DynamicRenowave - Life Cycle Assessment and Energy Simulation of Building Renovation Strategies

Building Carbon Emissions Modeling Framework

Online Webinar 1 on 24 April 2024

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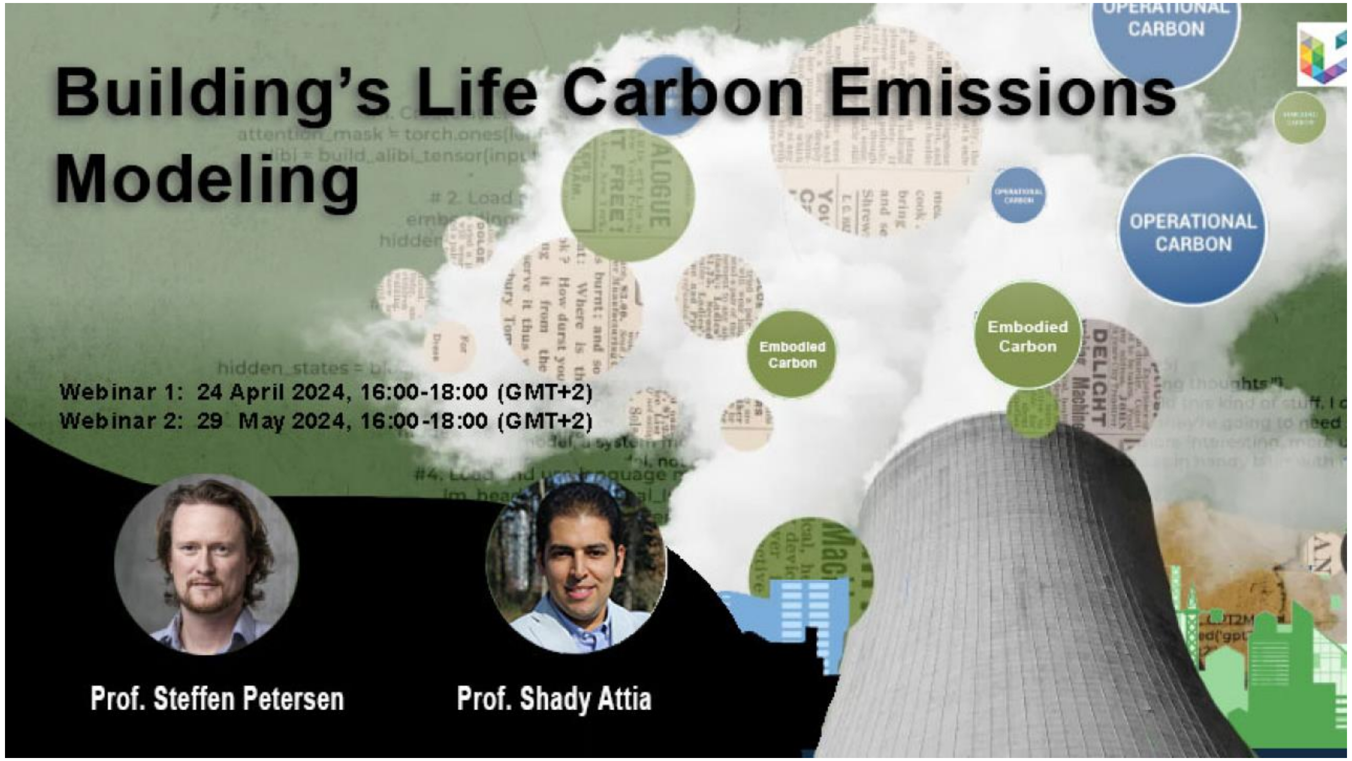

The safe operating space for buildings

The following is based on…

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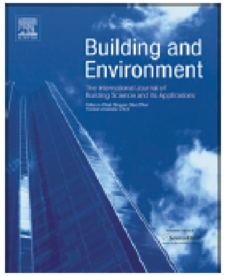

The absolute environmental performance of buildings

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First paper in the world featuring buildings and absolute limits for environmental impact

Earth carrying capacity

Definition of carrying capacity:

"…the maximum sustained environmental intervention a natural system can withstand without experiencing negative changes in structure or functioning that are difficult or impossible to revert."

Source: A. Bjørn, M. Hauschild, Introducing carrying capacity-based normalisation in LCA: framework and development of references at midpoint level, Int. J. Life Cycle Assess. 20 (2015) 1005-1018

Your fair share?

6.916.000.000 people
(2010)

Normalised (equality-based) carrying capacity within the categories of **The International Reference Life Cycle Data System (ILCD)** for world population in 2010 (6.916 billion)

Table 1
Global person equvivalent carrying capacity based normalization factors.

