Concrete world: a socio-metabolic perspective

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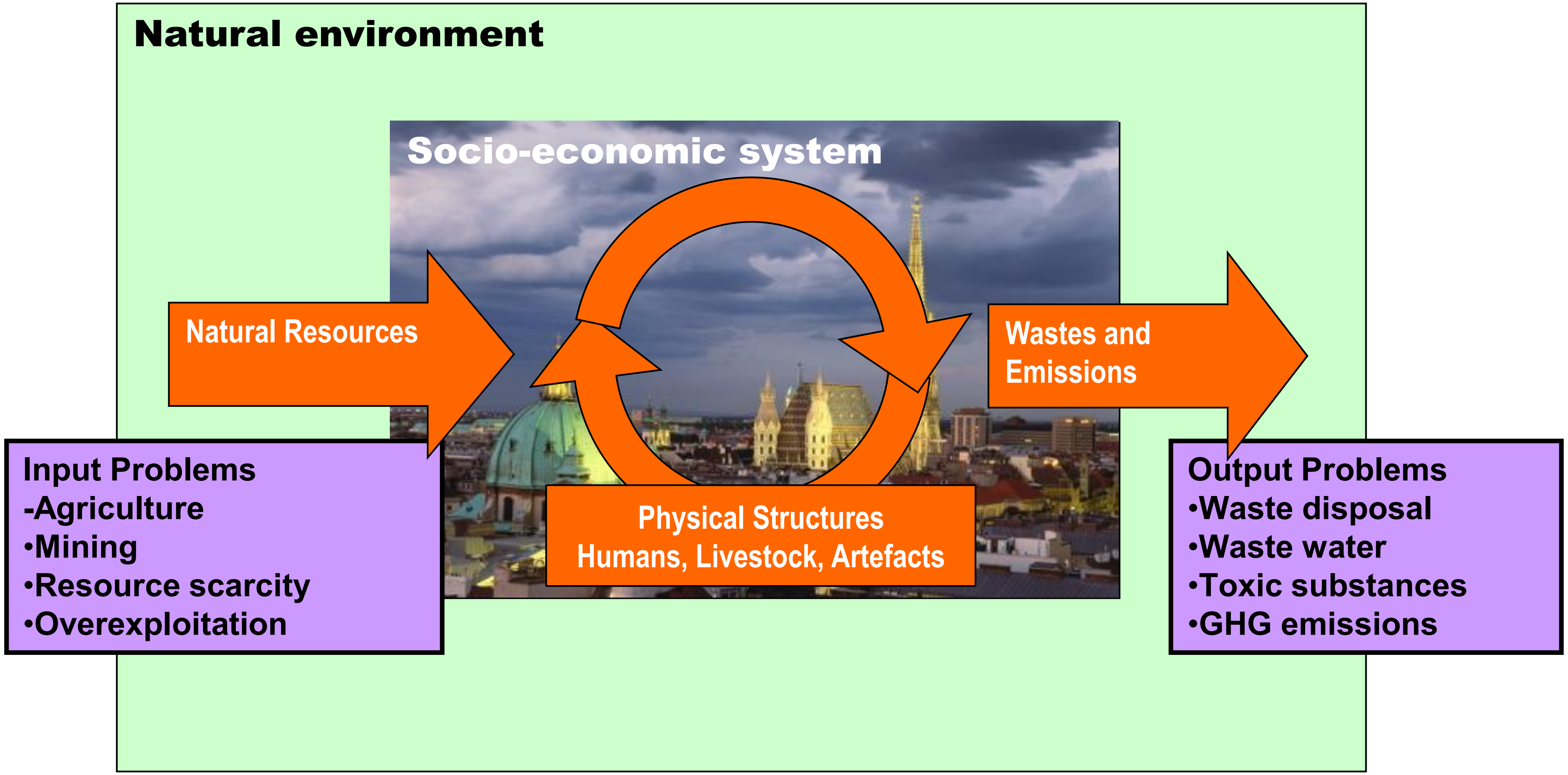
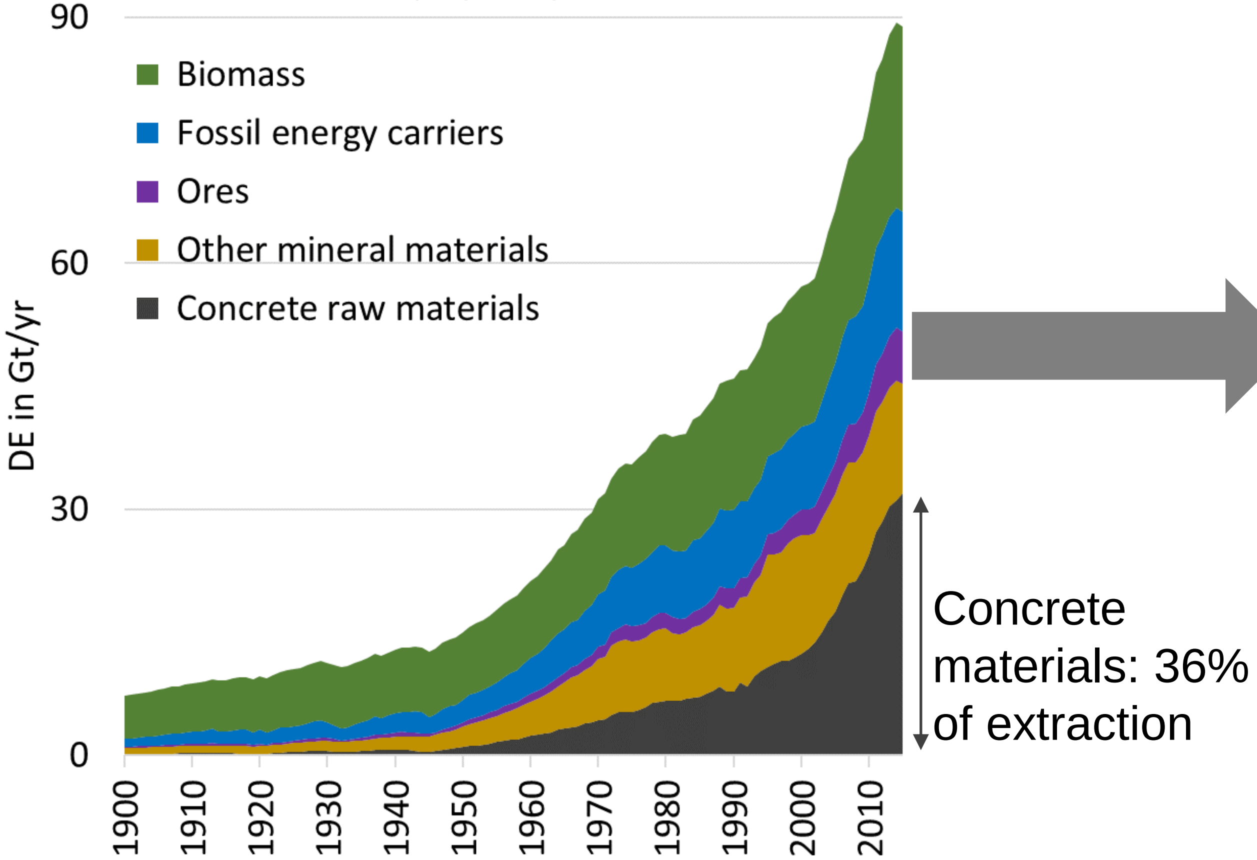
Societie‘s metabolism: Major cause of sustainability problems



