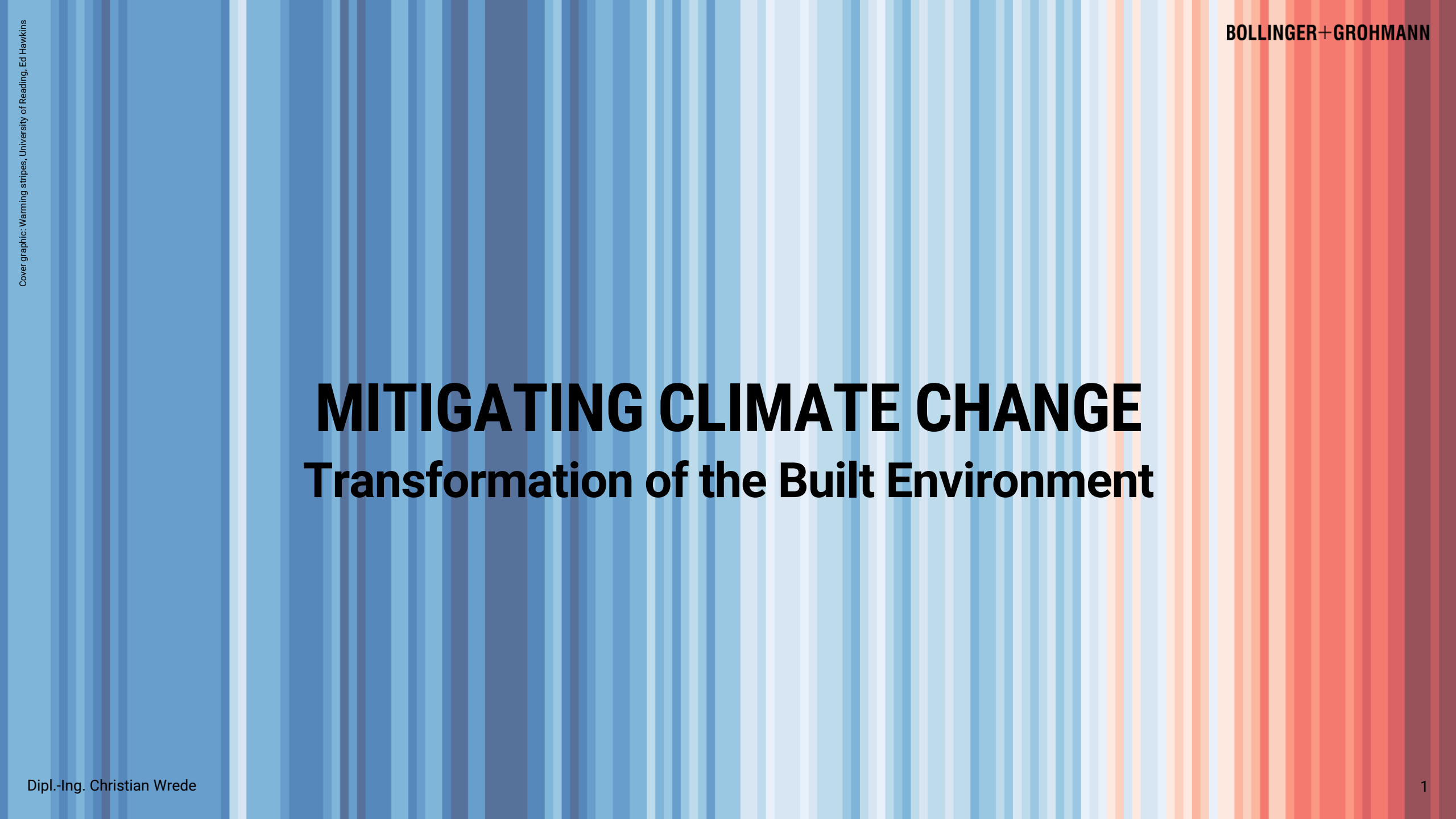

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MITIGATING CLIMATE CHANGE

Transformation of the Built Environment

Dipl.-Ing. Christian Wrede

1 GLOBAL RISKS LANDSCAPE AND CLIMATE EMERGENCY

2 GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

3 TRANSFORMATION OF THE BUILT ENVIRONMENT

4 STRUCTURAL DESIGN APPROACHES

5 CONCLUSIONS

GLOBAL RISKS LANDSCAPE AND CLIMATE EMERGENCY

Global risks landscape

The climate emergency is currently the greatest threat to our planet.

Environmental risks combine the biggest impact and highest likely-hood.

Source: World Economic Forum – The global risks report 2020

GLOBAL RISKS LANDSCAPE AND CLIMATE EMERGENCY

UN sustainable development goals

Climate action has an impact on virtually all of the 17 UN SDGs and is, therefore, the essential contribution to resolve interdependent crises.

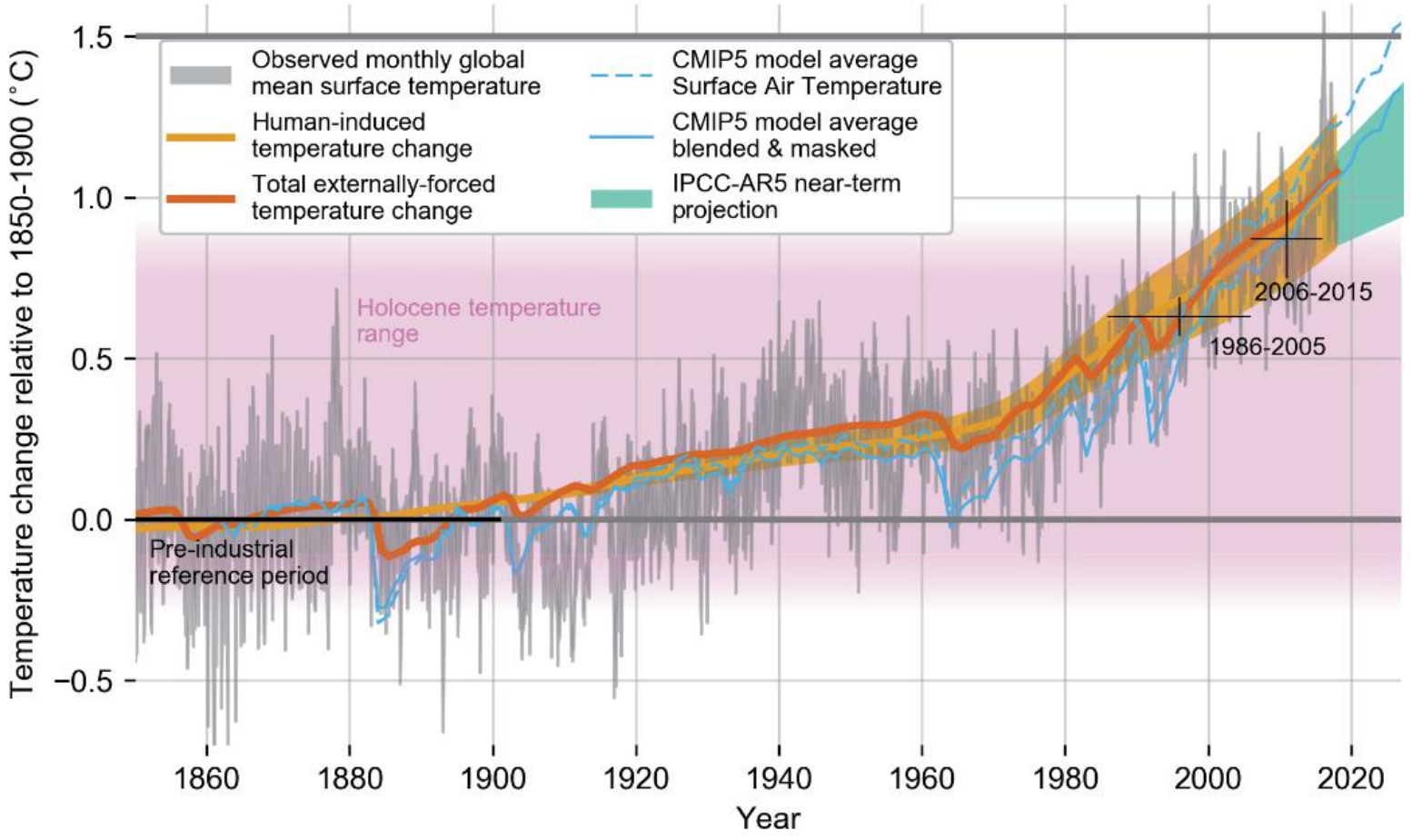
Source: United Nations - Sustainable Development Goals (SDGs)

GLOBAL RISKS LANDSCAPE AND CLIMATE EMERGENCY

Evolution of global mean surface temperature

Potsdam Institute for Climate Impact Research:

“Ocean floor deposits and model calculations have confirmed that in the past 3 million years, the global mean temperature has never been more than two degrees above pre-industrial levels, with fluctuating CO_2 levels in the atmosphere.”



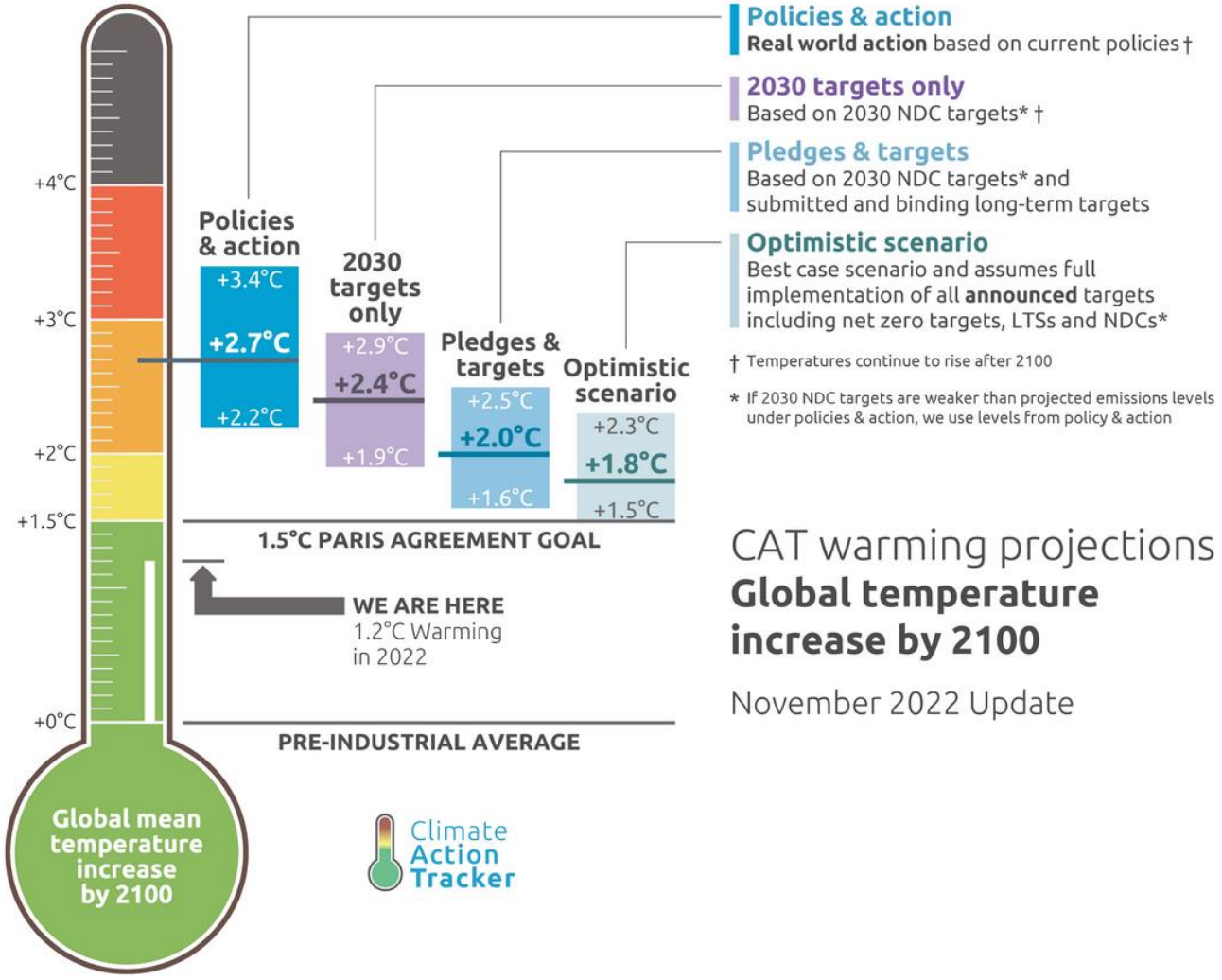
Source: IPCC – Global warming of 1.5°C

GLOBAL RISKS LANDSCAPE AND CLIMATE EMERGENCY

Global mean temperature increase by 2100

The temperatures on the CAT thermometer are median warming estimates in 2100.

There is a 50 % chance that the calculated temperature would be exceeded if the given emissions pathway is followed.

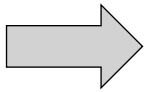


Source: Climate Action Tracker – The CAT thermometer

GLOBAL RISKS LANDSCAPE AND CLIMATE EMERGENCY

Direct impacts of global warming

- **Melting of global land and sea ice**
- **Melting of permafrost soils**
- **Disruption of global ocean and air streams**
- **Decay of rain and boreal forests**
- **Destruction of coralreefs**
- Increase of extreme weather events e.g. heat, cold, rain, drought and storms
- Rise of sea levels
- Dehydration and degradation of soils
- Decline in food production and biodiversity
- Advance of tropical deseases in regions not yet affected
- Health threats for vulnerable groups of people



These **tipping elements** are critical parts of the Earth system that are at risk of changing irreversibly if pushed too far.

They accelerate global warming themselves and cannot be controlled once crossing their critical tipping points.

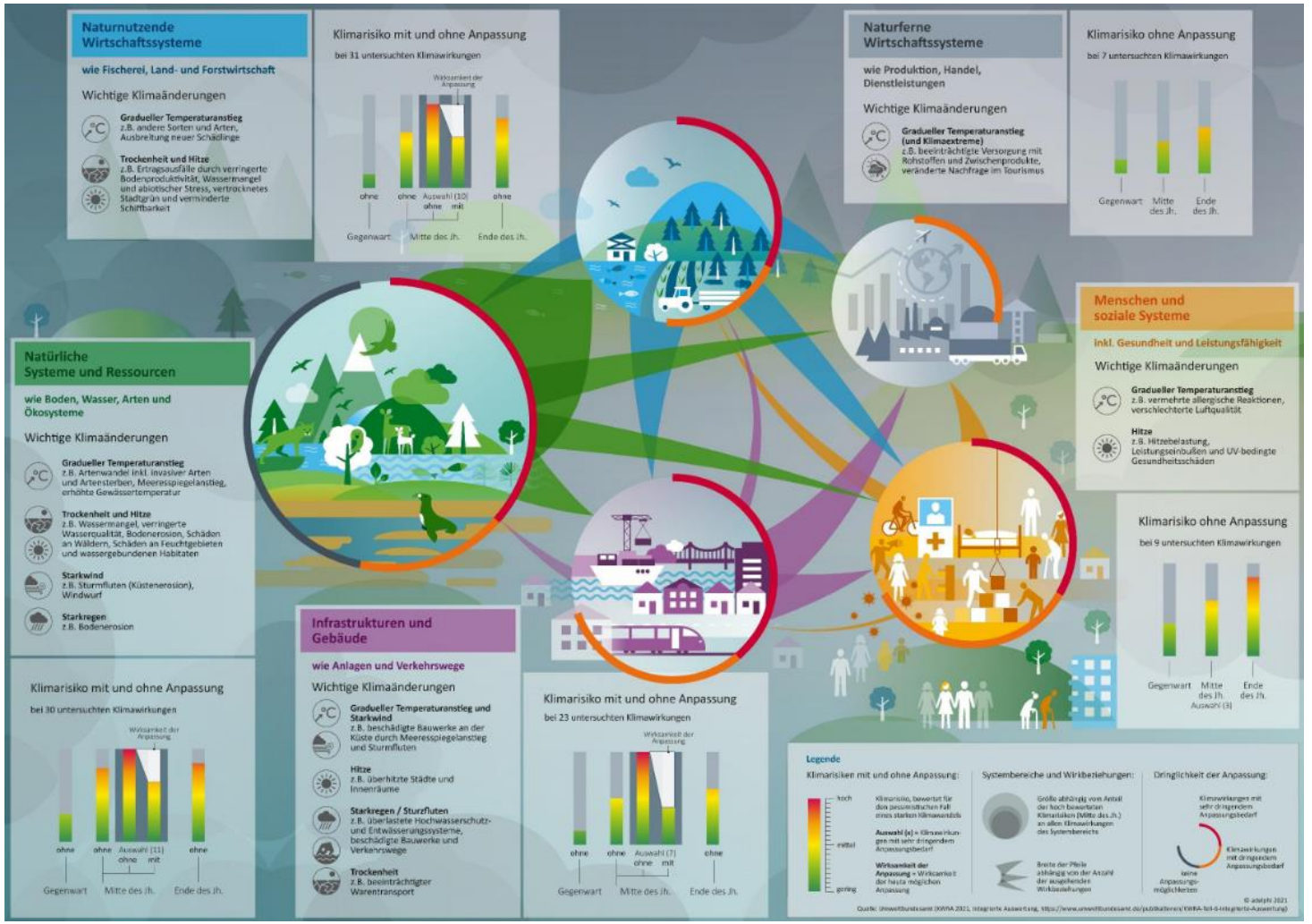
GLOBAL RISKS LANDSCAPE AND CLIMATE EMERGENCY

Climate risks for effected systems, their interdependencies and urgent adaptation needs

The impact of global warming is not limited on the environment.

