Pathways towards a net-zero carbon emissions cement: a modelling-based approach integrating demand and supply

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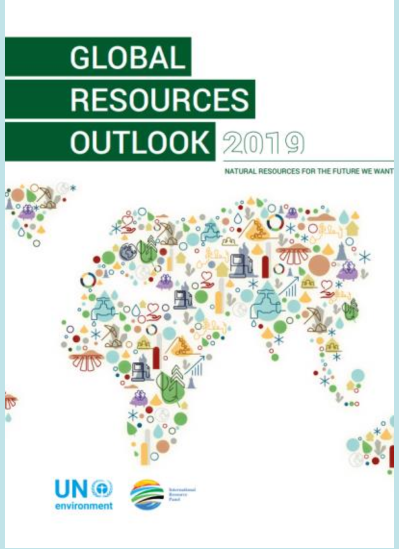
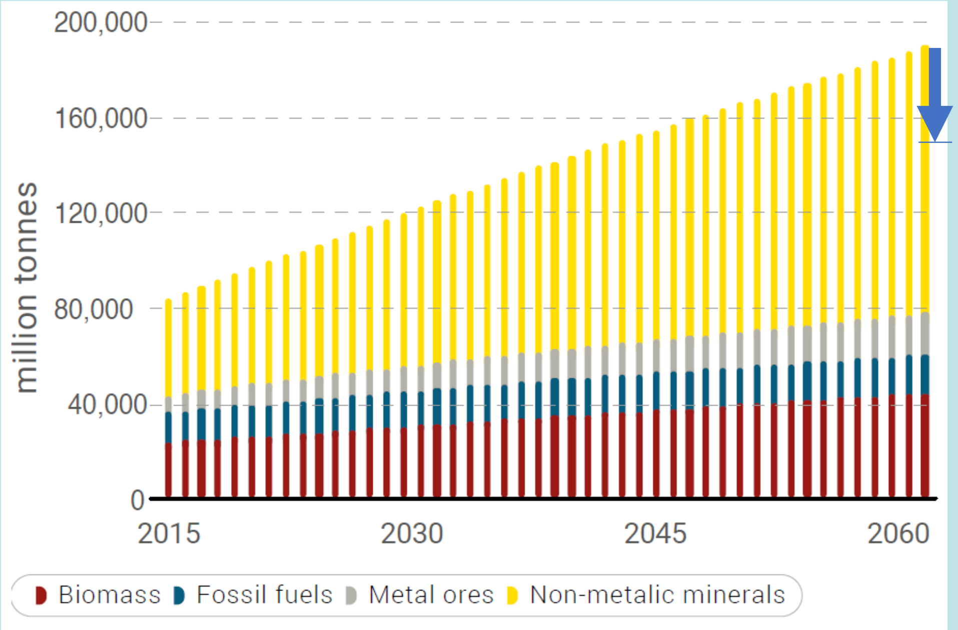
Agenda

1. **Introduction: why?**
2. Methodology: how?
3. Results: what & when?
4. Recommendations & Conclusions

