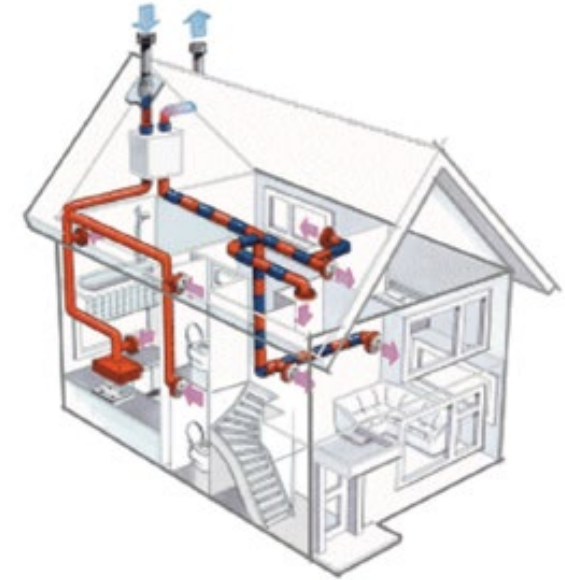
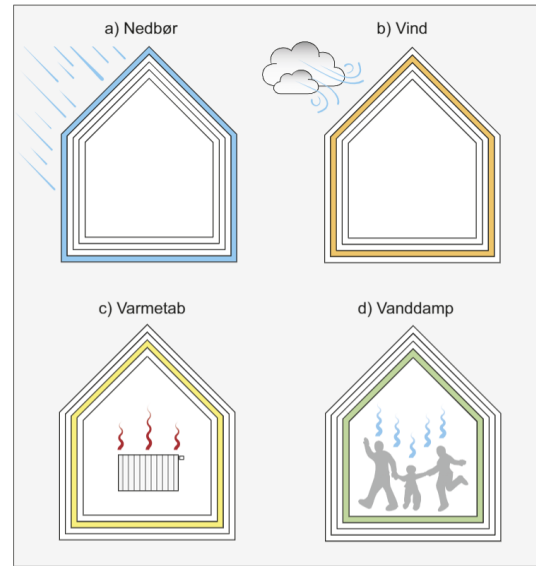
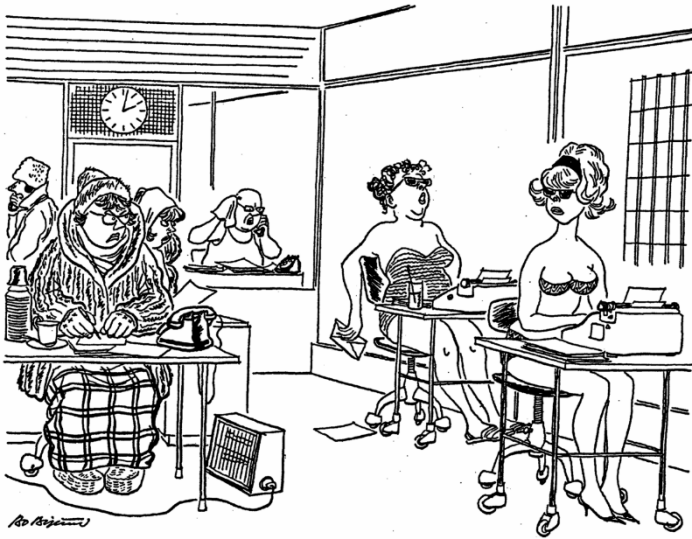


# Indeklima + Bygningsfysik + Installationer



## Bygningsvidenskab (Building Science)

# BYGNINGER OG DE PLANETÆRE GRÆNSER



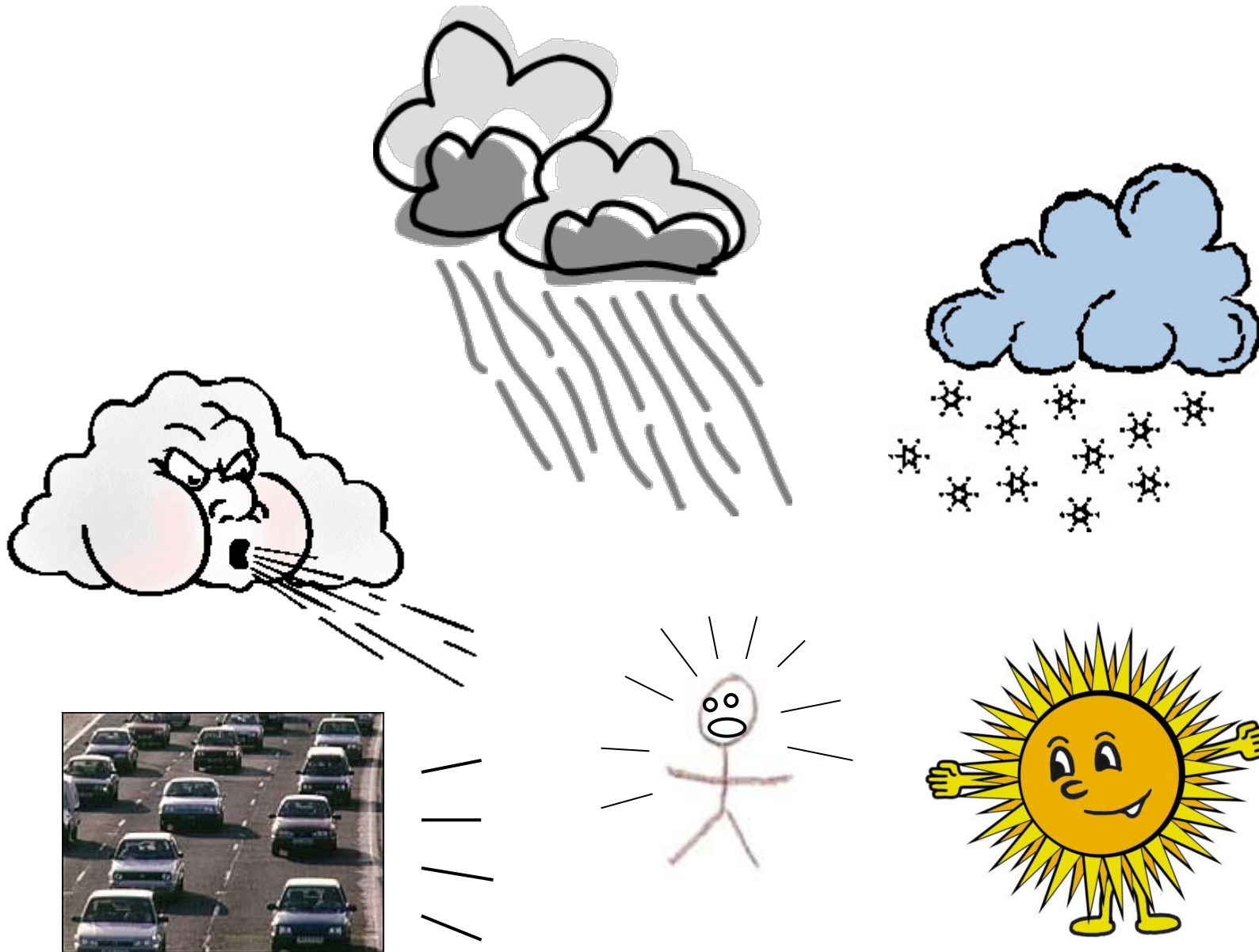
AARHUS  
UNIVERSITY  
DEPARTMENT OF CIVIL AND ARCHITECTURAL ENGINEERING

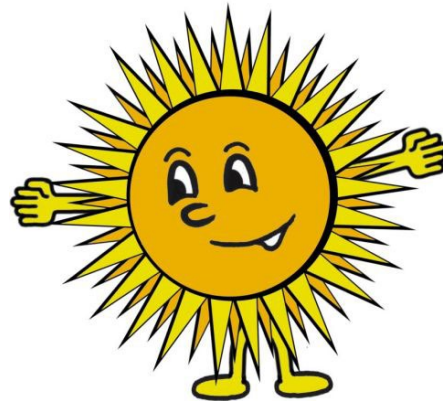
26 FEBRUARY 2023

STEFFEN PETERSEN  
PROFESSOR

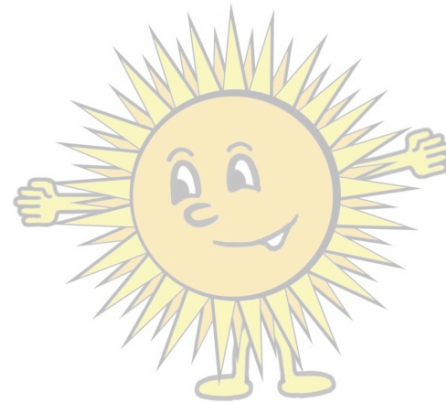
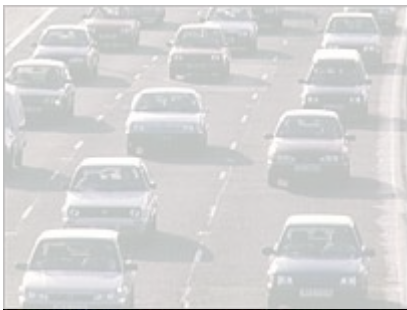








# Vi opholder os 90 % af vores liv indendøre



# BYGNINGER SKAL FACILITERE ET GODT INDEKLIMA

---

Et godt indeklima er sunde, komfortable og produktive forhold, der er egnet til længerevarende ophold af forskellig art under skiftende vejrforhold.

- **Termisk komfort**
- **God luftkvalitet**
- **Gode optiske forhold**
- **God akustik og ingen støj**

**...tilvejebragt i funktionelle og smukke omgivelser!**

**...i en bygning der bidrager til en bæredygtig udvikling!**

# UNDERVISNINGSSLIDE FRA 2007...

Globally we are consuming resources at a faster rate than the planet can replenish them. If the whole world consumes as:

Europe:



North  
America:



China:



...et initiativ fra 2004.

Source: One Planet Living (WWF):  
[http://assets.panda.org/downloads/opl\\_brochure.pdf](http://assets.panda.org/downloads/opl_brochure.pdf)  
<http://www.oneplanetliving.org/>  
[http://www.panda.org/about\\_wwf/what\\_we\\_do/policy/one\\_planet\\_living/index.cfm](http://www.panda.org/about_wwf/what_we_do/policy/one_planet_living/index.cfm)

# Country Overshoot Days 2018

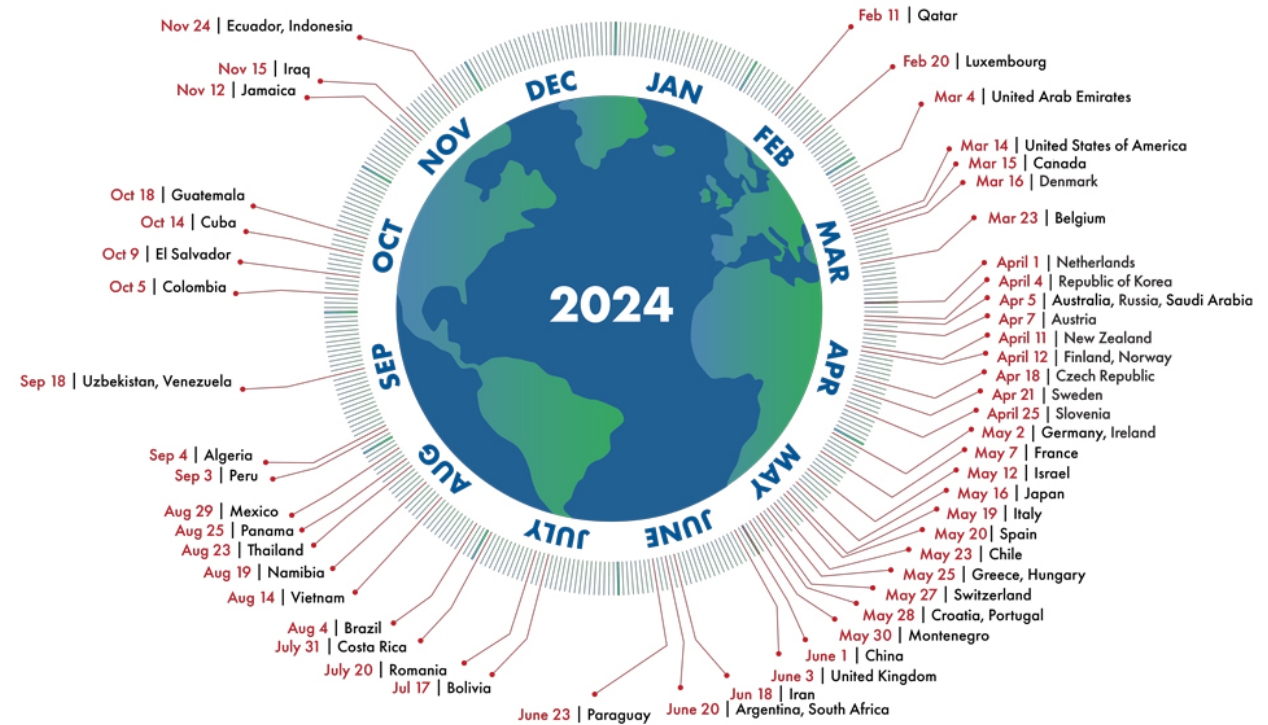
When would Earth Overshoot Day land if the world's population lived like...



Source: Global Footprint Network National Footprint Accounts 2018

# Country Overshoot Days 2024

When would Earth Overshoot Day land if the world's population lived like...