Impact Category	Global Normalisation Factor (Annual Person Equivalents) ($CC_{PE,i}$) [20]
Terrestrial Acidification (TA)	$2.3 \cdot 10^3$ mole H^+ eq./yr
Terrestrial Eutrophication (TE)	$2.8 \cdot 10^3$ mole N eq./yr
Water Depletion (WD)	306 m^3/yr
Land Use Soil Erosion (LUS)	1.8 ton eroded soil/yr
Land Use Biodiversity (LUB)	1.5·104 m^2 year/yr
Climate Change (CC, temp.*)	985 kg CO_2 eq./yr
Climate Change (CC, rad.**)	522 kg CO_2 eq./yr
Ozone Depletion (OD)	0.078 kg CFC-11 eq./yr
Freshwater Eutrophication (FE)	0.84 kg P eq./yr
Marine Eutrophication (EP)	29 kg N eq./yr
Photochemical Oxidant Formation (POF)	73 kg NMVOC eq./yr
Freshwater Ecotoxicity (FET)	1.9·104 [PAF]·m^3·day/yr

*2 °C climate change above pre-industrial levels
** 1 W/m^2 (1.06 ° C above pre-industrial levels)

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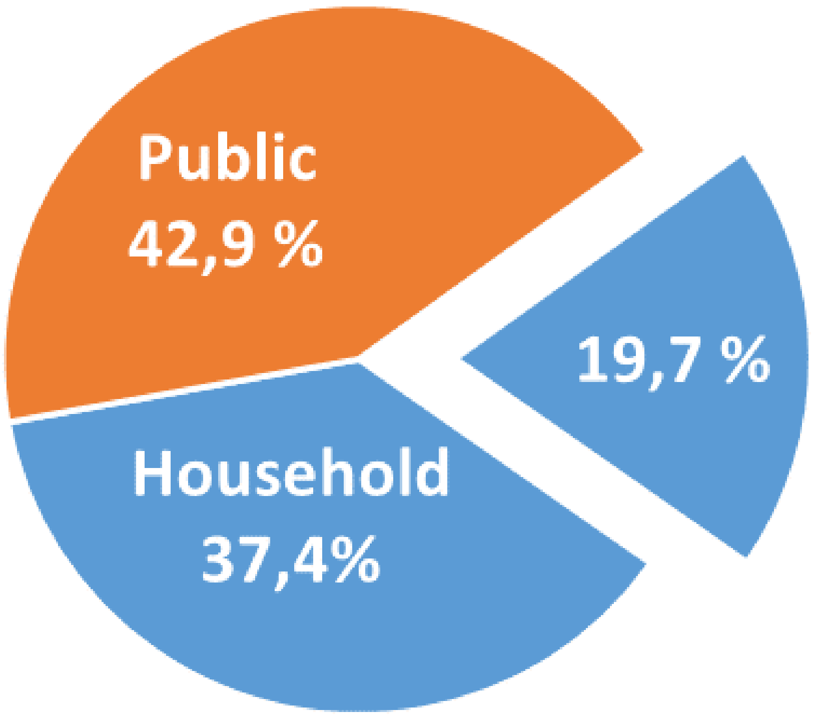
How much of the carrying capacity can we use for “dwelling”?

Economical allocation based on EU gross domestic product



Source: Household expenditure by consumption purpose, EU-28, 2016 (EUROSTAT)

Relevant COICOP categories and their fraction allocated to the dwelling life cycle

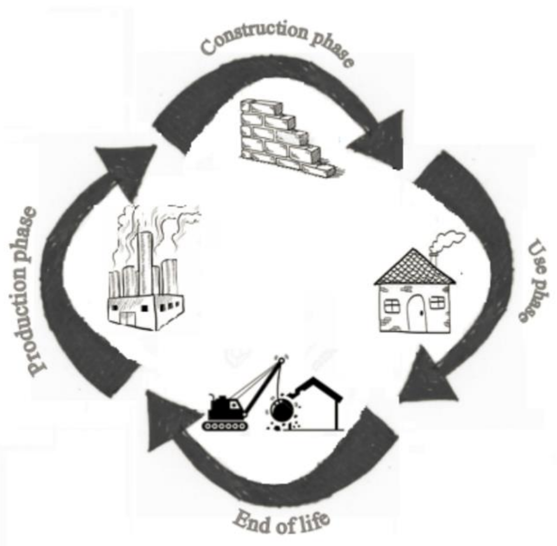
CP04 – Housing, Water, Electricity, Gas and Other Fuels (24,1%): **80,1 %**

CP05 – Furnishings, Household Equipment and Routine Household Maintenance (5,6 %): **6,2 %**

Classification Of Individual COnsumption by Purpose (COICOP)

How are we doing?

Advanced LCA in GABI used to estimate the environmental impact of the buildings.
Analysis for service life of 50 years



Production	*Extraction*	√
	Transport	√
	Production	√
Constructi	*Material spilled*	√
	Energy for cons.	√
	Transport	√
	Land conversion –	√
Use	*Maintenance*	–
	Replacements	√
	Repair	√
	Modifications	–
	Operational energy	√
	Water	–
	Land use – site	√
End of life	*Transport*	√
	Demolition	(√)
	Waste treatment	√
	Recycling	√
	Landfill	√

Figure 7 System boundaries used for the LCA. √ = included, – = not included, (√) = partial included

The International Reference Life Cycle Data System (ILCD)

Terrestrial Acidification (TA)
Terrestrial Eutrophication (TE)
Water Depletion (WD)
Land Use Soil Erosion (LUS)
Land Use Biodiversity (LUB)
Climate Change (CC, temp.*)
Climate Change (CC, rad.**)
Ozone Depletion (OD)
Freshwater Eutrophication (FE)
Marine Eutrophication (EP)
Photochemical Oxidant Formation (POF)
Freshwater Ecotoxicity (FET)