Materials and industry: challenges



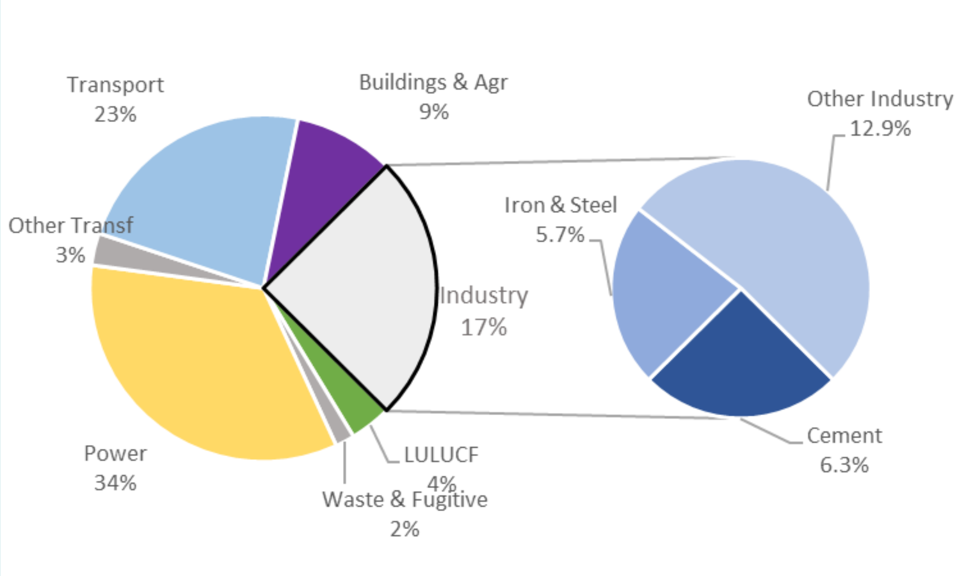
World materials extraction



Towards Sustainability scenario

Source: Global Resources Outlook 2019, UNEP International Resources Panel

World CO_2 emissions, 2018



Source: GECO 2020, JRC

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Materials and industry in the context of climate change

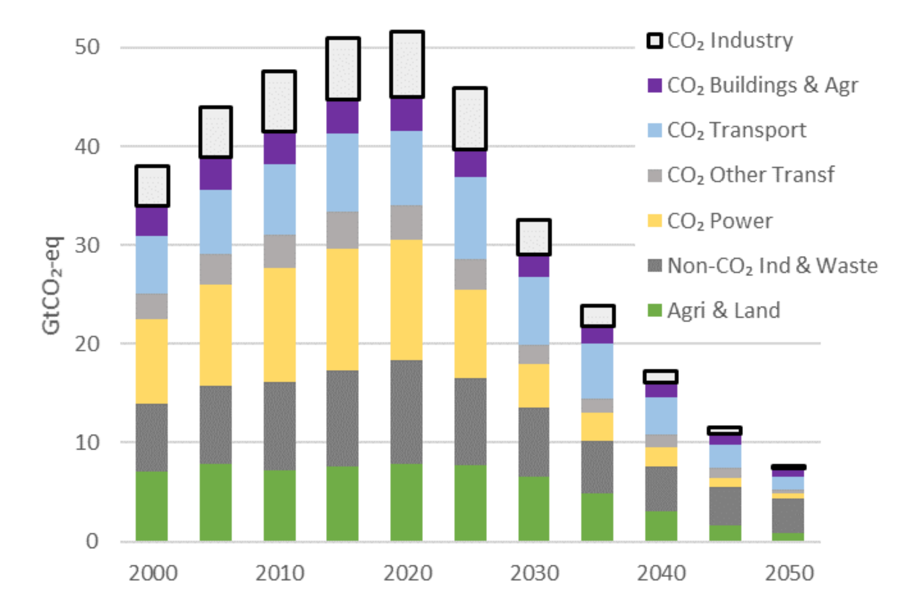
- Increasingly ambitious climate change mitigation strategies
  - EU, USA: net-zero GHG in 2050
  - China: net-zero CO2 in 2060

Is it possible to reconcile increase in well-being for all (and associated materials demand increase) with aspirations of decarbonization of the world economy?

- We propose to represent both material demand and production in an energy model

  → Focus on cement

World GHG emissions, 1.5C scenario



Source: GECO 2020, JRC

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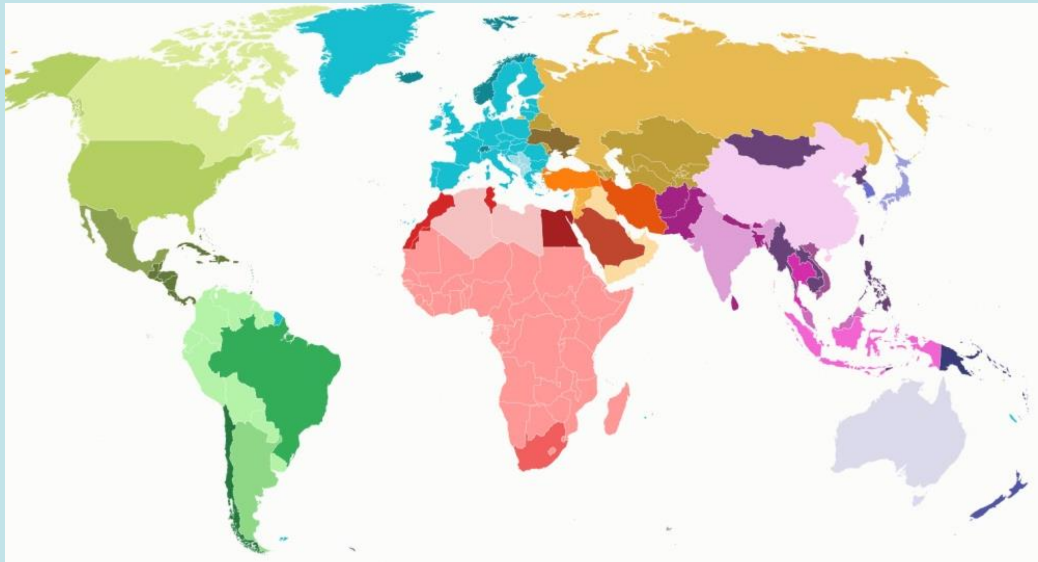
POLES: Prospective Outlook on Long-term Energy Systems

