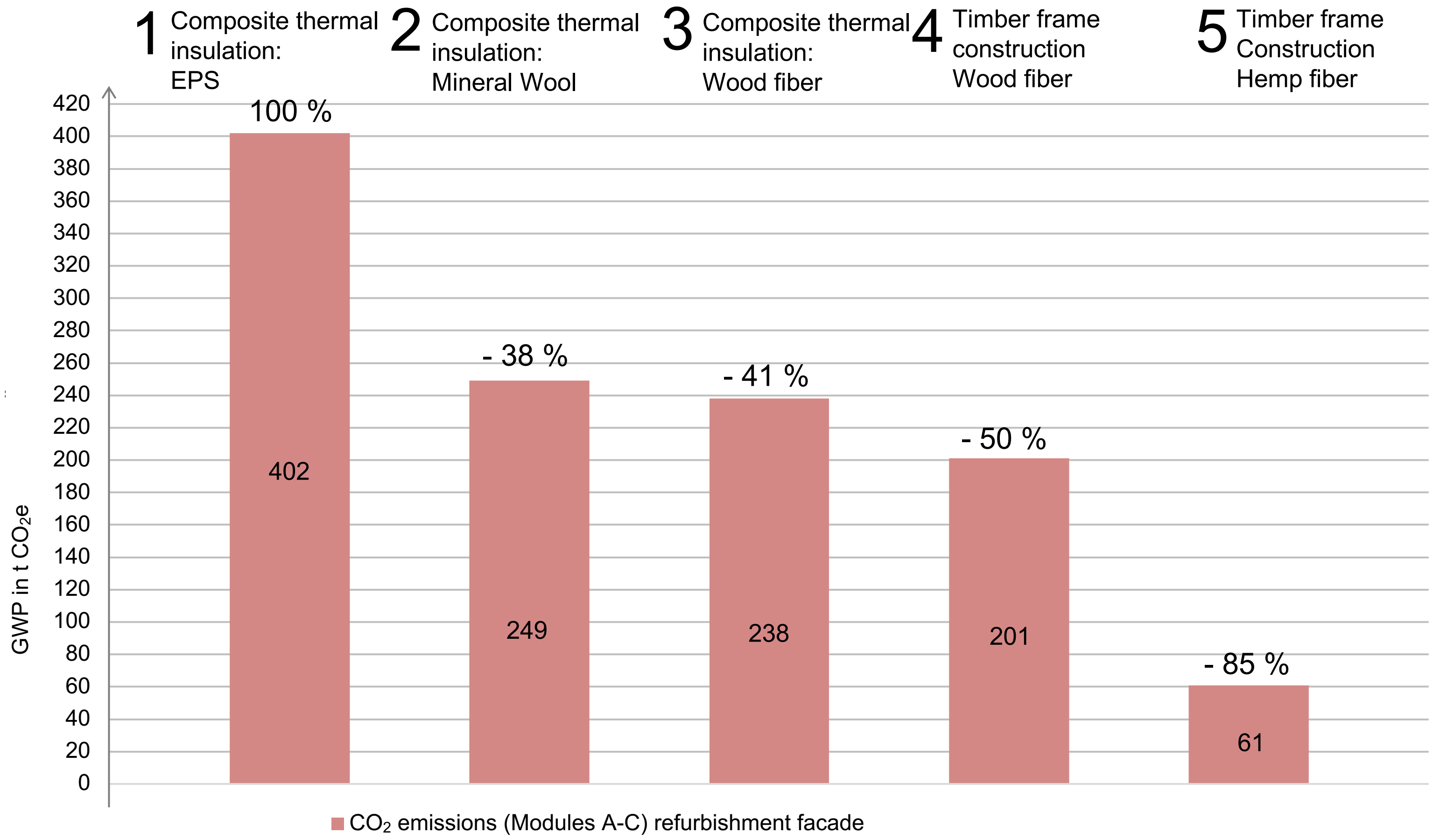
Building components



03 Life Cycle Analysis of conservation vs. demolition

Global Warming Potential (GWP) absolute

Observation period: 50 years



With the composite thermal insulation with mineral wool or wood fiber, 38 to 41% of CO_2 emissions can be saved compared to the initial variant.