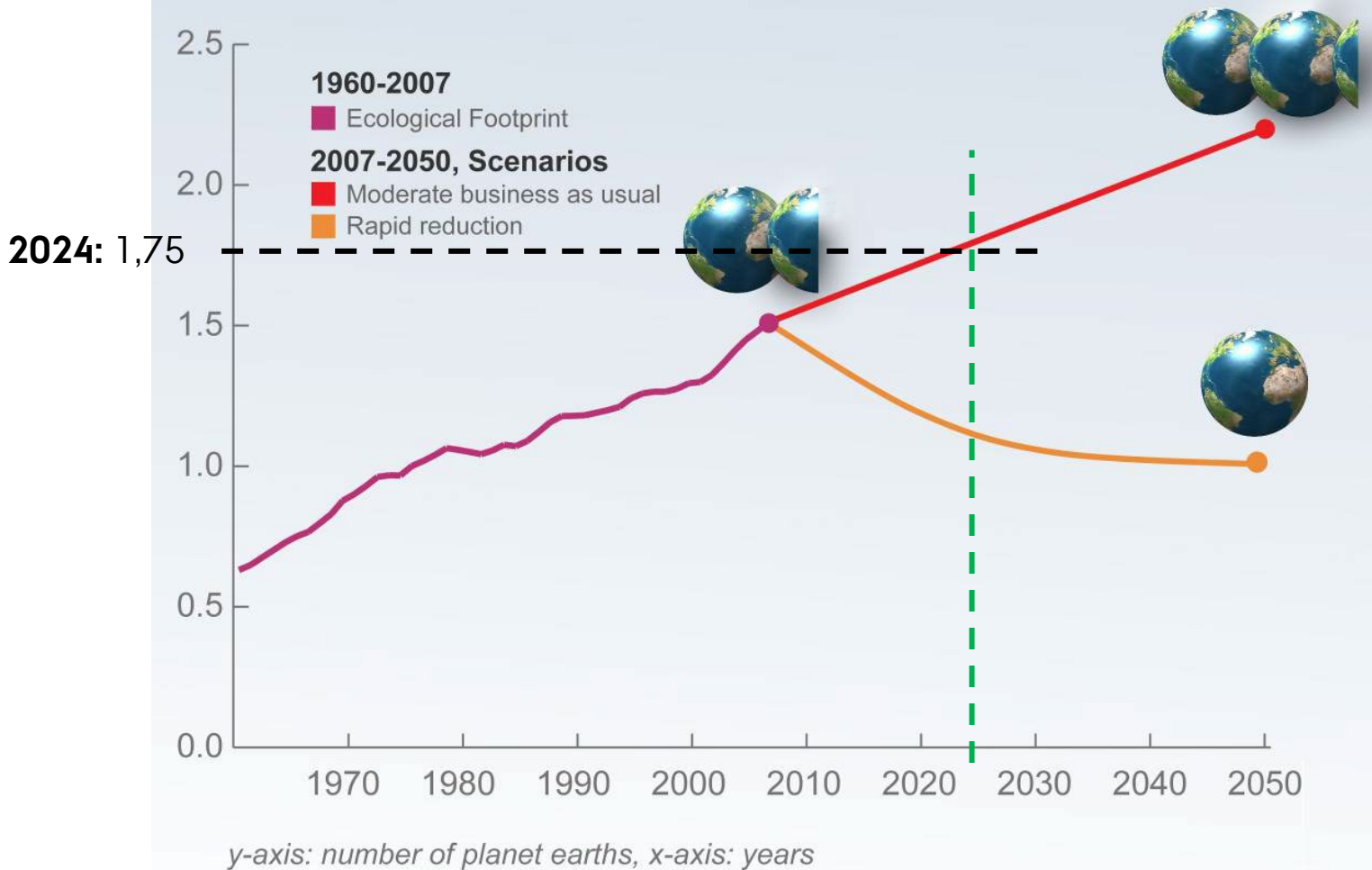


For a full list of countries, visit [overshootday.org/country-overshoot-days](https://overshootday.org/country-overshoot-days).

Source: National Footprint and Biocapacity Accounts, 2023 Edition  
data.footprintnetwork.org



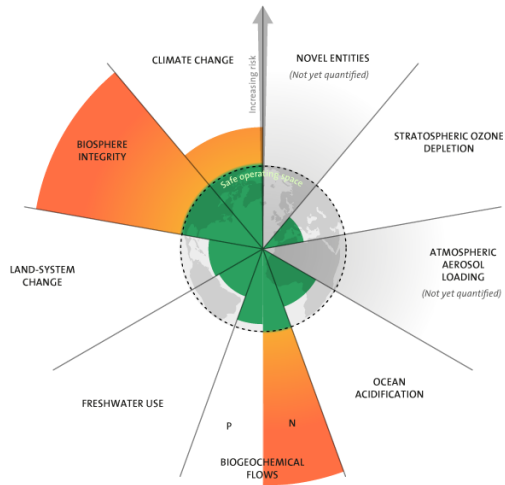
# TEACHING SLIDE I USED IN 2007



Source: [www.footprintnetwork.org](http://www.footprintnetwork.org)

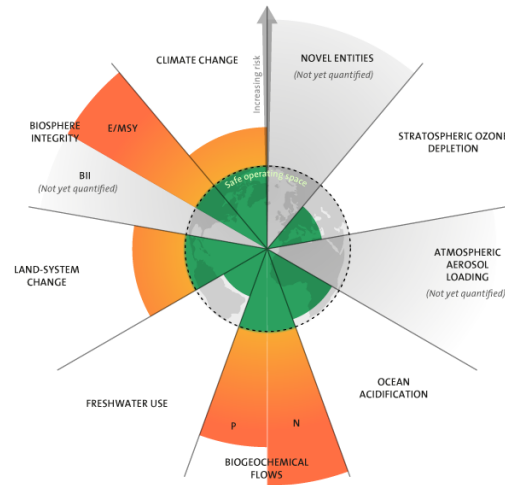
# PLANETÆRE GRÆNSER

2009



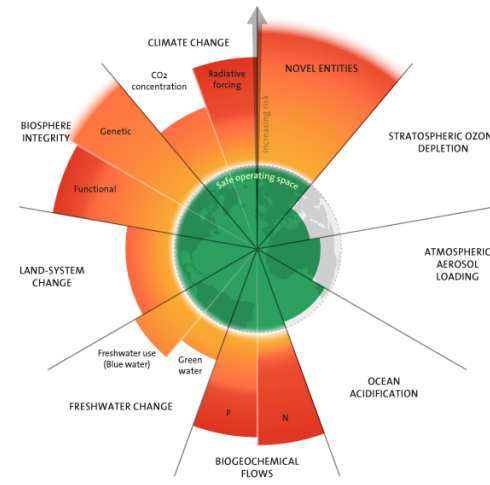
7 boundaries assessed,  
3 crossed

2015



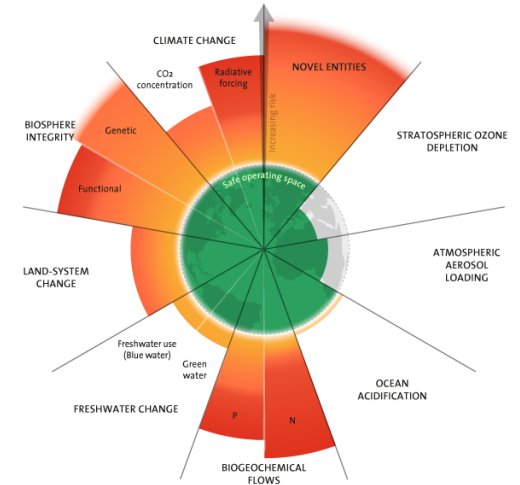
7 boundaries assessed,  
4 crossed

2023



9 boundaries assessed,  
6 crossed

2025

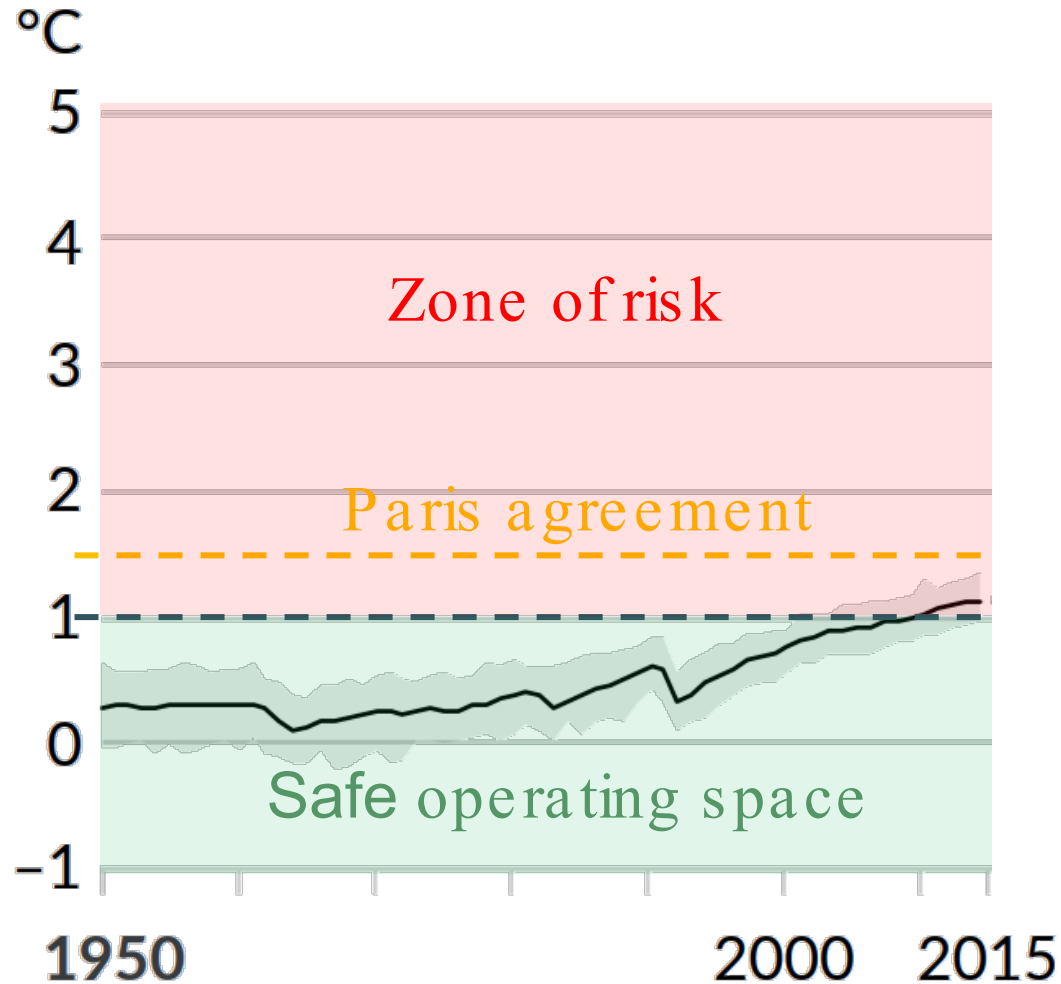


9 boundaries assessed,  
7 crossed

# BYGGERIET MILJØBELASTNING - KLIMAFORANDRINGER

# Global temperaturstigning over præ-industrielt niveau - scenarier

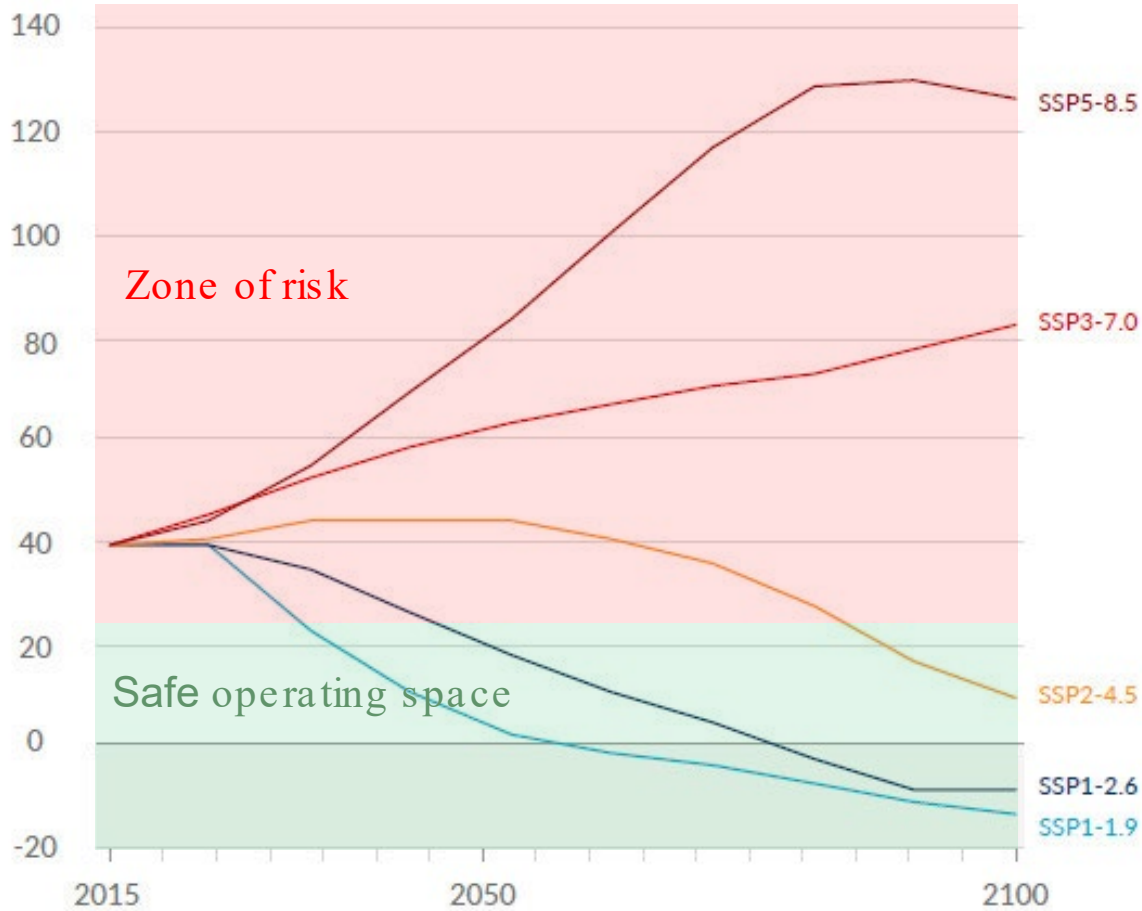
The Intergovernmental Panel on Climate Change Sixth Assessment Report 2023  
(Enriched by Steffen Petersen)



