Climate.now with built environment focus

5 credits

2.5.2023: Carbon budgets, construction materials and emissions

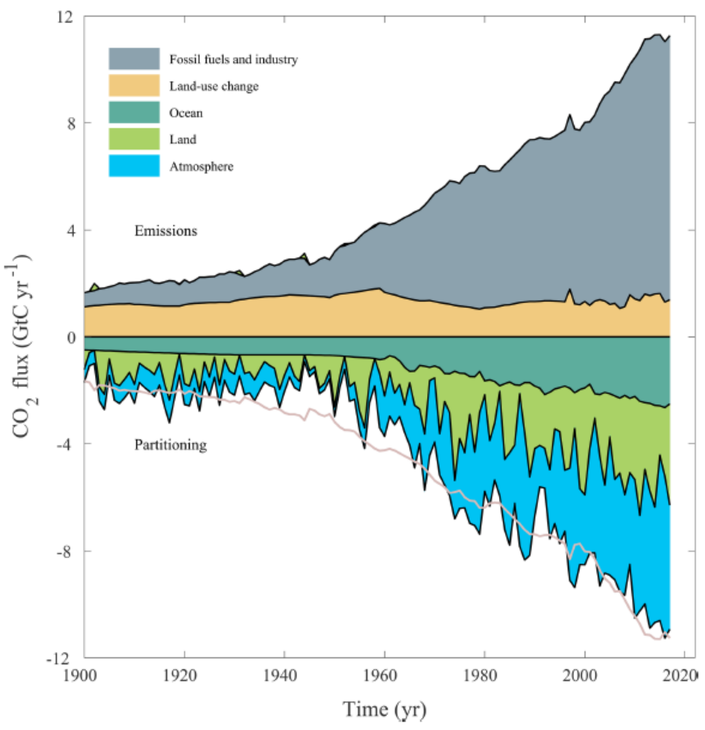
Dr Áróra Árnadóttir

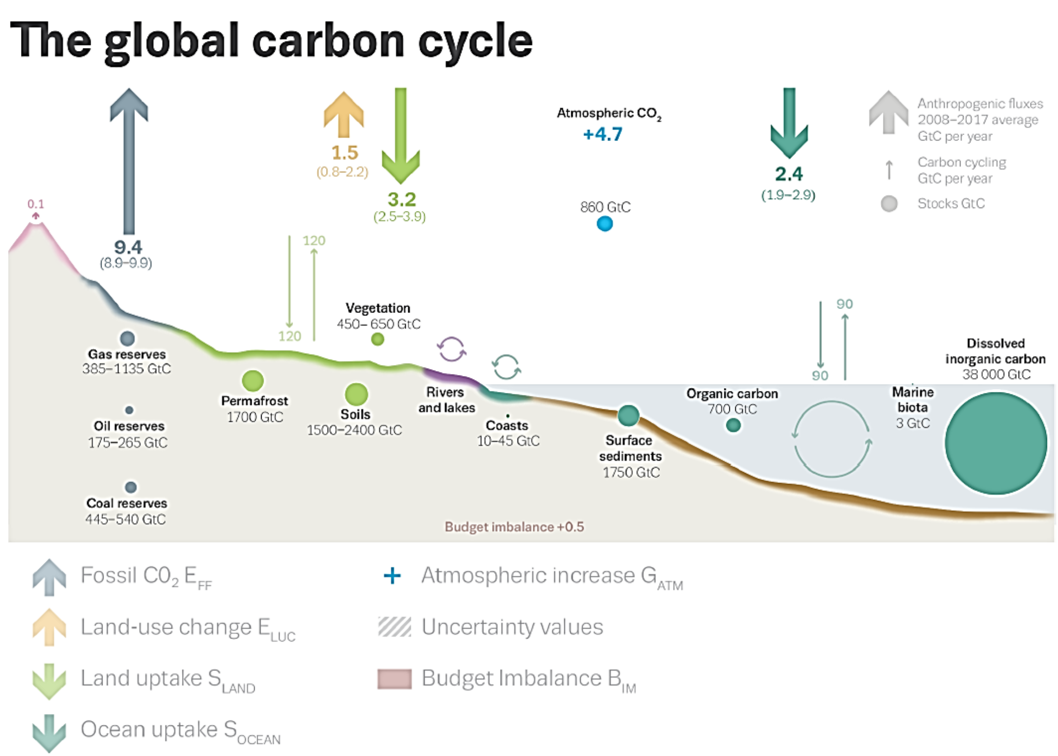
Today’s agenda

- Carbon budgets
- Environmental impacts of building materials
  - Concrete
  - Asphalt
  - Steel