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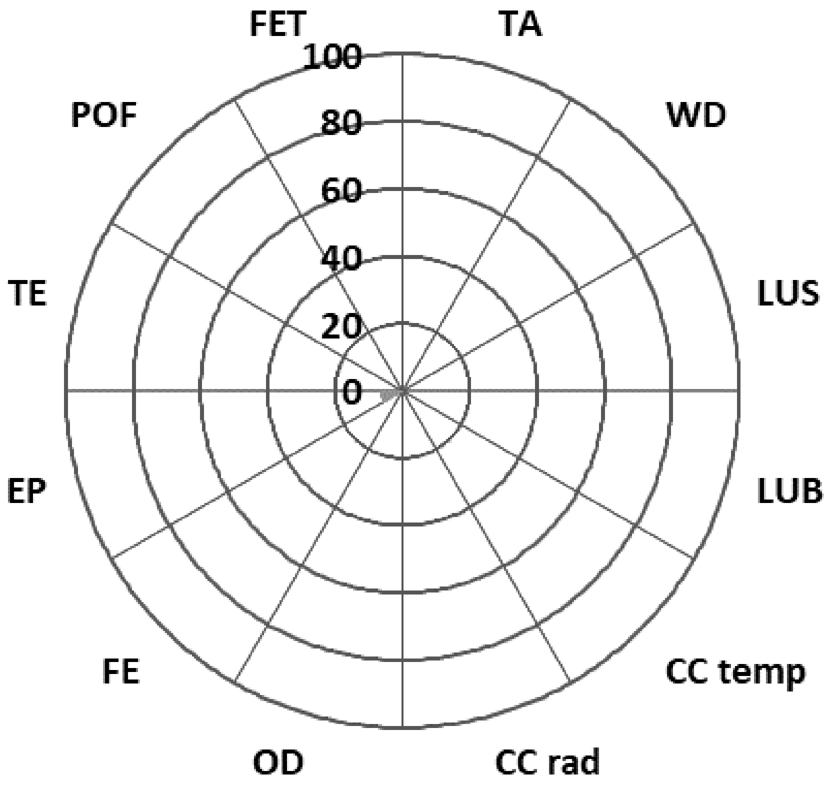
How are we doing?

X 100



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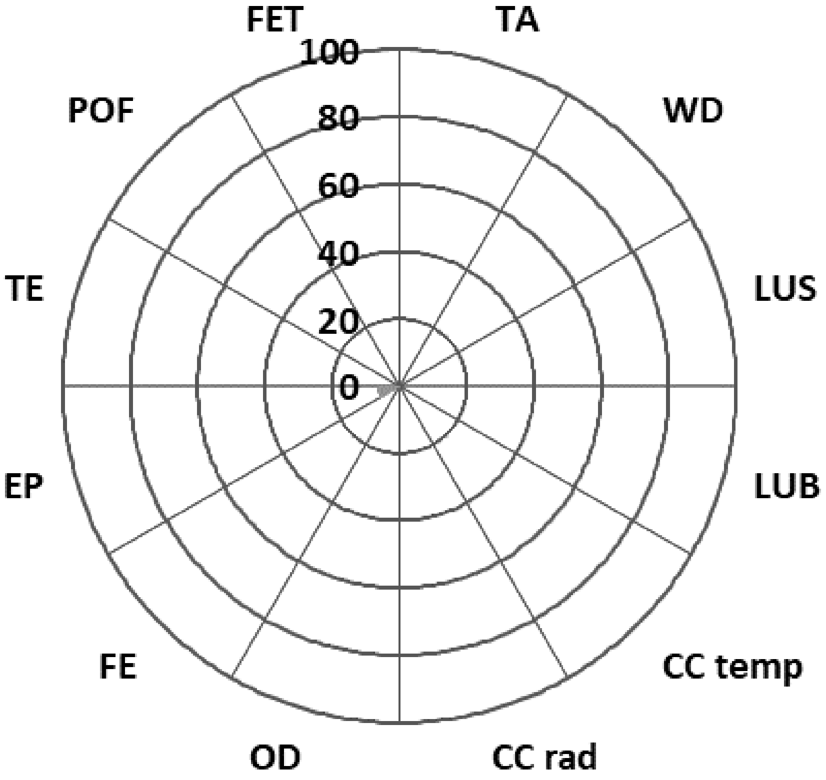
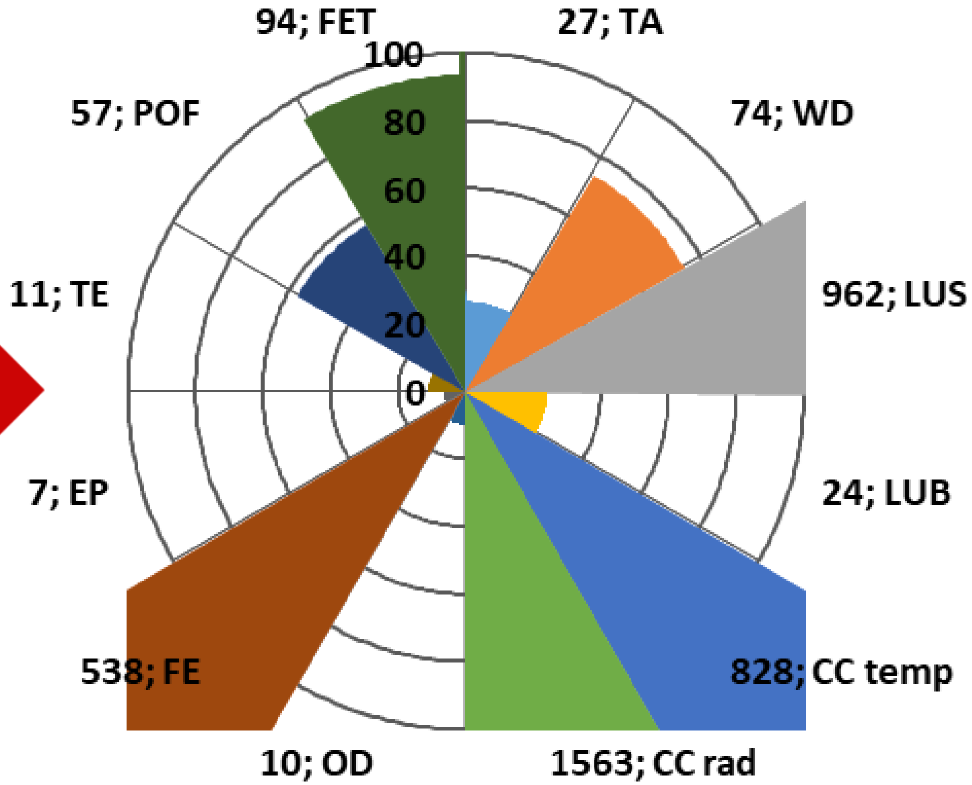
How are we doing – standard house