# Carbon emission scenarier

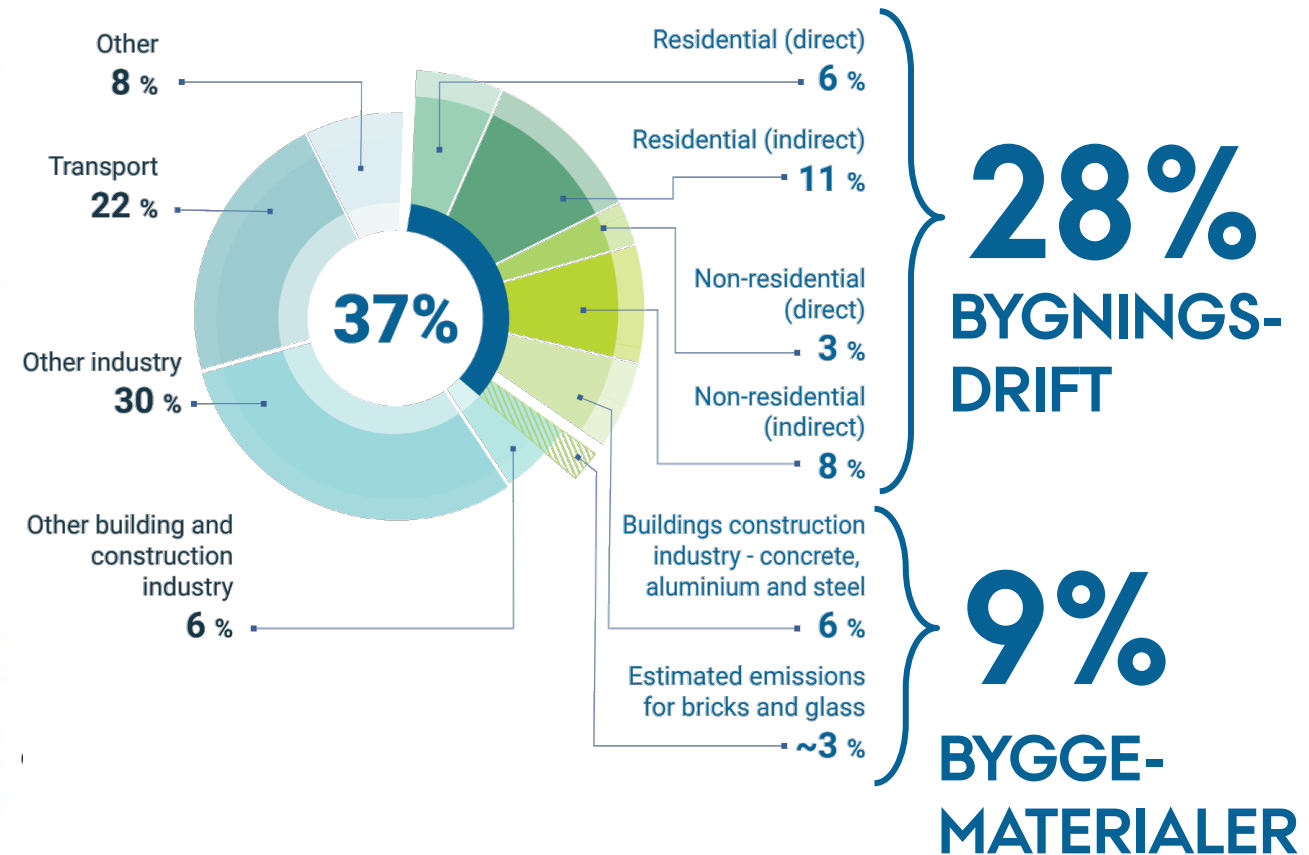
The Intergovernmental Panel on Climate Change Sixth Assessment Report 2023  
(Enriched by Steffen Petersen)

Carbon dioxide (GtCO<sub>2</sub>/yr)



# CO<sub>2</sub> emissioner fra bygninger

UN report. 2022 global status report for buildings and construction. ISBN No: 978-92-807-3984-8



# LIVSCYKLUS-ANALYSE

Typisk måde at evaluere 'ecosystem quality' i byggebranchen:

**Gør det 10% bedre end minimumskrav...**

Men er det godt nok?

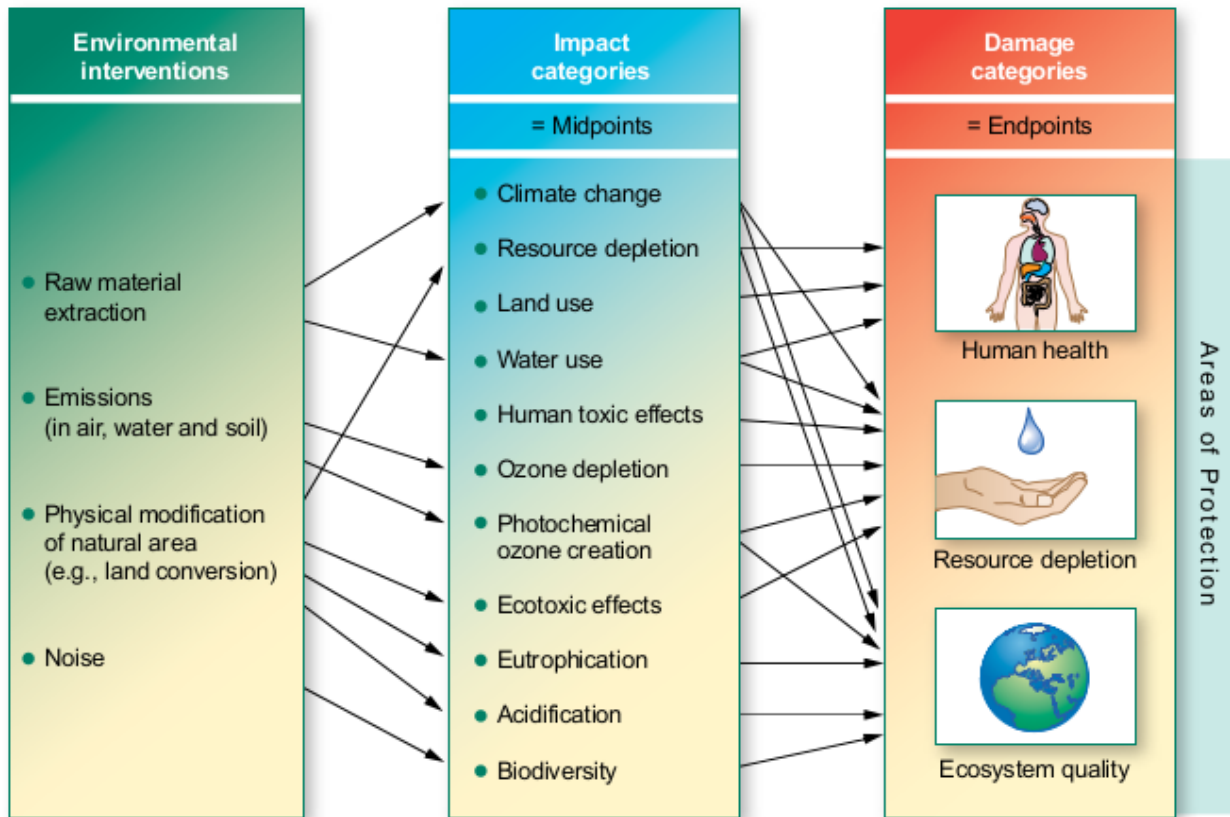


Illustration: [https://michaelminn.net/energy/life-cycle-analysis/Environmental Impact Points](https://michaelminn.net/energy/life-cycle-analysis/Environmental%20Impact%20Points) (UNEP 2011, adapted from Jolliet et al. 2003)





ELSEVIER

Contents lists available at ScienceDirect

## Building and Environment

journal homepage: [www.elsevier.com/locate/buildenv](http://www.elsevier.com/locate/buildenv)



### The absolute environmental performance of buildings



Kathrine Nykjær Brejnrod <sup>a</sup>, Pradip Kalbar <sup>b,\*,1</sup>, Steffen Petersen <sup>c</sup>, Morten Birkved <sup>b</sup>

<sup>a</sup> Transition Group, Inge Lehmanns Gade 10, DK-8000 Aarhus C, Denmark

<sup>b</sup> Quantitative Sustainability Assessment Division, Department of Management Engineering, Technical University of Denmark (DTU), Produktionstorvet 424, DK-2800 Kgs. Lyngby, Denmark

<sup>c</sup> Department of Engineering, Inge Lehmanns Gade 10, Aarhus University, DK-8000 Aarhus C, Denmark

**Den første videnskabelige artikel i verdenen,  
der sammenligner byggeris miljøpåvirkning  
med planetens bæreevne**

# 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.”*

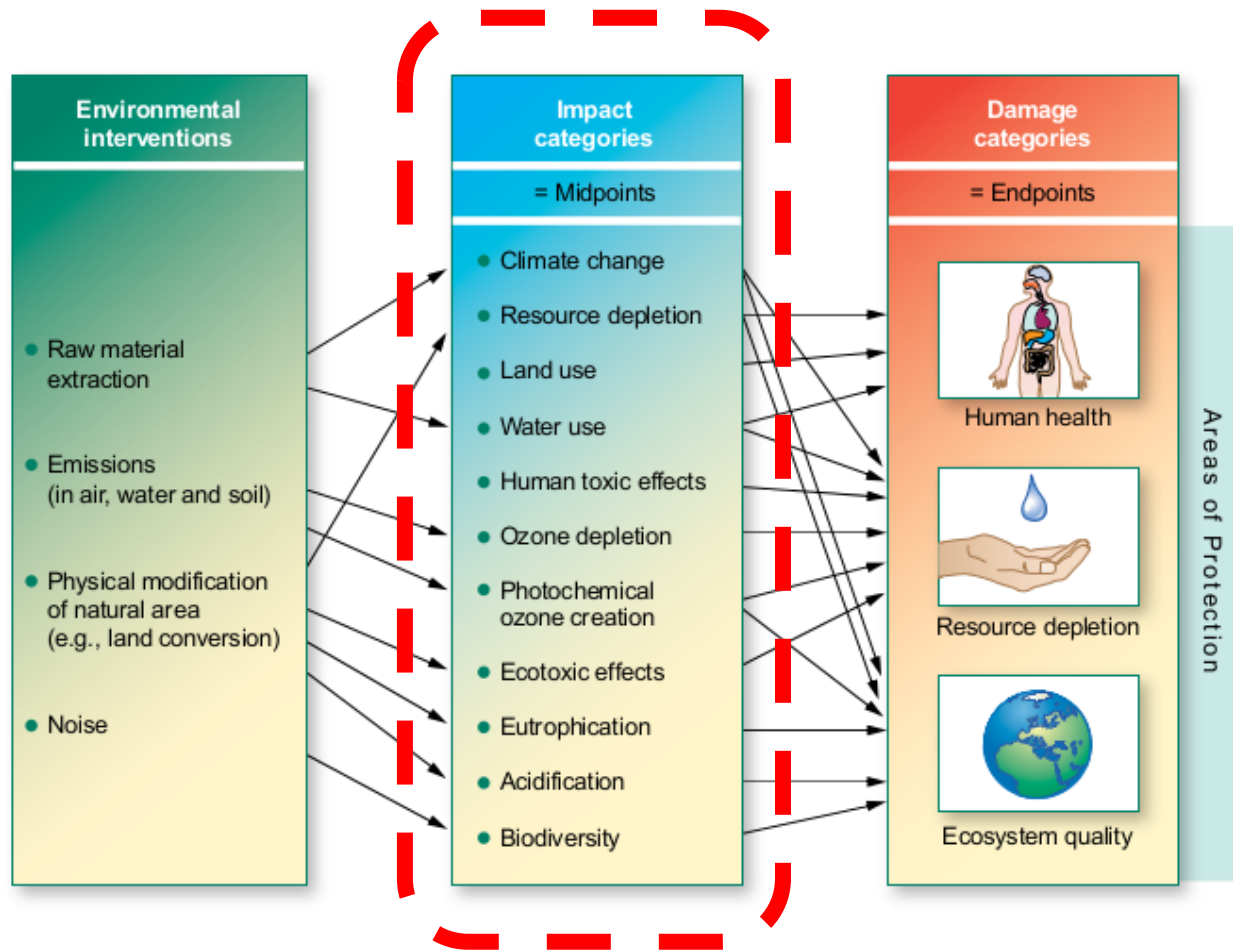
Source: A. Bjørn, M. Hauschild, Introducing carrying capacity-based normalisation in LCA: framework and development of references at midpoint level, *Int. J. Life Cycle Assess.* 20 (2015) 1005-1018