Instead it has a major impact on the following areas:

- Economy
- Humans and society
- Infrastructure and buildings
- Environmental systems and resources



Source: Umweltbundesamt – Klimawirkungs- und Risikoanalyse 2021 für Deutschland

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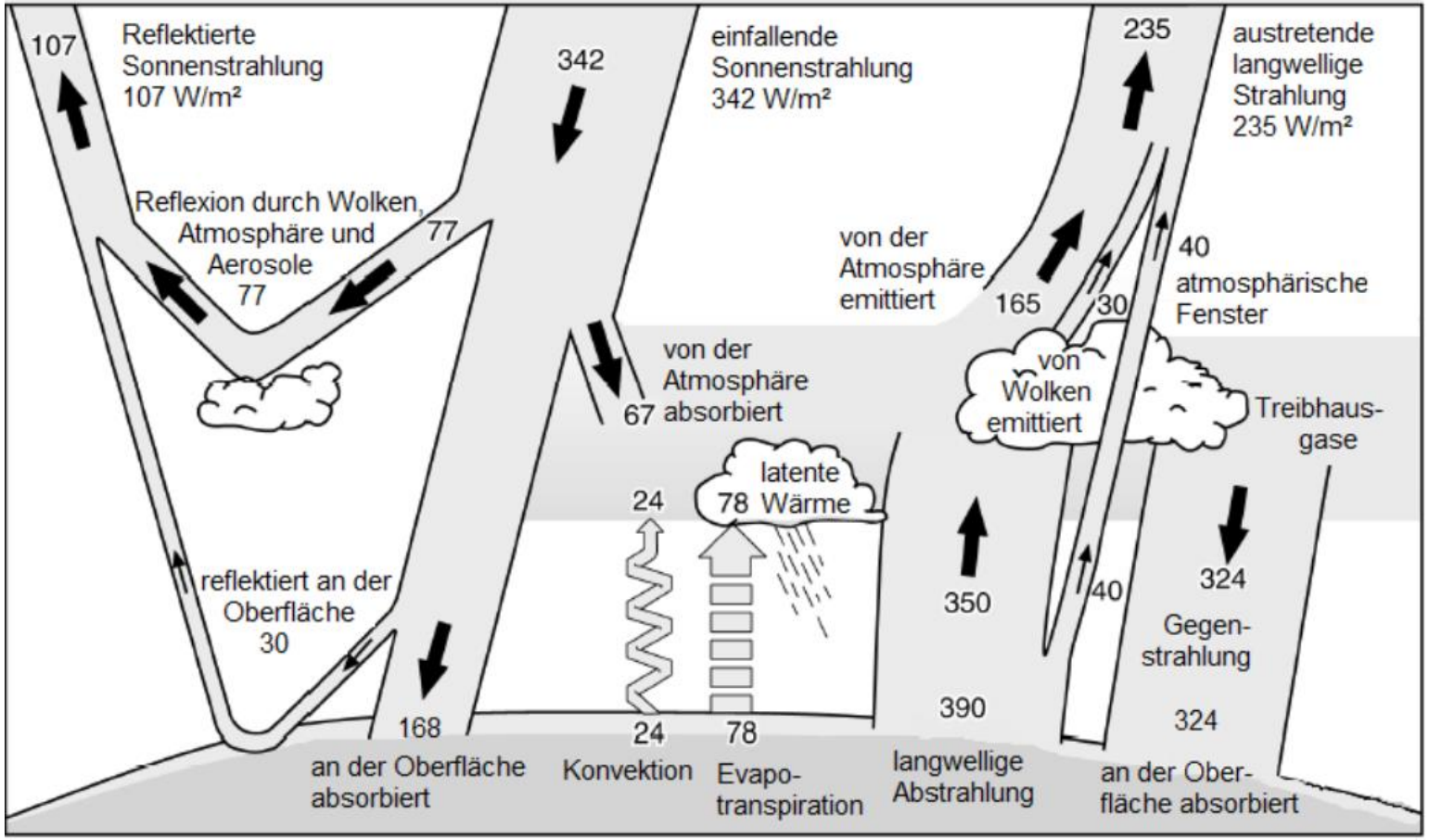
GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

Radiant energy balance and greenhouse effect

The global mean temperature is the result of a radiant energy balance.

Because of the natural greenhouse effect, the global mean temperature is around +15 °C instead of -18 °C.

Anthropogenic greenhouse gas emissions have intensified the natural greenhouse effect by around 2 % which is causing an increase of the global mean temperature.

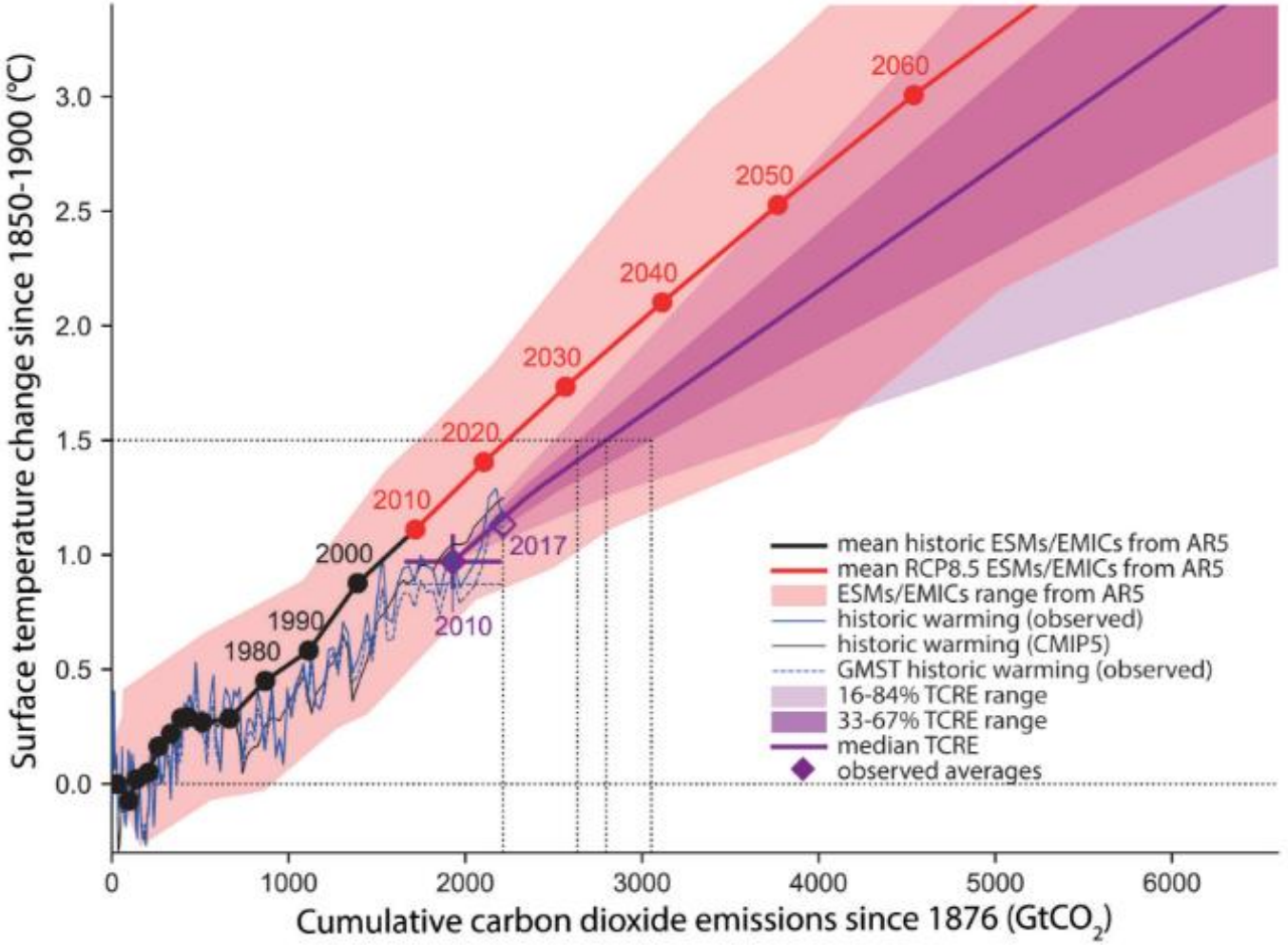


Source: PIK – Stefan Rahmstorf: How does the greenhouse effect work?

GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

Temperature changes versus cumulative CO_2 emissions since 1876

Global warming is close to linearly proportional to the total net amount of CO_2 that has ever been emitted into the atmosphere as a result of human activities.



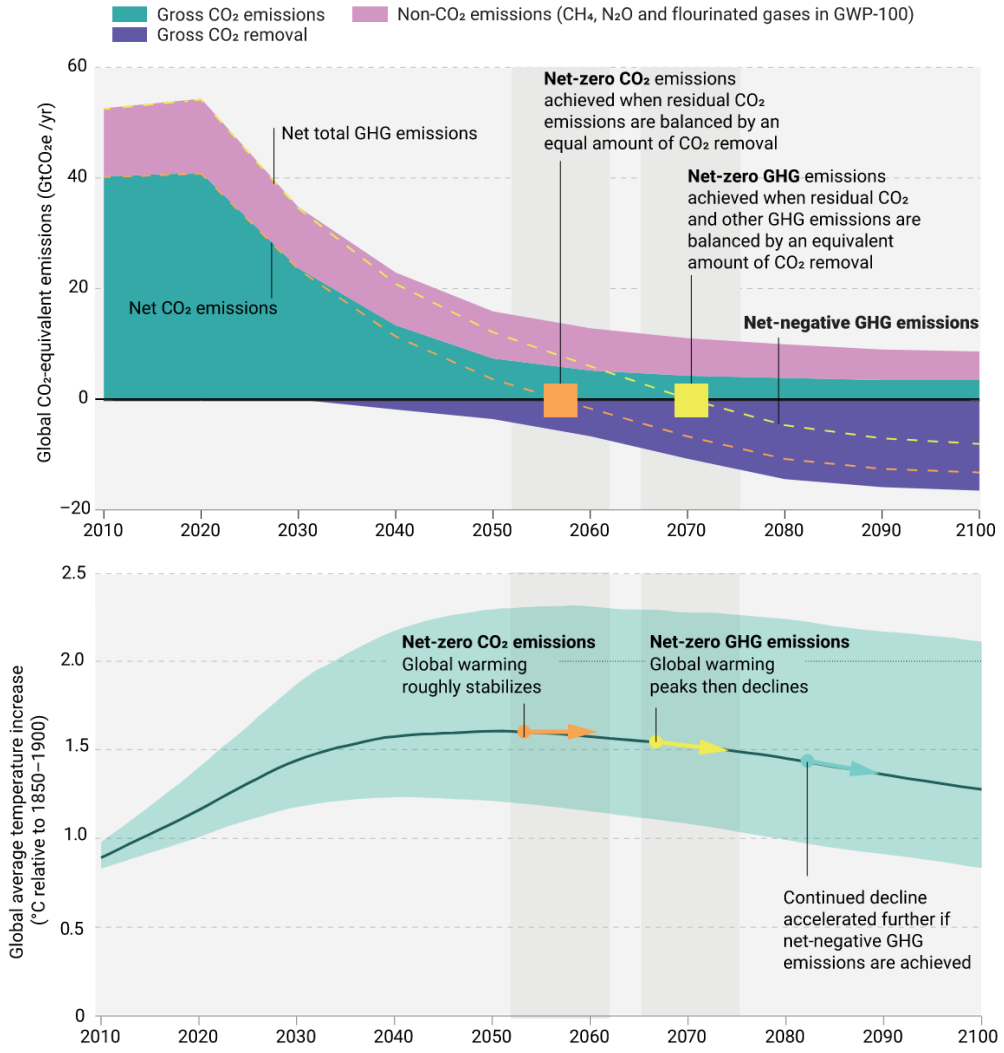
Source: IPCC – Global warming of 1.5°C

GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

Global GHG emissions and global warming implications

Net-zero emissions is a state where the sum of all anthropogenic emissions and removals is zero.

For the 1.5 °C pathway, CO_2 emissions must reach net zero around 2050, with GHG emissions reaching net zero 15-20 years later.

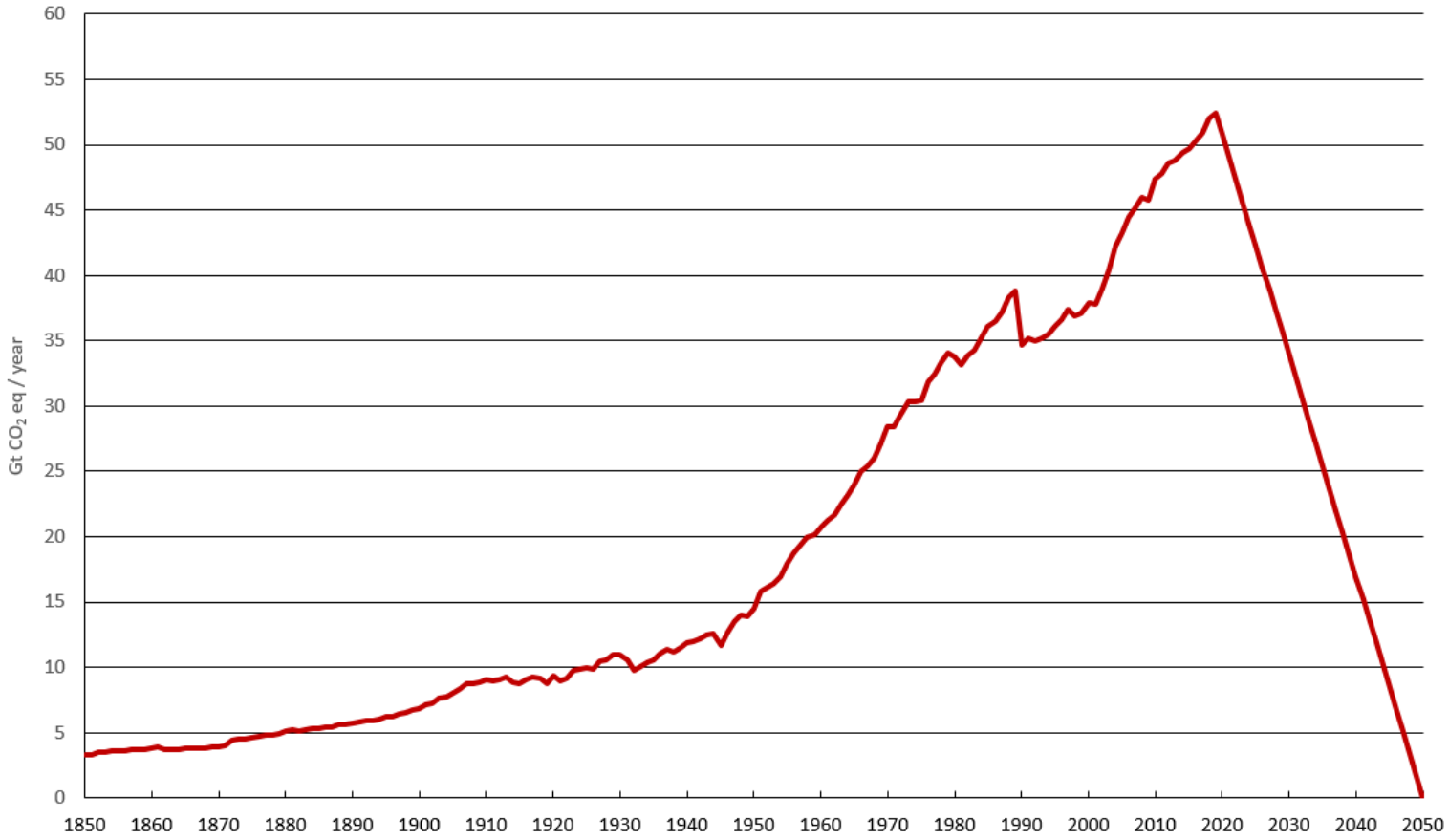


Source: UN Environment Programme – Emissions gap report 2021

GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

Historic and future annual GHG emissions

The challenge is obvious.