X 100



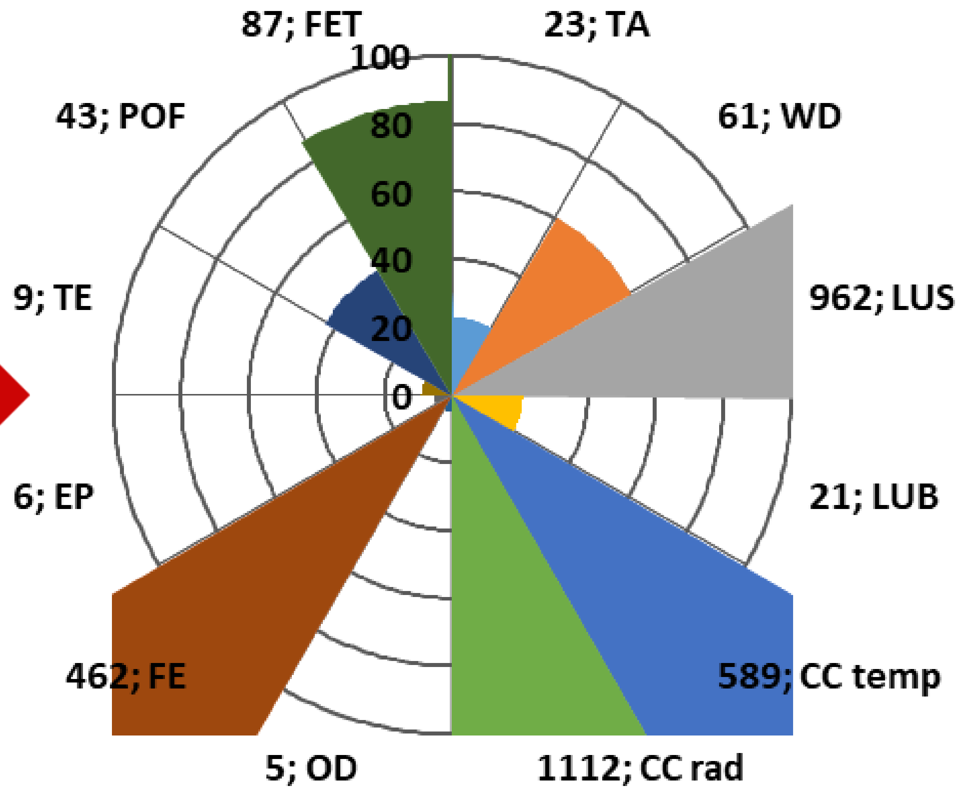
How are we doing – standard house

X 100



How are we doing – upcycle house

X 100



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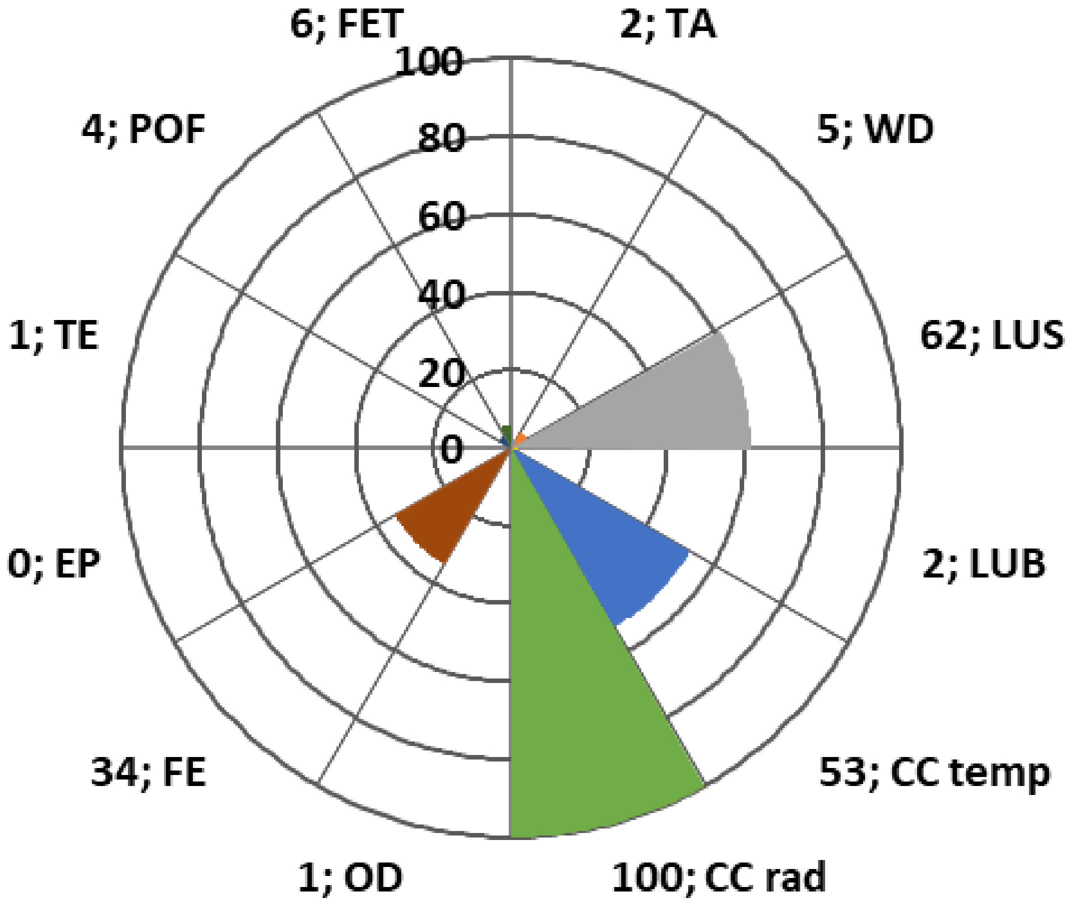
Mixed path to absolute sustainability -standard house (50 years)