# LIVSCYKLUS-ANALYSE

# JORDENS BÆREEVNE

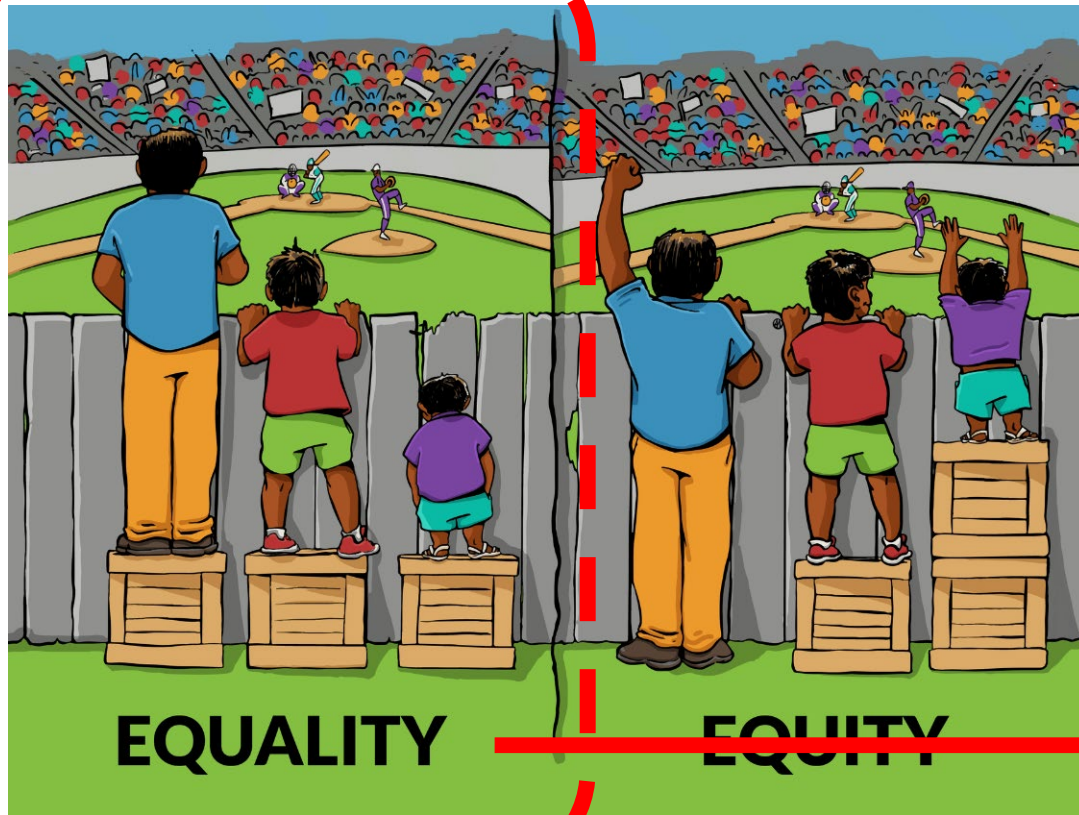
Samme enheder som LCA kategorier



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

Illustration: <https://michaelminn.net/energy/life-cycle-analysis/Environmental-Impact-Points> (UNEP 2011, adapted from Jolliet et al. 2003)

# PERSONLIG ANDEL AF JORDENS BÆREEVNE



6.916.000.000 personer  
(2010)

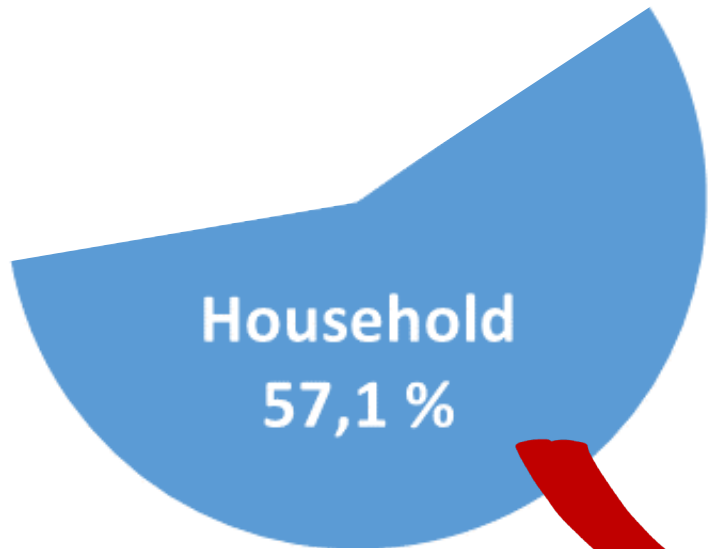
Current World Population 2024-08-17 (9:00 am)  
8,171,045,430 <http://www.worldometers.info/world-population/>

# HVOR MEGET AF PERSONLIG ANDEL ALLOKERES TIL BOLIGEN?

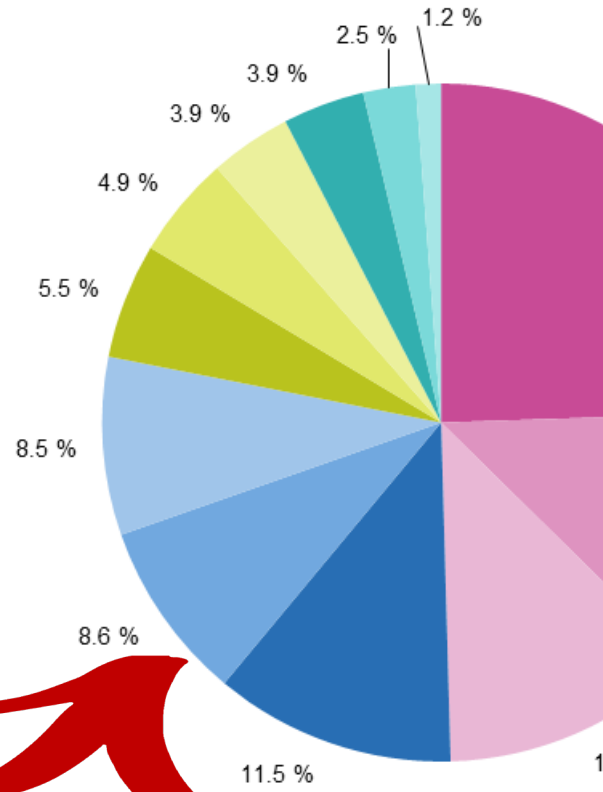
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# HVOR MEGET AF PERSONLIG ANDEL ALLOKERES TIL BOLIGEN?



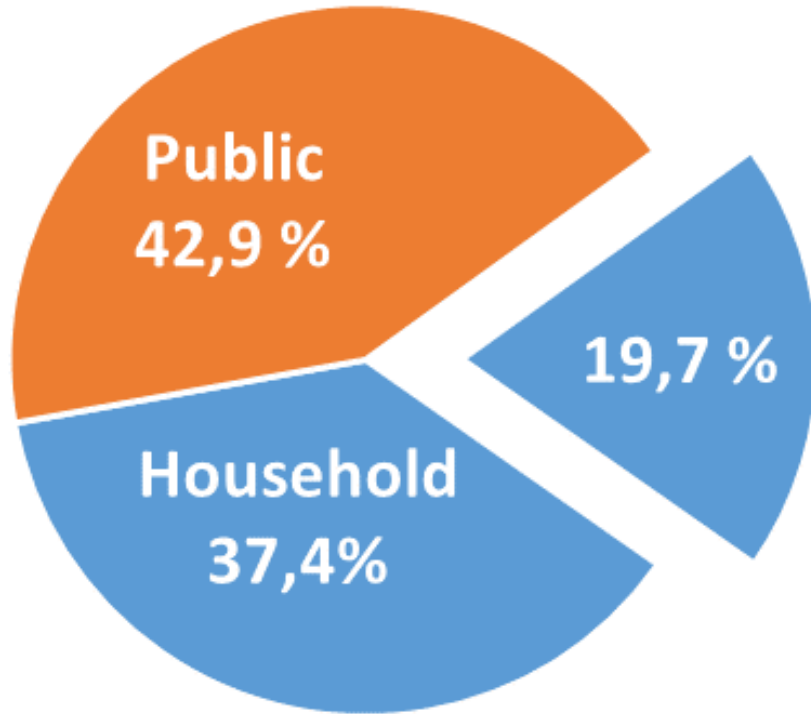
Source: Household expenditure by consumption purpose, EU-28, 2016 (EUROSTAT)



Classification Of Individual CONSt

- P010 - Food and non-alcoholic beverages
- P011 - Food
- P012 - Non-alcoholic beverages
- P020 - Alcoholic beverages, tobacco and narcotics
- P021 - Alcoholic beverages
- P022 - Tobacco
- P023 - Narcotics
- P030 - Clothing and footwear
- P031 - Clothing
- P032 - Footwear
- P040 - Housing, water, electricity, gas and other fuels
- P041 - Actual rentals for housing
- P042 - Imputed rentals for housing
- P043 - Maintenance and repair of the dwelling
- P044 - Water supply and miscellaneous services relating to the dwelling
- P045 - Electricity, gas and other fuels
- P050 - Furnishings, household equipment and routine household maintenance
- P051 - Furniture and furnishings, carpets and other floor coverings
- P052 - Household textiles
- P053 - Household appliances
- P054 - Glassware, tableware and household utensils
- P055 - Tools and equipment for house and garden
- P056 - Goods and services for routine household maintenance
- P060 - Health
- P061 - Medical products, appliances and equipment
- P062 - Outpatient services
- P063 - Hospital services
- P070 - Transport
- P071 - Purchase of vehicles
- P072 - Operation of personal transport equipment
- P073 - Transport services
- P080 - Communication
- P081 - Postal services
- P082 - Telephone and telefax equipment
- P083 - Telephone and telefax services
- P090 - Recreation and culture
- P091 - Audio-visual, photographic and information processing equipment
- P092 - Other major durables for recreation and culture
- P093 - Other recreational items and equipment, gardens and pets
- P094 - Recreational and cultural services
- P095 - Newspapers, books and stationery
- P096 - Package holidays
- P100 - Education
- P101 - Pre-primary and primary education
- P102 - Secondary education
- P103 - Post-secondary non-tertiary education
- P104 - Tertiary education
- P105 - Education not definable by level
- P110 - Restaurants and hotels
- P111 - Catering services
- P112 - Accommodation services
- P120 - Miscellaneous goods and services
- P121 - Personal care
- P122 - Prostitution
- P123 - Personal effects n.e.c.
- P124 - Social protection
- P125 - Insurance
- P126 - Financial services n.e.c.
- P127 - Other services n.e.c.

# HVOR MEGET AF PERSONLIG ANDEL ALLOKERES TIL BOLIGEN?



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 %**

# PERSONLIGT BUDGET TIL EN BOLIG

---

103 kg CO<sub>2</sub>-eq. pr .år

# DANSKERNES FORETRUKNE BOLIG



## LIVSCYKLUS-ANALYSE (LCA) AF BYGNINGERS MILJØPÅVIRKNING

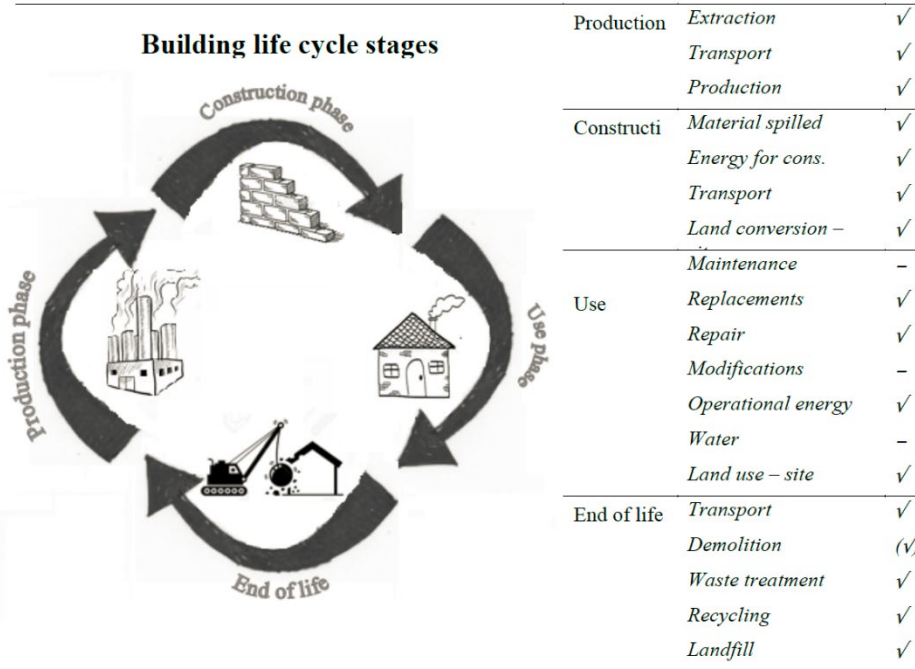


Figure 7 System boundaries used for the LCA. ✓ = included, - = not included, (✓) = partial included