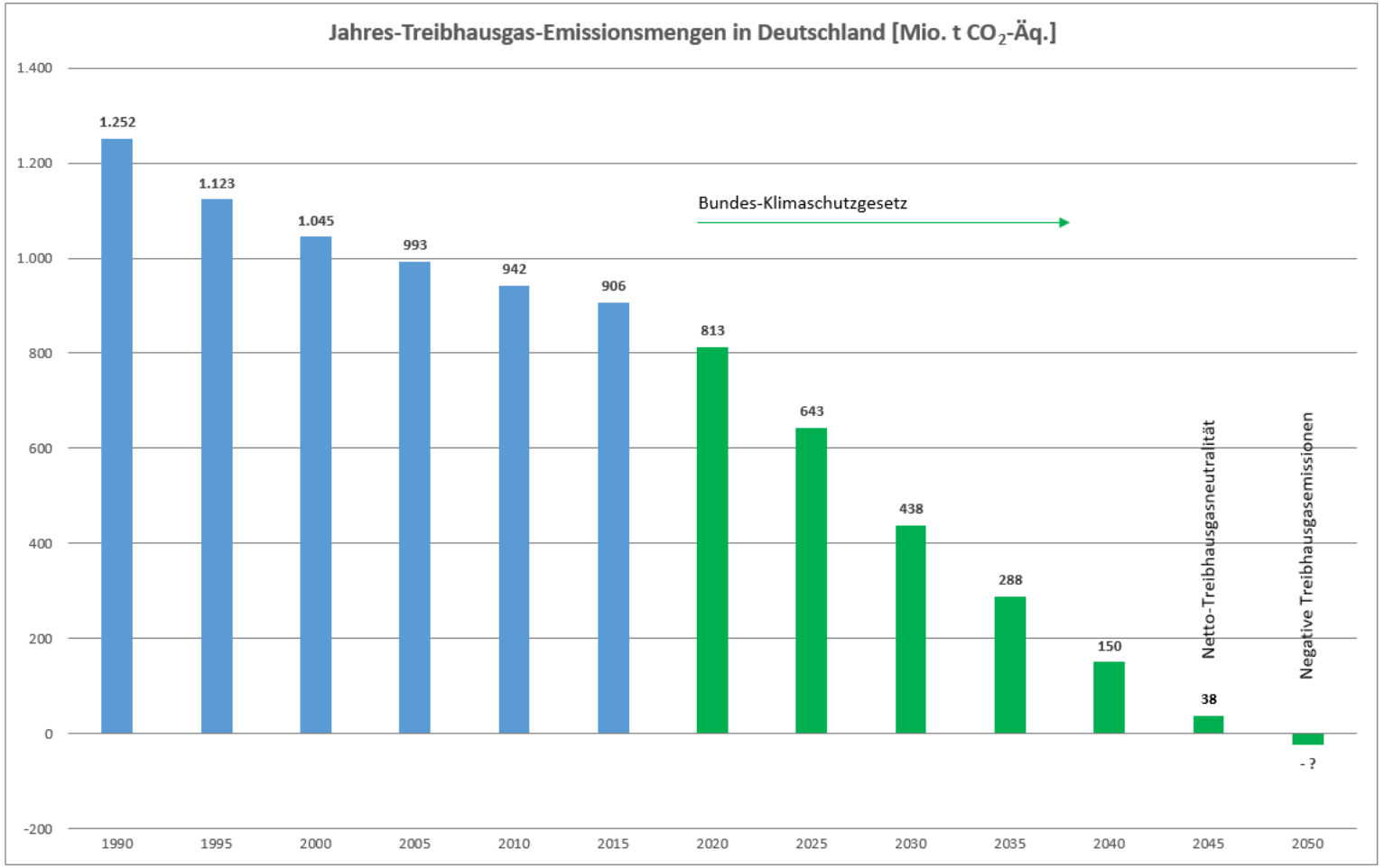


Source: PIK - PIK PRIMAP-hist GHG Dataset

GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

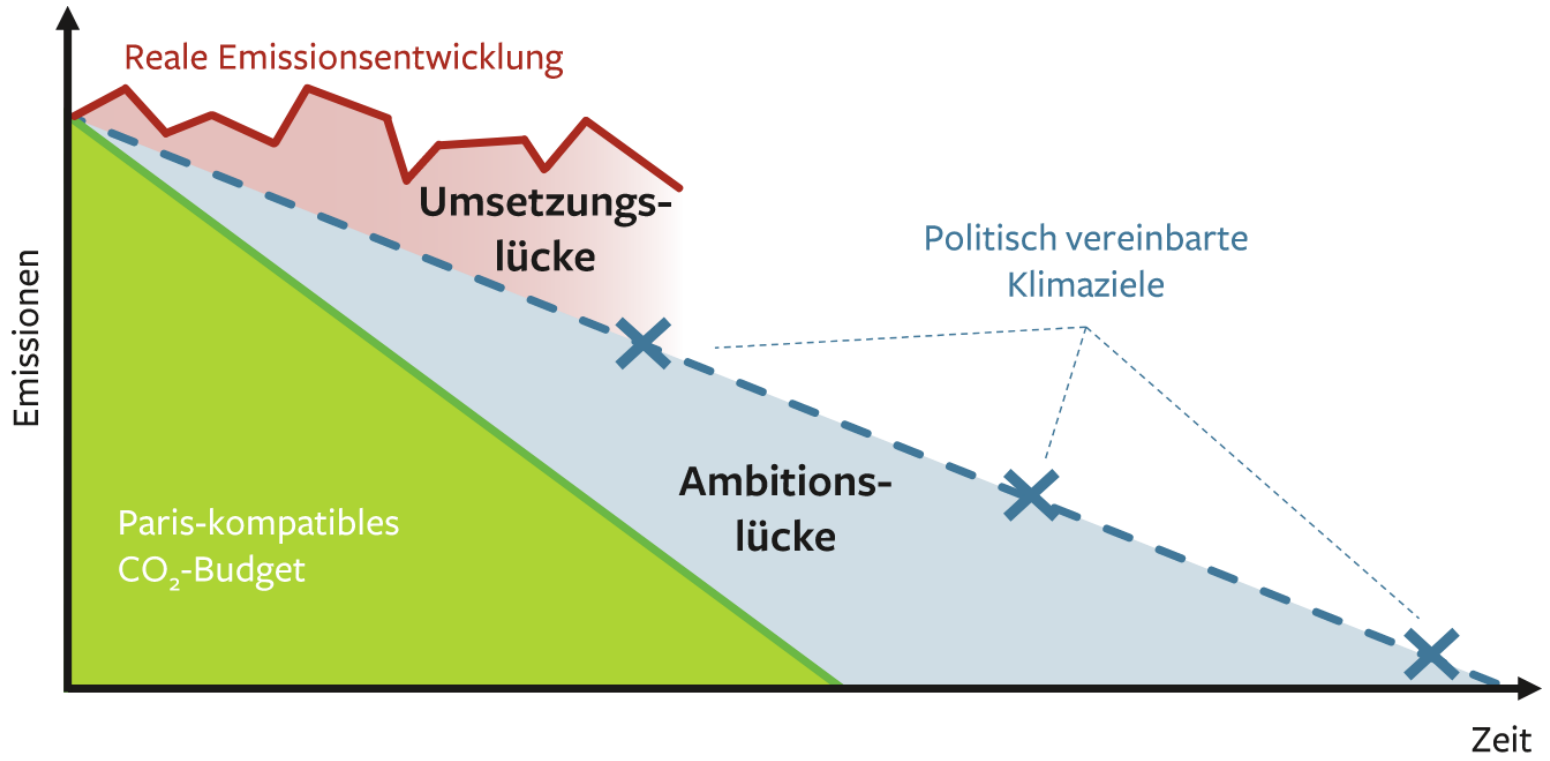
Bundes-Klimaschutzgesetz

The Bundes-Klimaschutzgesetz defines the allowable annual GHG emissions in Germany between 2020 and 2045 and beyond.



GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

Implementation gap for the reduction of GHG emissions



Source: SRU – Für eine entschlossene Umweltpolitik in Deutschland und Europa 2020

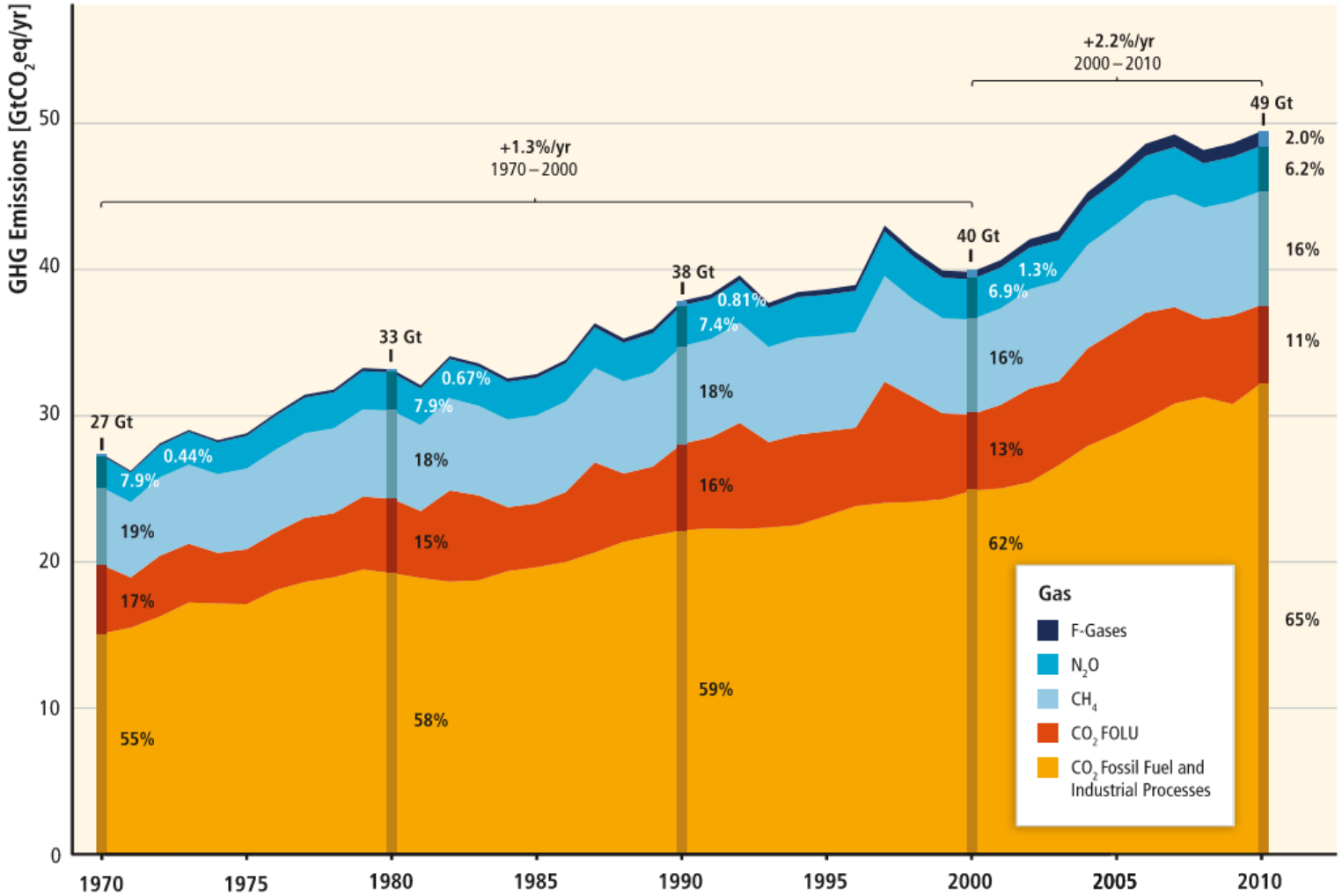
GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

Total annual GHG emissions by groups of gases

Greenhouse gases:

- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)
- fluorinated gases (SF_6, NF_3, HFCs, PFCs)

All have a different global warming potential (GWP). Their combined overall impact is usually described in CO_2 equivalents.



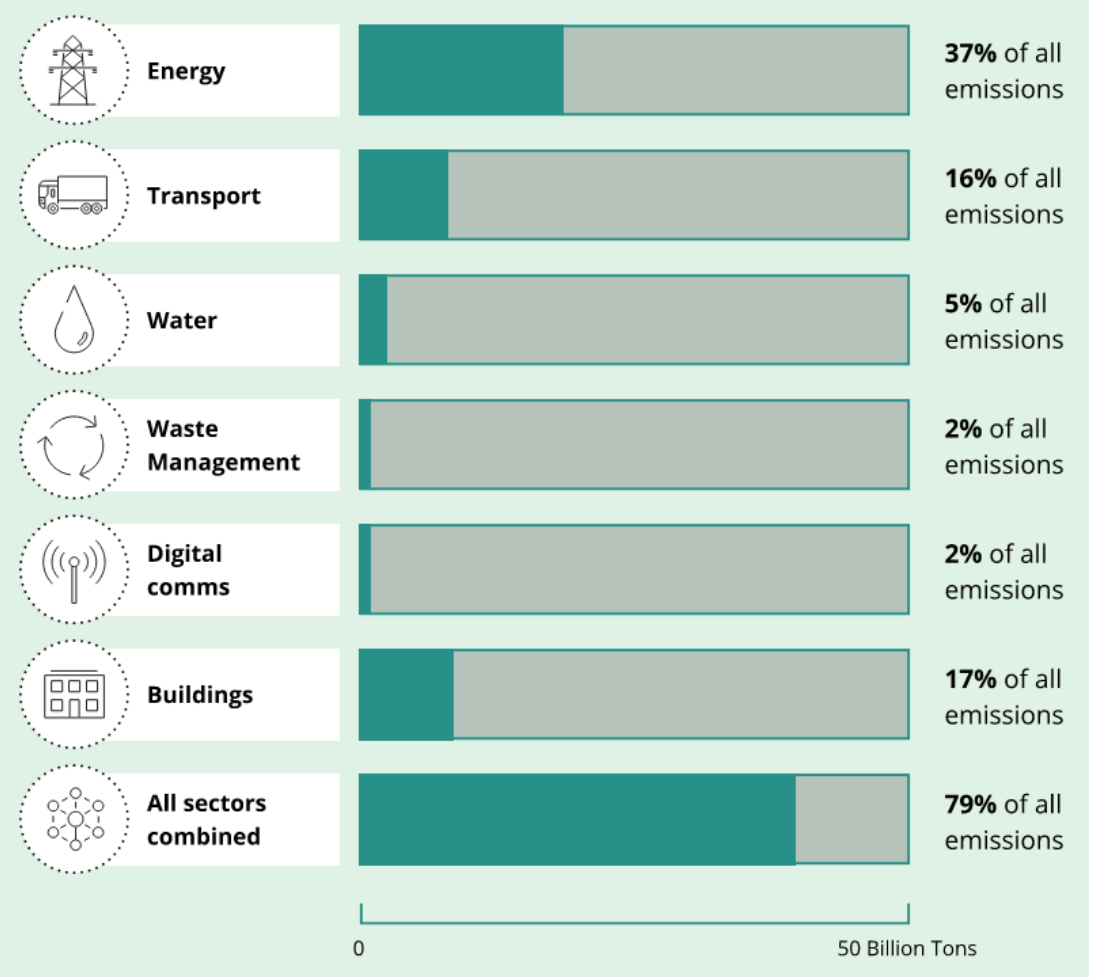
Source: IPCC - Climate change 2014, Mitigation of climate change, working group III contribution to the fifth assessment report of the IPCC on climate change

GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

Built environment sector contribution to global total annual GHG emissions

The built environment sector with its construction and operation is responsible for 79 % of global total annual GHG emissions.

The buildings sector as defined here does not include all indirect emissions which are reflected under the energy sector instead.



Source: UN Office for Project Services – Infrastructure for climate action, 2021

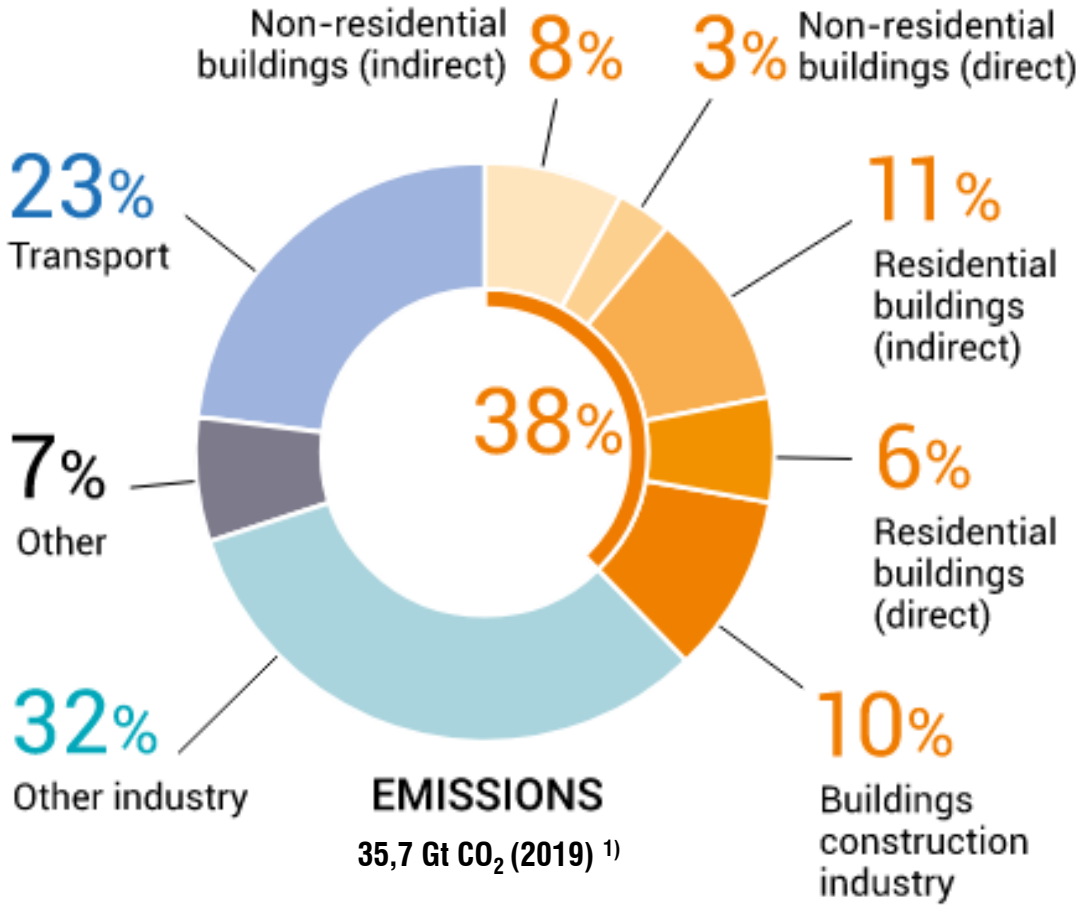
GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

Buildings sector contribution to global energy-related CO_2 emissions in 2019

The buildings and construction sector should be a primary target for GHG emissions mitigation efforts.

Construction and operation of buildings account for 38 % of global energy-related CO_2 emissions.

This does not include civil infrastructure e.g. roads, bridges, tunnels and public utility services.



1) Based on IEA reporting of global energy-related CO_2 emissions i.e. from fossil fuel combustion and industrial processes excluding agriculture, forestry and other land use (AFOLU)

Source: Global Alliance for Buildings and Construction - 2020 Global status report for buildings and construction

GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

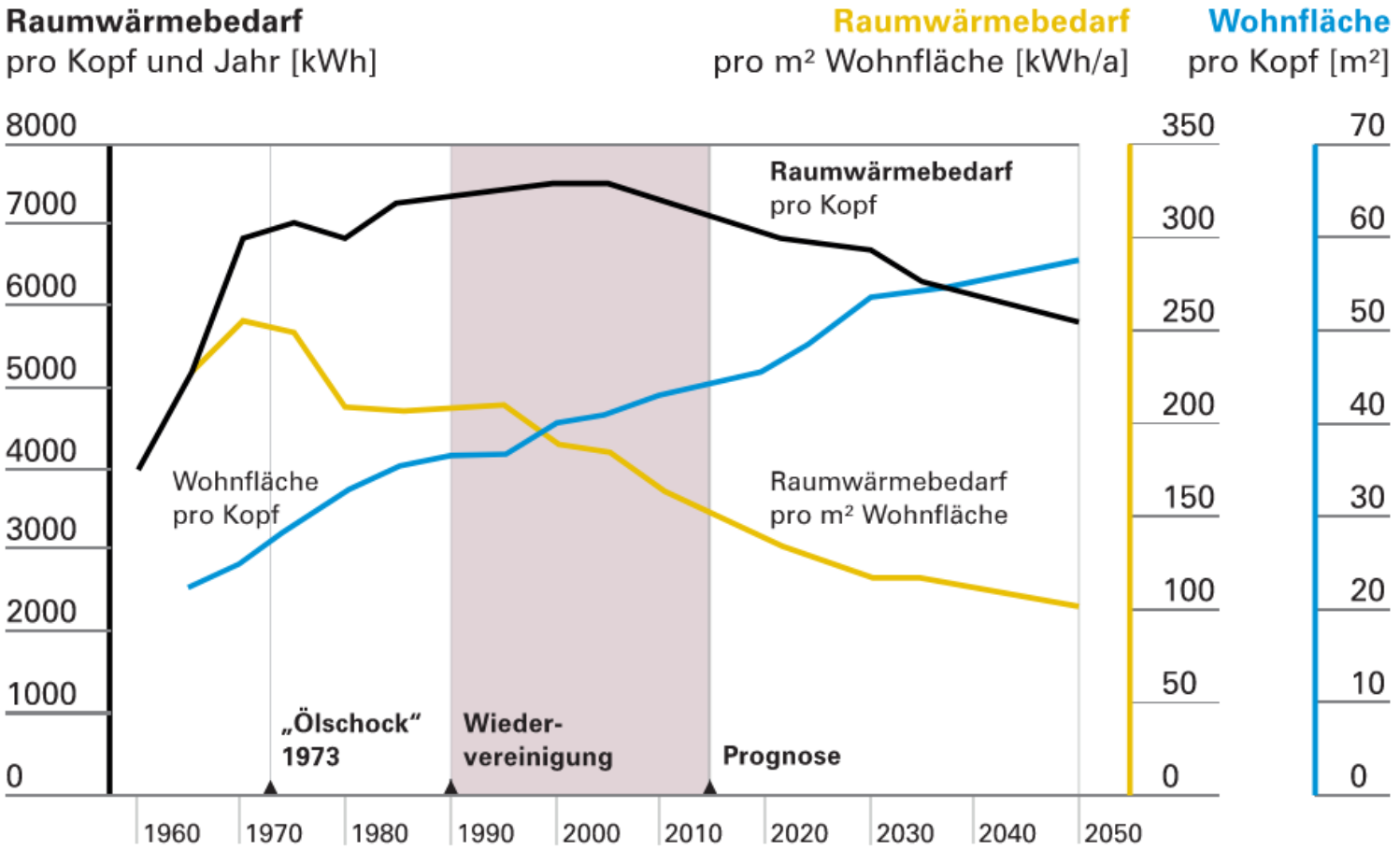
Sufficiency challenge

We need to exploit the potentials of

- sufficiency and
- efficiency

at the same time.