Projections of the evolution of the world energy system

- Long-term model (to 2050-2100)
- EU + 39 countries / regions (OECD, G20)
- Partial equilibrium, simulation

Output

- International energy prices & trade
- All energy sources and vectors
- All GHG emissions (linkage with specialist tools for non-energy)



https://ec.europa.eu/jrc/en/poles

Resources & production → Trade → Transformation → Consumption → GHGs & other externalities

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Scenarios: policy context

New/updated work

- Enhancement of existing industry module
  - Physical quantities as driver to industry demand
  - Techno-economic options in industry mitigation

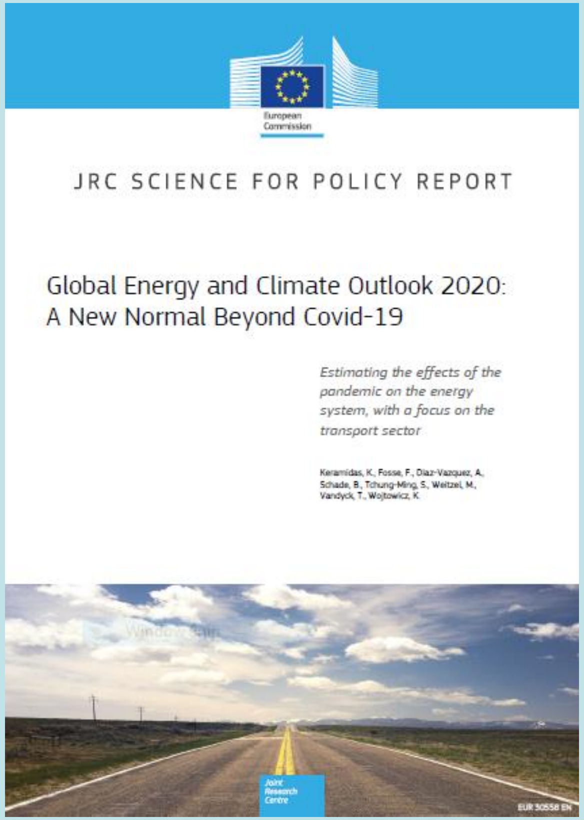
- Industry emissions: result of overall economy pathway (relative costs vs other sectors)

Policy context from JRC annual report GECO

→ Reference scenario (current policies)