Carbon budgets

- Calculated as $E_{FF} + E_{LUC} = G_{ATM} + S_{OCEAN} + S_{LAND} + B_{IM}$





Le Quéré et al. 2018. Global Carbon Budget, Earth Syst. Sci. Data, 10, 2141–2194

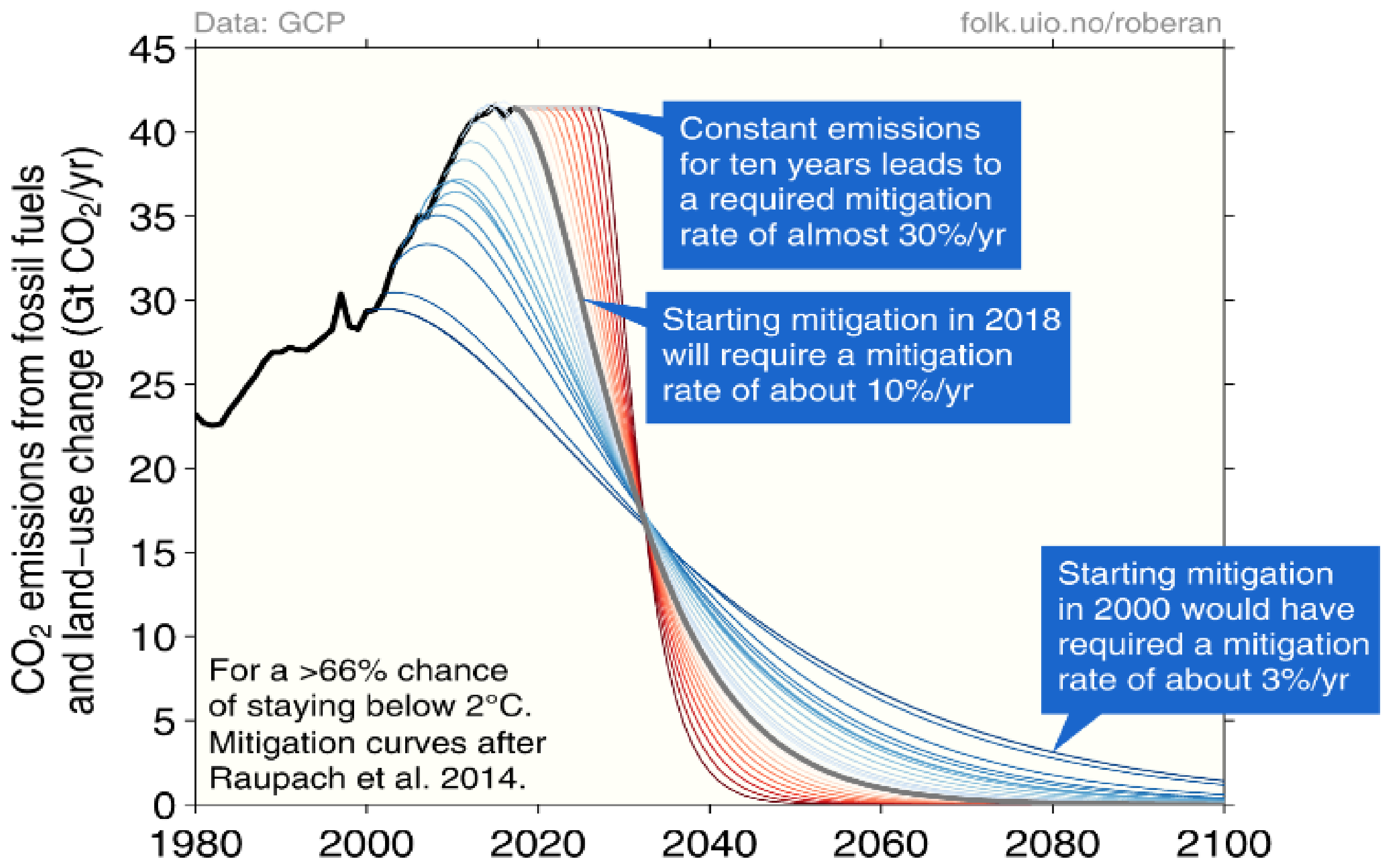
Carbon budgets

- Remaining budget
  - for 1.5°C warming = ~400 GtCO2
  - For 2.0°C warming = ~1000 GtCO2
- 2022 annual emissions 37 GtCO2

Excluding methane and other GHGs

Excluding additional Earth-system feedbacks such as permafrost melting or methane released from wetlands

...meaning that year after year the mitigation curve to reach a certain warming target becomes steeper and steeper



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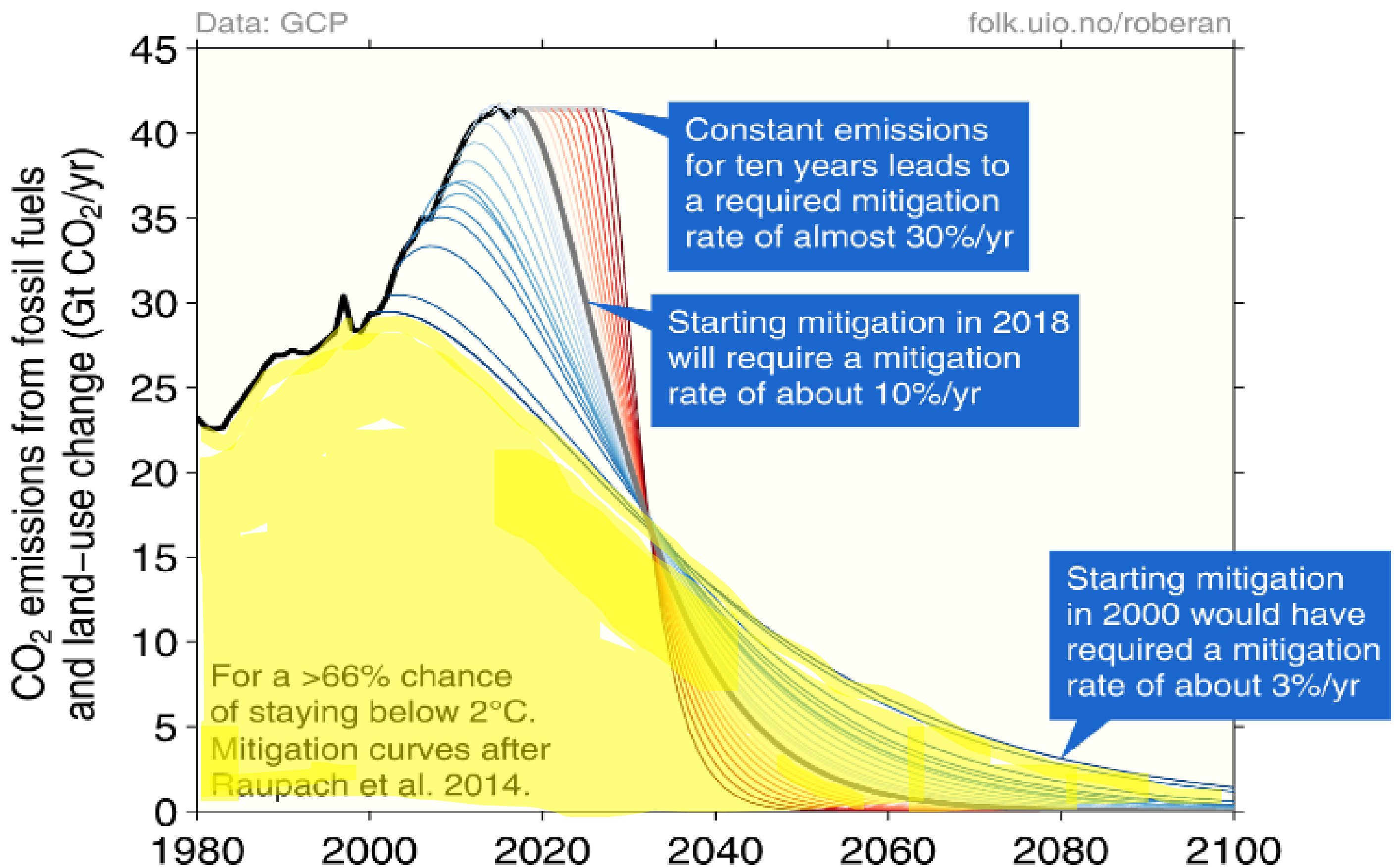

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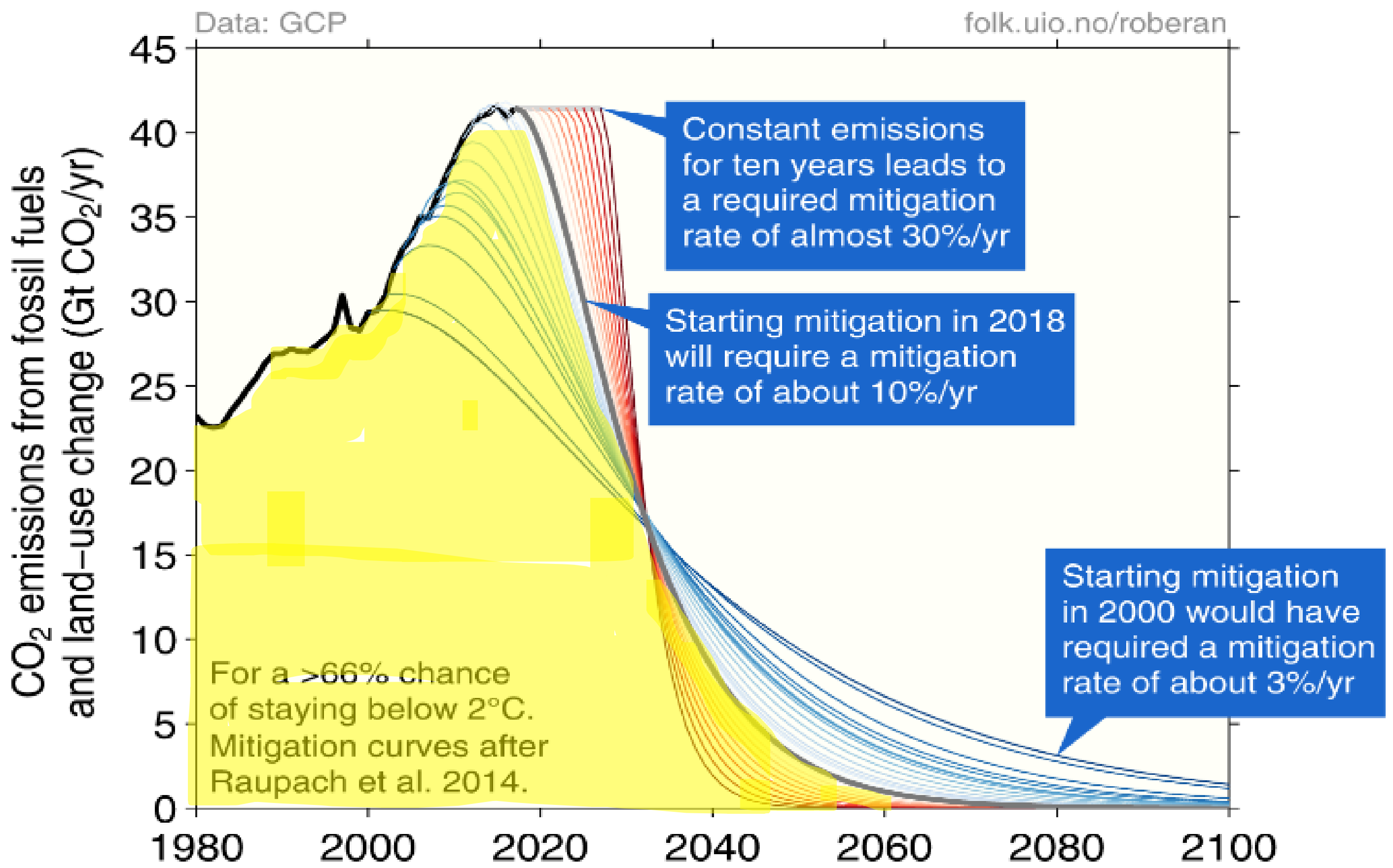