Effective benchmarks should be based on headcount instead of area.



Source: Bayerische Architektenkammer – Nachhaltigkeit gestalten

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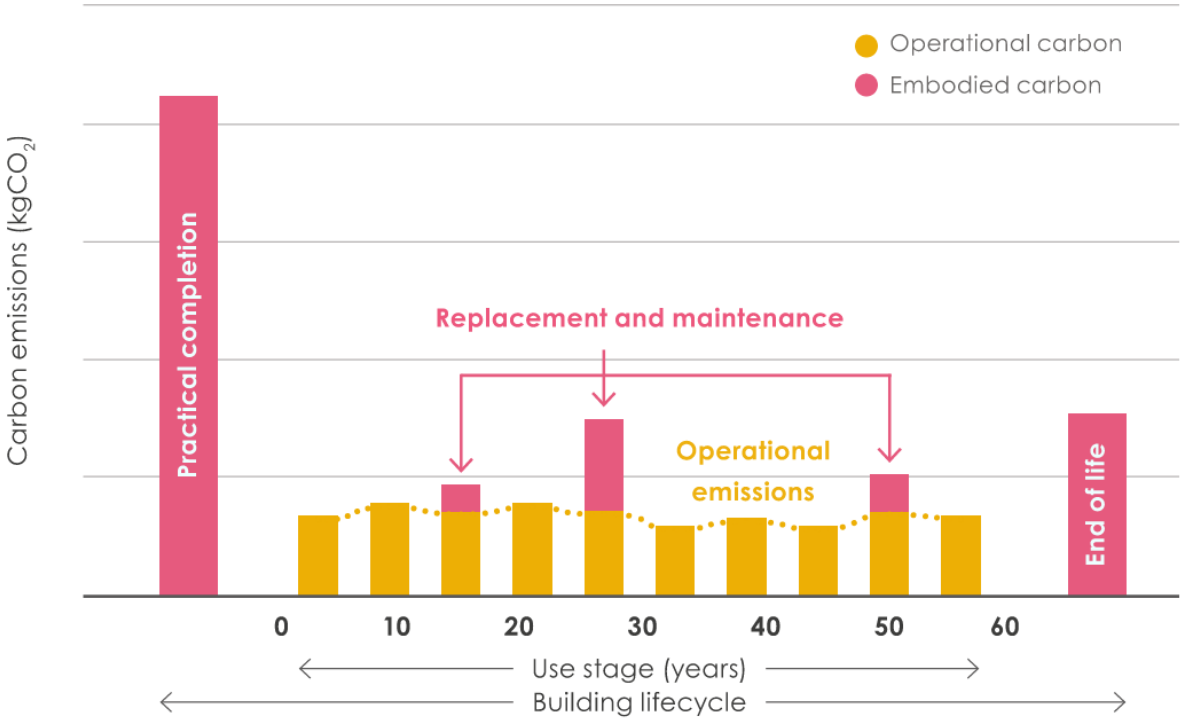
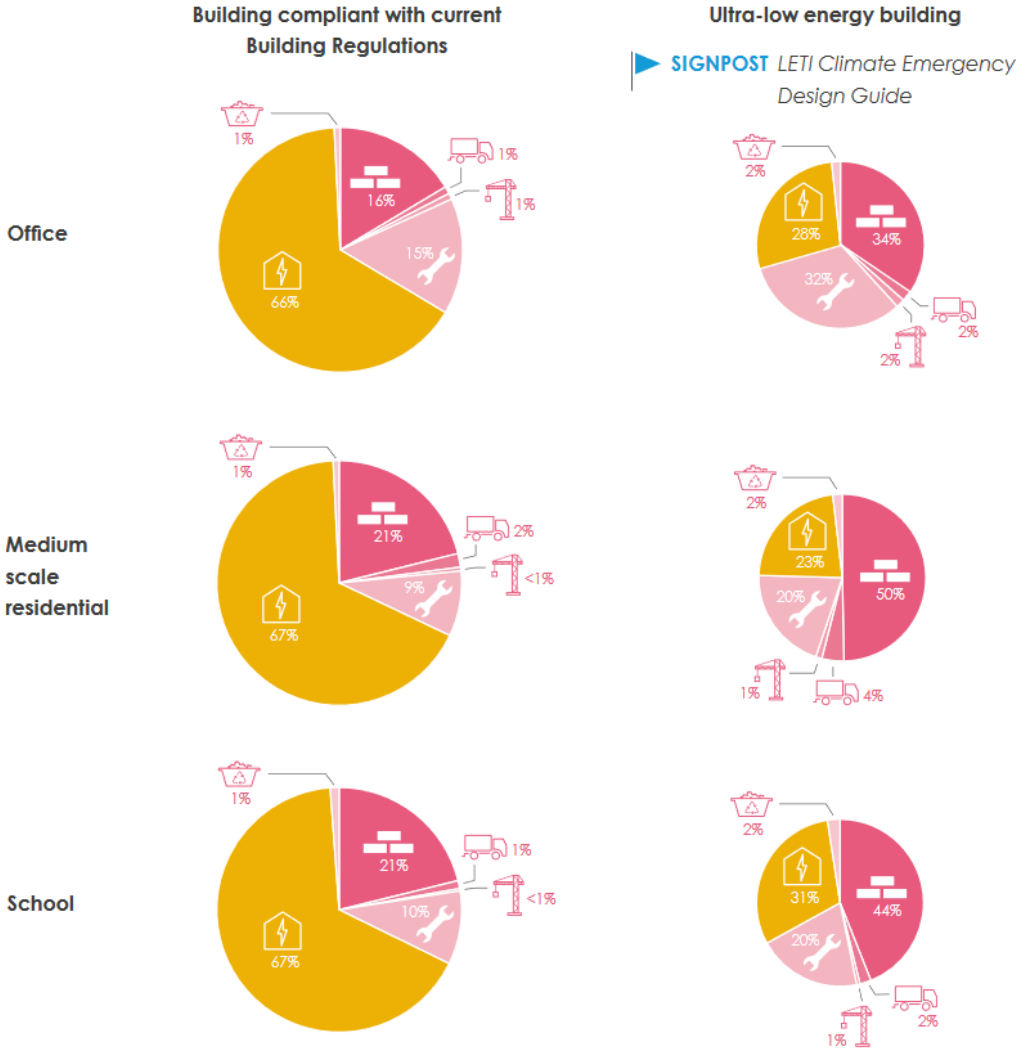
GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

Breakdown of a building's whole life carbon over 60 years

Embodied carbon is around 30-80 %
of a building's whole life carbon,
depending on its energy efficiency.





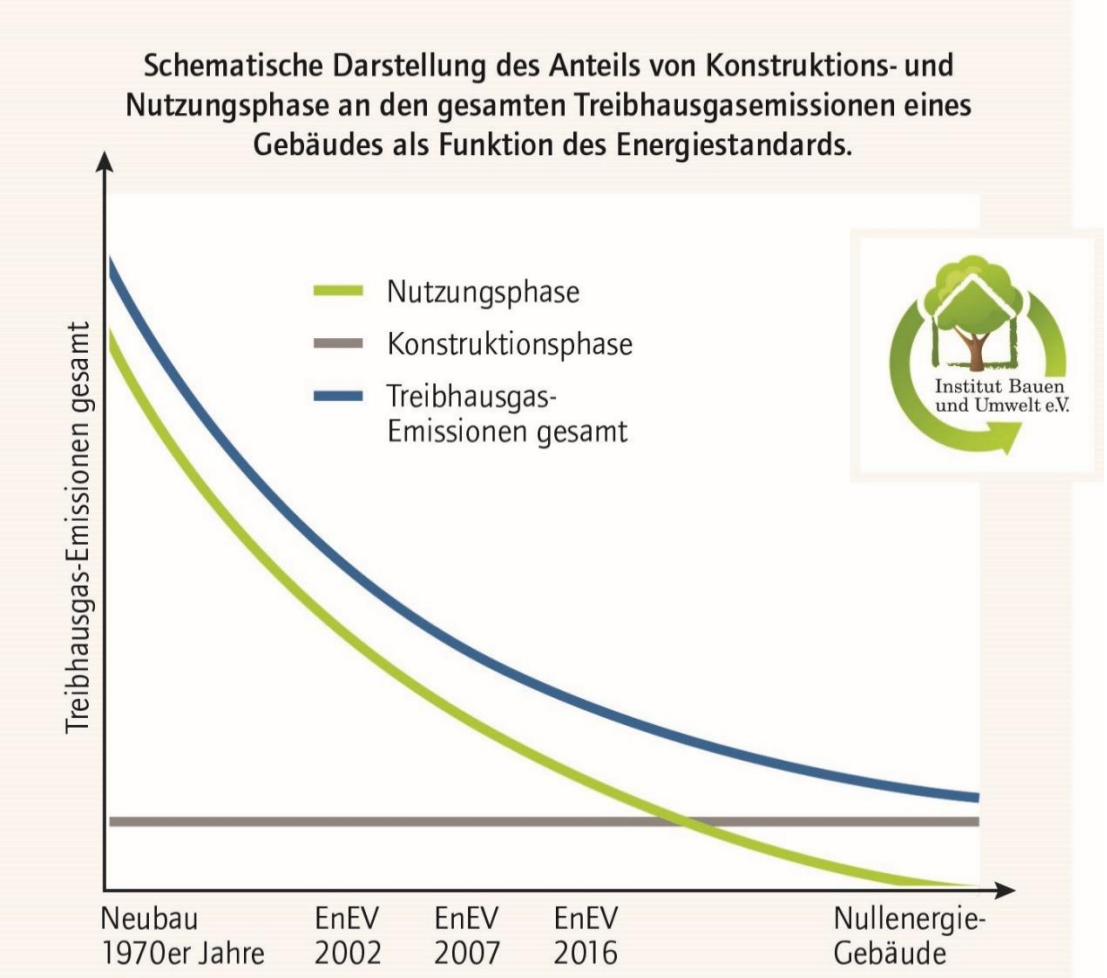
Source: Low Energy Transformation Initiative (LETI) – Embodied carbon primer, 2020

GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

Breakdown of a building's whole life carbon into embodied and operational carbon

For buildings that comply with current building energy standards, embodied carbon is around 50 % of their whole life carbon.

Reduction of embodied carbon and mandatory embodied carbon limits for buildings and civil infrastructure are essential in mitigating global warming.



Source: Institut Bauen und Umwelt

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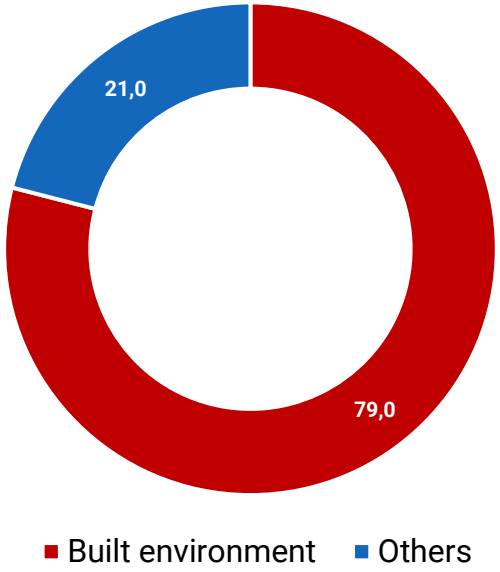
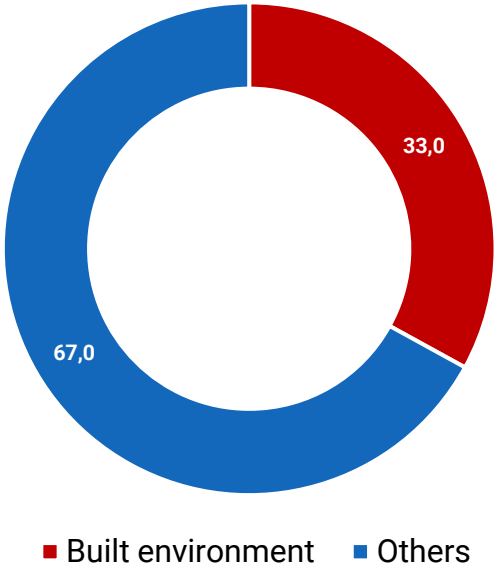
TRANSFORMATION OF THE BUILT ENVIRONMENT

Global environmental impact of the built environment

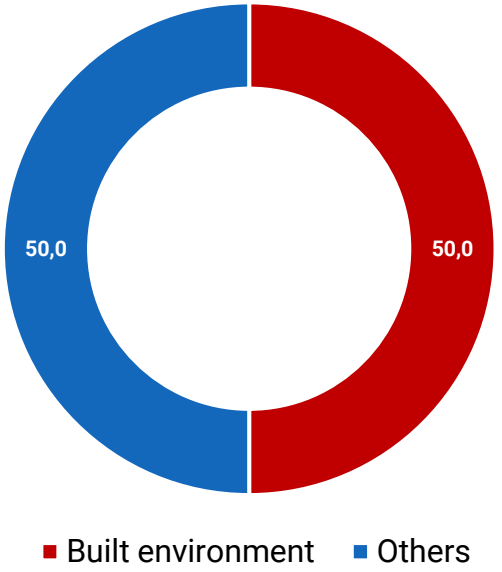
GHG Emissions [%]



Waste Production [%]



Raw Materials Consumption [%]



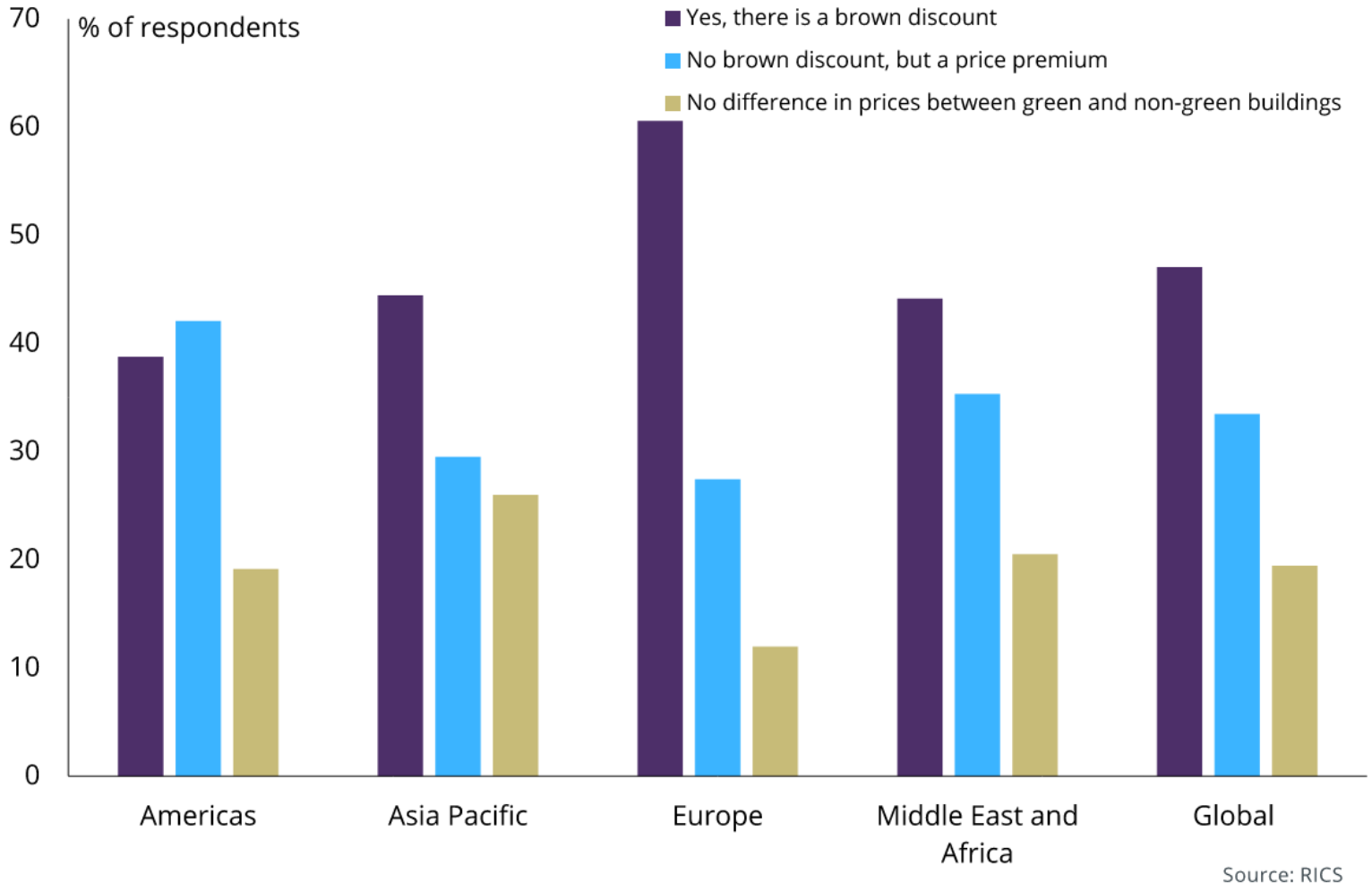
Source: BBC - Future Planet, The industry creating a third of the world's waste, 2021

TRANSFORMATION OF THE BUILT ENVIRONMENT

Brown discount for prices

RICS drew on the expert opinions of around 4.000 professionals working in commercial real estate and construction across over 30 countries.