- Environmental impact from constructions **reduced by 84 %**
- Environmental impact from operational energy **reduced by 84 %**
- Square meters per person **reduced to 20 m² (60 %)**



Update of safe operating space (CC)

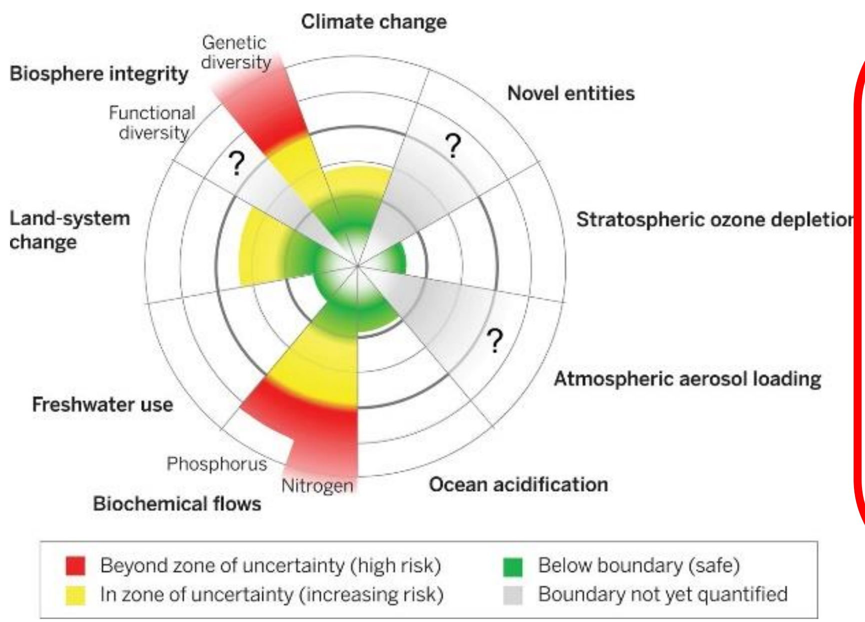


Table 3. Scenarios for a safe operating space for the annual emissions of CO2-equivalents based on the Planetary Boundary for radiative forcing of 1 W/m^2.

Scenario	Safe operating space [gigaton CO_2-eq/year]	Notes on assumption
Method 1: Weighted average of substance-specific contributions [8]		
M1-Original	3.61	-
M1-AR6	2.90	AR5 data replaced with AR6 data
M1-AR6+	2.61	AR6 data + only GHG with ERF>0.001 W/m^2 included + new emission data
M1-AR6+ (95%)	2.51	As AR6+ but using the 95% confidence interval of GHG input from AR6 in the GTP model.
M1-AR6+ (99.7%)	2.35	As AR6+ but using the 99.73% confidence interval of GHG input from AR6 in the GTP model.
Method 2: Characterisation factors [15]		
M2-AR6+	3.79	The calculation of CFs is based on data from AR6. Data for 20 global GHG emissions are from 2018.
M2-AR6+ (95%)	3.63	Using the provided confidence interval of GHG input from AR6 in the GTP model and for GWP-100 leads to the lowest safe operating space

The following are notes on the uncertainties of the calculations:

- The variation in the outcome of the scenarios is up to 38%.
- The outcome of Method 1 and Method 2 is sensitive to the input on annual emission data. No detailed sensitivity analysis was performed but for method 1, a simple sensitivity analysis indicates that this could be ±30% in all scenarios.
- It is noted that **the main driver for the difference between the original calculation in Method 1 and the new scenarios is the updated data on methane (CH_4) from AR6** which seems to have **a ~25% higher radiative efficiency than previously assumed**.
- For Method 1, it is noted that the safe operating space in all calculations is derived using methods (GEOCARB [11] and GTP [12]) that have some inherent uncertainties. The safe operating space also relies on the realisation of crucial assumptions about important inputs to the GEOCARB model.