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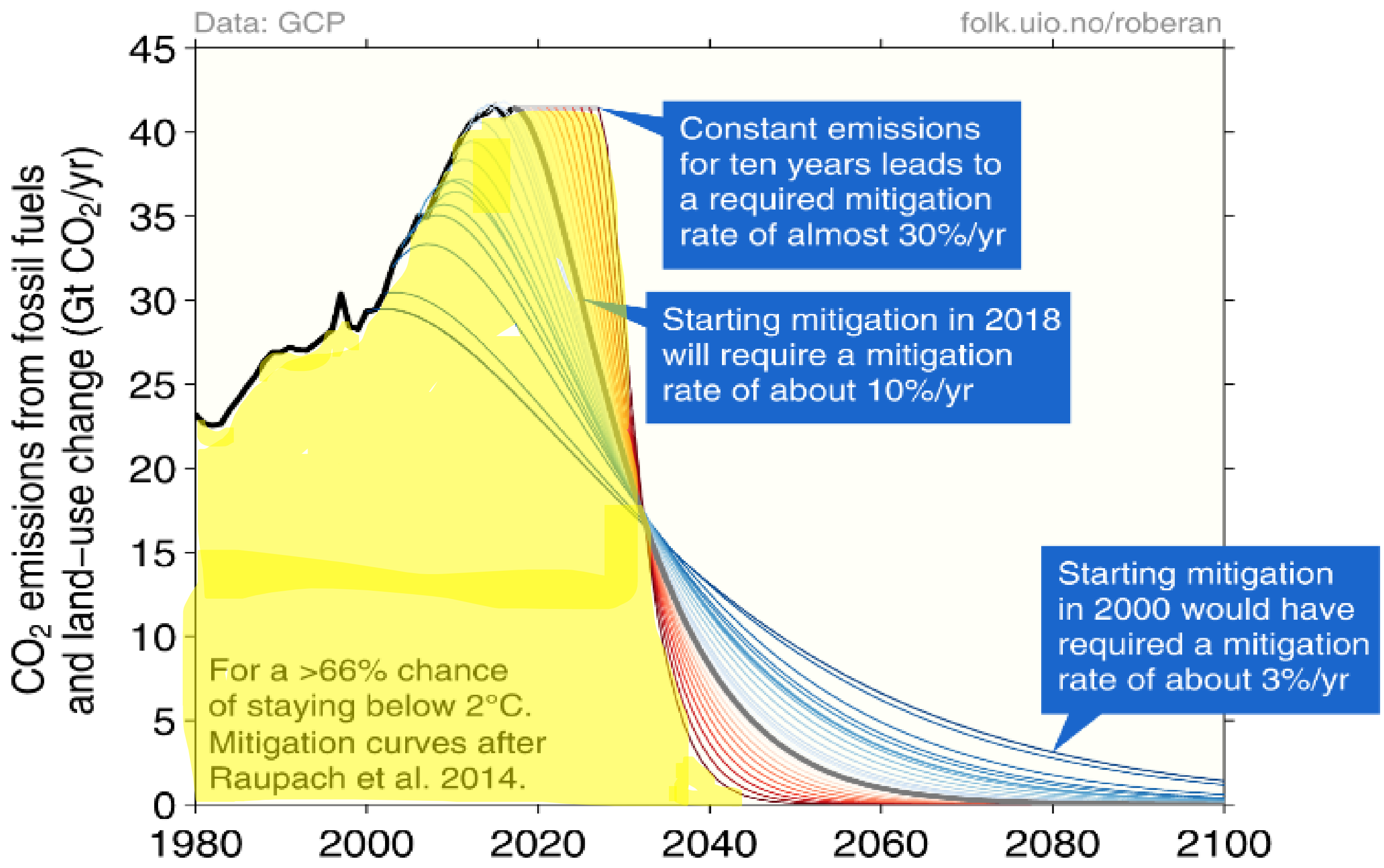
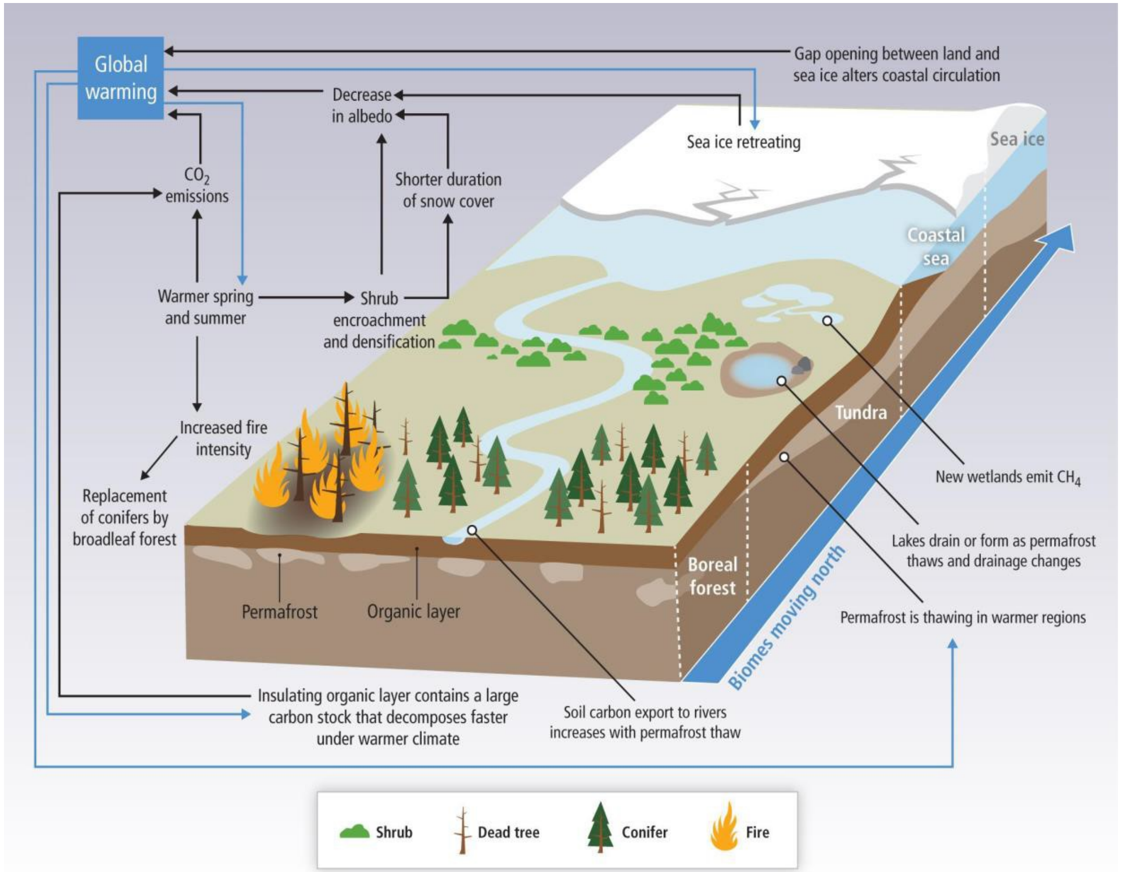