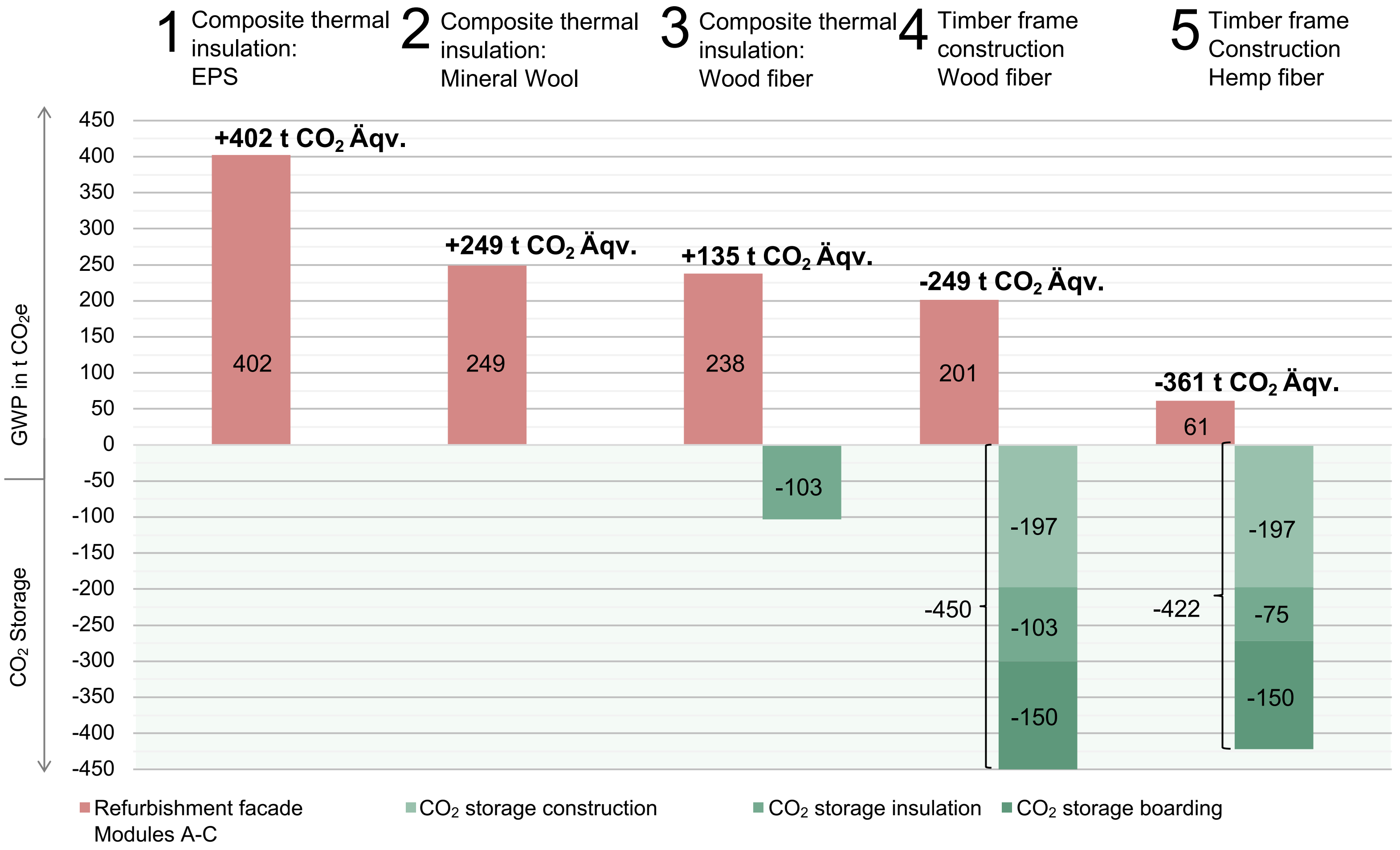
The timber frame construction with the wood fiber insulation saves 50% in CO_2 emissions.

With the timber frame construction with hemp insulation, 85% of the CO2 emissions can be saved compared to the conventional variant.

03 Life Cycle Analysis of conservation vs. demolition

Global Warming Potential (GWP) absolute and Carbon storage capacity

Observation period: 50 years



The variant 3 with wood fiber insulation as well as variant 4 and 5 store carbon due to their renewable raw materials such as wood and hemp.

Wood stores **917 kg CO_2/m³** of material.