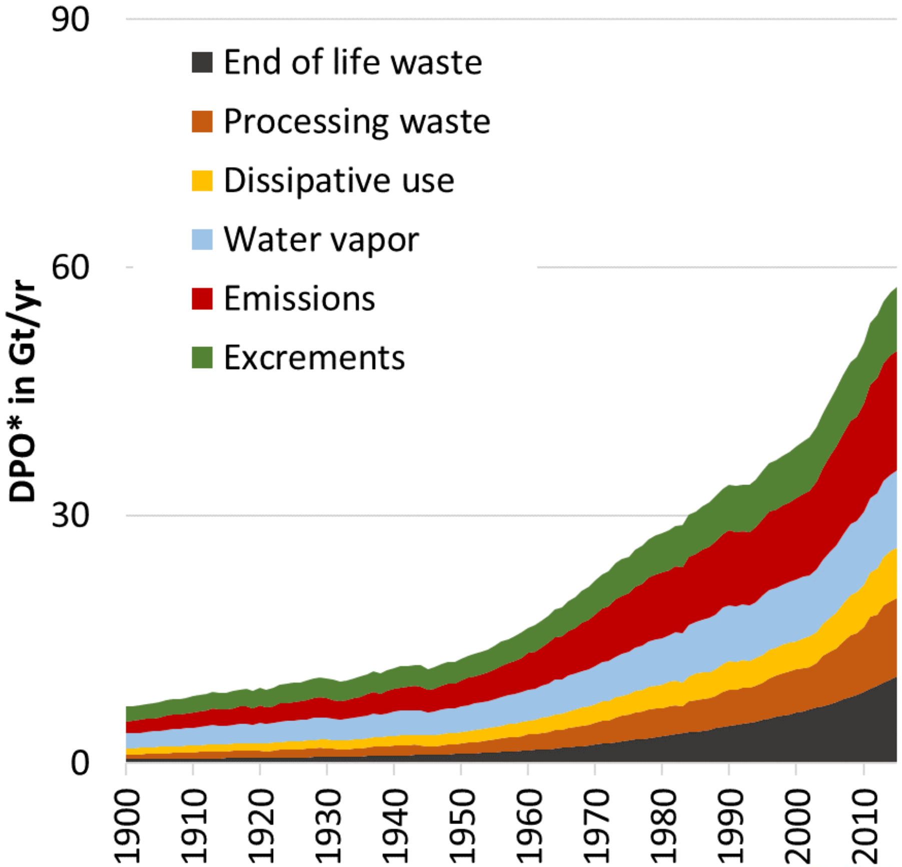
Global material material use 1900-2015

(1Gt = 1 billion t = 10^9 t)

Extraction



Waste & Emissions



Source: Krausmann et al. 2018

Stock-flow-service nexus

- Building up and maintaining stocks (infrastructures, buildings, machinery) requires material and energy.
- Making use of stocks requires energy.
- Stocks and flows together provide essential services to meet human needs.
  - Increase the efficiency of service provision
  - Increase the intensity of stock use
  - Which level of stocks is required for a good life?