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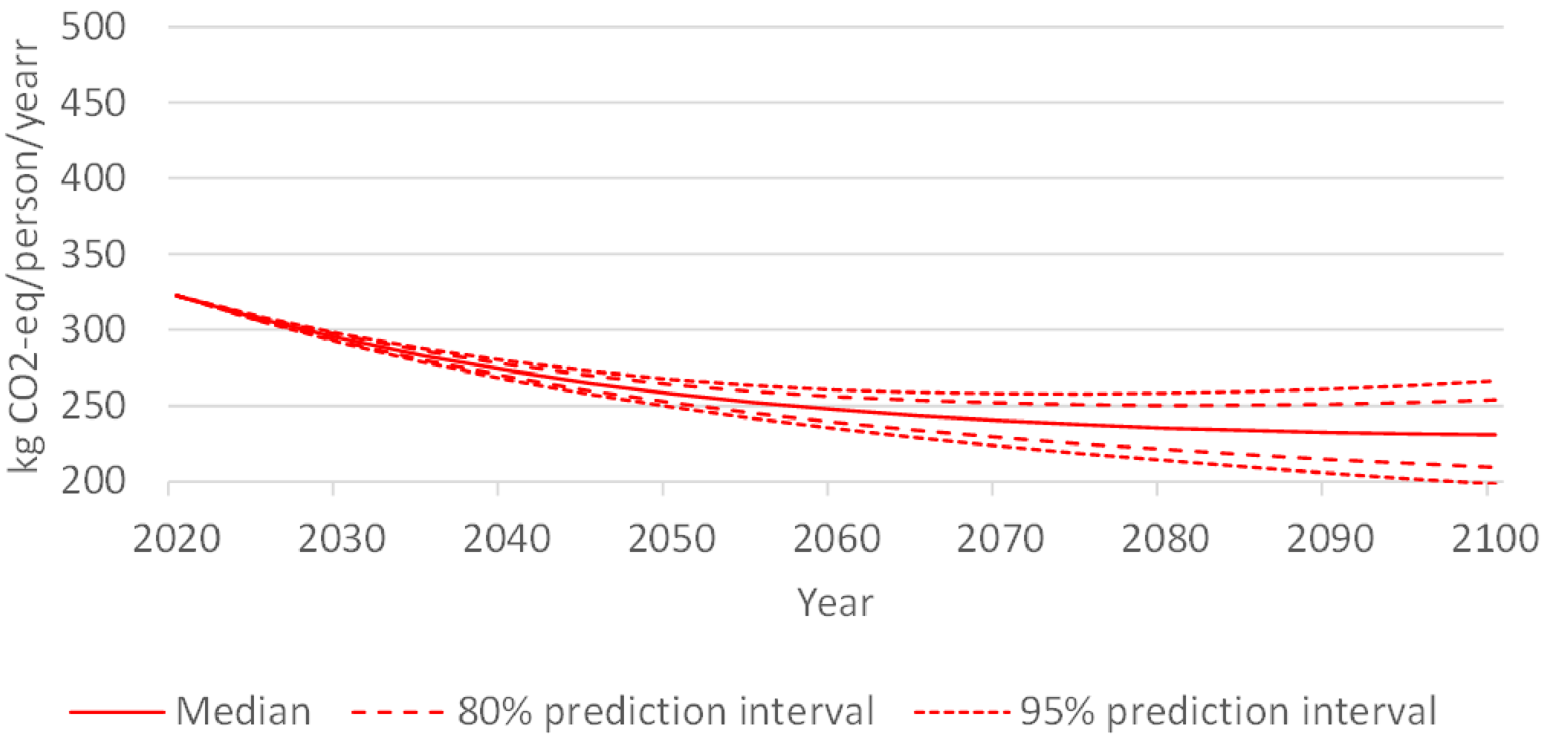
Budget per person (egalitarian)



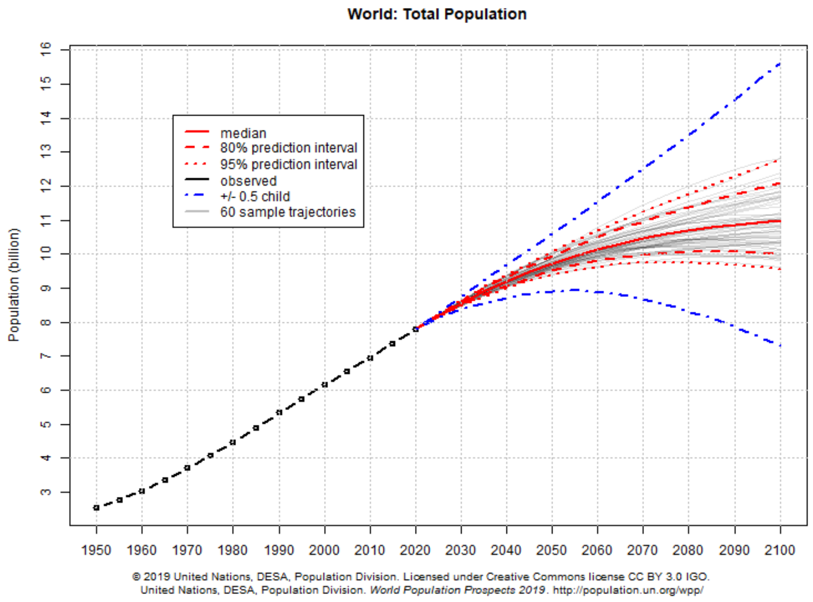


Figure 6. Annual personal safe operating space for scenario M1-AR6+(95%)

…but the boundary is overstepped?