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03 Life Cycle Analysis of conservation vs. demolition

Ecological footprint of refurbishment options (Observation period: 50 years/ per m^2 facade)

Composite EPS

EMISSIONS

GWP 56 kg CO_2e/m^2

CO_2 0 CO_2/m^2

CONSTRUCTION

C2C Finish Insulation Structure

Eco Glue, pollutants, landfilling

Composite MiWo

EMISSIONS

GWP 35 kg CO_2e/m^2

CO_2 0 CO_2/m^2

CONSTRUCTION

C2C Finish Insulation Structure

Eco Glue, pollutants, landfilling

Composite wood fiber

EMISSIONS

GWP 34 kg CO_2e/m^2 (thermal utilization)

CO_2 14 CO_2/m^2

CONSTRUCTION

C2C Finish Insulation Structure

Eco Additives in insulation

Timber frame/ Wood fiber

EMISSIONS

GWP 28 kg CO_2e/m^2 (thermal utilization)

CO_2 63 CO_2/m^2

CONSTRUCTION

C2C Finish Insulation Structure

Eco Additives in insulation

Timber frame/ Hemp fiber

EMISSIONS

GWP 8 kg CO_2e/m^2 (thermal utilization)

CO_2 59 CO_2/m^2

CONSTRUCTION

C2C Finish Insulation Structure

Eco Pure ecological material

Evaluation absolute numbers from:

Global Warming Potential (GWP) Modules A-C

- GWP: > 50 kg CO_2e/m^2
- GWP: 20 bis 50 kg CO_2e/m^2
- GWP: < 20 kg CO_2e/m^2

CO_2 Storage (CO_2)

- Without CO_2 Storage capacity
- CO_2 Storage < GWP
- CO_2 Storage > GWP

Circularity (C2C)

- C2C: Not recyclable
- C2C: Partly recyclable
- C2C: Recyclable

Ecology (Eco)

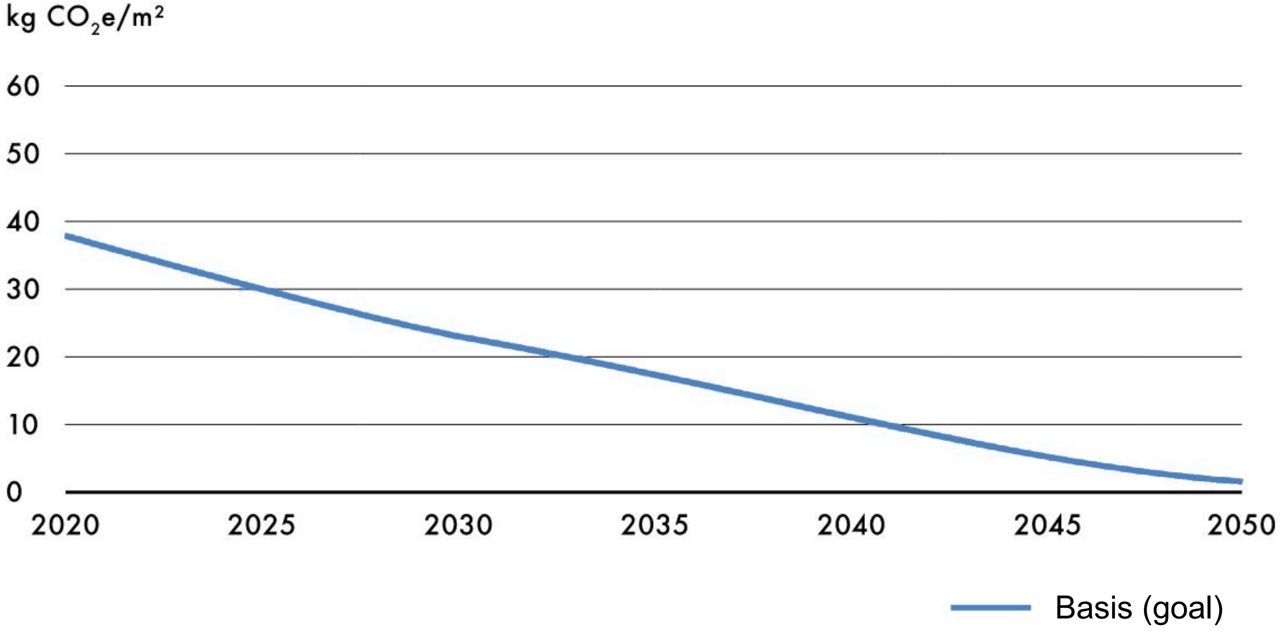
- Fossil raw material
- Renewable raw material with additives
- Renewable raw material without additives

03 Life Cycle Analysis of conservation vs. demolition

Explanation of climate goal for the buildings sector

Observation period: 50 years

Decarbonization path



CO_2e Budget 1.5 degree goal

	2019-2050	2019	2050
EU GHG emissions	72 Gt CO_2e	4,3 Gt CO_2e	380 Mt CO_2e
EU Real-estate total	22 Gt CO_2e	1,2 Gt CO_2e	144 Mt CO_2e
EU Real-estate per m^2		114 kg CO_2e/m^2	11 kg CO_2e/m^2
Residential building Germany per m^2	638 kg CO_2e/m^2	42,1 kg CO_2e/m^2	1,5 kg CO_2e/m^2