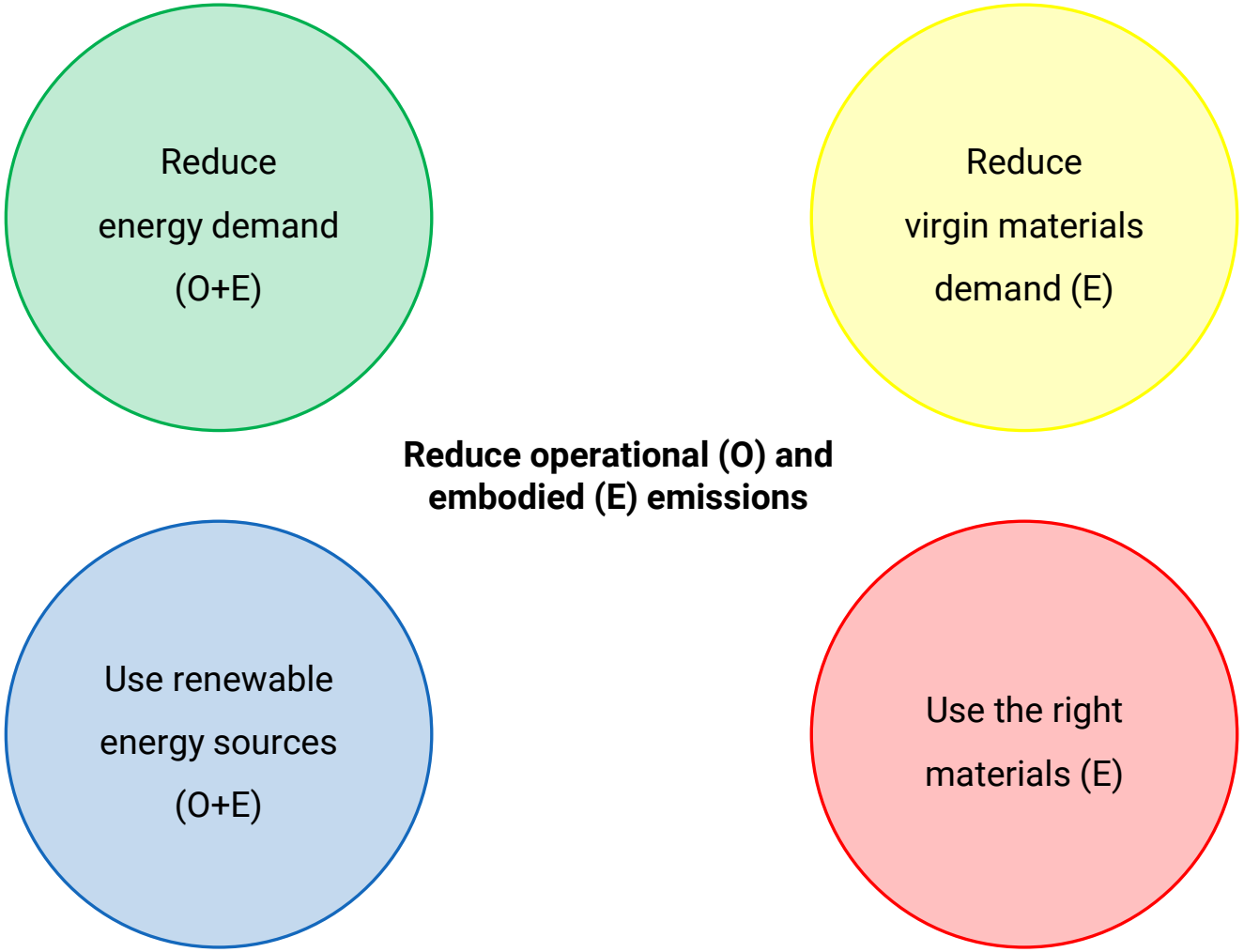
Buildings not classed as either green or sustainable are subject to a brown discount.



Source: RICS – Sustainability report 2022

TRANSFORMATION OF THE BUILT ENVIRONMENT

Reduction of GHG emissions from the built environment across the entire life cycle



TRANSFORMATION OF THE BUILT ENVIRONMENT

Roadmap for the transformation

Raise awareness for the climate emergency and GHG emissions from the built environment

Enable designers to use low carbon design approaches and to conduct life cycle assessments

Implement low carbon design solutions and collaborate across disciplines for further optimisation

Collect harmonised project data for GWP and establish and refine GWP benchmarks

Introduce legal regulations that set limitations to whole life GHG emissions

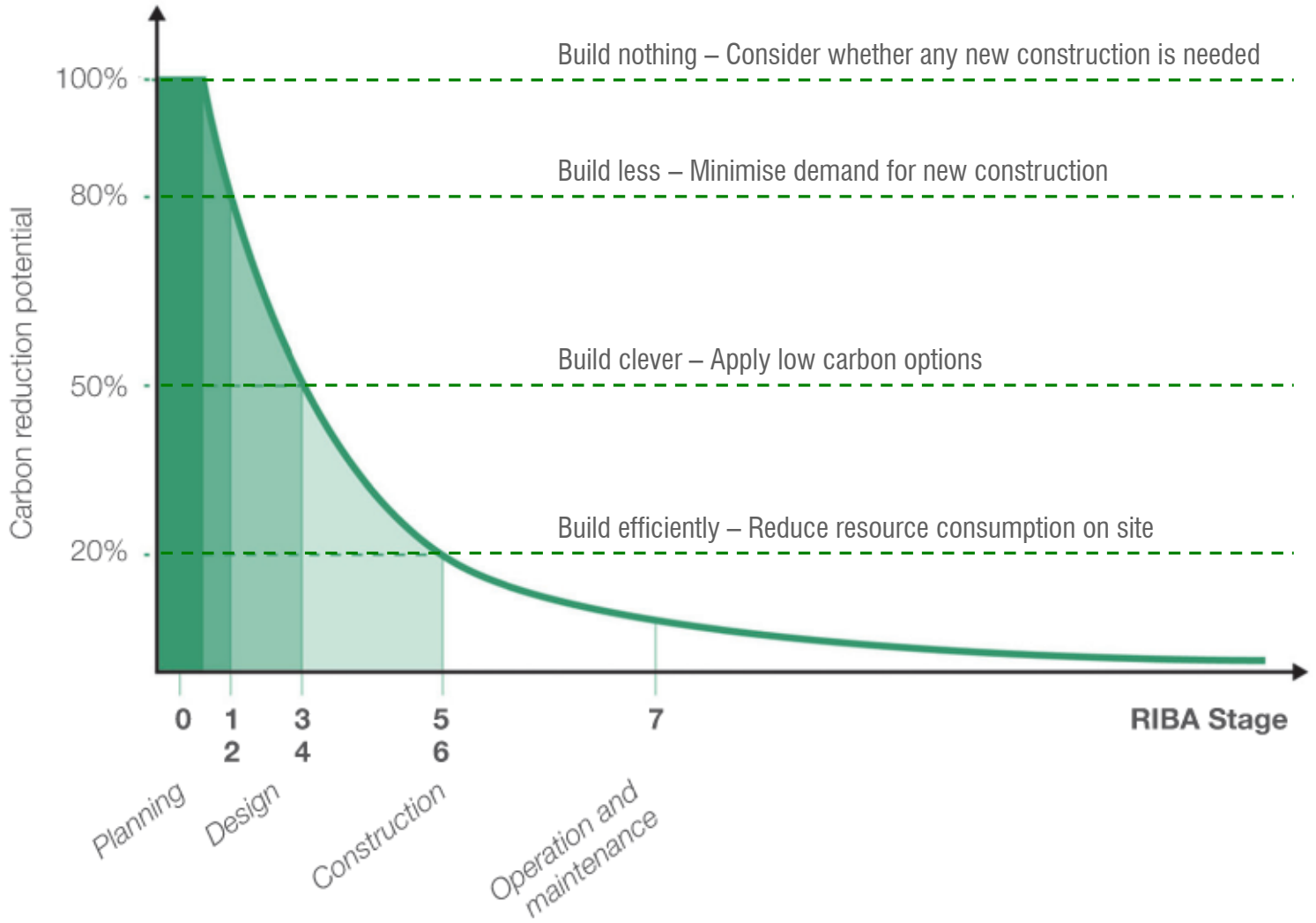
Establish financial incentives to reduce GHG emissions beyond legal regulations

TRANSFORMATION OF THE BUILT ENVIRONMENT

Carbon reduction potential over time / project stages

Planning and design are the most important factors in determining greenhouse gas emissions over the lifetime of a building or civil infrastructure.

The objective of carbon reduction has to be implemented from the very beginning of a project or better even earlier.



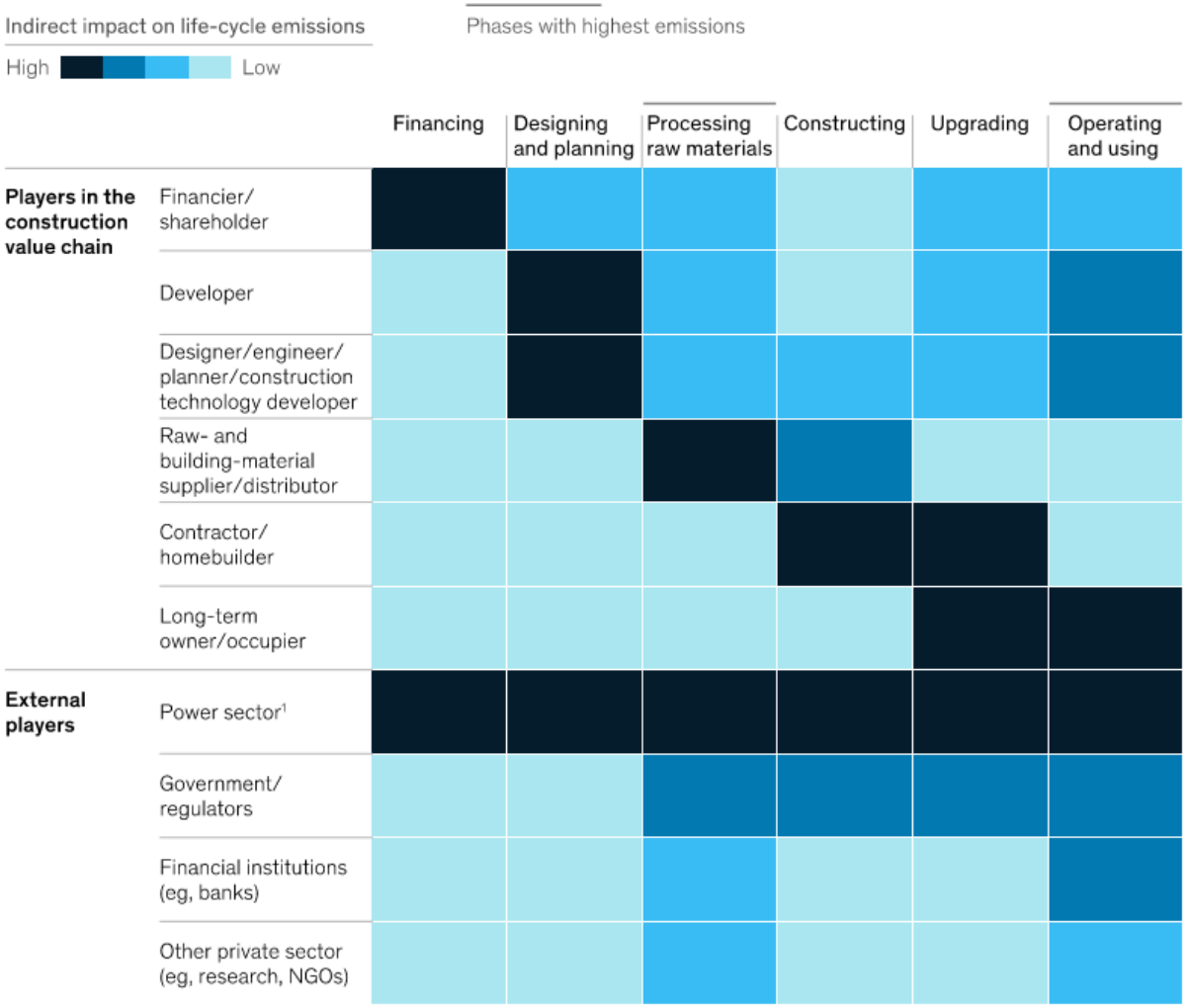
Source: IStructE – How to calculate embodied carbon

TRANSFORMATION OF THE BUILT ENVIRONMENT

Impact and influence on emissions at each stage of the construction lifecycle

The construction ecosystem is highly fragmented, with many steps along the product life cycle.

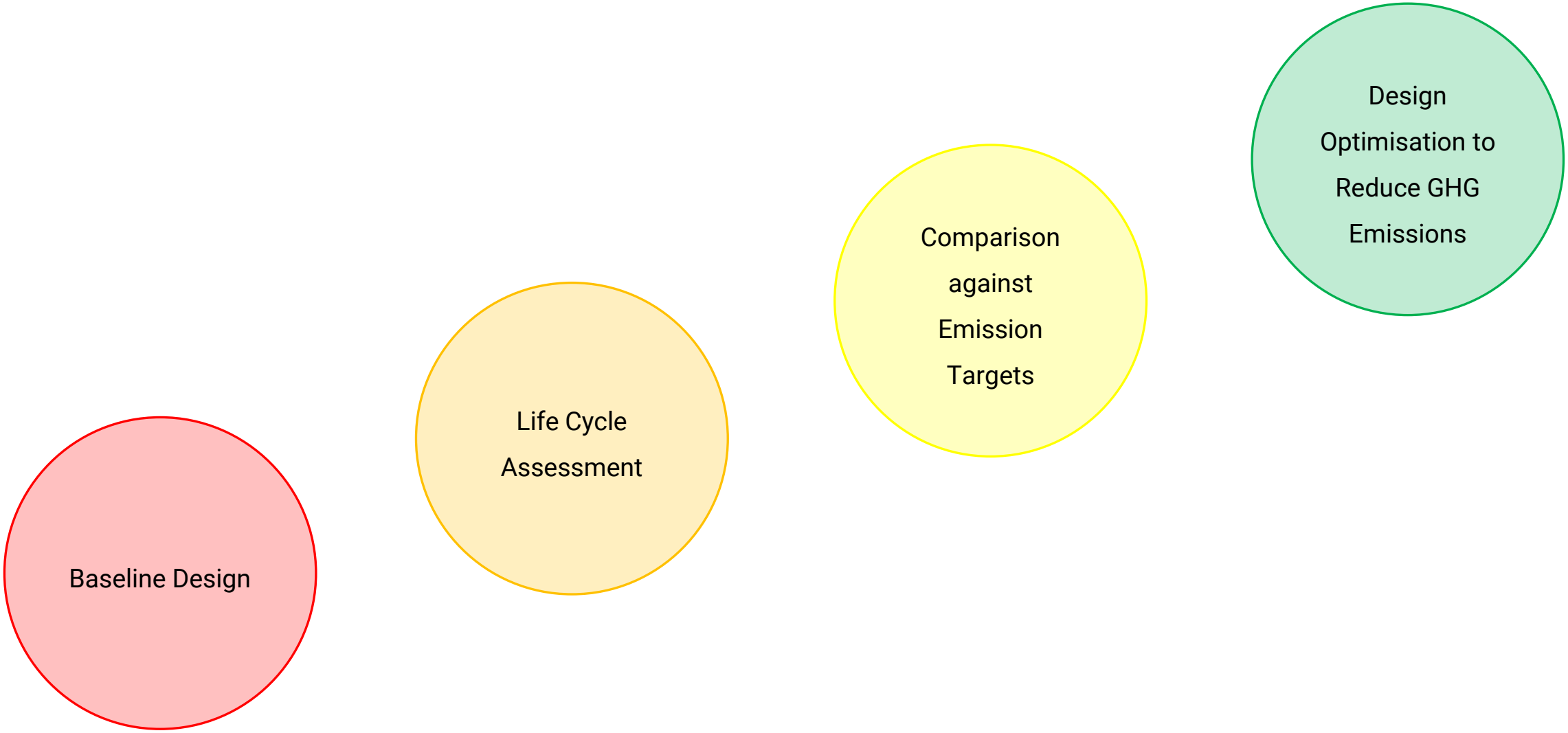
Each player has an impact at a specific phase of the construction life cycle. Major opportunities require collaborative action.



Source: McKinsey & Company – Call for action: Seizing the decarbonization opportunity in construction

TRANSFORMATION OF THE BUILT ENVIRONMENT

Design approach for the transformation



TRANSFORMATION OF THE BUILT ENVIRONMENT

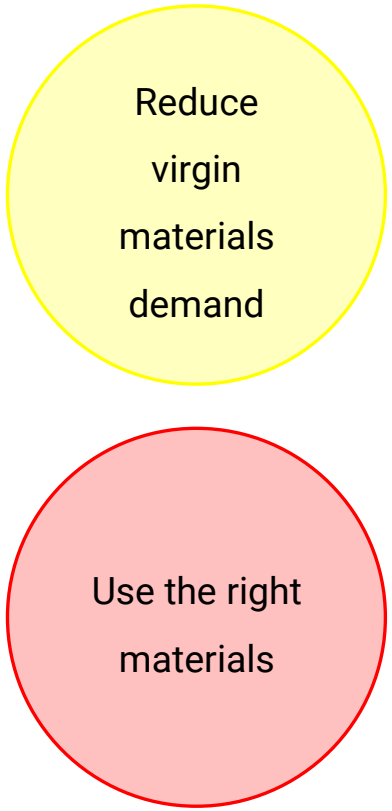
Design approaches for decarbonisation of buildings and civil infrastructure

1. Reduce virgin materials demand

- consider sufficiency principles
- re-use existing buildings
- re-use existing components
- re-use of existing materials
- increase material efficiency
- adopt low maintenance and repair strategies

2. Use the right materials

- use materials with carbon storage capacity (carbon sink)
- use materials with low GWP



TRANSFORMATION OF THE BUILT ENVIRONMENT

Sustainability certifications (QNG)

The QNG certification is a prerequisite for financial subsidies by KfW under the umbrella of BEG regulations.

To achieve the QNG certification general requirements (BNB, DGNB, NaWoh or BNK certification) and additional requirements (e.g. target values for GHG emissions including embodied carbon) have to be met.