Tipping points

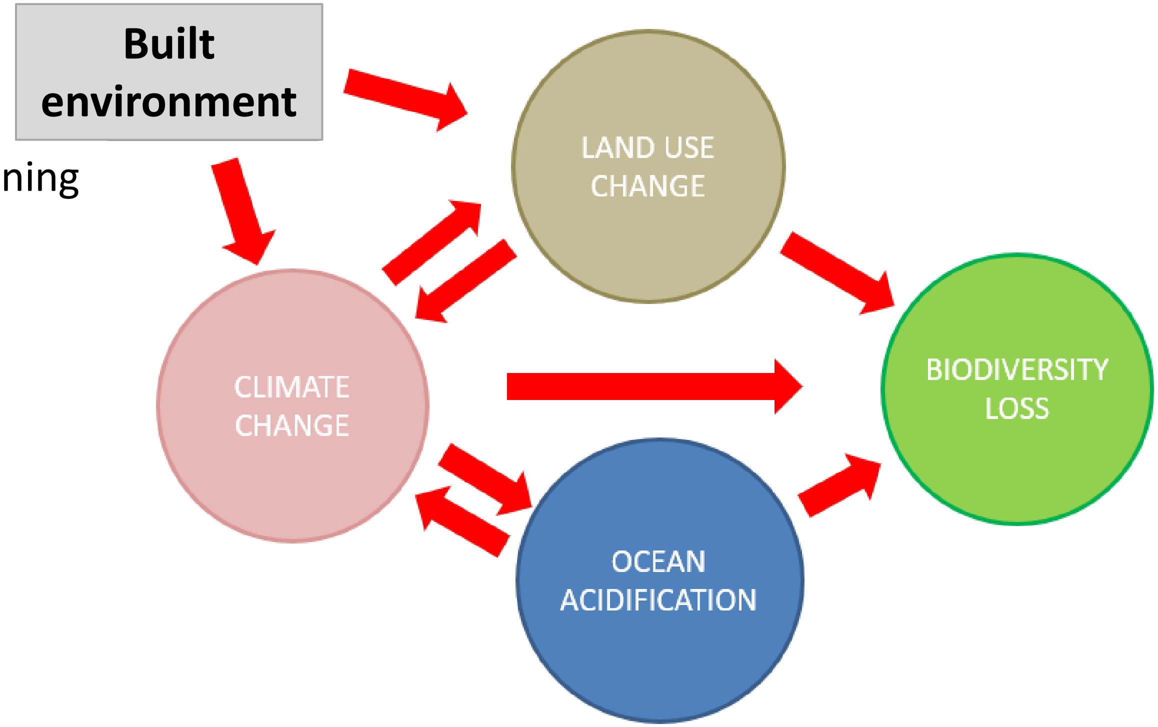
- Do we actually have a quota to keep warming below 1.5° / 2° warming?
- Climate feedbacks could more than double the amount of warming caused by carbon dioxide alone



Potential global processes bringing the tipping points closer (or taking us beyond them)

- Permafrost melt
- Ocean acidification reducing the carbon uptake
- Snowcover reduction
- Deforestation
- Watercover darkening
- Snow and icecover darkening
- Erosion

The major global environmental problems are not isolated issues, but deeply connected



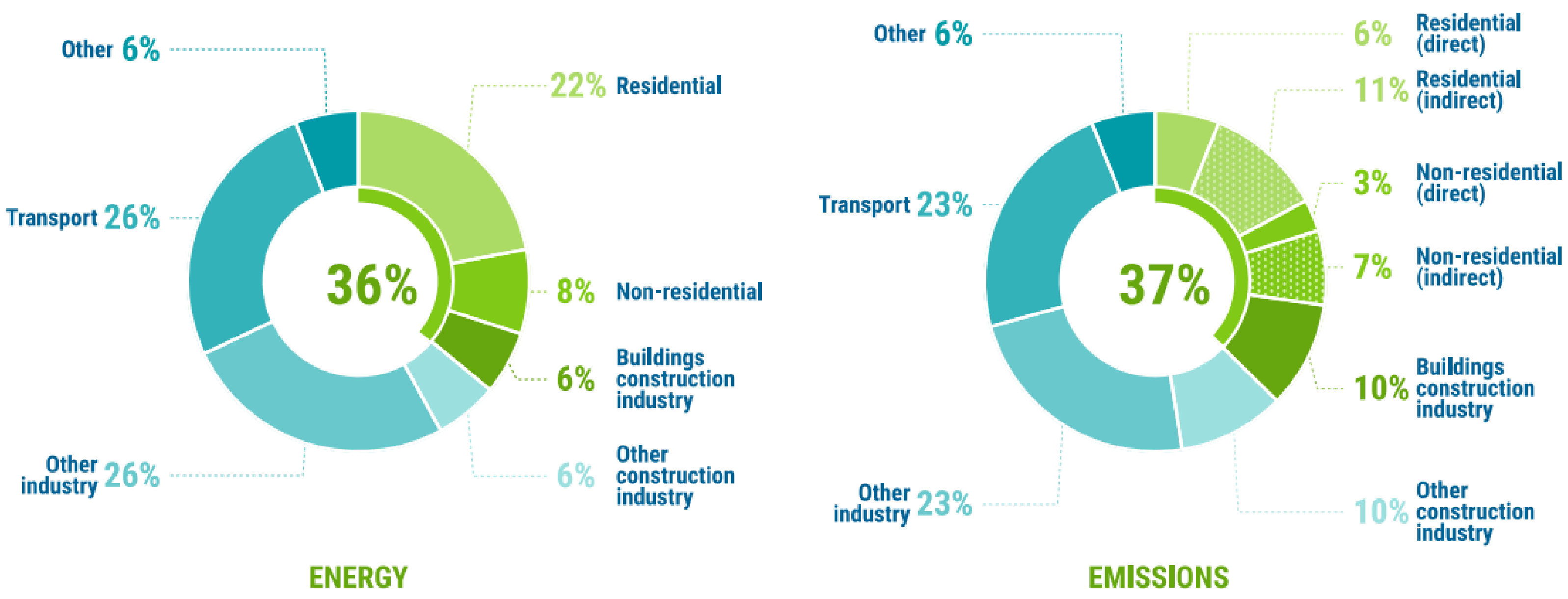
Environmental impact of building materials

- Civil works and building construction consumes 60% of the raw materials extracted from the lithosphere (buildings 24%)
- In Europe, 4.8 tonnes per inhabitant per year
- Building sector accounts for:
  - 36% of total global final energy use
  - 54% of final electricity demand
  - 37% of energy-related CO_2 emissions

Global load

- Concrete and steel responsible for 6.5% and 7.0% of global CO2 emissions, respectively

Figure 2. Buildings and construction's share of global final energy and energy-related CO_2 emissions, 2020



United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector. Nairobi.