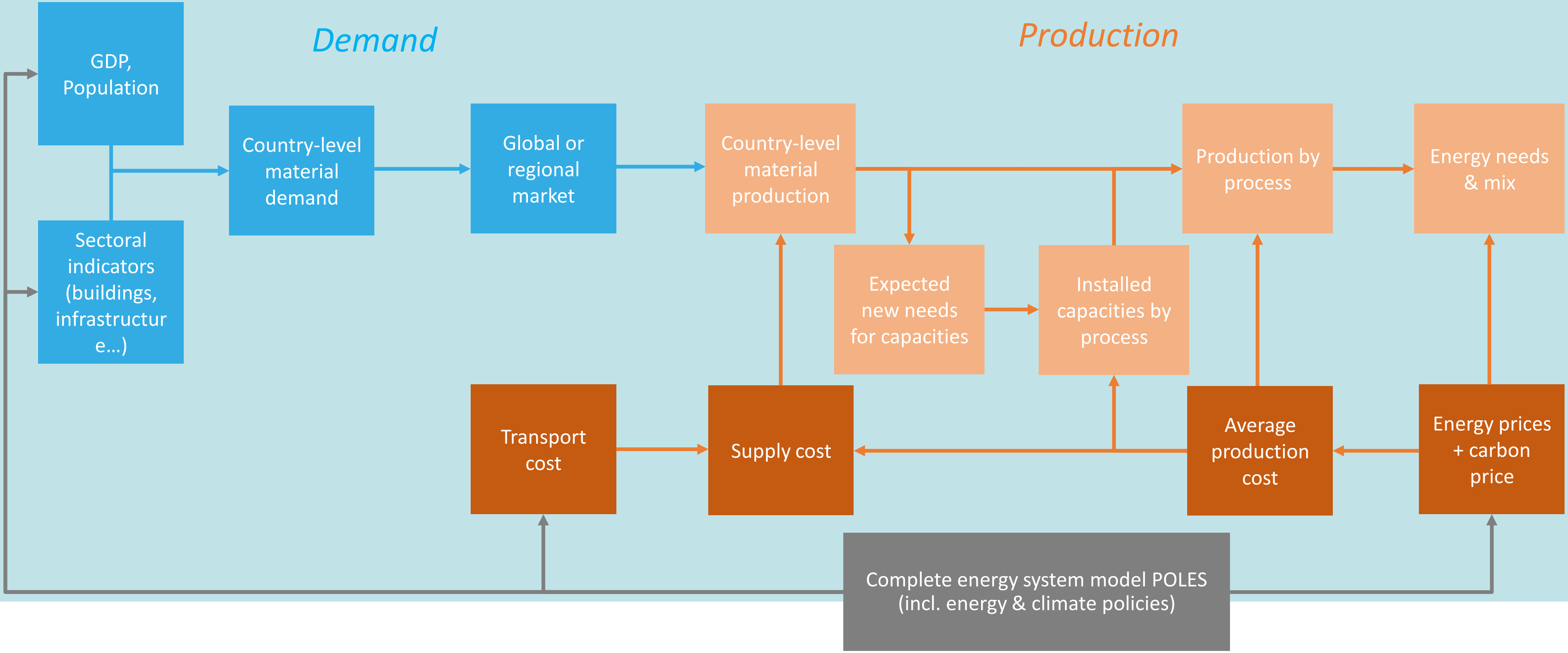
→ 2°C climate change scenario

→ 1.5°C climate change scenario



https://ec.europa.eu/jrc/en/geco

Cement Industry - POLES module: Methodology



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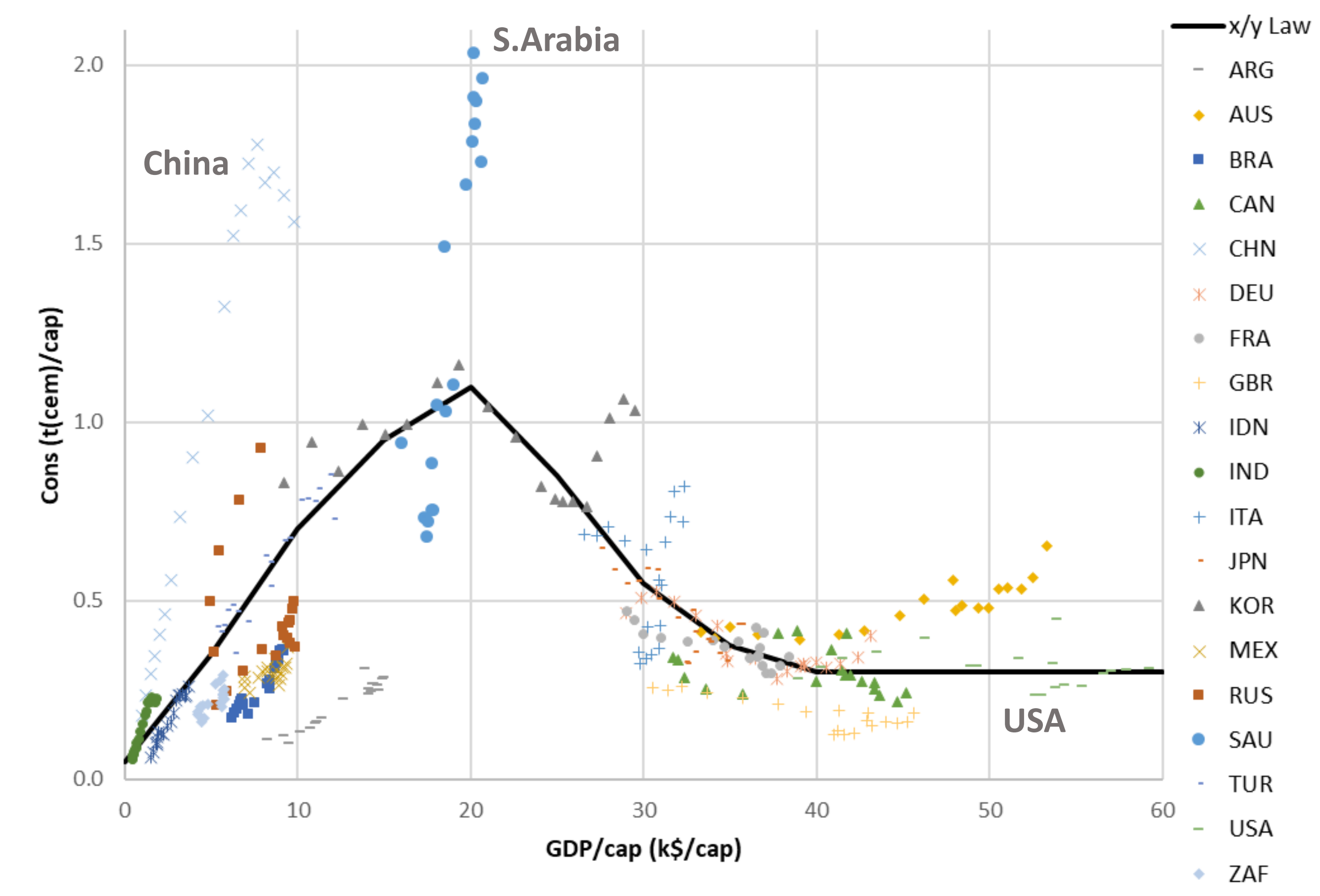
Cement demand: Intensity of use & Specific uses