	Residential Buildings (New Built)	**Commercial Buildings (New Built)**
QNG - Plus	$GWP_{100} \leq 28$ kg CO_2 eq. / (m_{NRF}^2 a)	$GWP_{100} \leq 12$ kg CO_2 eq. / (m_{NRF}^2 a)
QNG - Premium	$GWP_{100} \leq 20$ kg CO_2 eq. / (m_{NRF}^2 a)	$GWP_{100} \leq 9{,}5$ kg CO_2 eq. / (m_{NRF}^2 a)
Reference period LCA modules Elements	50 years A1 to A3 + B4 + B6 + C3 + C4 KG 300 + 400 (+ 500)	50 years A1 to A3 + B4 + C3 + C4 KG 300 + 400 (+ 500)

Source: Bundesministerium für Wohnen, Stadtentwicklung und Bauen – Qualitätssiegel Nachhaltiges Gebäude (QNG)

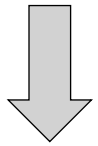
TRANSFORMATION OF THE BUILT ENVIRONMENT

Gebäudeenergiegesetz (GEG)

The Gebäudeenergiegesetz was passed in 2020 but it does not include any regulations on embodied carbon emissions.

An amendment of this act should be made to include whole lifecycle GHG emissions. The next amendment is planned for 2025.

Gebäudeenergiegesetz

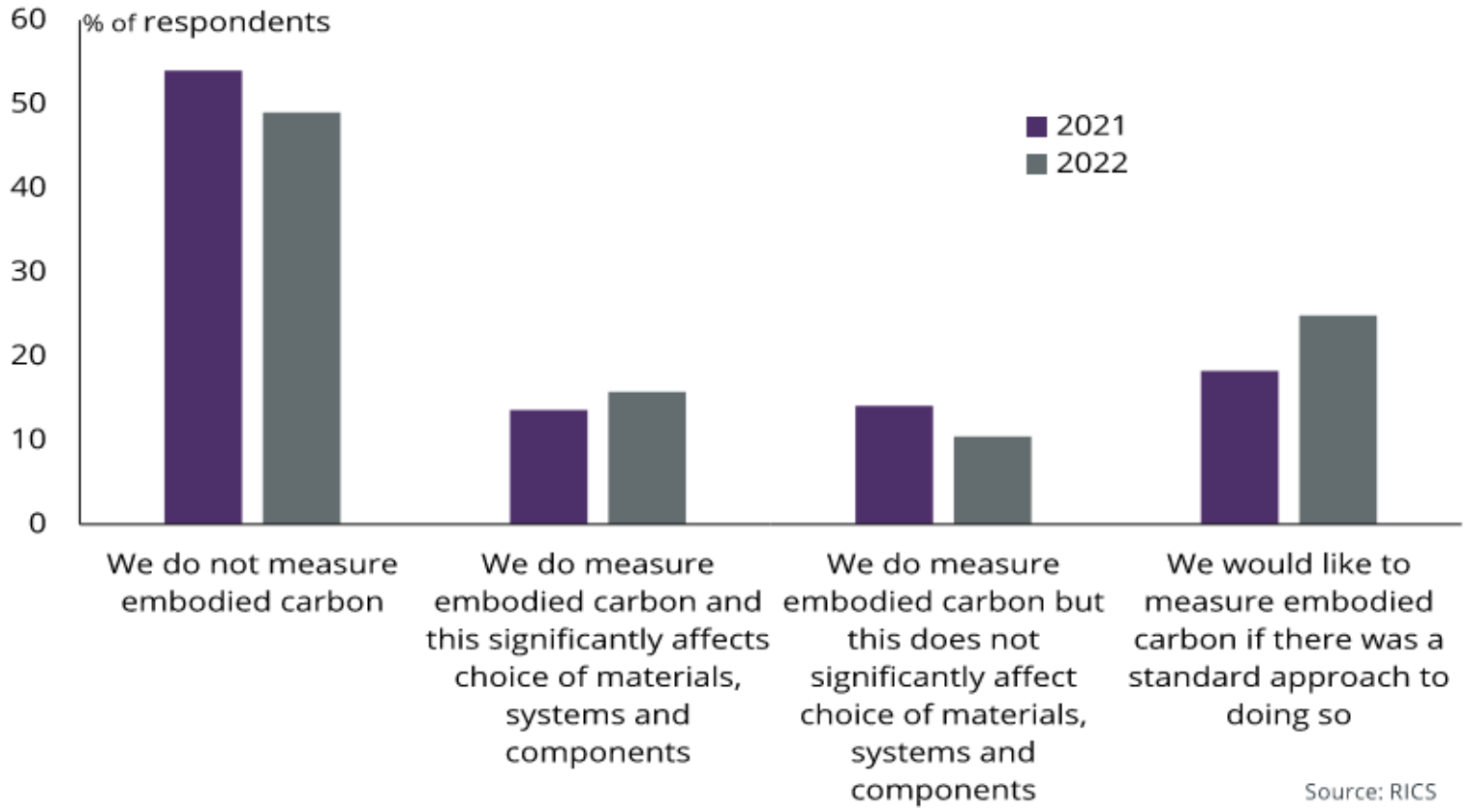


Gebäudeemissionsgesetz

TRANSFORMATION OF THE BUILT ENVIRONMENT

Do you currently measure embodied carbon on your projects?

Only around 16 % of respondents globally report that they both measure embodied carbon and use these assessments to guide their selection of materials and components.



Source: RICS – Sustainability report 2022

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STRUCTURAL DESIGN APPROACHES

Contextualising the potential impact of structural engineers

Source: IStructE – How to calculate embodied carbon

STRUCTURAL DESIGN APPROACHES

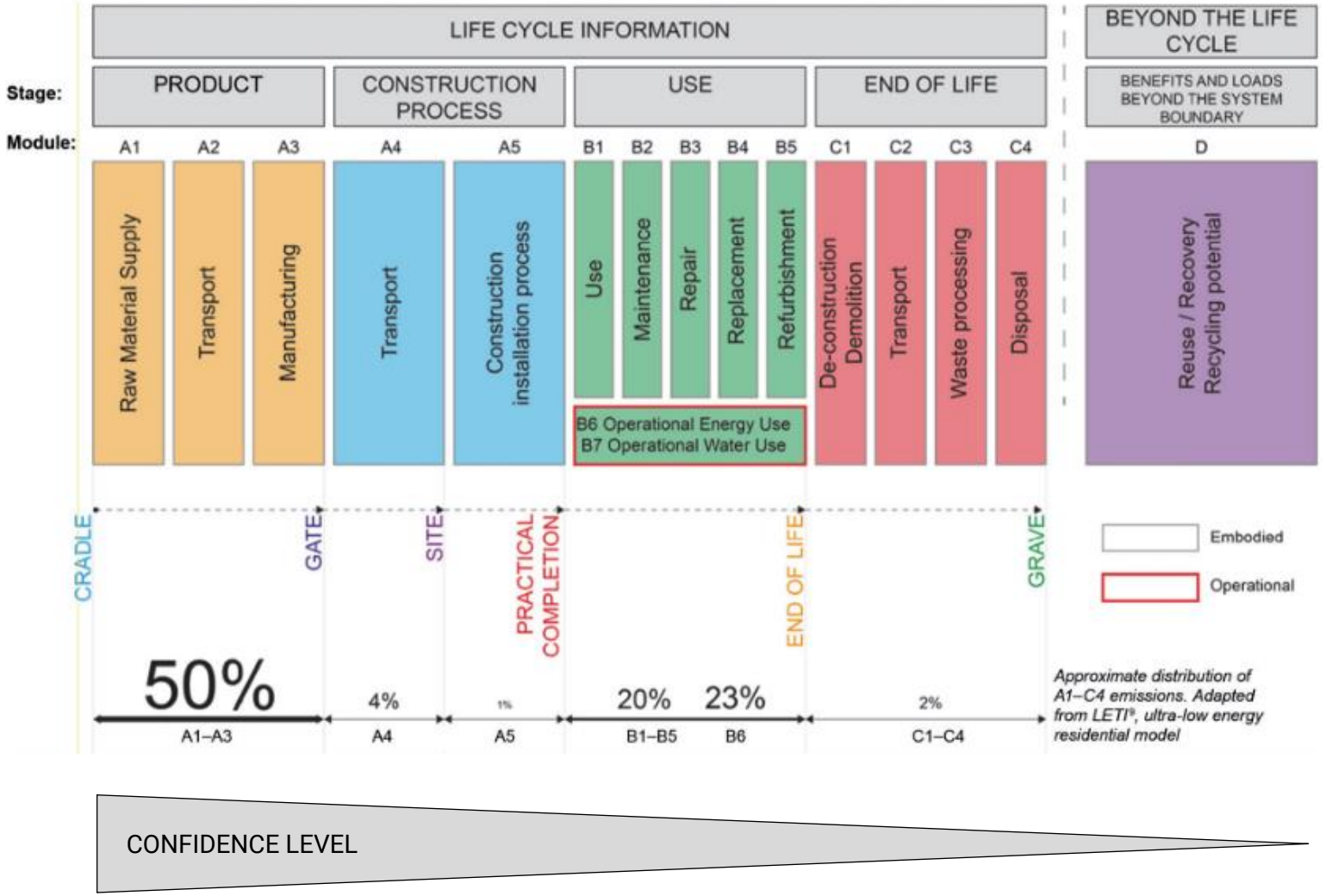
Life cycle assessment (LCA)

Life cycle assessments are broken down into various life cycle modules (A to D).

LCAs for structural elements should include modules A1 to A5 as a minimum but preferably all modules A to D.

DGNB suggests to consider modules A1 to A3, B4, B6, C3, C4 and D for LCAs of buildings.

Replacement of structural elements is usually not required within the design life of a building.



Source: IStructE – How to calculate embodied carbon

STRUCTURAL DESIGN APPROACHES

Carbon factor databases

Available datasets:

- Specific dataset (for a particular product and manufacturing plant)
- Average dataset (for various products and manufacturers)
- Representative dataset (average or worst? for products from a particular country or region)
- Generic datasets (based on literature or scientific research without industry data)

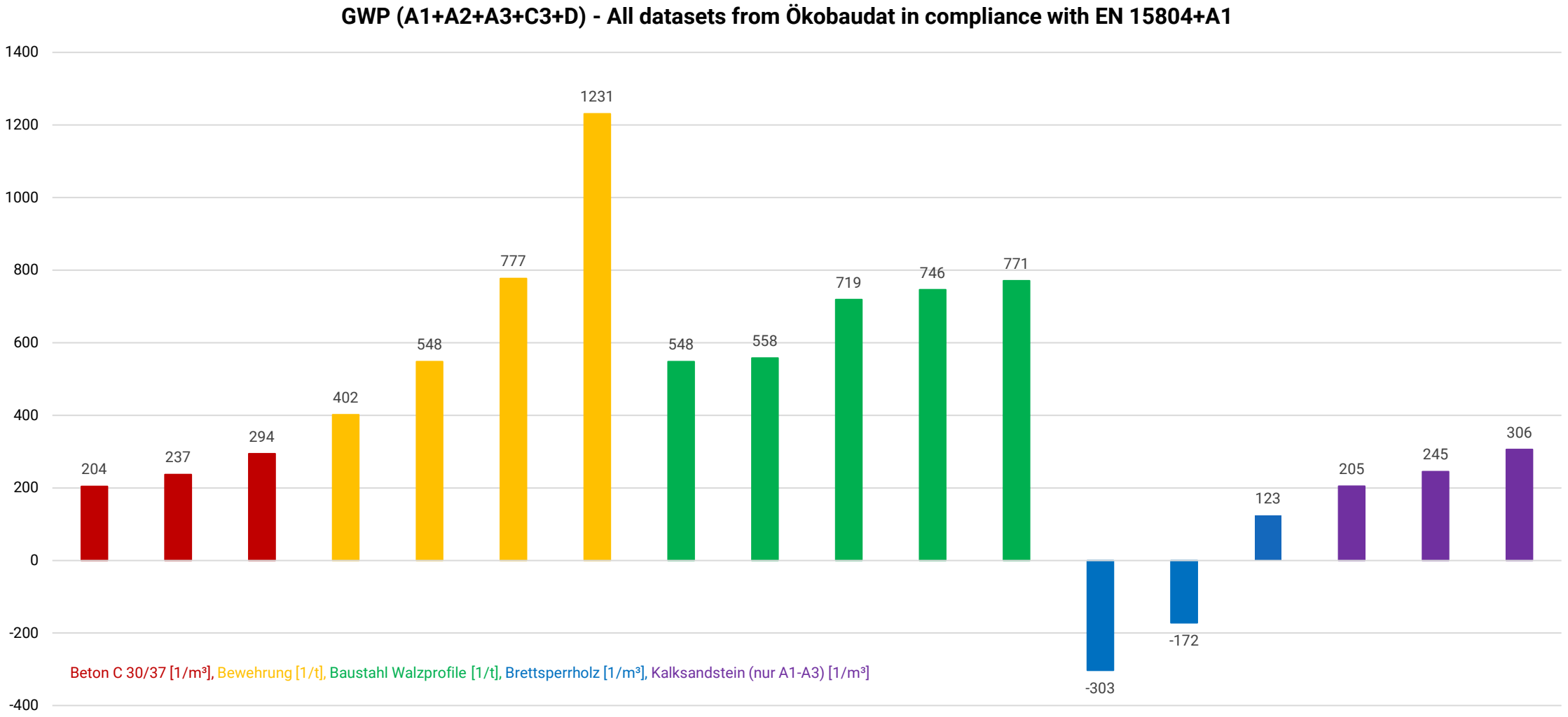
STRUCTURAL DESIGN APPROACHES

Environmental product declaration (EPD)

- EPDs are the preferred source of environmental impact data e.g. GWP
- EPDs are prepared by product suppliers in compliance with DIN EN ISO 14025, DIN EN 15804 and DIN EN 16485
- They are checked and approved by an independent party
- They are published in Germany by Institut Bauen und Umwelt (IBU)

STRUCTURAL DESIGN APPROACHES

Selecting GWP data



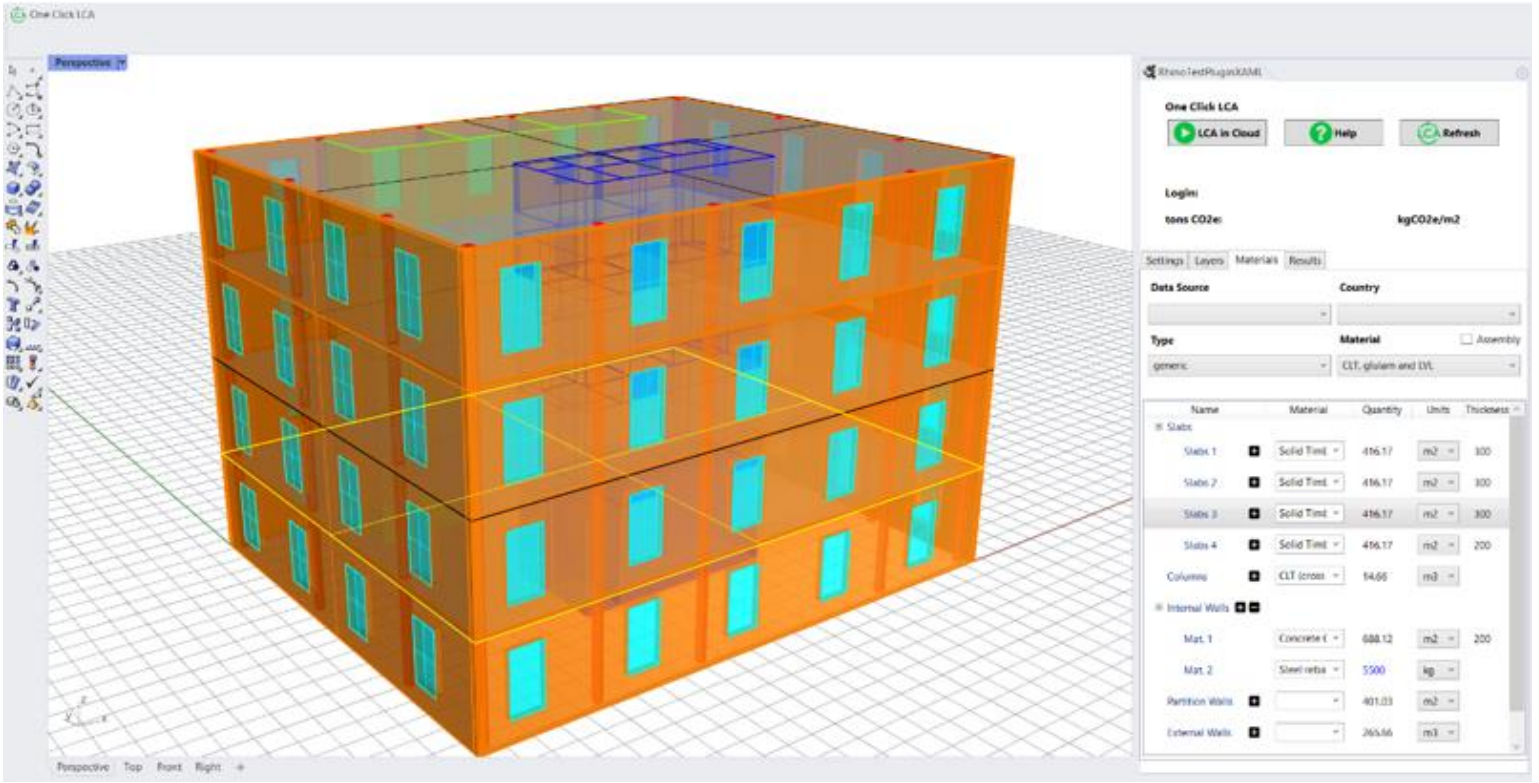
STRUCTURAL DESIGN APPROACHES

Tools for life cycle assessments

- Excel spreadsheet
- IStructE - The structural carbon tool
- eLCA
- CAALA
- One Click LCA