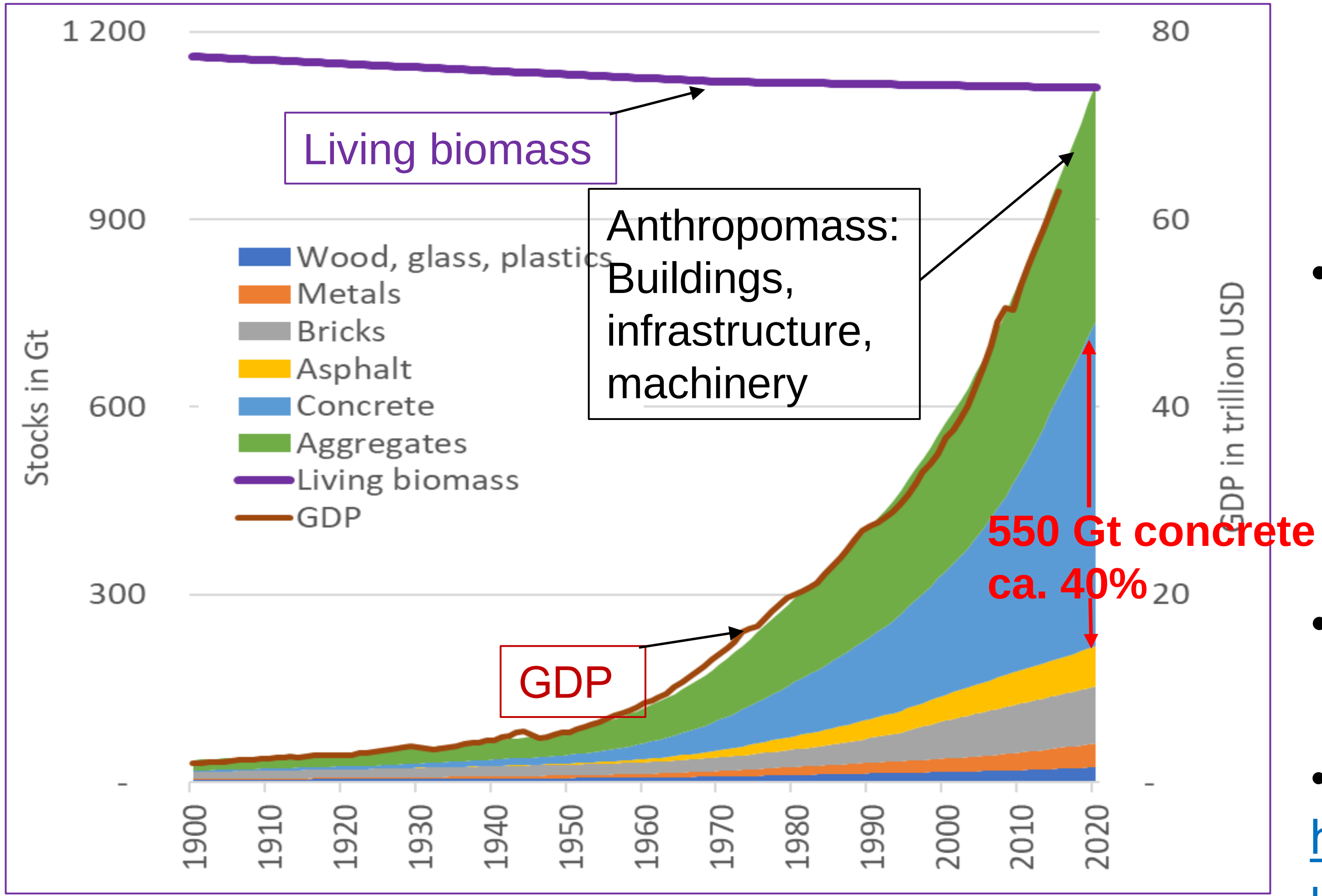
Stocks
Buildings, infra-structures, machinery