Concrete

- Concrete alone consumes 65% of the total embodied energy of a home
  - Concrete is a mix of cement, water, aggregate and additives
  - Most common building material
  - Portland cement the most common cement in concrete
  - In 2009, the cement industry in the EU responsible for 38.5% of total European CO_2 emissions from industry

Asphalt concrete

- Asphalt concrete is a mix of asphalt or „bitumen“ and aggregate
- Mainly for road surfaces
- Asphalt obtained from petroleum
  - high pressure and temperatures up to 425 °C required
  - Most common mix requires 165 °C to process asphalt as component in asphalt concrete
  - …but temperature for mix varies, HMA, WMA, CMA

Steel

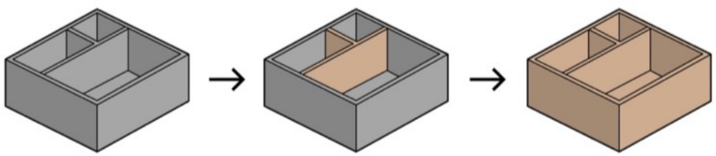
- Iron and steel production accounts for ~20% of global final energy use
  - Largest industrial source of CO_2 emissions
  - Half is used for construction
- Made from iron ore or scrap
  - 98% of mined iron ore goes into making steel
  - Requires high temperatures
  - Reliance on carbon-based fuels

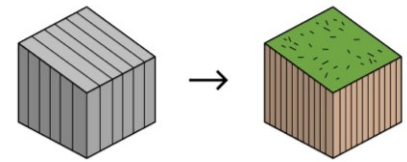
LCA results differ, one example:

Building product	Density (kg/m3)	Primary energy demand (MJ-Eq/kg)	GWP (kg CO2-Eq/kg)	Water demand (l/kg)	GWP (kg CO2-Eq/m3)
Cement	3150	4.235	0.819	3.937	2580
Reinforced concrete	2546	1.802	0.179	2.768	456
Sawn timber, softwood, planed, air dried	600	18.395	0.267	4.192	160
Glued laminated timber, indoor use	600	27.309	0.541	8.366	325
Reinforced steel	7900	24.336	1.526	26.149	12055
Flat glass	2500	15.511	1.136	77.794	2840

Zabalza Bribián et al. (2011). Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. *Building and Environment*, **46**, 1133-1140.

The impact of material replacement





Impact categories	total base case	total scenario 2	Unit	Decrease / Increase	%
Climate change	17,319,130	9,775,484	kg CO2-Eq	7,543,646	44%
Ozone depletion	0.86	0.7	kg CFC-11-Eq	0.16	19%
Terrestrial acidification	51,814	39,685	SO2-Eq	12,129	23%
Freshwater eutrophication	3,810	3,156	kg P-Eq	654	17%
Photochemical oxidant formation	62,104	49,921	kg NMVOC	12,183	20%
Freshwater ecotoxicity	259,620	210,250	kg 1,4-DCB-Eq	49,370	19%
Human toxicity	3,734,476	3,057,572	kg 1,4-DCB-Eq	676,904	18%
Particulate matter formation	28,915	21,555	kg PM10-Eq	7,360	25%
Agricultural land occupation	481,906	74,595,042	m2a	74,113,136	15379%
Water depletion	216,317	74,099	m3	142,218	66%
Ionising radiation	646,404	721,513	kg U235-Eq	75,109	12%
Fossil depletion	3,320,639	2,554,296	kg oil-Eq	766,343	23%
Marine ecotoxicity	244,212	198,328	kg 1,4-DCB-Eq	45,884	19%
Marine eutrophication	155	129	kg N-Eq	26	17%
Metal depletion	4,068,833	3,416,525	kg Fe-Eq	652,308	16%
Natural land transform	4,765	3,372	m2	1,393	29%
Terrestrial ecotoxicity	1,298	2,154	kg 1,4-DCB-Eq	856	66%
Urban land occupation	780,777	1,231,060	m2a	450,282	58%

Not even taking sequestration potential into account

Hjördís Sigurðardóttir, Master thesis, 2022

Transport

- The environmental impact of building materials differs depending on transport method
- Primary energy demand (MJ-Eq/km) of transporting 1 tonne of materials is...
  - 3.266 by road
  - 0.751 by rail
  - 0.170 by ship

Weight, location and fuel source matter!

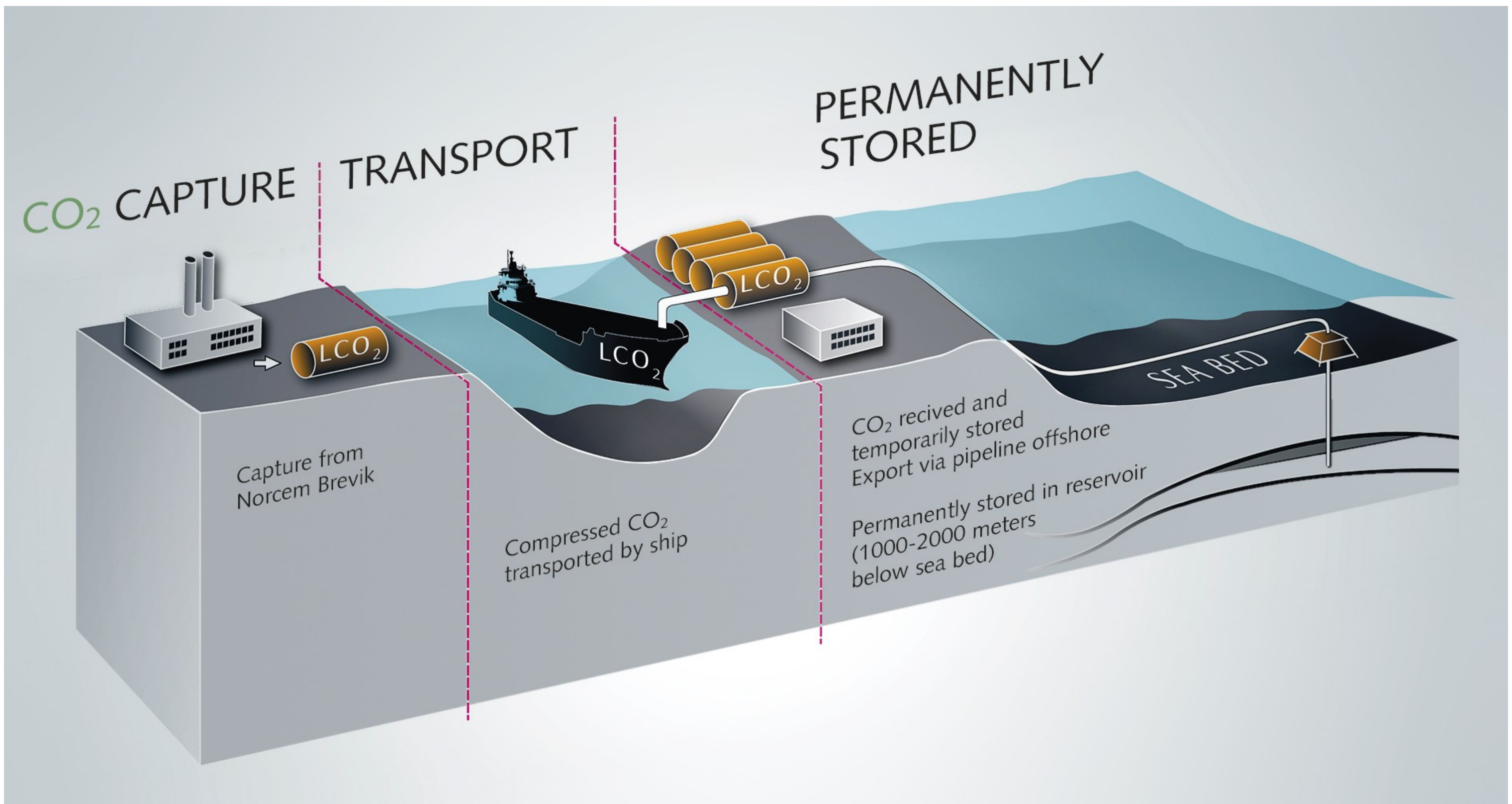
Zabalza Bribián et al. (2011). Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. *Building and Environment*, **46**, 1133-1140.