Betragtningsperiode på 50 år

## International Reference Life Cycle Data System (ILCD)

### Impact categories (Midpoint)

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

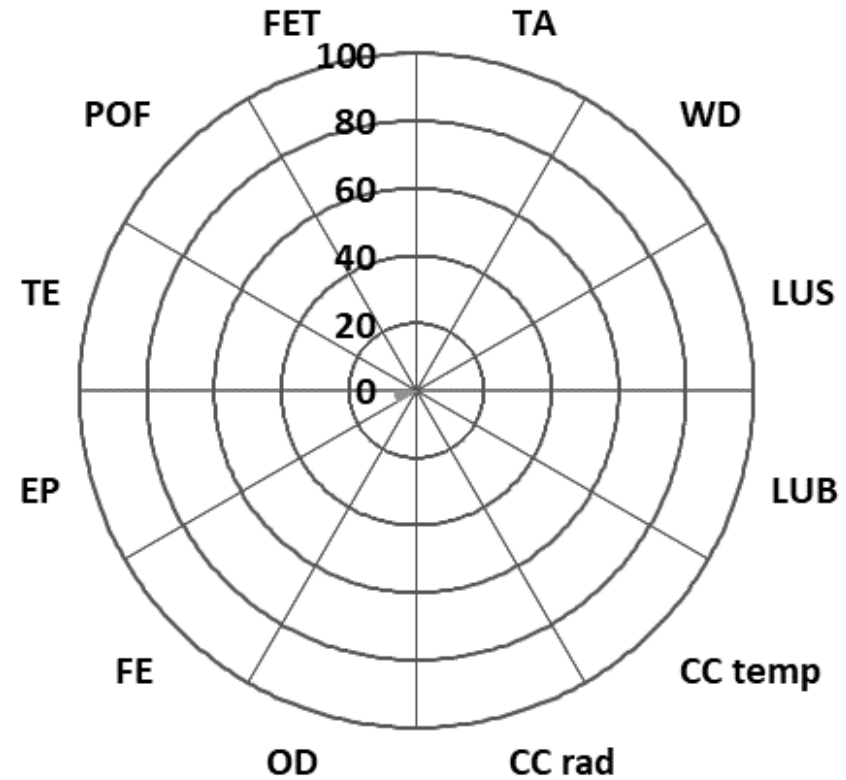


Samme enheder som budget for Jordens bæreevne



**250**  
kg CO<sub>2</sub>-eq. pr .år

X 100



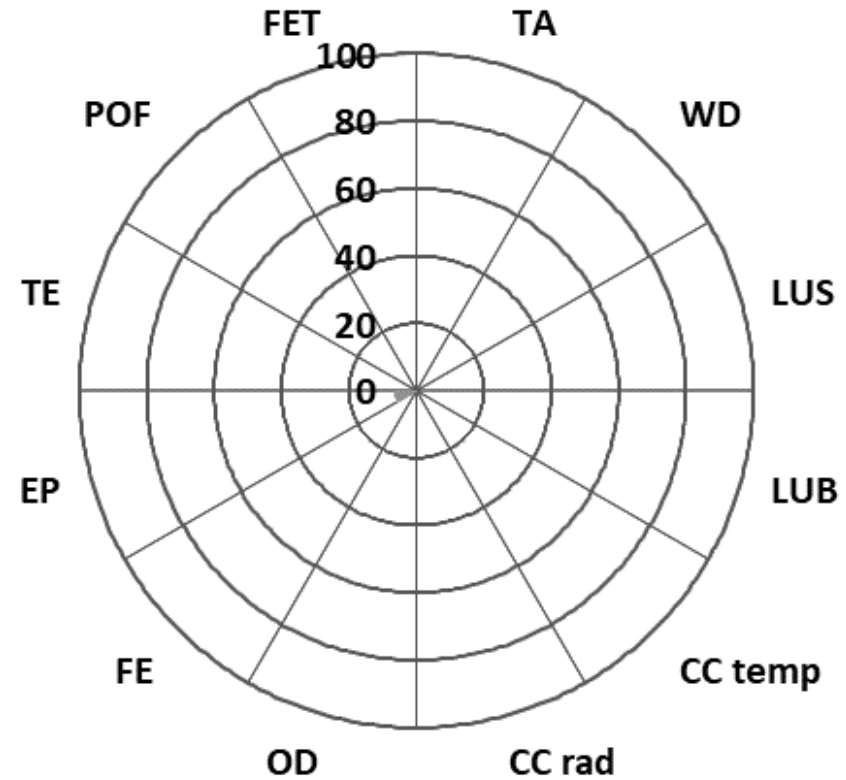
Gennemsnitlig antal personer i  
parcelhus: 2,4 personer



**250**  
kg CO<sub>2</sub>-eq. pr .år

---

X 100



Gennemsnitlig antal personer i  
parcelhus: 2,4 personer

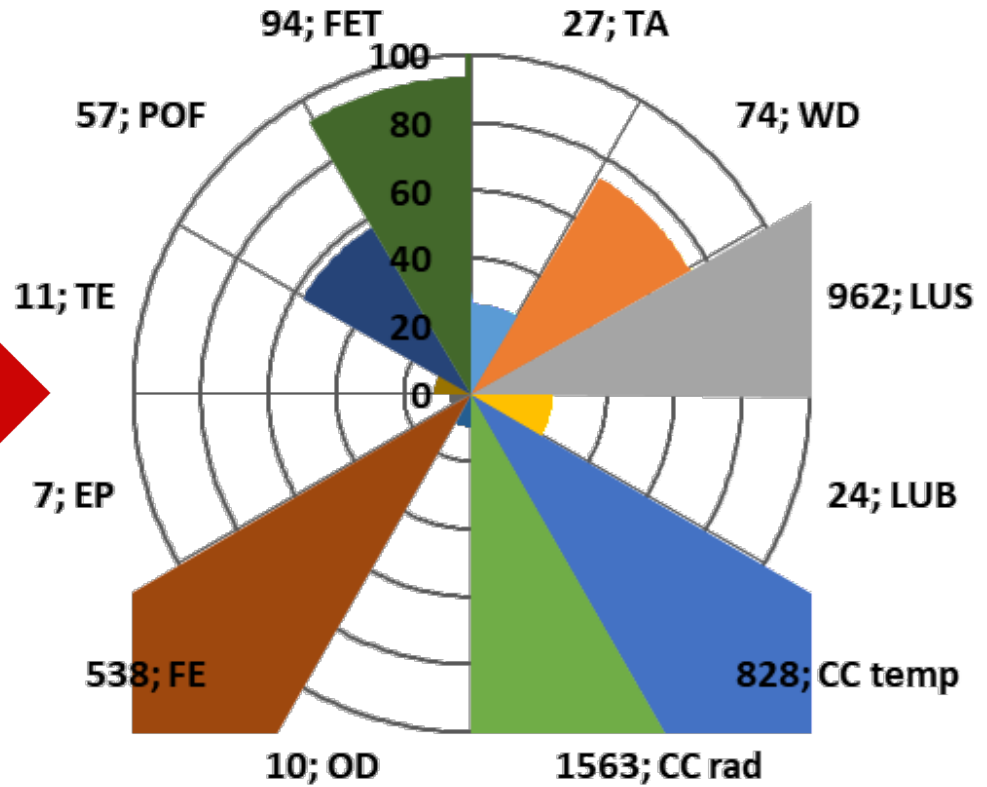


X 100

**250**

kg CO<sub>2</sub>-eq. pr .år

Gennemsnitlig antal personer i parcelhus: 2,4 personer



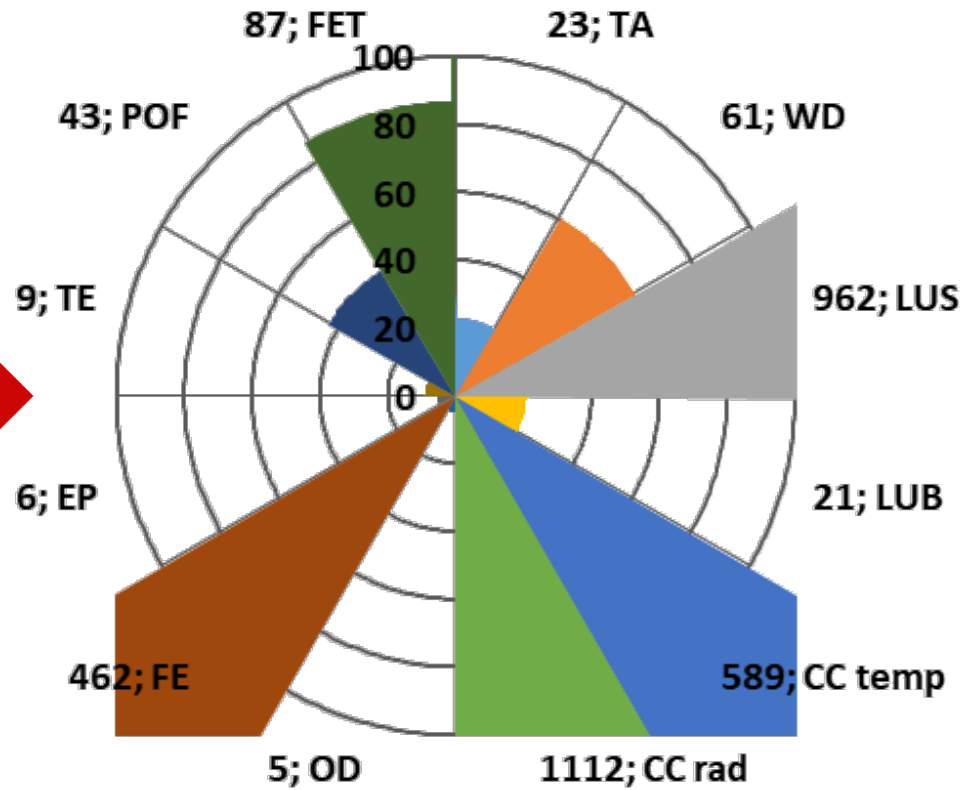


X 100

**250**

kg CO<sub>2</sub>-eq. pr .år

Gennemsnitlig antal personer i  
parcelhus: 2,4 personer



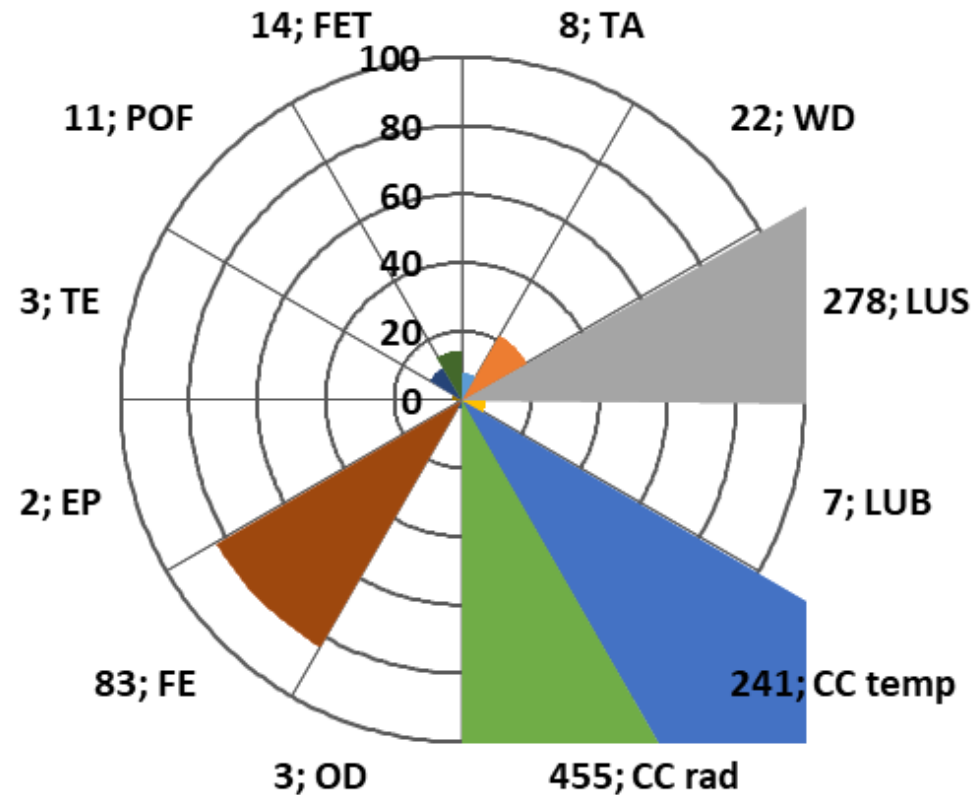
# HVAD KAN VI GØRE?