Flows
Energy, materials

Services
Contributions to social well-being

Fotos: Helmut Haberl

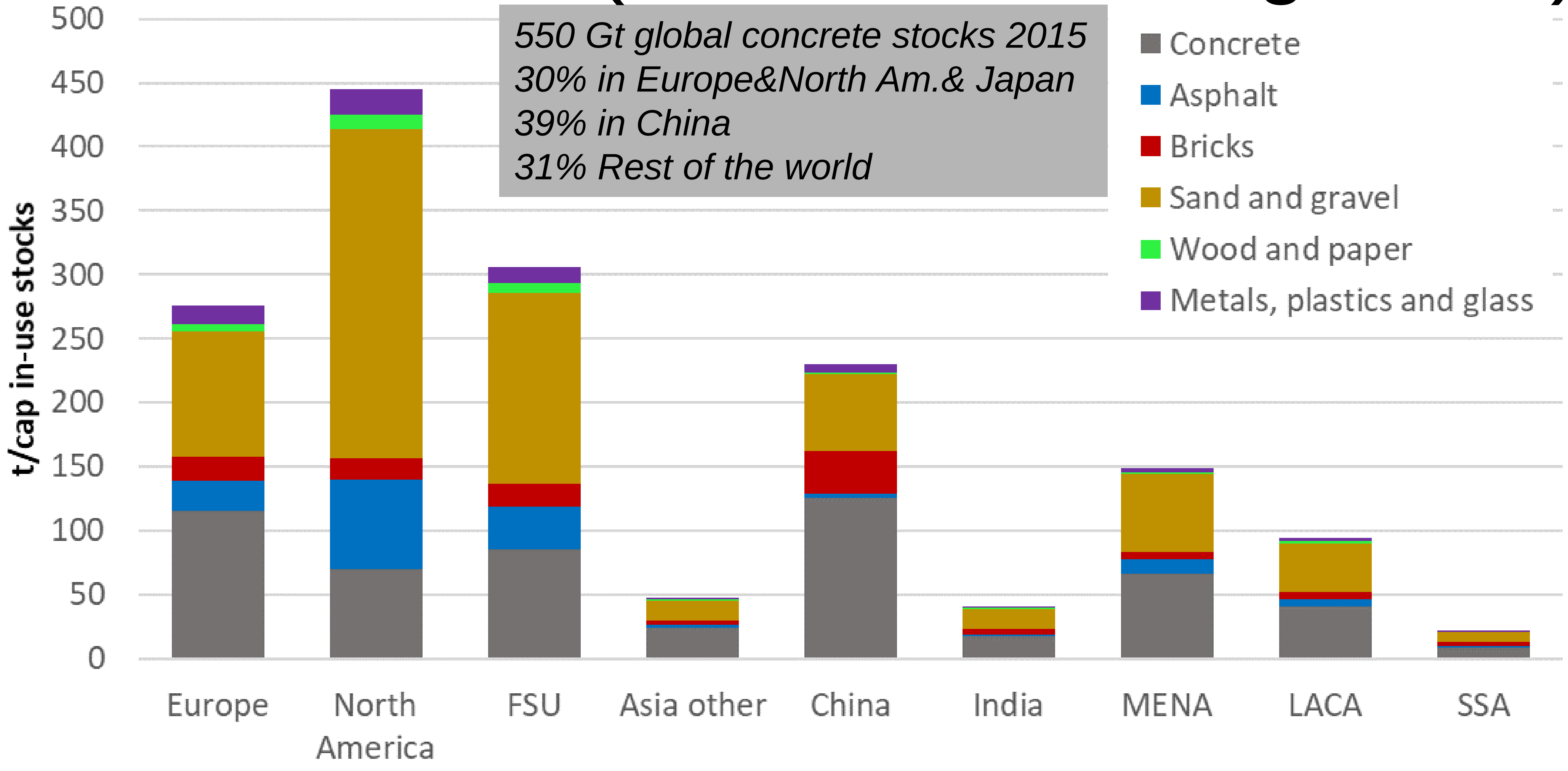
Global stocks of „anthropogenic mass“ vs. biomass



- The mass of in-use stocks (artifacts) increased 27-fold in the last century to 1000 Gt and exceeds the mass of all living biomass on the planet.
- Concrete is the most used (building) material. Globally, ca. 550 Gt of concrete in buildings and infrastructure; ca. 60% in buildings, 40% in civil engineering.
- Global material stocks are growing with GDP
- see: https://anthropomass.org/ or https://www.newcapitalmgmt.com/news/visualizing-the-accumulation-of-human-made-mass-on-earth