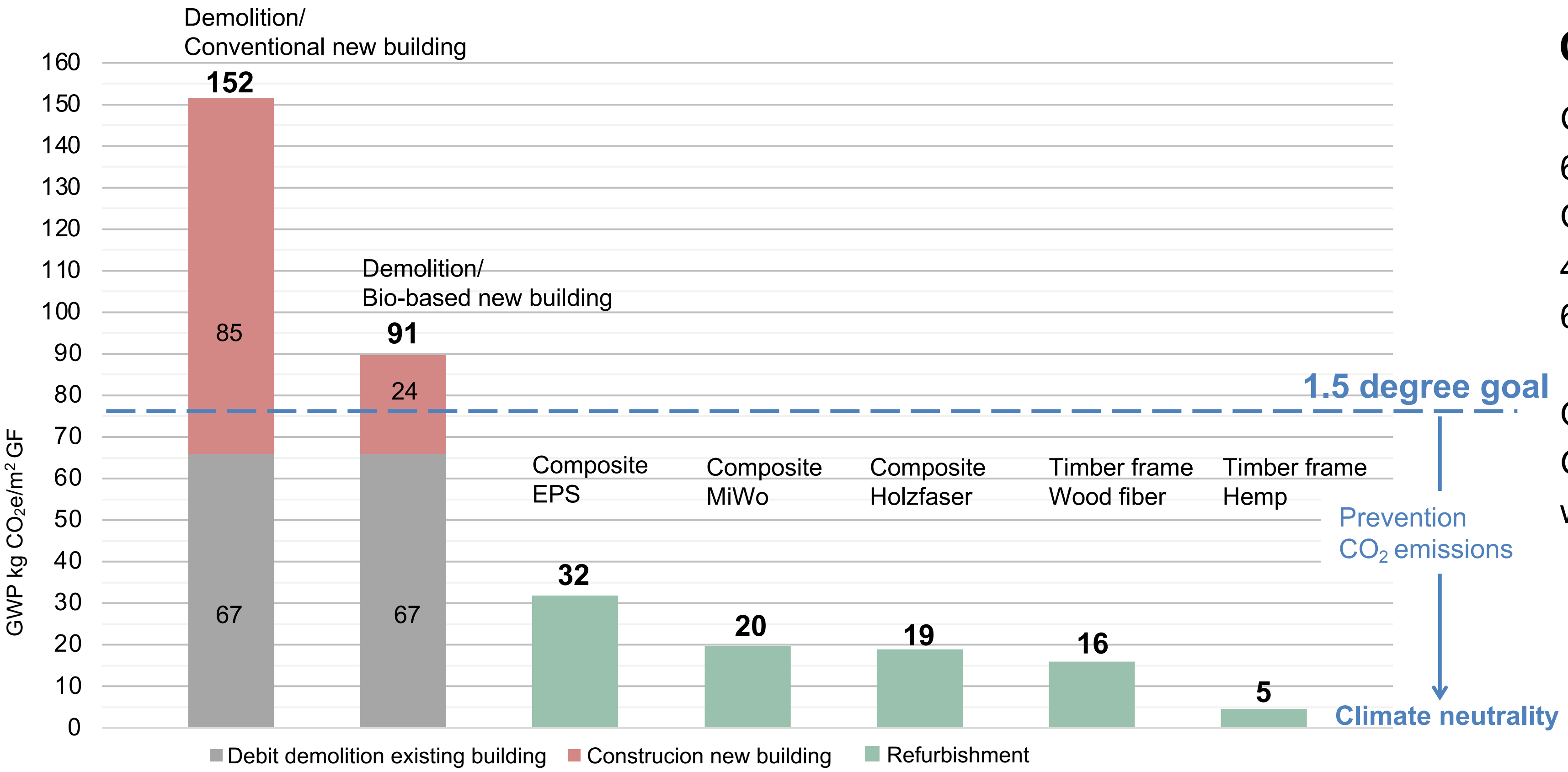
The European research project CRREM (Carbon Risk Real Estate Monitor) has developed scenarios and budgets in detailed publications to be able to achieve the 1.5 degree and 2.0 degree goals.

Source: https://www.crrem.eu/stranding-risk-carbon/

03 Life Cycle Analysis of conservation vs. demolition

Consideration 1.5 degree goal

Benchmark for facade refurbishment (observation period 50 years, based on gross floor area)



Calculation

Guideline value for 1.5 degree goal:

638 kg CO_2e/m²GF.

Of which:

40% CO_2 emissions operating energy

60% CO_2 emissions material/ construction

Of 60% material: 20% for exterior wall

Guideline value for 1.5 degree goal exterior wall: **76.56 kg CO_2e/m²GF**

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