1990-2018 for G20 countries

Annual demand per capita

General shape of growth-peak-decrease

- From industrialization to services
- Rich countries: apparent plateau at non-zero level
- Outliers

+ Uses within total,
with specific material consumption

1. Buildings: kg/m2 of floor surface
2. Road infrastructure: kg/km2 of paved network
3. Power: kg/MW of installed capacity (by technology)
   + kg/GWh of T&D network extension

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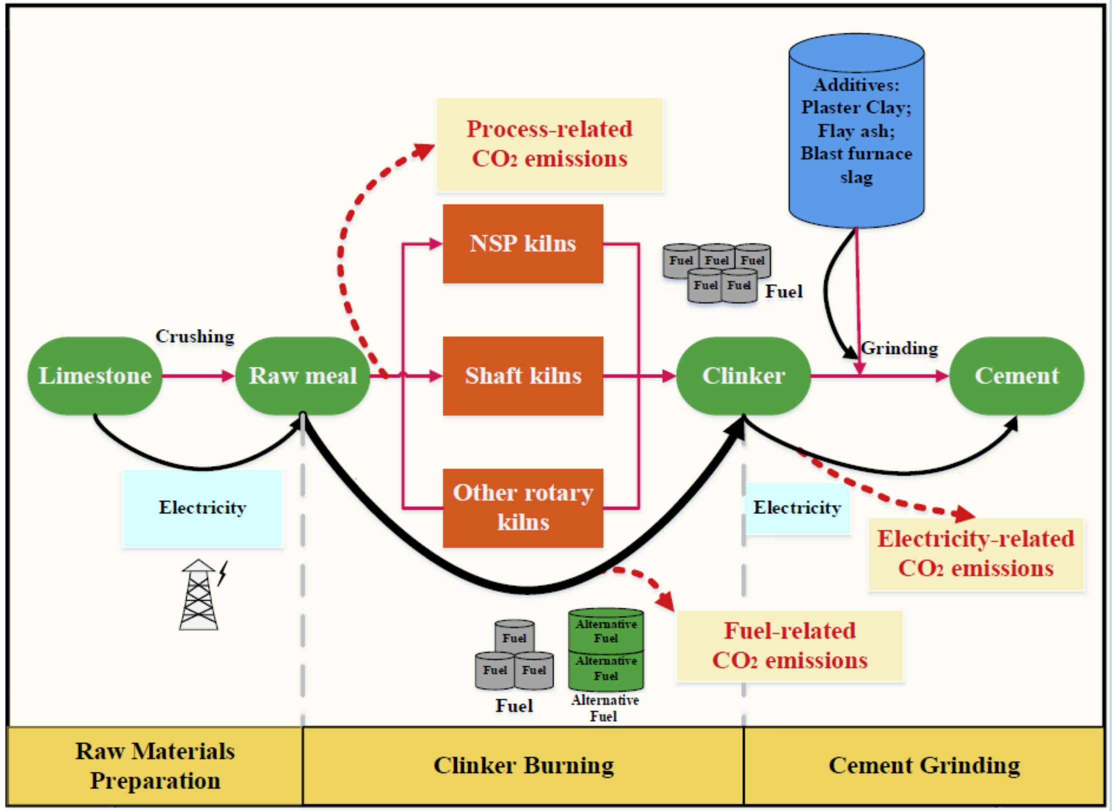
Cement production processes