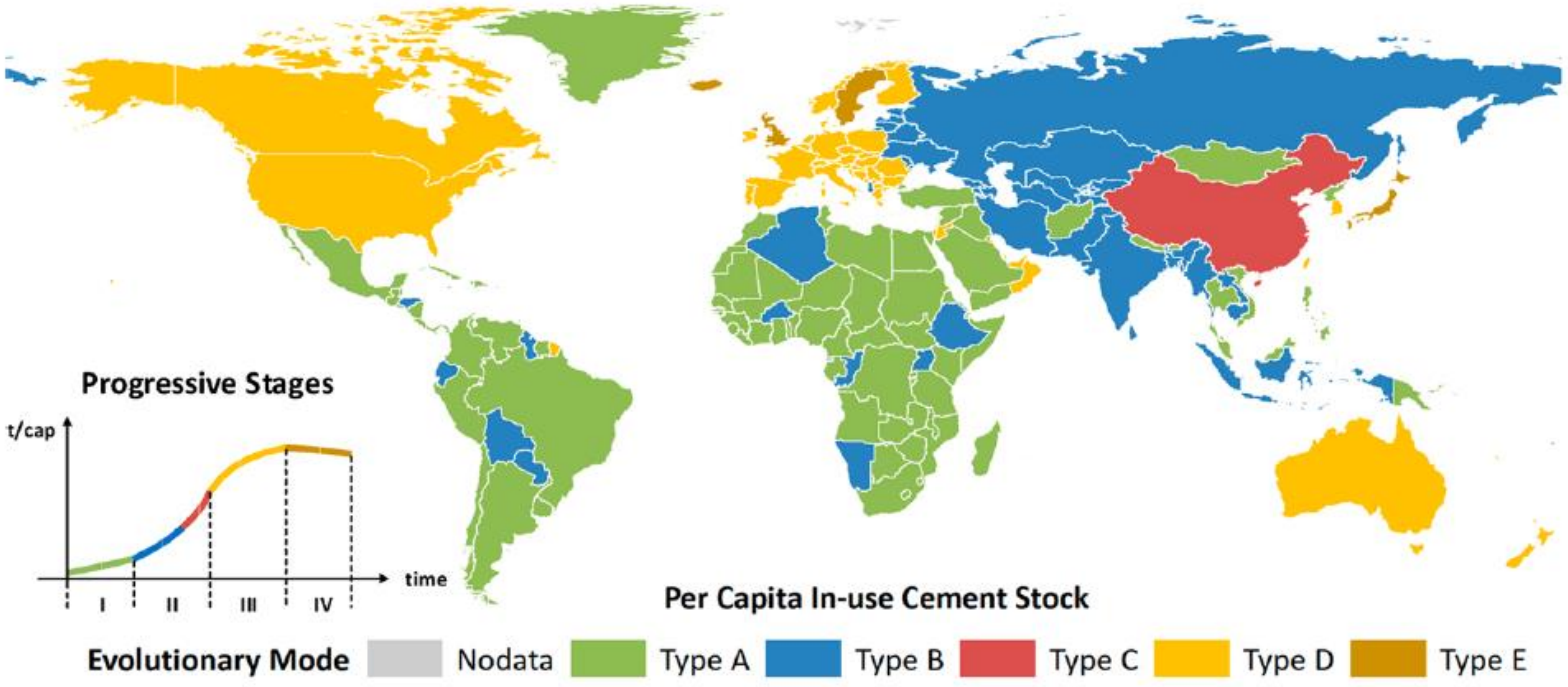
Based on: Elhacham et al. 2020, Wiedenhofer et al. 2021

Large regional differences in per capita concrete stocks (one order of magnitude)