PARCELHUS (50 ÅR)



Hele det personlige budget bruges til boligen

- Re-allokering



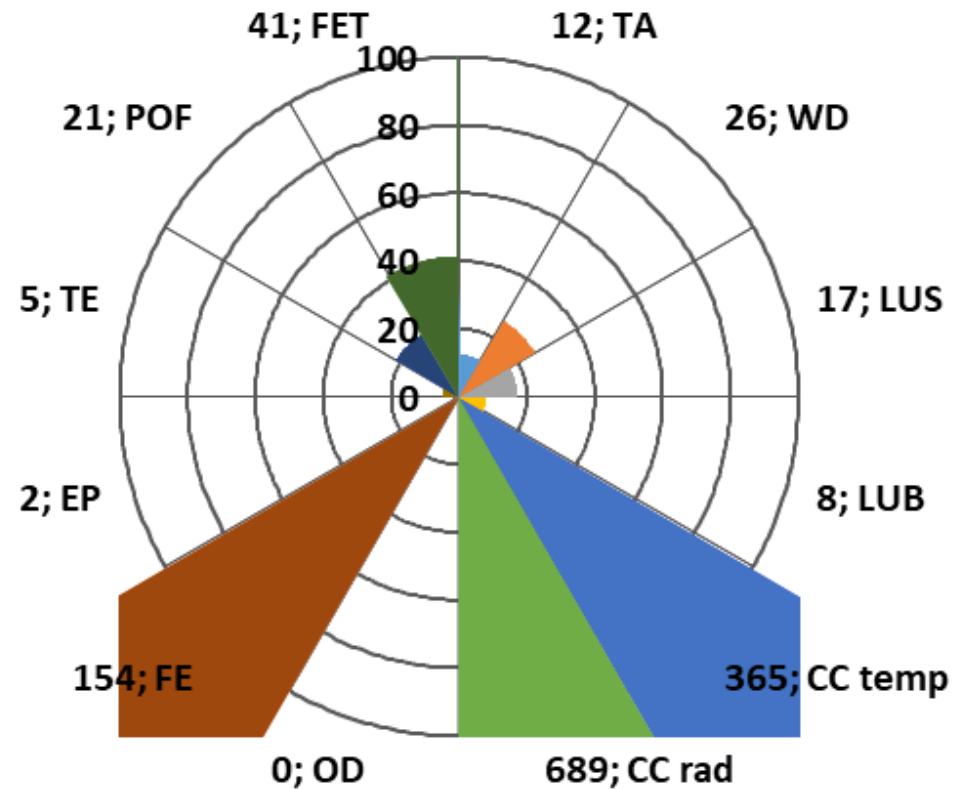
# HVAD KAN VI GØRE?

PARCELHUS (50 ÅR)

- Re-allokering
- **Energi til drift: 0% udledning**



**Ingen miljøbelastning fra energiforbrug til bygningsdrift**



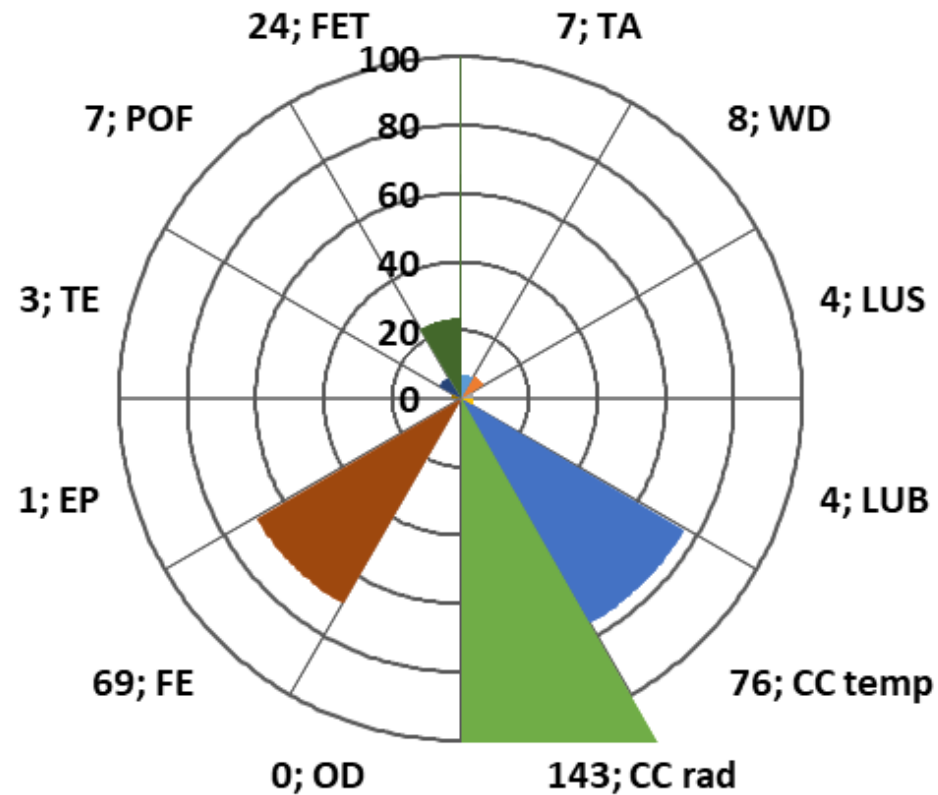
# HVAD KAN VI GØRE?

PARCELHUS (50 ÅR)



## Data fra Upcycle House

- Re-allokering
- Energi til drift: 0% udledning
- **Energi 0% udledning + Upcycle materialer**



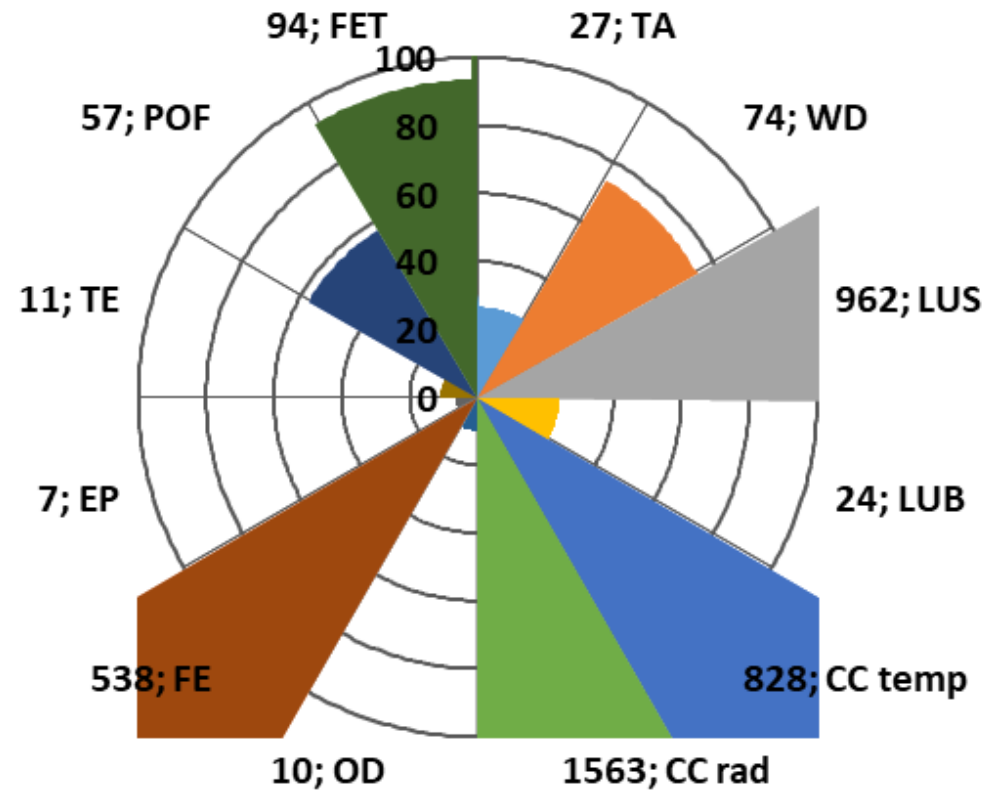
# HVAD KAN VI GØRE?

## PARCELHUS (50 ÅR)

- Re-allokering
- Energi til drift: 0% udledning
- Energi 0% udledning + Upcycle materialer
- **Boligstørrelse (m<sup>2</sup>/person)**



**49,3 m<sup>2</sup> per person**  
(Gennemsnit er 52,1 m<sup>2</sup> i 2014)

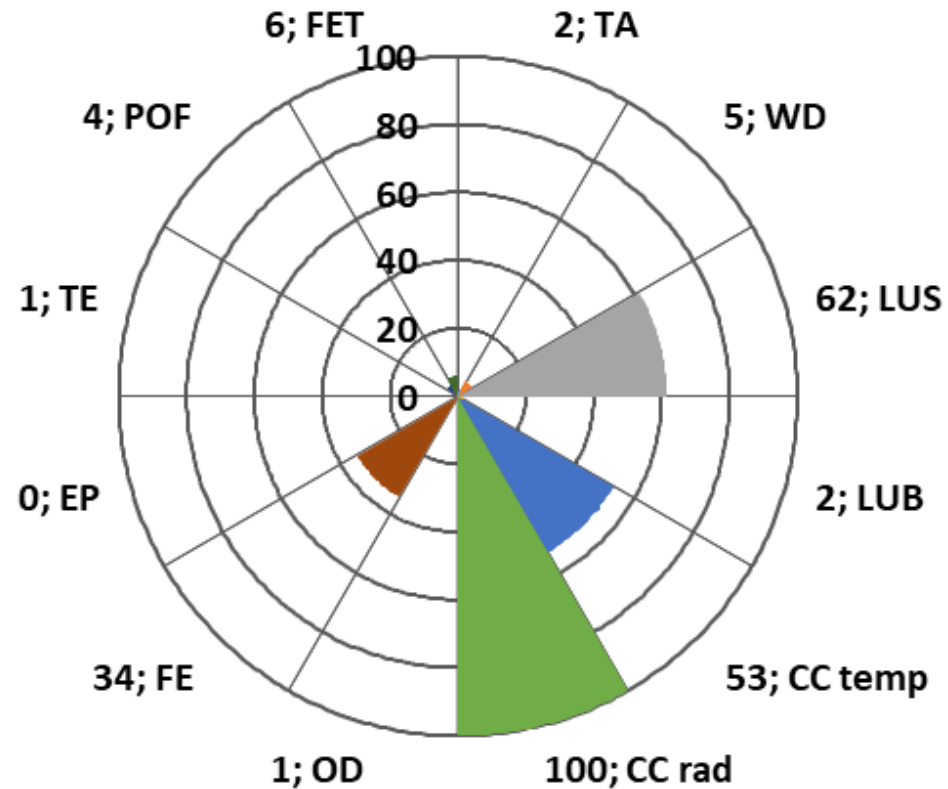


# HVAD KAN VI GØRE?

## PARCELHUS (50 ÅR)

- Re-allokering
- Energi til drift: 0% udledning
- Energi 0% udledning + Upcycle materialer
- **Boligstørrelse (m<sup>2</sup>/person)**