Which processes?

- Vertical shaft: old technology
- Wet/Semi-wet/semi-dry rotary kiln: 2nd half of 20th century
- Dry-long rotary kiln: currently dominant
- Under development: pure electric kiln (indirect heating)



Source: Zhang et al, Journal of Cleaner Production, 2018

Process steps:

1. Electricity for raw material preparation and product grinding
2. Pre-calciner (up to 900 °C) → possibility to electrify
3. Kiln (up to 1400 °C) → thermal fuels
   + use of kiln waste heat in pre-heater

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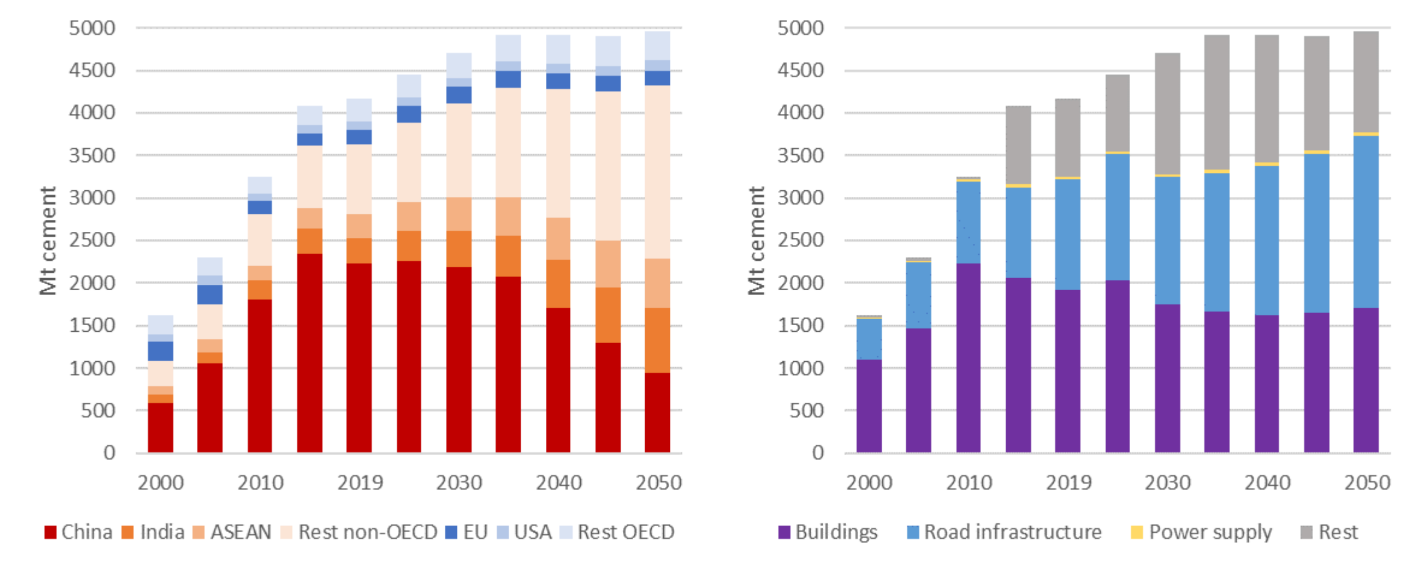
Projections: Cement demand: By region and by use

- China demand plateaus, then global demand plateaus
- Growth of demand driven by other Asia and other non-OECD