Future scenarios

- Possible for a sustainable future scenario to rely on these highly unnatural high-impact materials?
- Durability
  - How long do they actually need to last?
  - The Icelandic turf house
    - Repair and reuse
    - Evolved with household composition
- End of life
  - They don’t dissolve naturally

The cement industry reacting, but too late?

- Norcem
  - CCS to be used in production by 2030



Examples of more sustainable materials, available now

- Mycelium
- Hempcrete
- Biocrete
- Biocement
- CLT and other timber and bamboo products

Mycelium

https://materialdistrict.com/article/leaning-mycelium-mycotree/

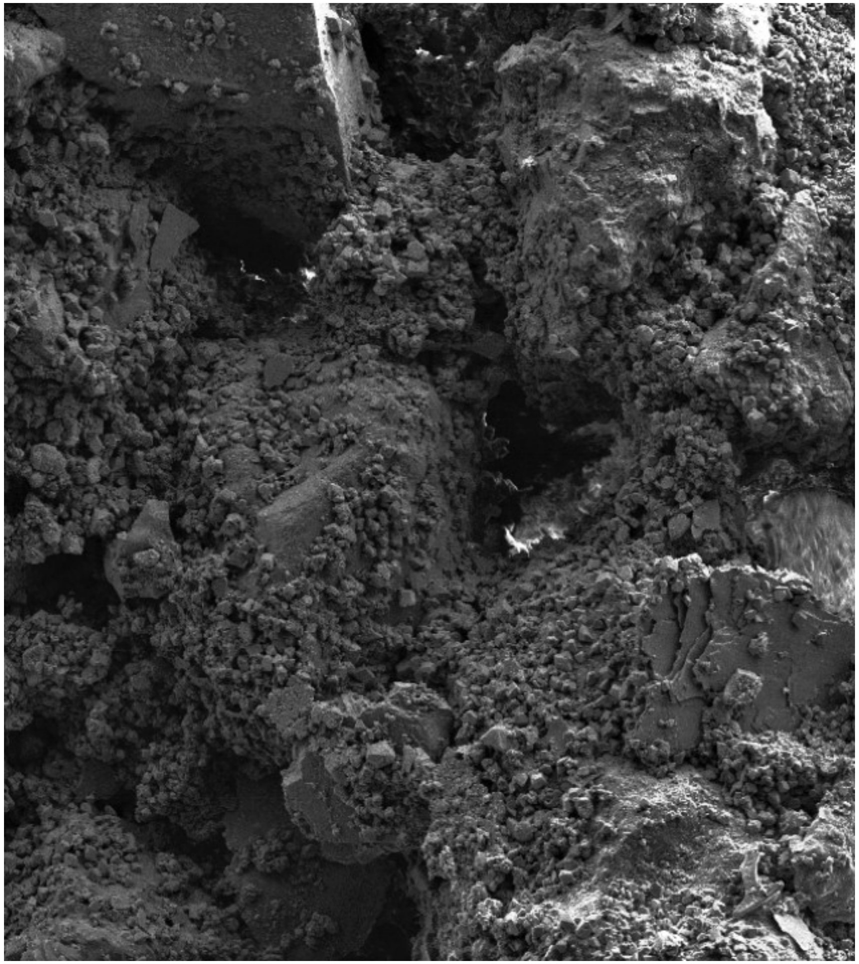