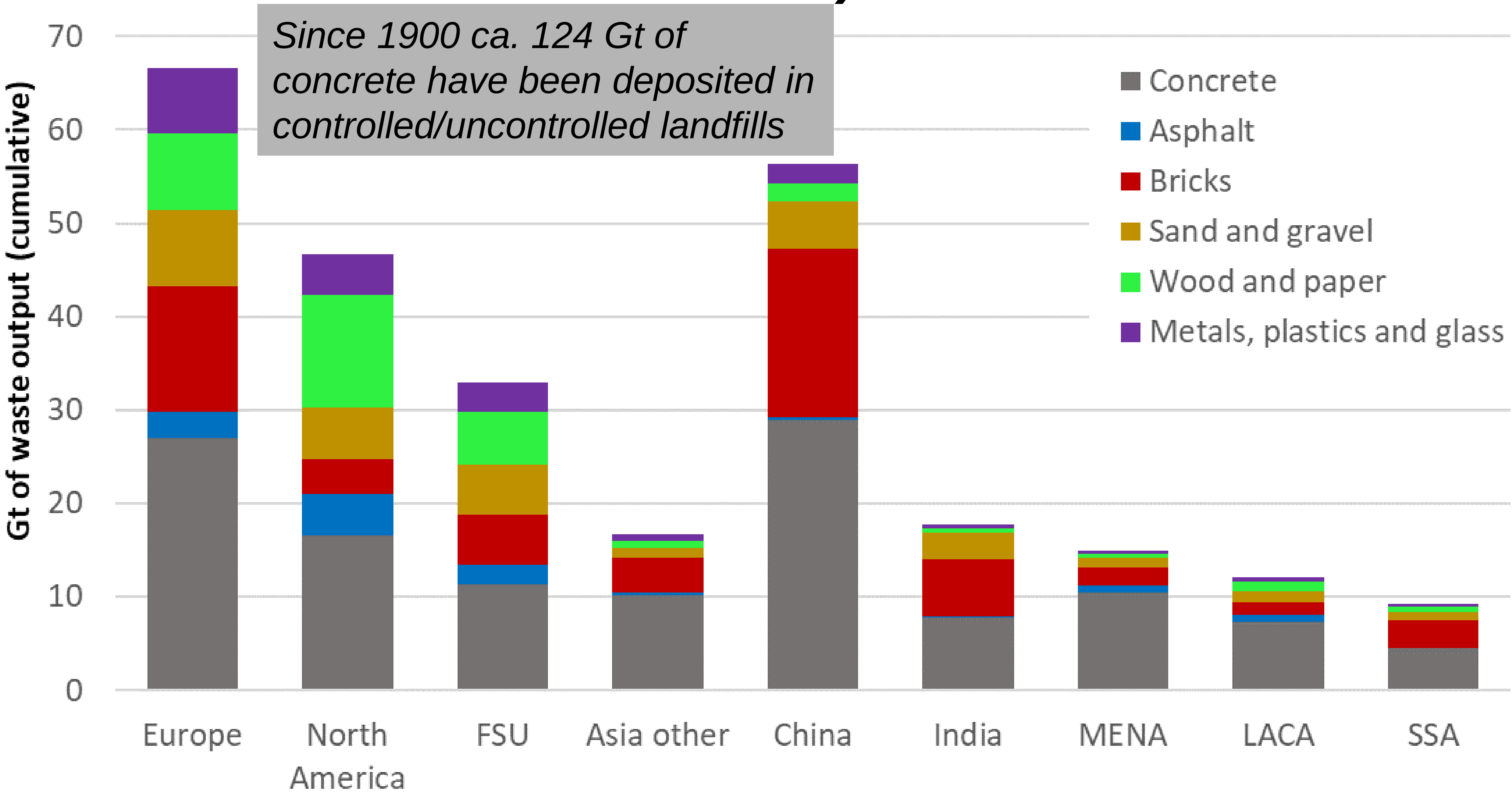
Based on: Wiedenhofer et al. 2021

Global cement stocks will continue to grow: +50% / +70% until 2050 (BAU)



Cao, Z. et al. (2017). Elaborating the history of our cementing societies: an in-use stock perspective. *Environmental Science & Technology*, *51*(19), 11468-11475.

Discarded stocks: Waste output (cumulative 1900-2015)

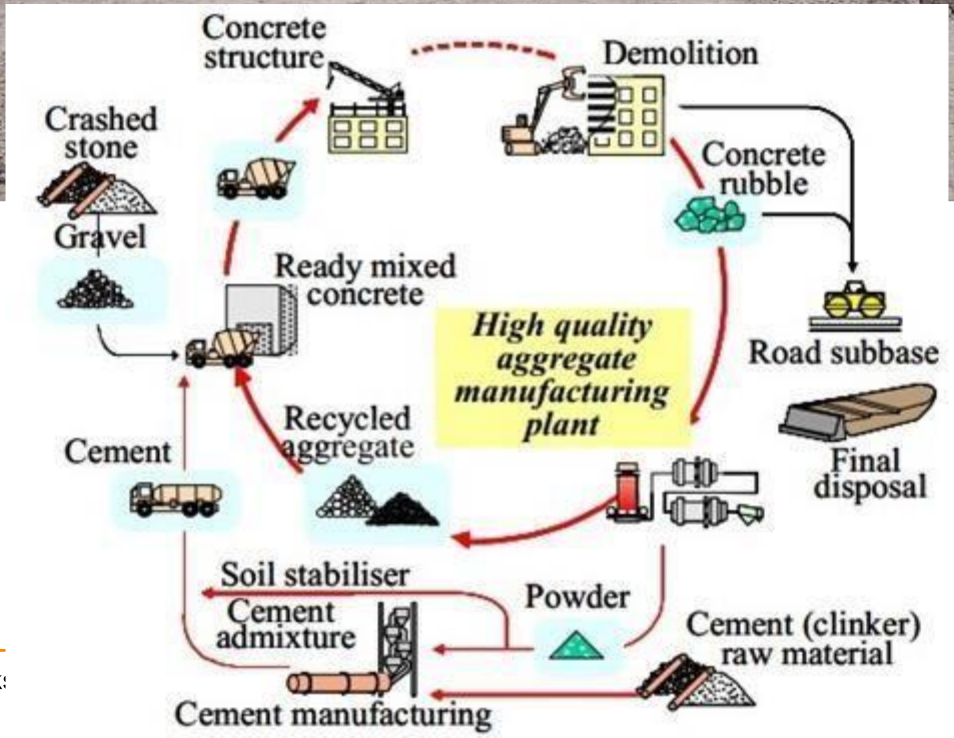


Based on: Wiedenhofer et al. 2021

Concrete Recycling

- Since 1900 ca. 124 Gt of concrete have been discarded to the environment; currently at a rate of ca. 6 Gt/yr
- For Europe it has been estimated that 60% of concrete debris is downcycled (e.g. for use in road subbase layers) and 40% are landfilled; globally, the largest part is dumped to uncontrolled landfills.
- Downcycled concrete replaces natural aggregates; recycling of concrete is practically non existent

https://en.wikipedia.org/wiki/Concrete_recycling#/media/File:Recycling_an_airfield_N03_-_geograph.org.uk_-_379756.jpg



Hirokazu *et al.* 2005

Cement production and GHG emissions

- The production of 4.1 Gt/yr cement accounts for ca. 4% of global CO_2 emissions (process emissions only!).
- Cement production is the 3rd largest source of CO_2 emissions after fossil fuel use and land use change.
- The average intensity of carbon dioxide emissions from total global cement production is 222 kg of C/t of cement (58% from calcination, 42% from fuel combustion).
- Sponge effect: ca. 20% of the emissions from cement production are reabsorbed by the carbonation of concrete