Demand, Reference



- Global demand for buildings construction stabilizes
  → decrease in China, increase elsewhere non-OECD
  → urbanization: decrease in demand per floor space

Unlikely return to global high growth of 2000-2015

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Projections: Cement demand: Changes in material uses (1)

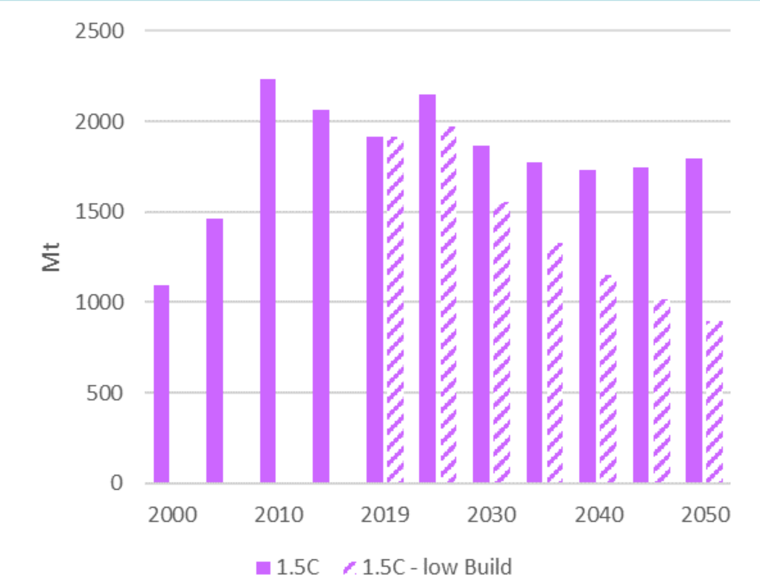
- Different materials for **buildings**?
  1. Material substitution: wood, steel, glass
  2. Decrease clinker/cement ratio (current avg 80%) or cement content in concrete (current avg 20%)
     - As much as half less possible without loss in physical properties?
     - *…but dependent on availability of substitutes (fly ash, slags)*

- Case study: new construction by 2050 globally uses 50% less cement
- Cumulated 2020-50: -24% (-14,000 Mt)
- *…but to fully substitute with wood: timber plantation needs equivalent to 40% of EU surface area!*

Construction standards globally: key driver in material efficiency

Source: Haut-Bois, France, 2020
(80% less concrete)

Cement for Buildings



Projections: Cement demand: Changes in material uses (2)

- Indirect system impacts?
- Shift to low-carbon **power** system & electrification impacts cement demand
- Cum. 2020-50: +62% (+600 Mt)
- *an additional 0.3 $GtCO_2$…to avoid >180 $GtCO_2$ with low-carbon power*