Hempcrete

https://www.hempitecture.com/hempcrete

Biocrete

https://www.biocrete.no/

Biocement



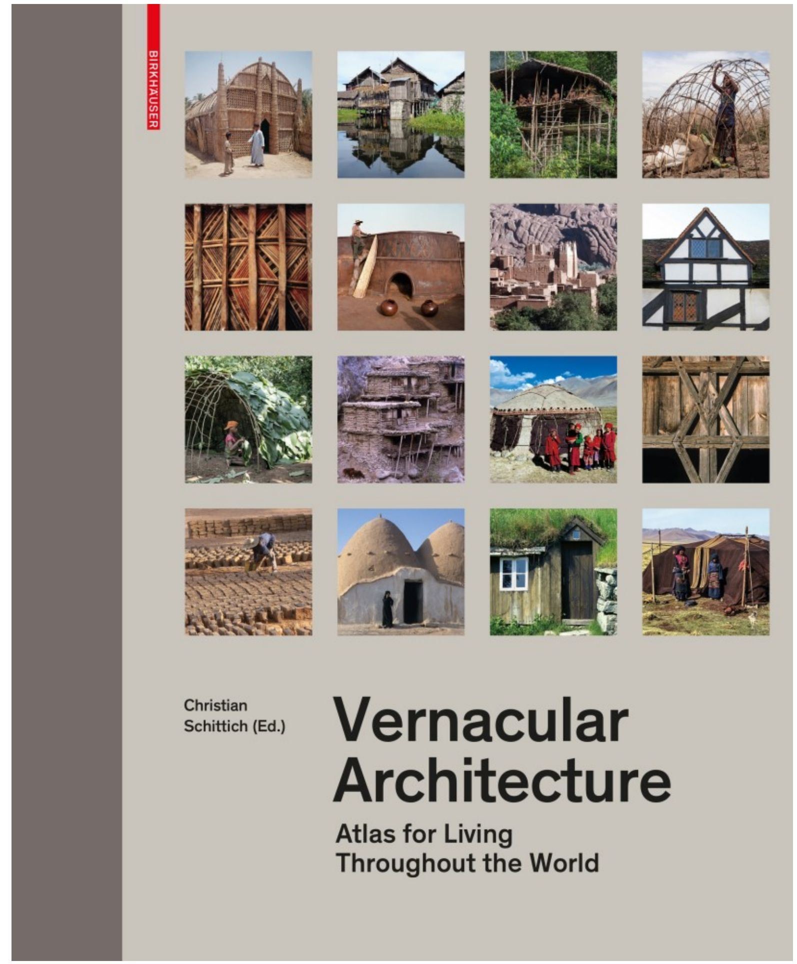
https://biocement.com/

CLT

https://www.storaenso.com/en/products/mass-timber-construction

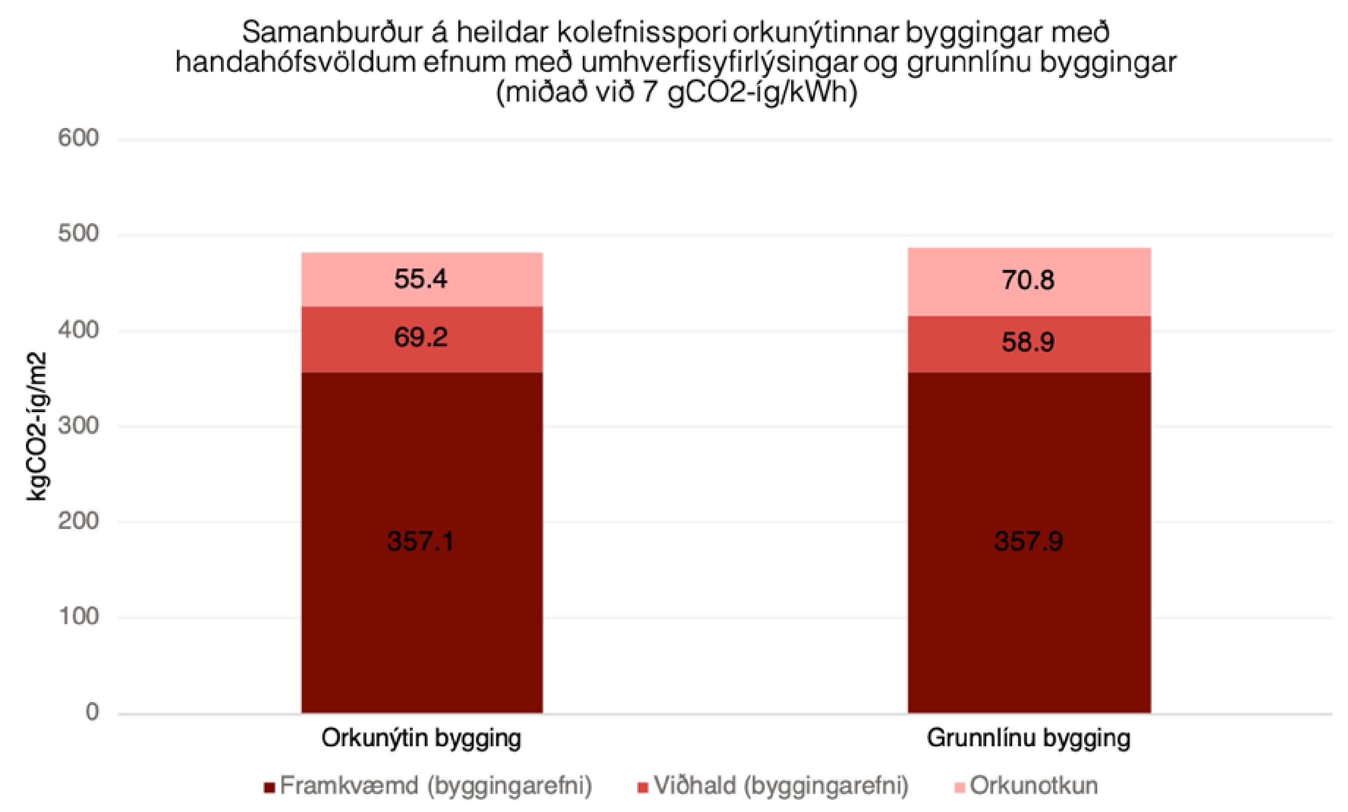
And in general vernacular architecture…

- Use of local resources
- Buildings responsive to local climate
- Less energy-intensive manufacturing
- E.g. Clay, straw, earth, snow, turf, wood

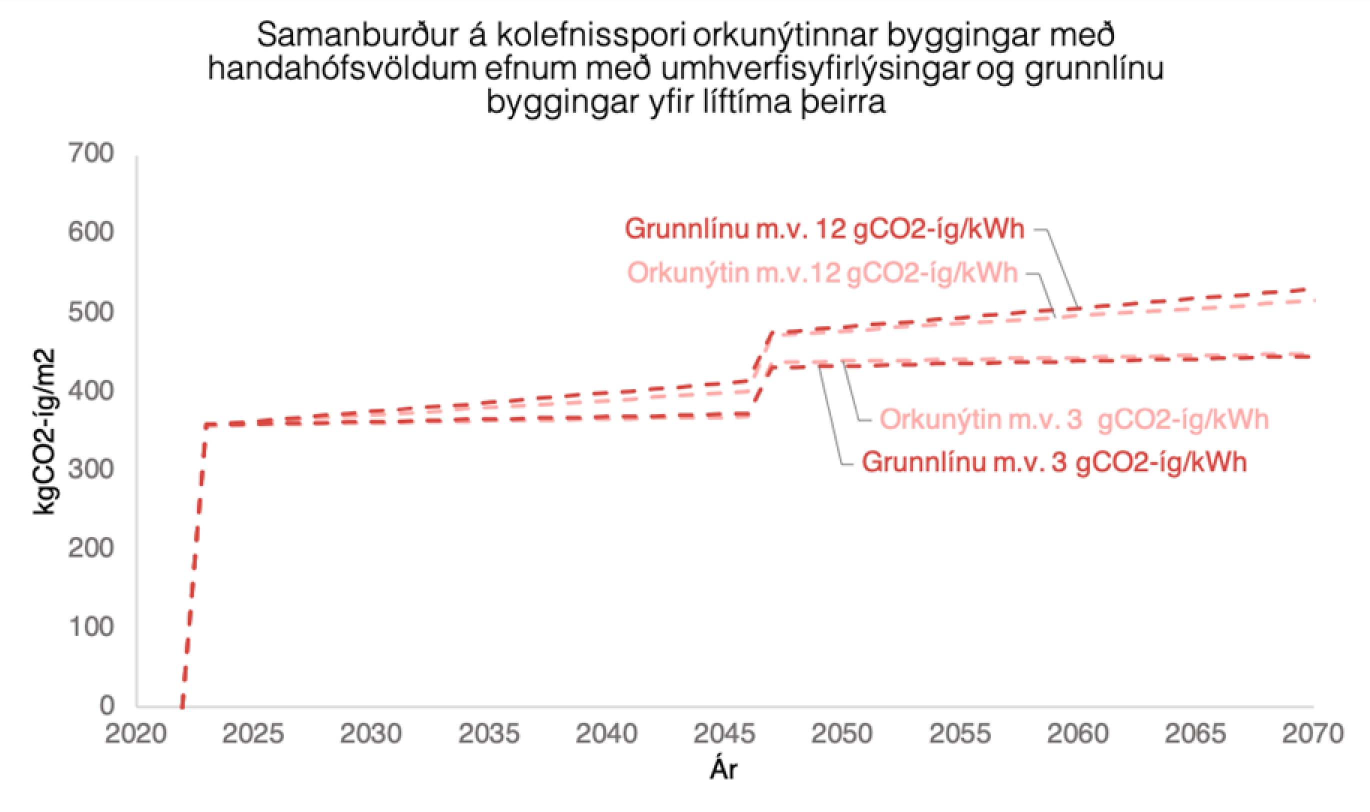



Thus far, anyway, with bright eyes we call combinations of thousands of tons of concrete, steel, glass, and aluminium sustainable buildings