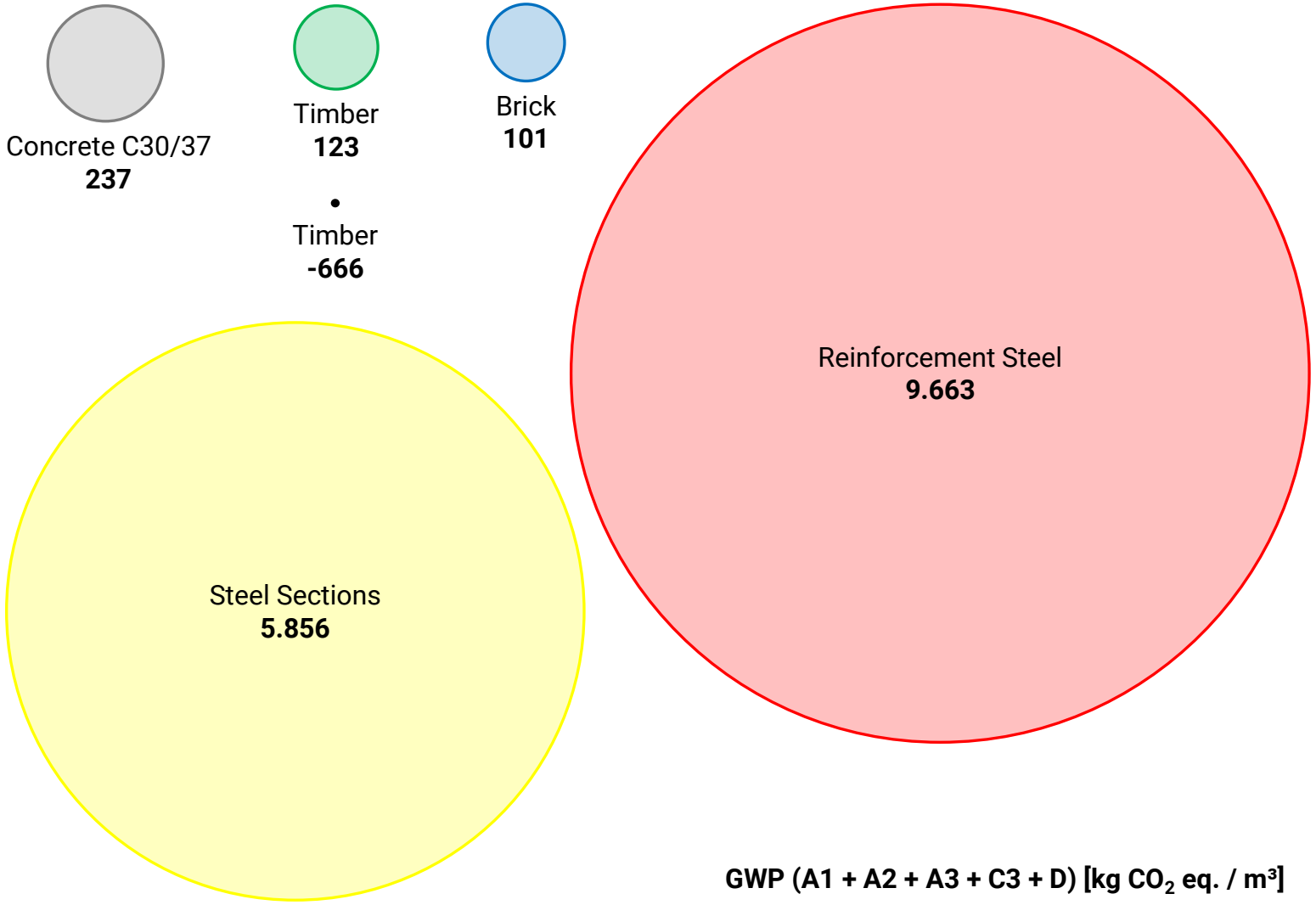
Bollinger+Grohmann has developed Rhino/Grasshopper and Revit plugins for One Click LCA to facilitate big data processing.

These plugins support a parametric approach to life cycle assessments that allows an efficient comparison of a wide range of design options.



STRUCTURAL DESIGN APPROACHES

GWP of different materials



The GWP of a material can only be a first indicator as all materials have different structural properties.

Locking biogenic carbon is a major advantage of timber structures.

GWP (A1 + A2 + A3 + C3 + D) [kg CO_2 eq. / m^3]

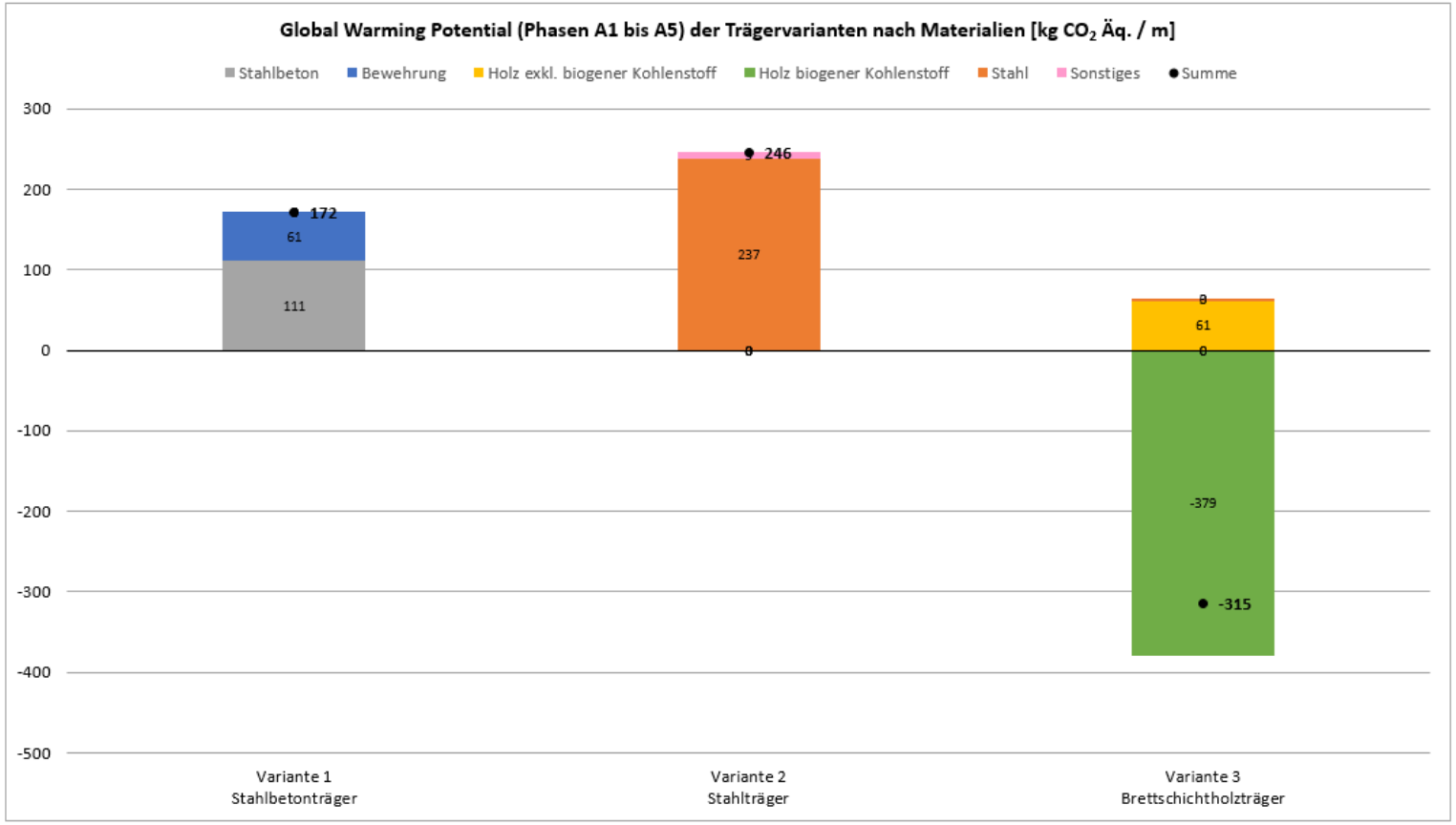
STRUCTURAL DESIGN APPROACHES

GWP of different beam design options

All options were designed and evaluated based on the same design criteria:

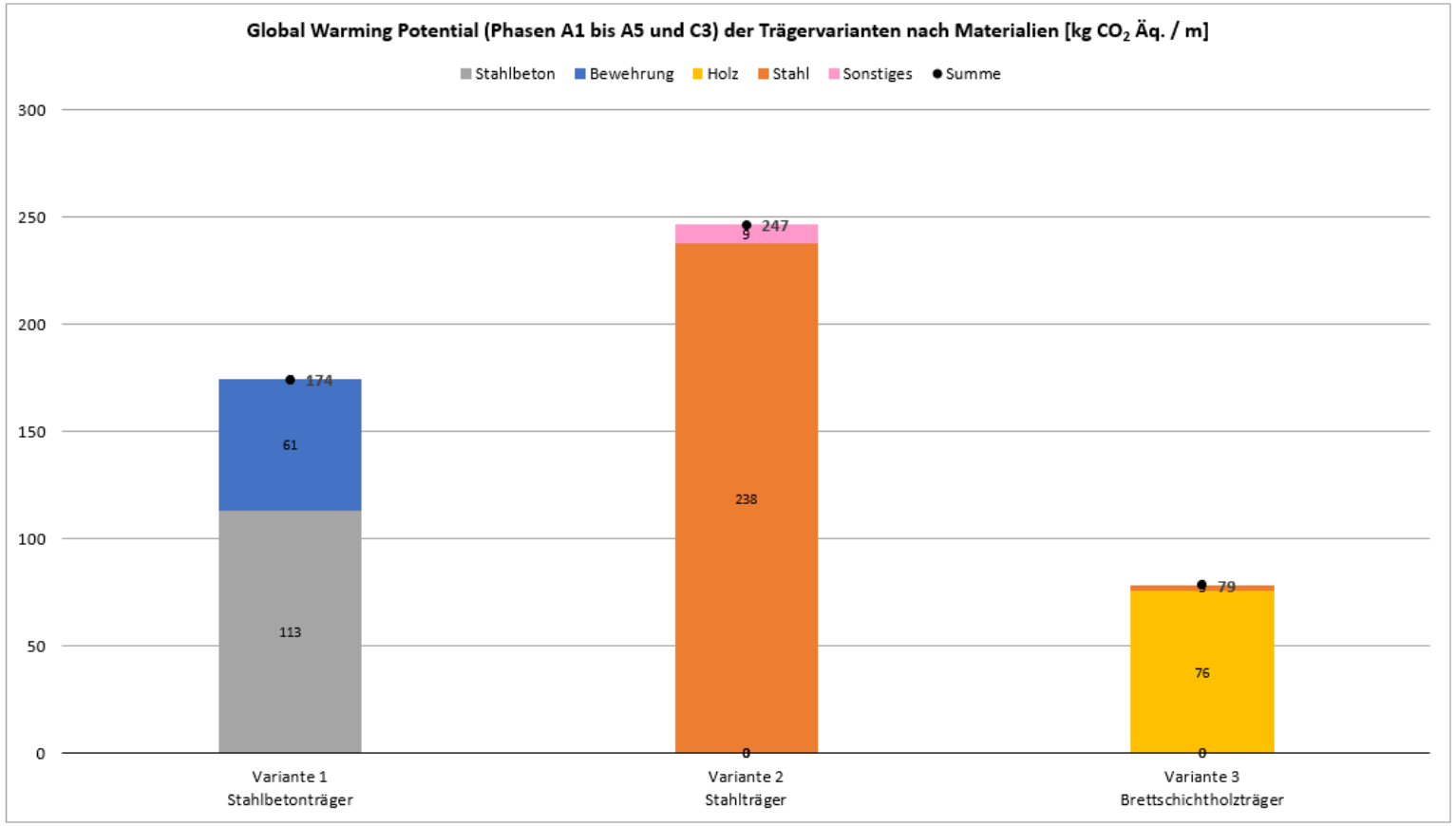
- Span 8.0 m
- Loading 178.5 kN/m + SW
- Deflection limit L/300
- Fire rating R 90