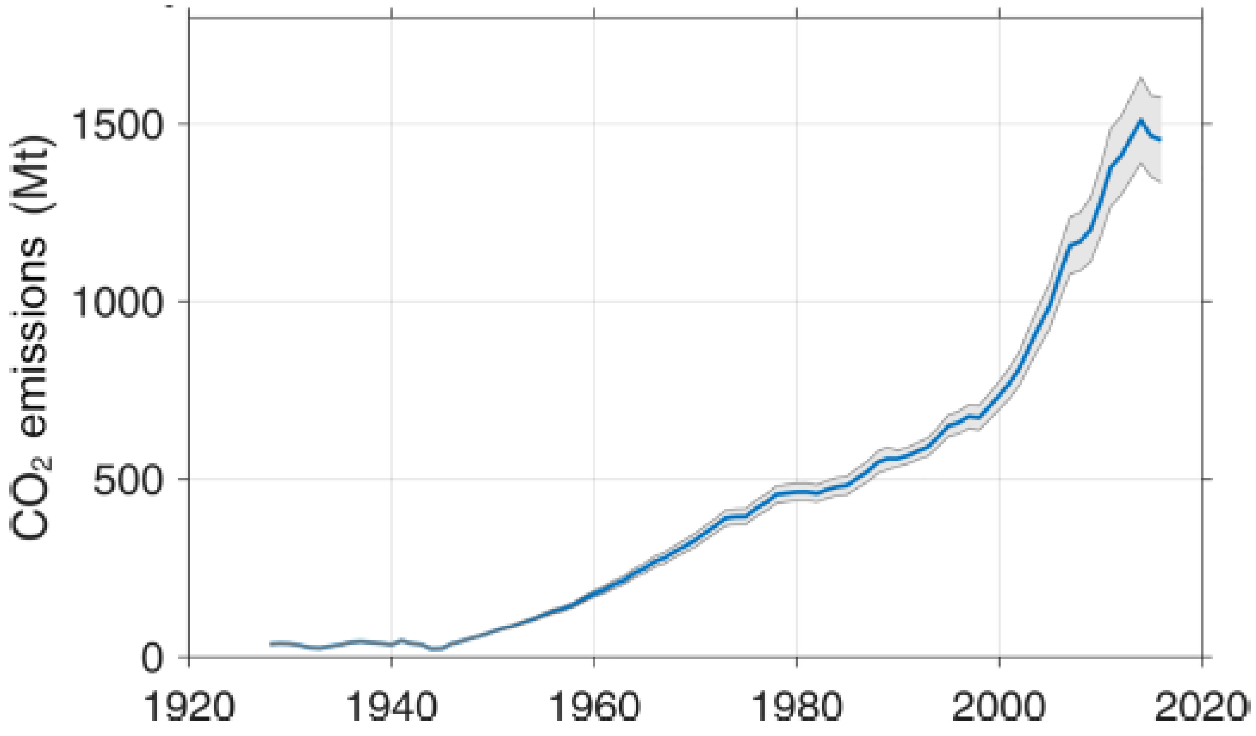


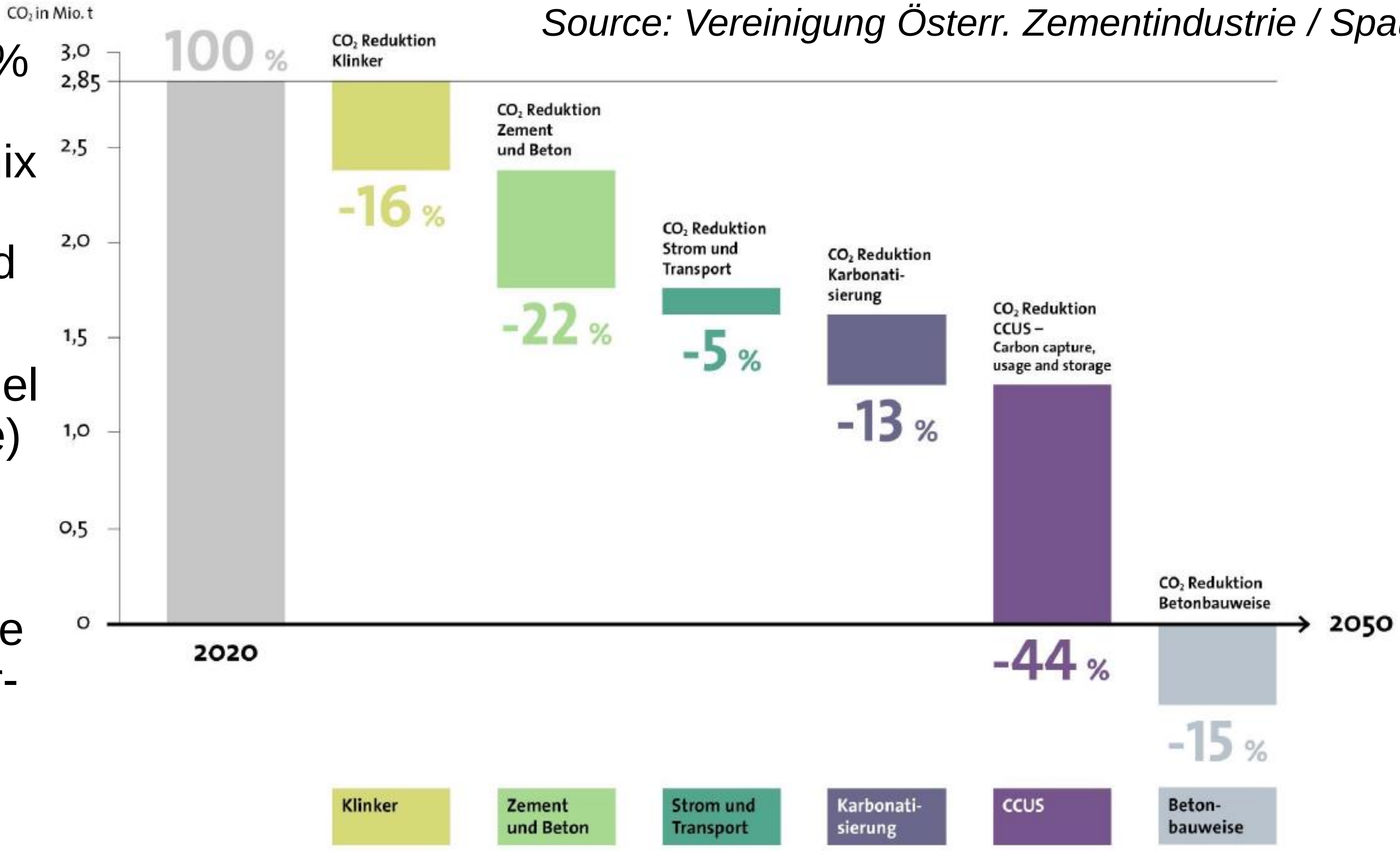
Figure 2. Global process emissions from cement production, with 95 % confidence interval. A step change in uncertainty occurs in 1990, reflecting a significant change in data availability.