BREEAM vs non-certified

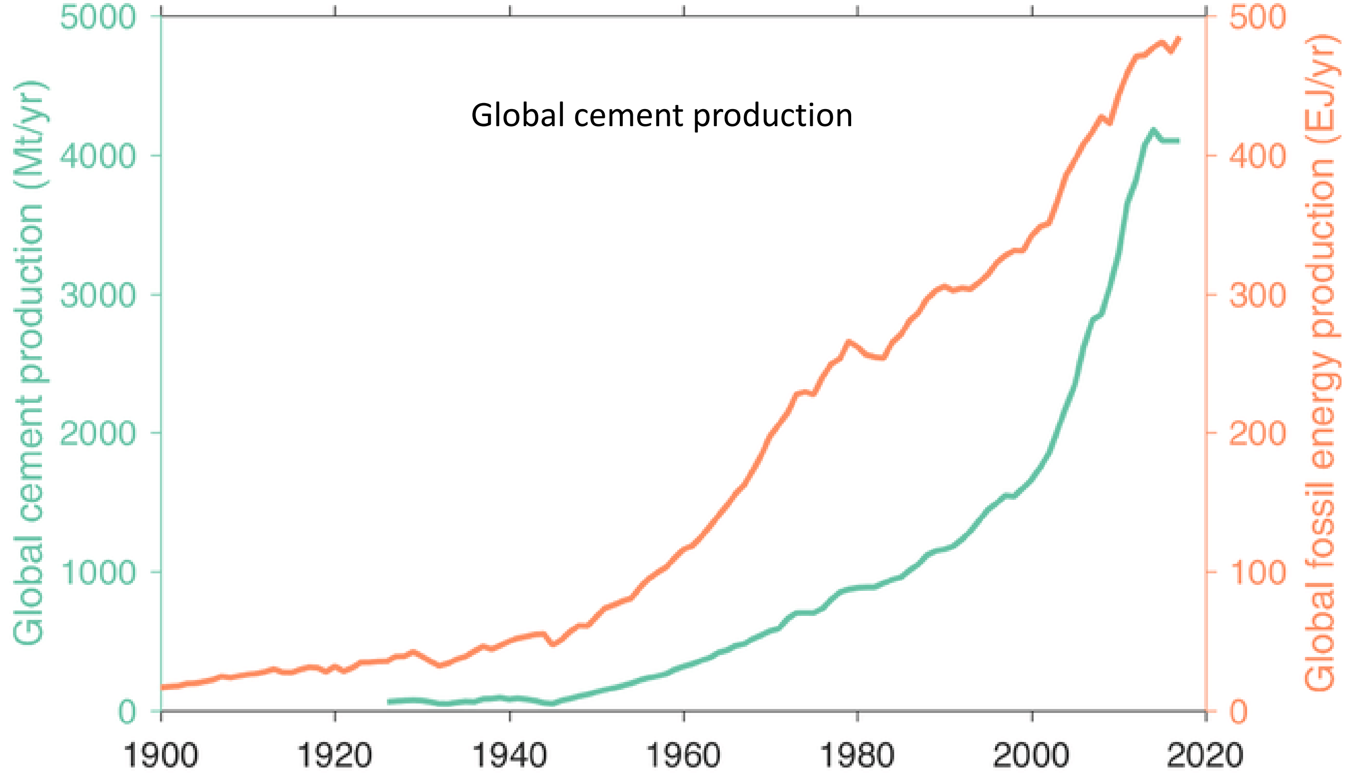


BREEAM vs non-certified

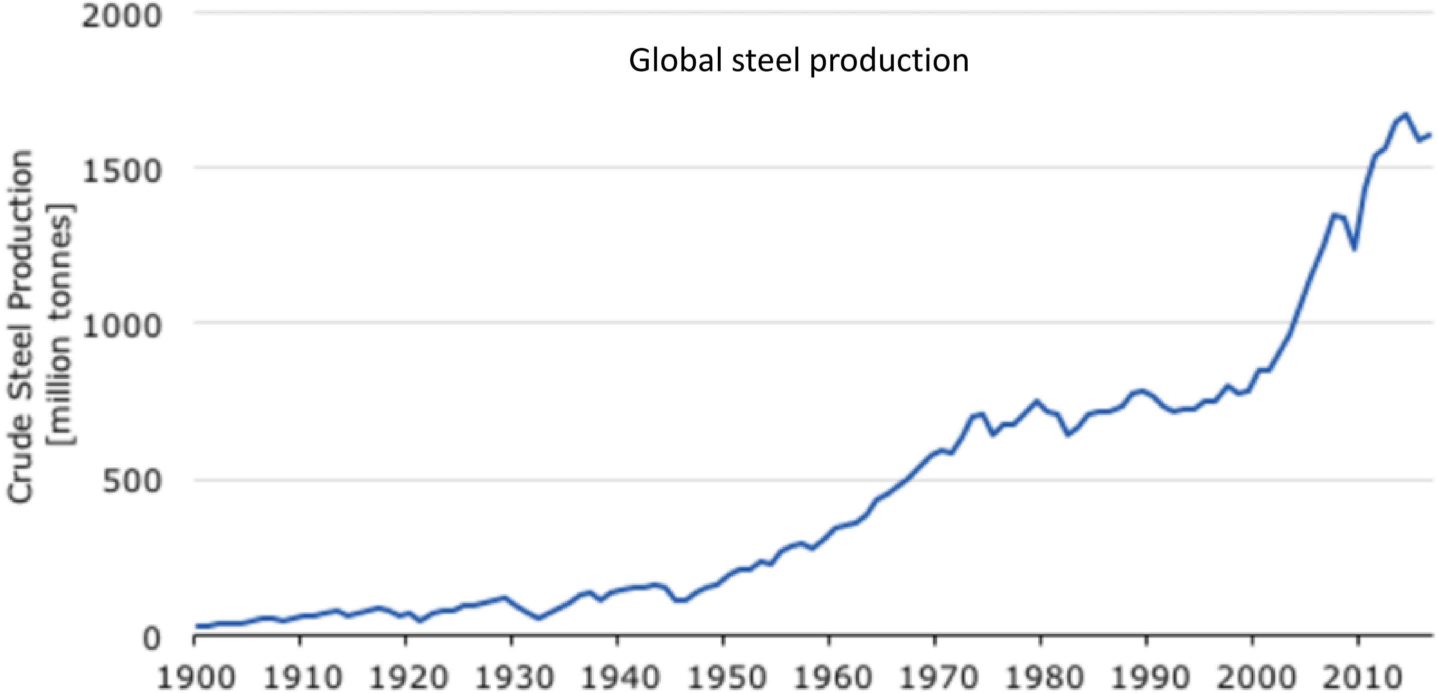


To give a bit of perspective for the importance of the issue:

Poorer countries catching up with Western infrastructure stocks, using current technologies, would cause approximately 350 Gt CO_2 from materials production (Müller et al.), which roughly equals the TOTAL carbon budget available for 1.5 degrees warming



Global cement production
Global cement production (Mt/yr)
Global fossil energy production (EJ/yr)
0
1000
2000
3000
4000
5000
0
100
200
300
400
500
1900
1920
1940
1960
1980
2000
2020


Global steel production
Crude Steel Production [million tonnes]
2000
1500
1000
500
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Next lecture

09.05

LCA, Carbon spike and WLC perspective

- Dr Jukka Heinonen
- In-person (R003F239a Auditorio)

Calculation estimate example from Iceland

- 35.000 apartments in the next 10 years
- Average size 100m2
- Typical emissions per m2 are 500kg
- 35.000 * 100 * 0,5 tonns = 1.75 million
- Annual national CO_2 emissions= 3.5 million tonns