GWP excluding fit-out



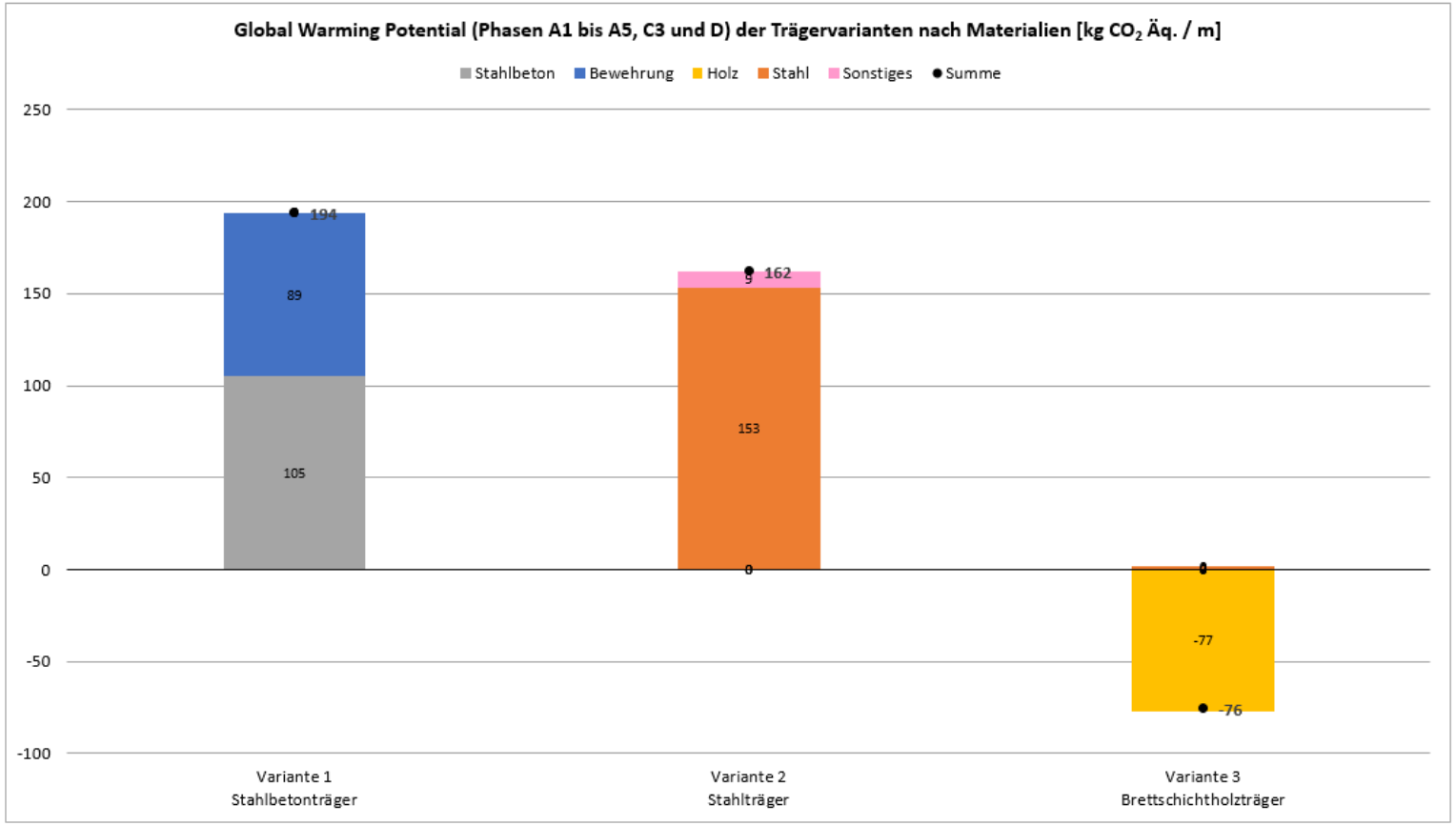
STRUCTURAL DESIGN APPROACHES

GWP of different beam design options



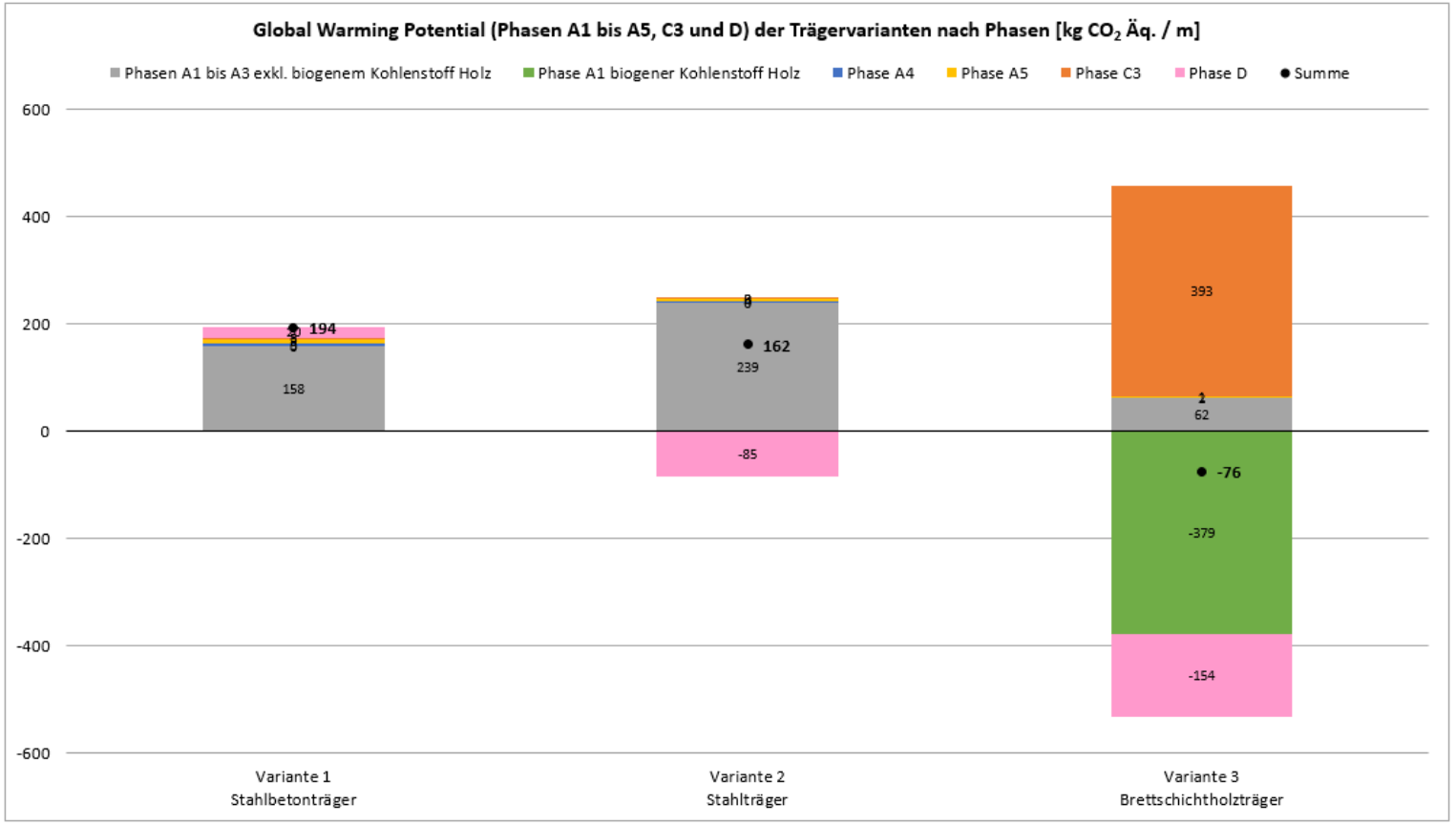
STRUCTURAL DESIGN APPROACHES

GWP of different beam design options



STRUCTURAL DESIGN APPROACHES

GWP of different beam design options



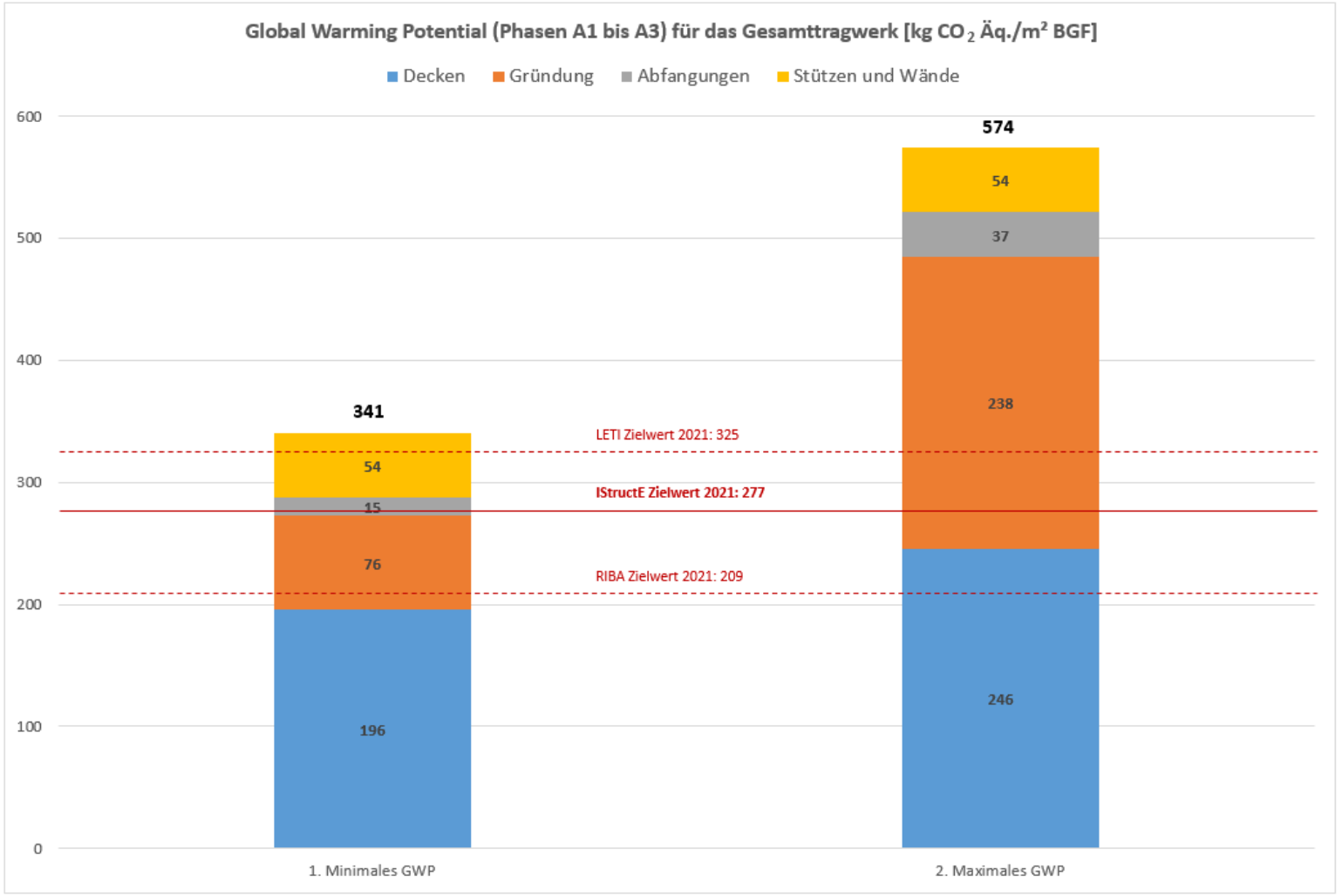
STRUCTURAL DESIGN APPROACHES

GWP of different structural design options for an entire building's structure

All options were designed and evaluated based on the same design criteria.

Overall reduction potential of greenhouse gas emissions for the entire building's structure: 7.728 t CO_2eq.

GWP excluding fit-out

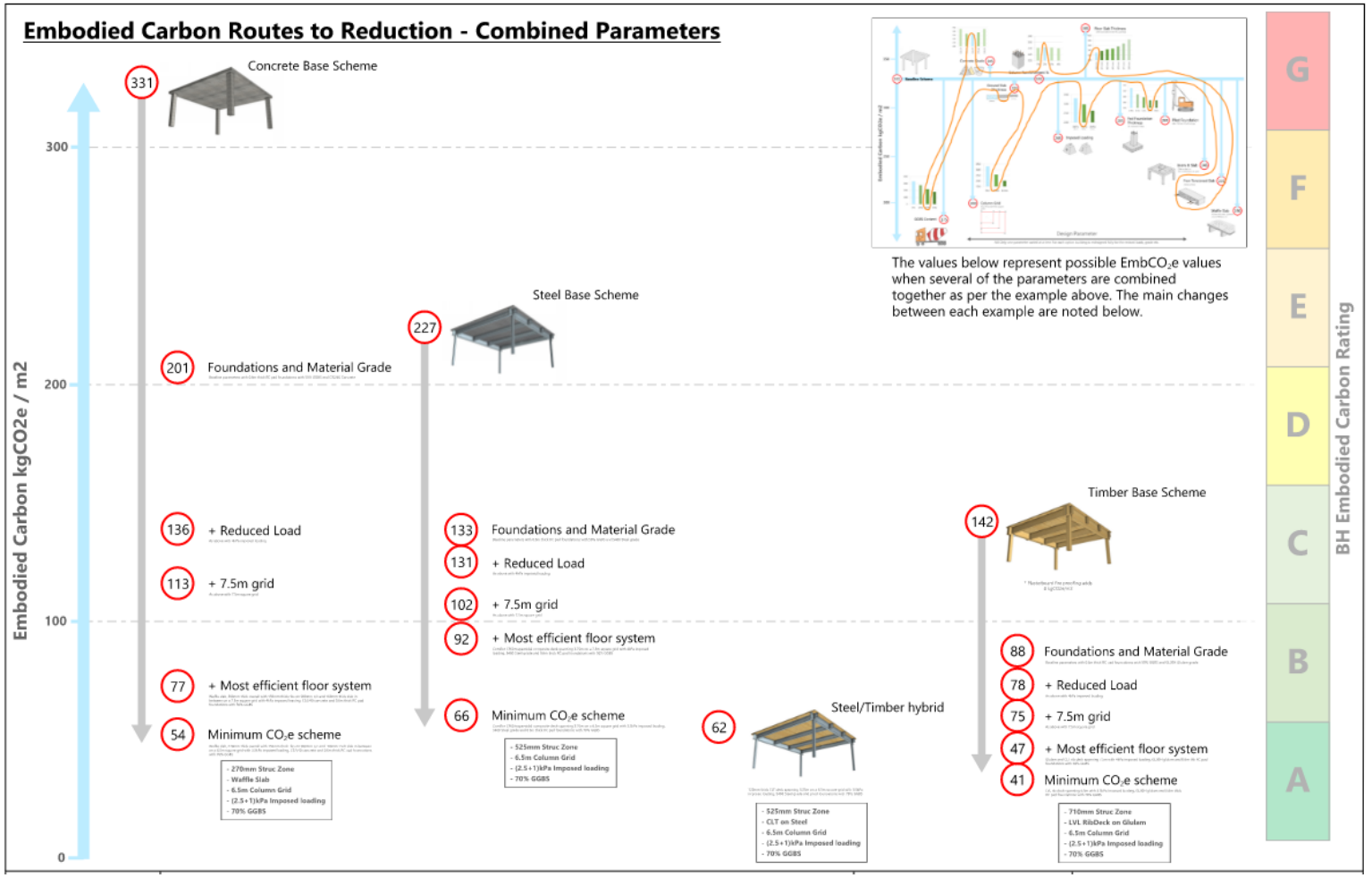


STRUCTURAL DESIGN APPROACHES

Embodied carbon (A1-A3) for different structural design options of an entire building's structure

All options were designed and evaluated based on the same design criteria:

- Building size: 8.000 m² six storeys
- Column grid: 9.0 / 9.0 m
- Loading: g = 1.5 kN/m², q=5.0 kN/m²
- Deflection limit: to code but < 20 mm
- Fire rating: R 60



Source: Buro Happold – Embodied carbon structural sensitivity study

STRUCTURAL DESIGN APPROACHES

Design path towards reduction of a structure’s global warming potential (schematic)

Step 1

Conventional design approach

Step 2

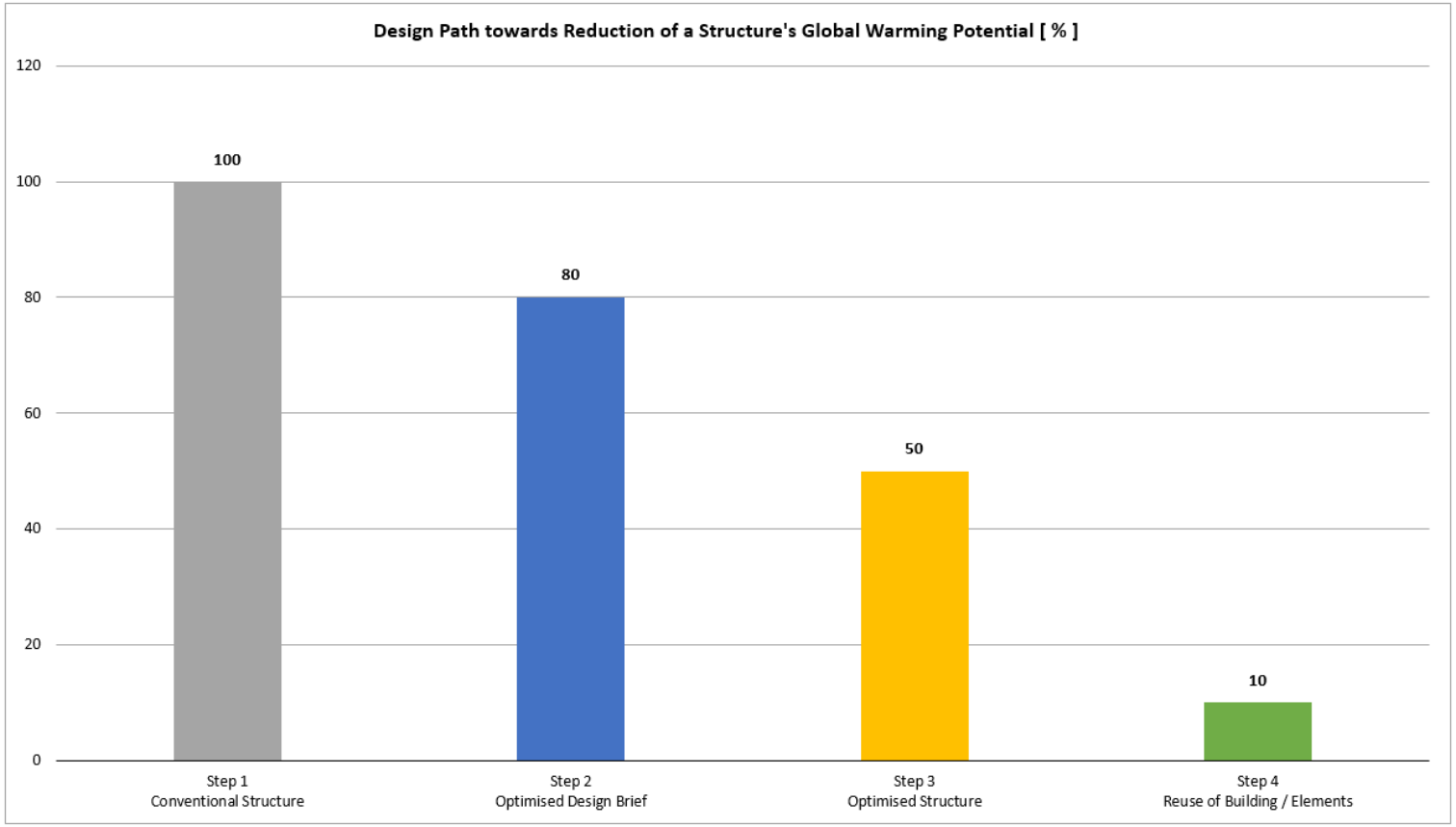
Optimised design brief (relaxed structural performance criteria e.g. spans, loads, deflections, vibration)

Step 3

Optimised structure (improved material efficiency and use of the right materials)

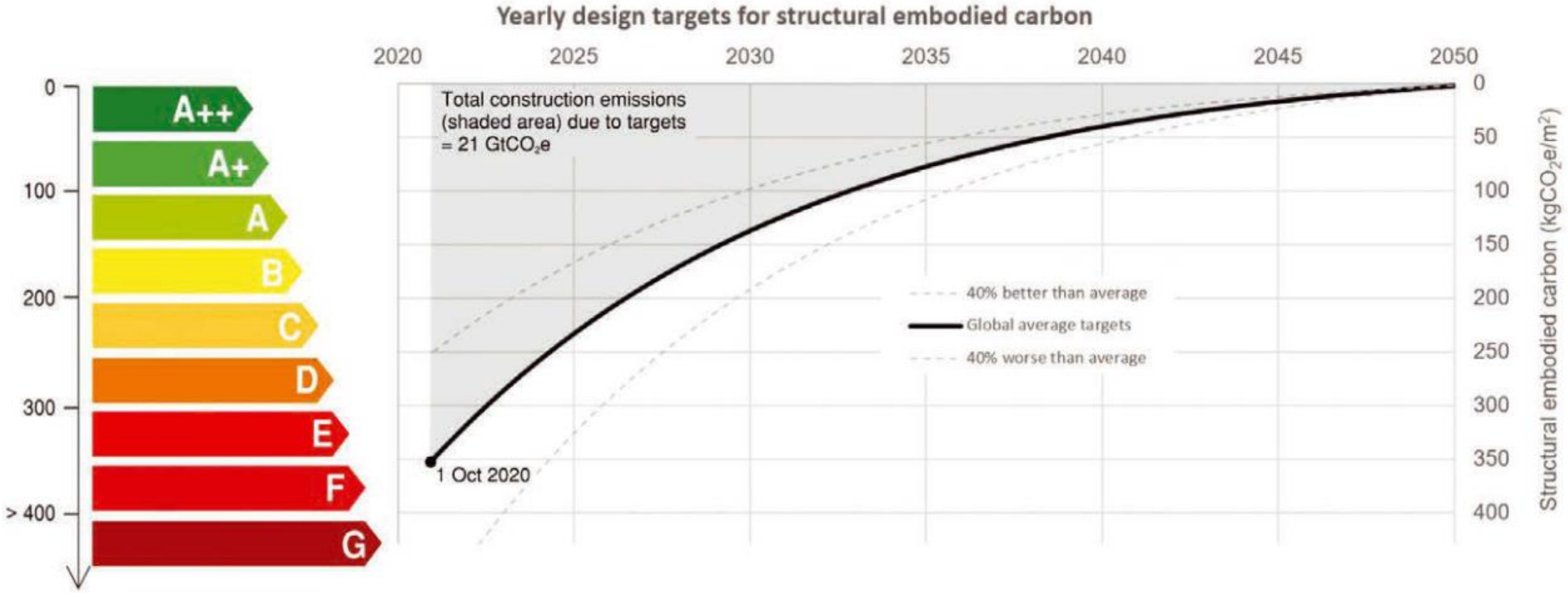
Step 4

Reuse of the entire building or its structural elements



STRUCTURAL DESIGN APPROACHES

Spending the global carbon budget (A1-A5 emissions of the primary structure)



Source: IStructE – Setting carbon targets

STRUCTURAL DESIGN APPROACHES

Action steps by project stage

LPH 1	LPH 2	LPH 3	LPH 4	LPH 5	LPH 6	LPH 7	LPH 8
Understand client‘s current ambitions on climate change and GHG emissions Try to convince client and design team to consider GWP in the design and construction process Influence the brief and support client to set GWP targets	Conduct initial estimates of GWP for proposed design options Consider GWP in design option evaluation Identify any interdisciplinary impediments to GWP reductions	Calculate GWP for chosen design option Try to reduce GWP for chosen design option based on major GWP contributors Identify any adversary effects of the chosen design option	Ensure high utilisation ratios Exploit material engineering potentials	Avoid unintended amendments to the design when preparing construction drawings	Prepare tender specifications Ensure contractor is contractually obliged to: implement the designed GWP targets offset excessive emissions provide approriate supply chain documentation	Challenge bidders in tender interviews on: how they will achieve the designed GWP whether they have any additional proposals for further GWP reductions	Review documentation provided by contractors Check that all materials and construction processes comply with specified GWP targets

1 GLOBAL RISKS LANDSCAPE AND CLIMATE EMERGENCY

2 GLOBAL WARMING AND GREENHOUSE GAS EMISSIONS

3 TRANSFORMATION OF THE BUILT ENVIRONMENT

4 STRUCTURAL DESIGN APPROACHES

5 CONCLUSIONS

CONCLUSIONS

- The climate emergency caused by GHG emissions is the greatest threat to our planet.
- In order to limit global warming to 1.5 °C rapid, far-reaching and unprecedented changes are required.
- Construction and operation of buildings and civil infrastructure are responsible for 79 % of total annual GHG emissions, with buildings alone accounting for 38 % of energy-related annual CO_2 emissions.
- A transformation of the built environment is required to reduce whole lifecycle GHG emissions immediately and all involved stakeholders have a responsibility for driving this transformation forward in a collaborative effort.
- Legal regulations and financial incentives to limit embodied GHG emissions are necessary to enforce this transformation, now.
- **Every project matters, every action counts.**

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