**3,2 m<sup>2</sup> per person**  
(Gennemsnit er 52,1 m<sup>2</sup> i 2014)

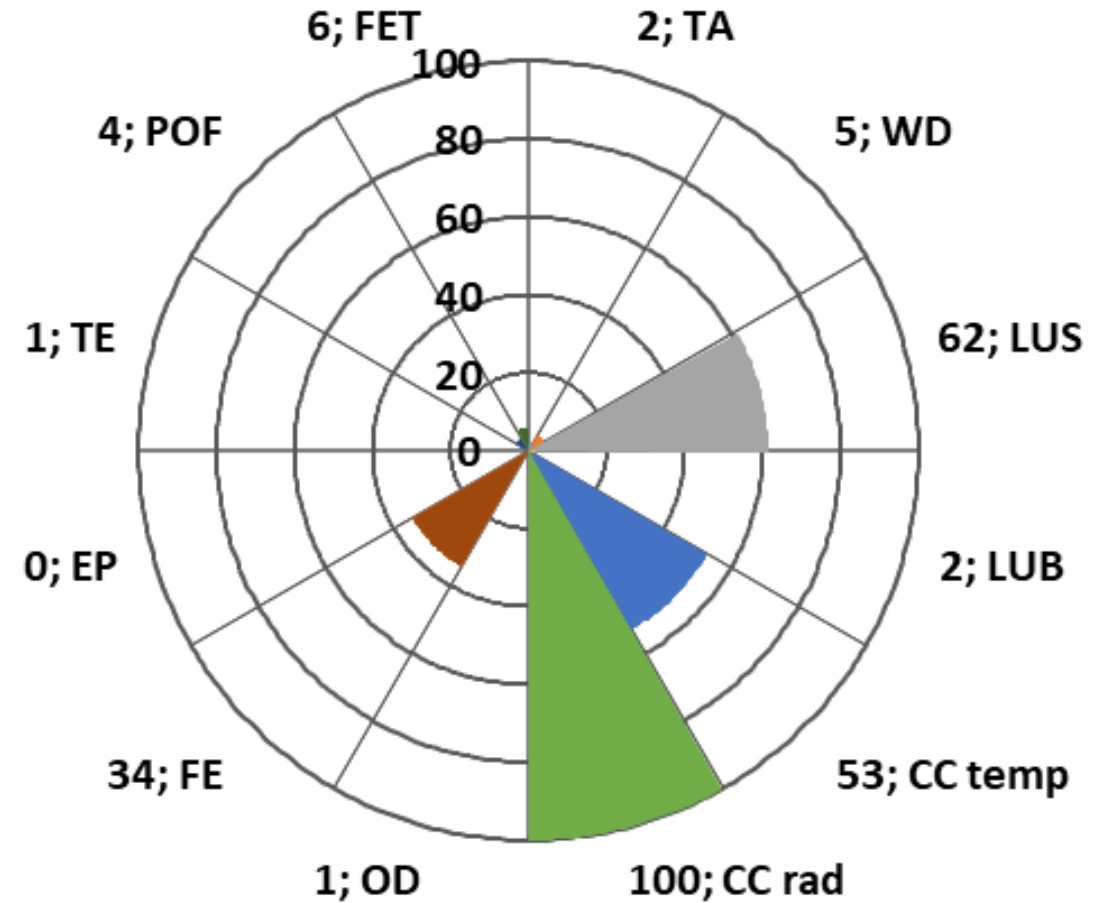


# HVAD KAN VI GØRE?

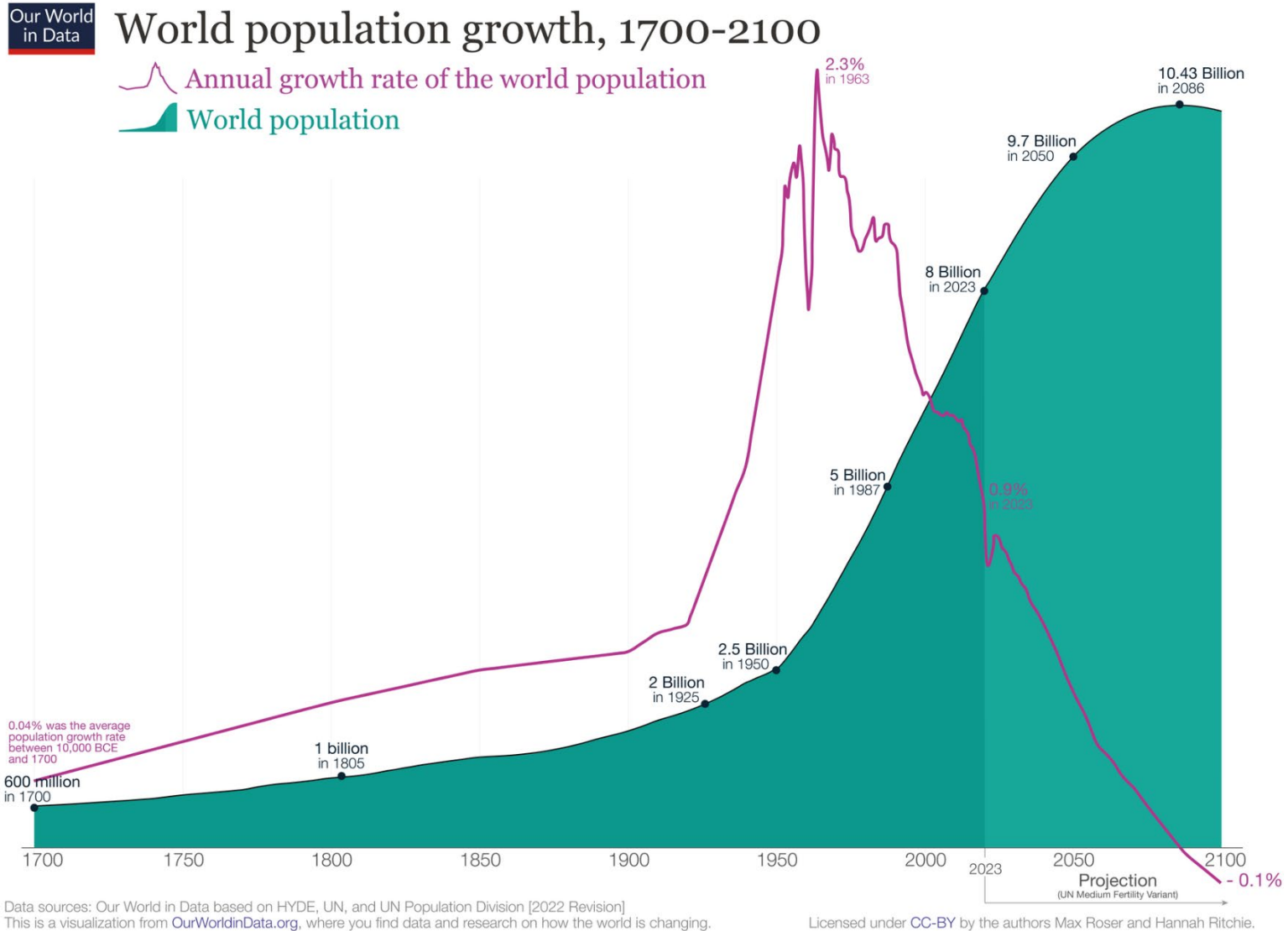
## PARCELHUS (50 ÅR)

- Miljøbelastning fra materialer **reduceres med 84 %**
- Miljøbelastning fra energi til drift **reduceres med 84 %**
- Kvadratmeter pr. person **reduceres til 20 m<sup>2</sup> (60 %)**

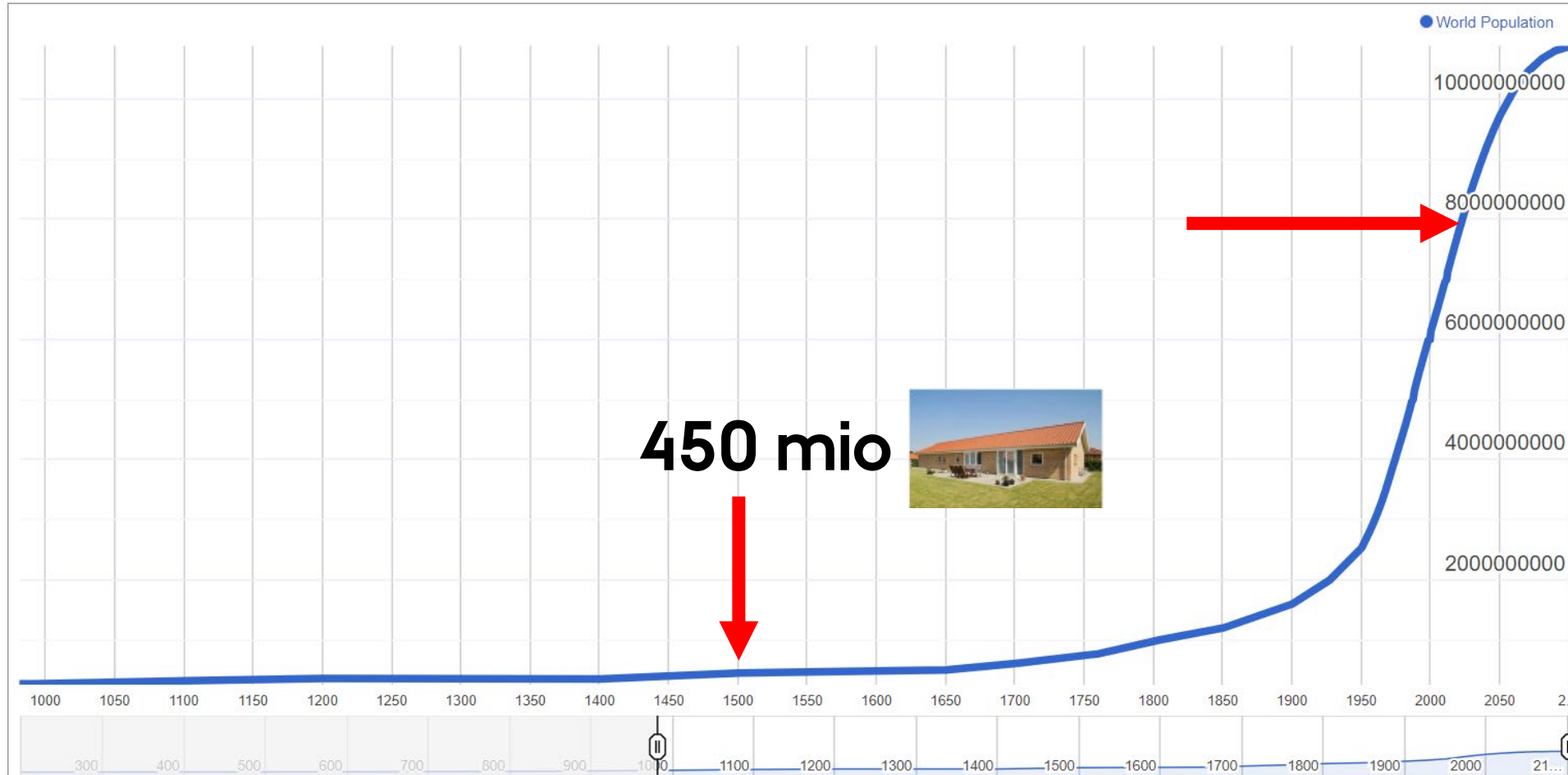
Andre knapper at skrue på?



# ER VI FOR MANGE PÅ JORDEN?



# ER VI FOR MANGE PÅ JORDEN?

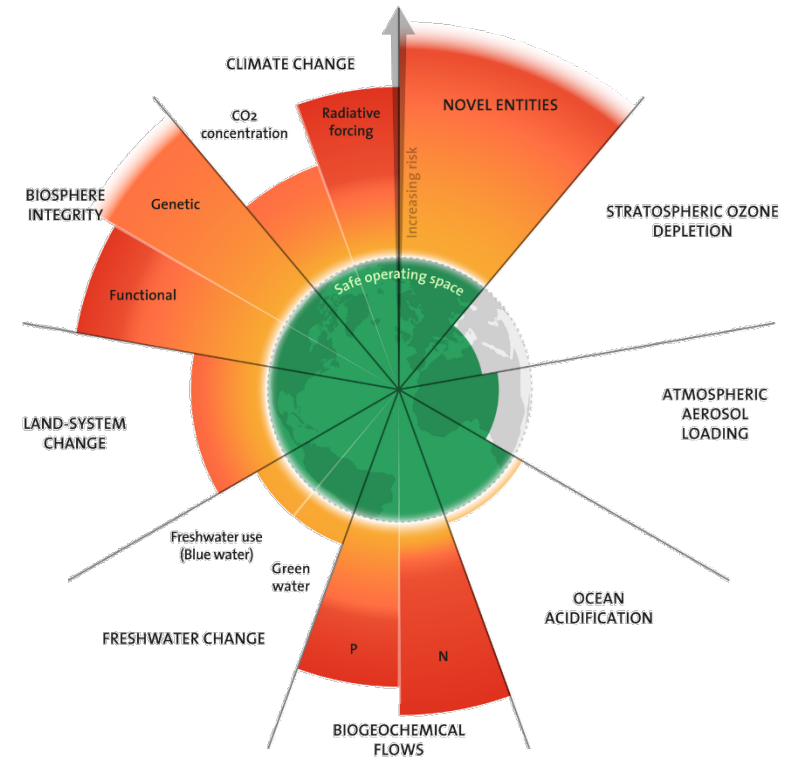


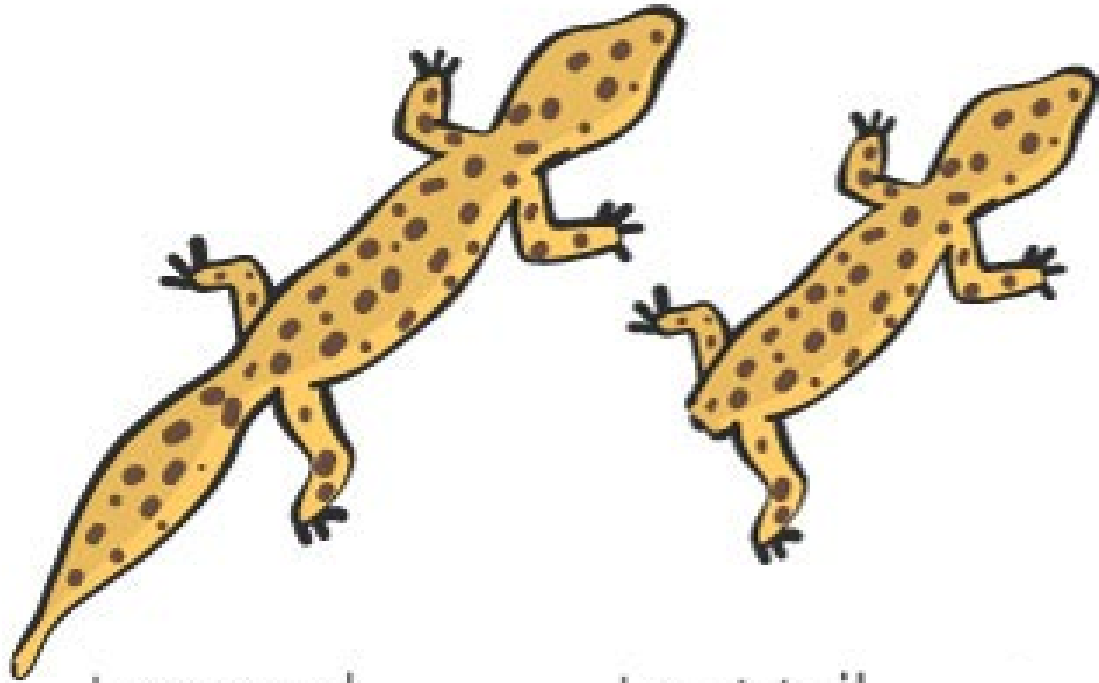
<https://www.worldometers.info/world-population/#table-historical>

Kør langsommere!