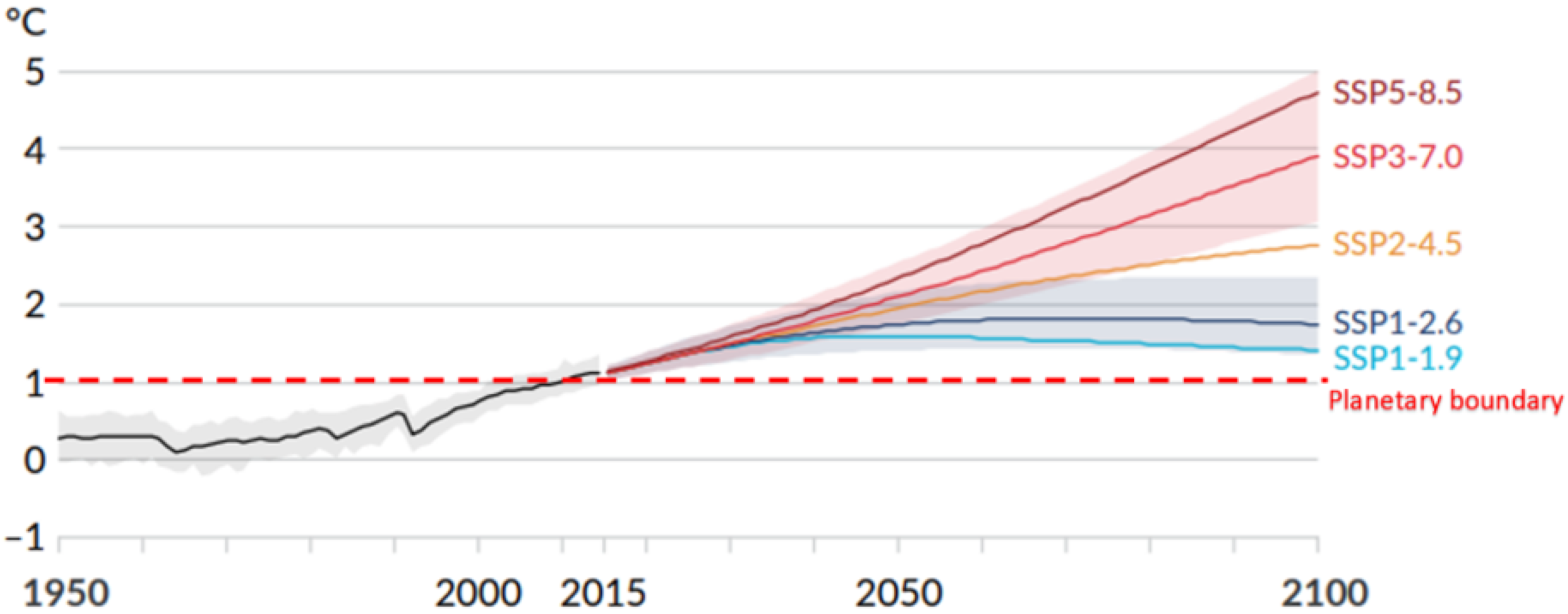


Figure 3. Selected indicators of global climate change under the five illustrative scenarios used in this Report

Reduction scenarios

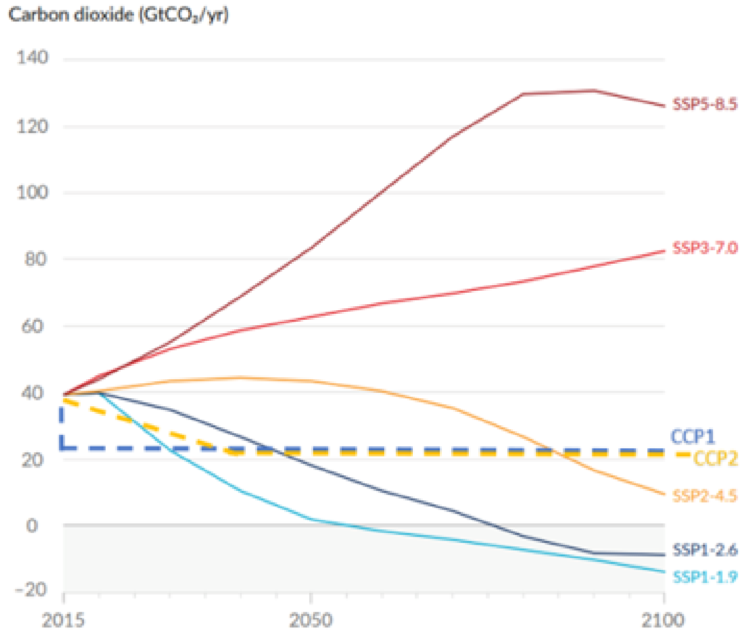


Figure 4. Pathways for future CO_2 emissions from IPCC AR6 and principal pathways using Planetary Boundaries