Source: Andrew, 2018, Earth Syst. Sci. Data, 10, 195–217, 2018

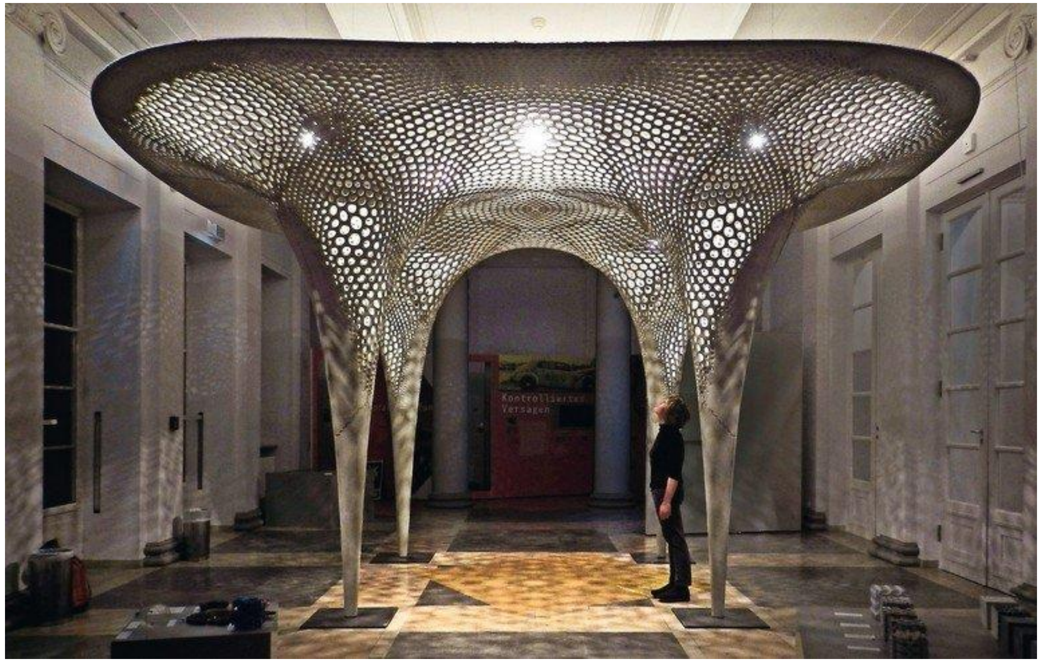
Decarbonization roadmap of the Austrian cement&concrete industry until 2050

- Low-clinker cement (70% -> 52% due to finer grinding, raw material mix (calc. Ton); clinker determines curing speed of concrete!)
- Energy efficiency and fuel mix (combustable waste)
- Carbonatisation (in the recycling phase)
- Carbon Capture and Use (with Borealis – polymer-chemistry)

Source: Vereinigung Österr. Zementindustrie / Spaun



Demand reduction through material efficient construction?



Source: ILEK Stuttgart

Source: ETH Zürich

Source: ILEK Stuttgart

Further reading

- Cao, Z., Shen, L., Løvik, A. N., Müller, D. B., & Liu, G. (2017). Elaborating the history of our cementing societies: an in-use stock perspective. *Environmental Science & Technology*, *51*(19), 11468-11475.
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- Gebremariam, A. T., Di Maio, F., Vahidi, A., & Rem, P. (2020). Innovative technologies for recycling End-of-Life concrete waste in the built environment. *Resources, Conservation and Recycling*, *163*, 104911.