2025





Leopard  
gecko  
before  
autotomy

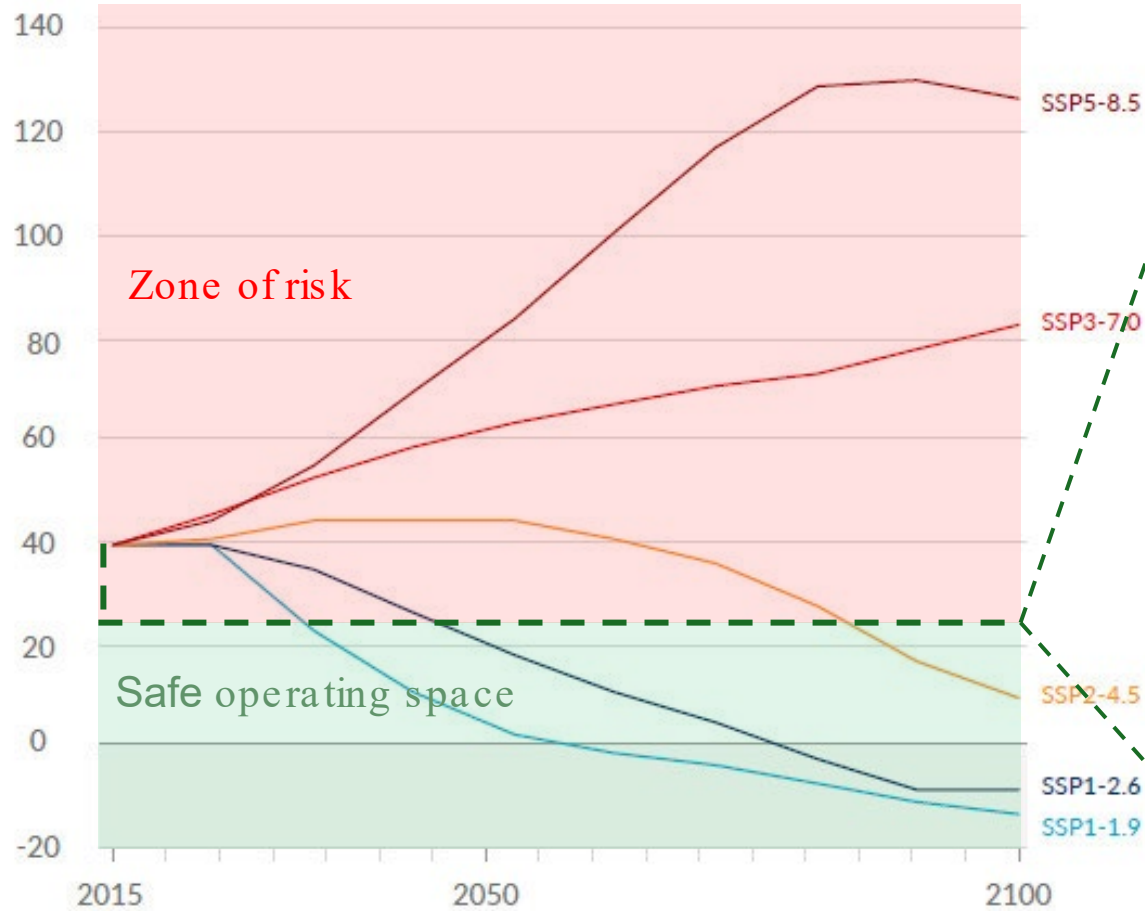
Lost tail

**Regeneration**

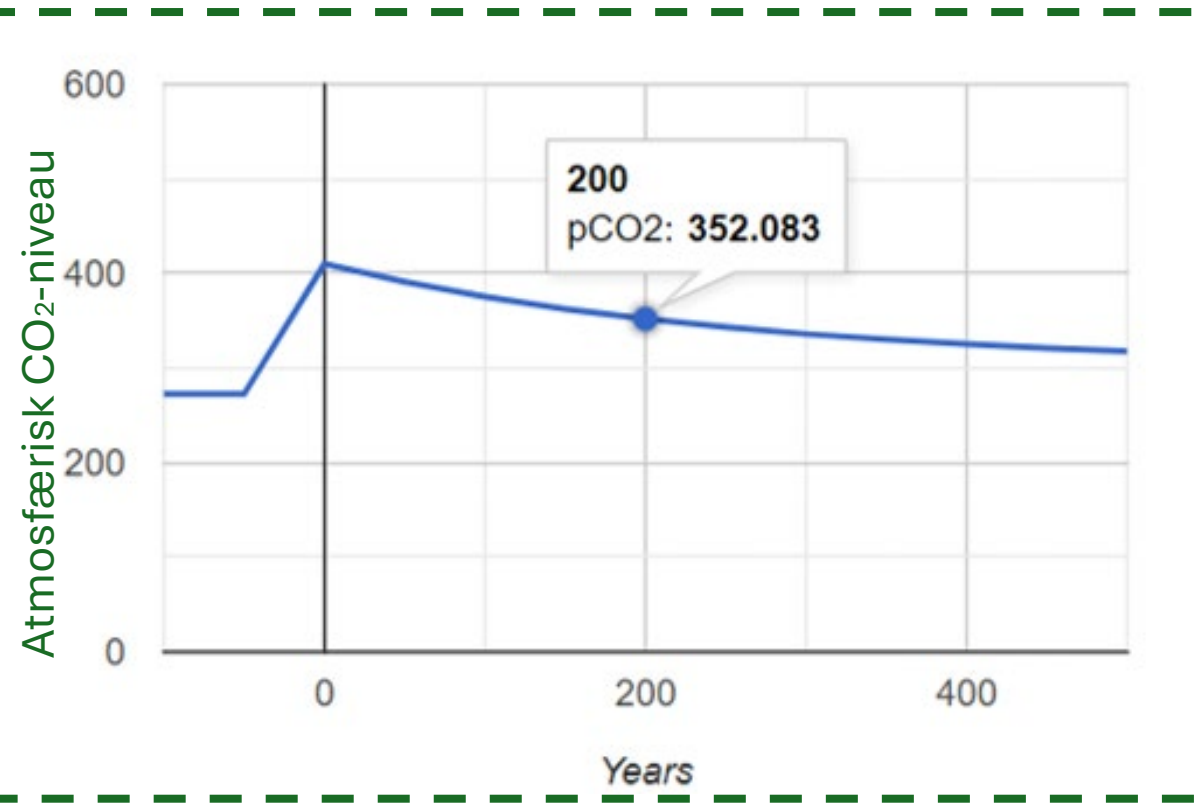
# CO<sub>2</sub> emission scenarier

The Intergovernmental Panel on Climate Change Sixth Assessment Report 2023  
(Enriched by Steffen Petersen)

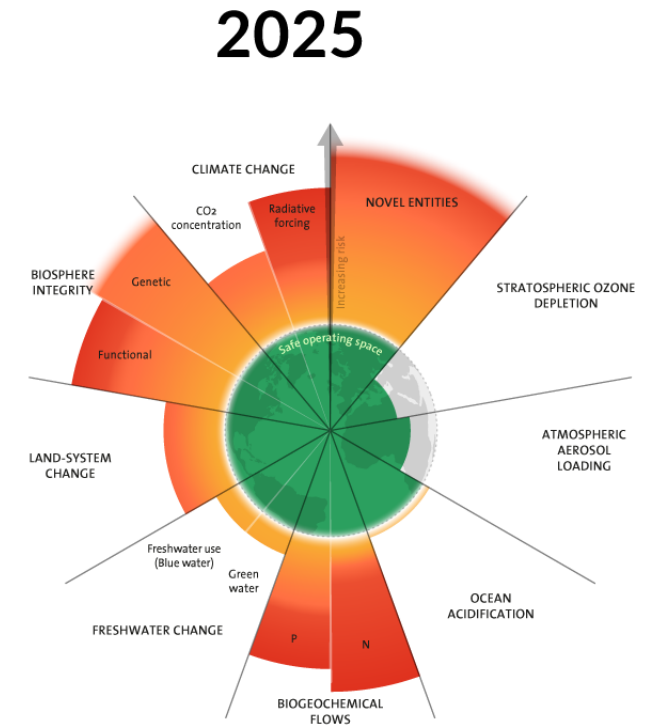
Carbon dioxide (GtCO<sub>2</sub>/yr)



Den tid det tager økosystemernes **regenerative egenskaber** at bringe os tilbage til **Safe Operating Space**



# Regenerativt Byggeri



9 boundaries assessed,  
7 crossed

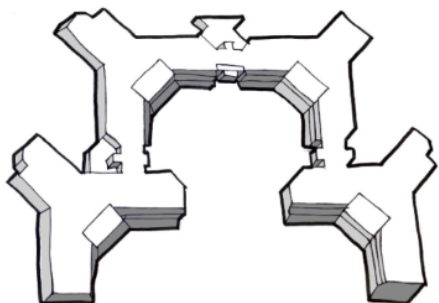
# GENERELLE STRATEGIER FOR BÆREDYGTIG OMSTILLING AF BYGGERIET

# NAUTICON

## MATERIALEKATALOG

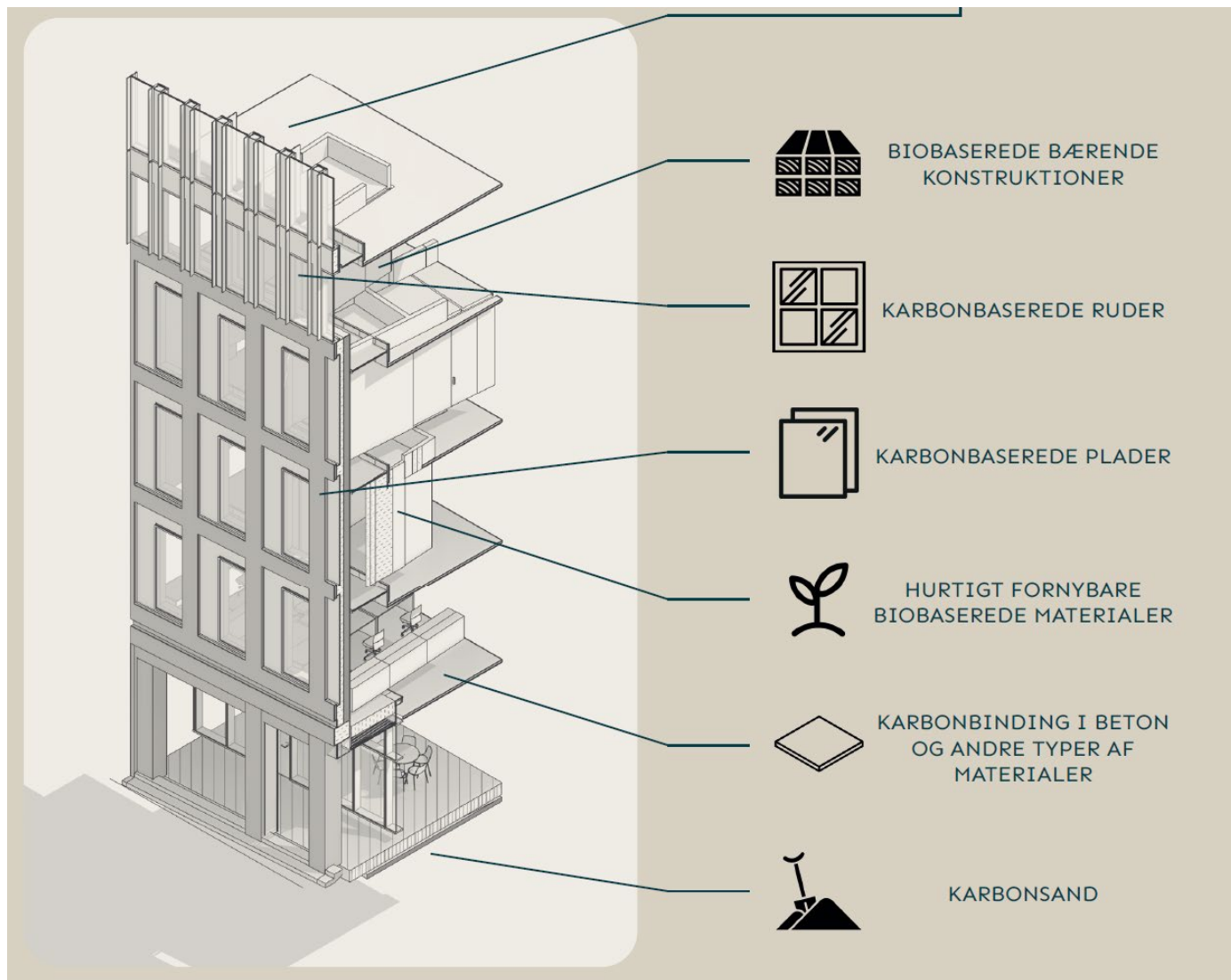
NYT LIV TIL FREMTIDENS BYGGERI

Materialekatalog udarbejdet på baggrund af screening og ressourcekortlægning udført december 22 - april 23 af Søren Jensen Rådgivende Ingeniørfirma



Søren Jensen rådgivende ingeniørfirma | +45 86 12 26 11 | www.sj.dk | CVR 15 88 40 46 | 1

Bygnings transformation, renovering, genbrug af produkter og materialer



Karbonbinding i byggeriets materialer

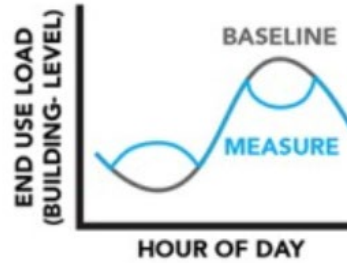


Direct Air Carbon Capture (DACC)

Energy efficiency



Demand flexibility



Efficiency + flexibility



Energi-effektive og energi-fleksible bygninger



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# Aarhus Center for Regenerativt Byggeri

Building Construction

Aarhus, Central Denmark Region

2K followers



6 connections work here

Message

Following



# KONTAKTINFORMATION

---

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## LinkedIn

<https://www.linkedin.com/in/steffen-petersen-9b71687/>