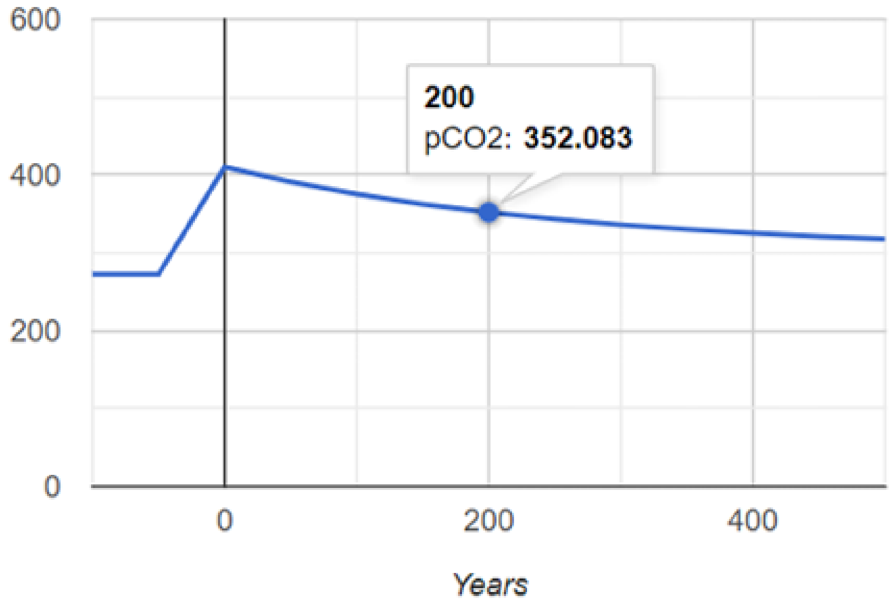


Figure 5. The trajectory of atmospheric CO_2 if CO_2 emissions are reduced to scenario M1-AR6+

CCP1: Reducing "right now" to the level of PB (ca. 200 years)
CCP2: Some kind of roadmap will postpone the return to PB

The big question…

How much of the safe operating space can we use for buildings?

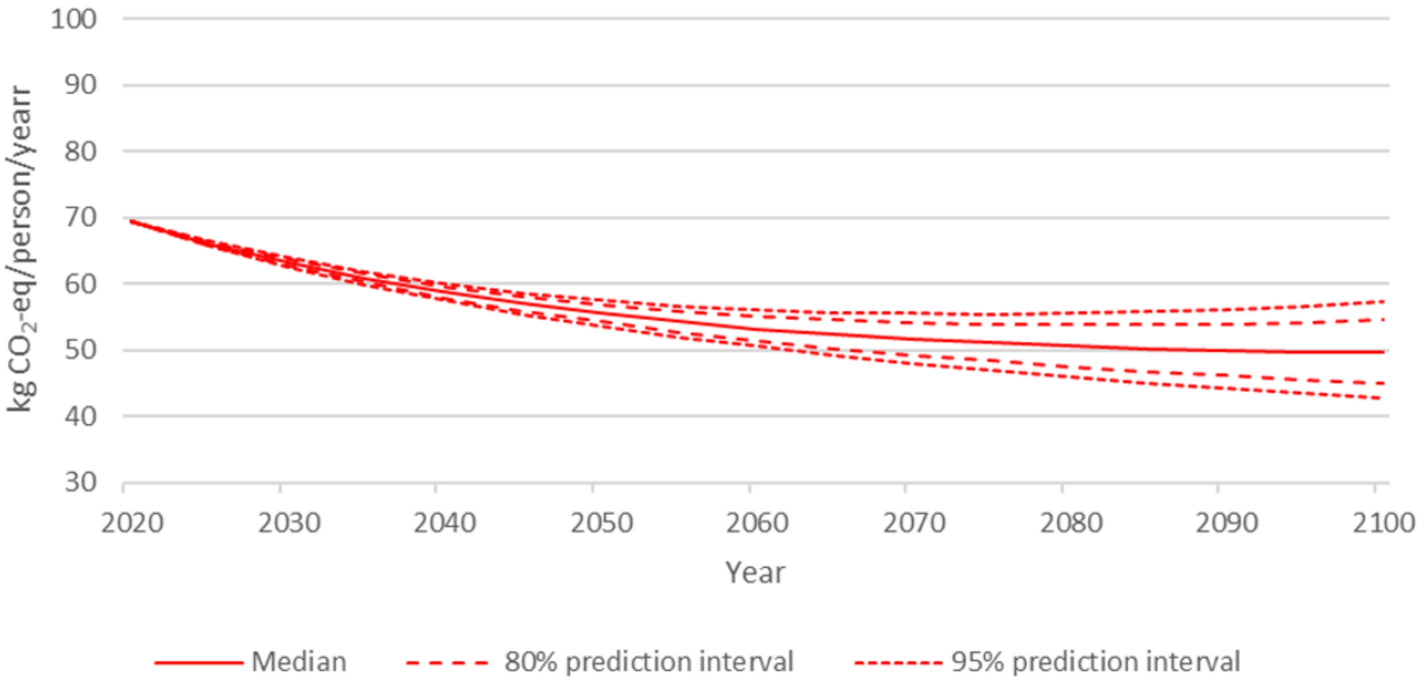


Figure 9. Personal safe operating space from scenario M1-AR+(95%) allocated to dwelling as a function of population growth.

Same allocation method:

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…which is a debatable method

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Tool for setting a PB-based budget

Case: Danish dwellings

	Parameter	Unit		Note
	SoS global	kg CO2eq/year	2,51E+12	Scenario AR+(95%)
	P global	No of people	8223573750	UN population, 95% fractile in 2025
	Alpha	-	0,215	Fraction of personal SoS used for "dwelling"
	Beta	-	1	Political factor - reallocate the SoS for any reason...
	P_dwelling	No of people	4	Variable
	A_dwelling	m2	110	Variable
	SoS_dwelling	kg CO2eq/m2/year	**2,4**	Safe operating space for dwelling
	SoS_dwelling	kg CO2eq/year	**262**	Safe operating space for dwelling

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Q & A

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[1] Brejnrod, K. N., Kalbar, P., Petersen, S., & Birkved, M. (2017). The absolute environmental performance of buildings. *Building and environment*, *119*, 87-98.
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