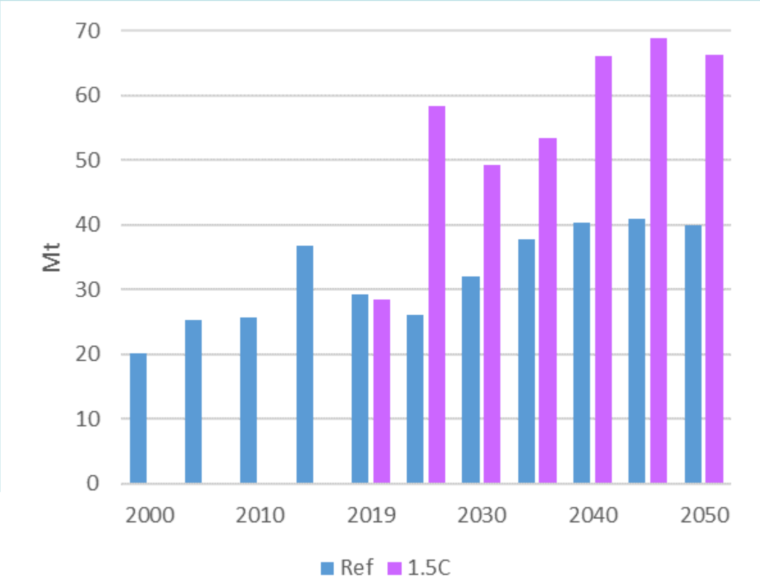
Coal: 250 t(concr)/MW

Wind: 420 t(concr)/MW

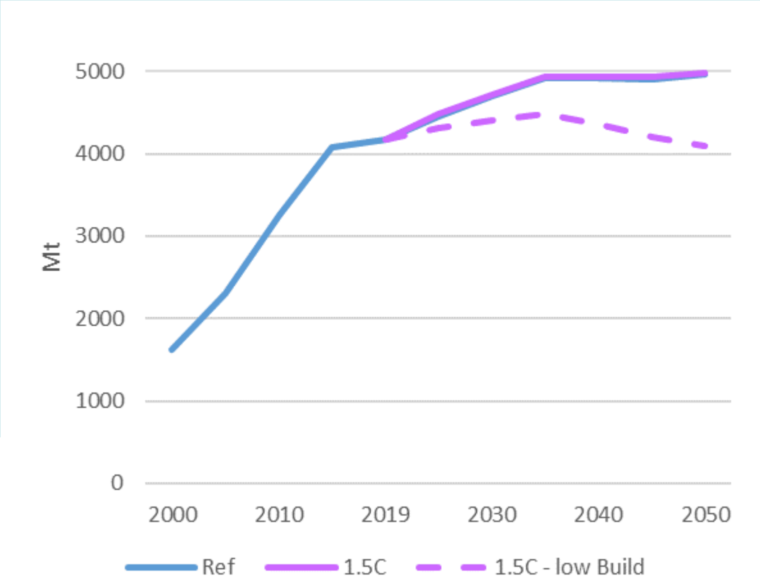
Source: IFPEN, 2019

Rebound effect for power generation decarbonization relatively small on overall cement demand

Cement for Power



Total cement demand



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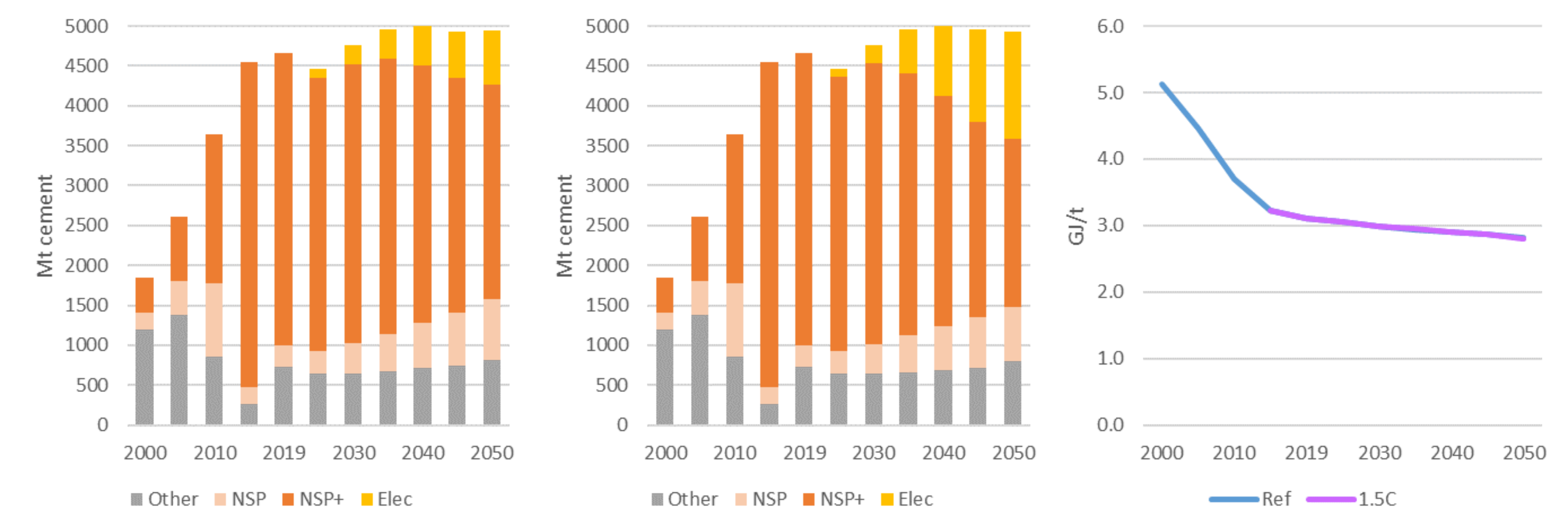
Projections: Cement production: Production capacities

- Recent past: major shift to most energy-efficient (and costlier) process (esp. China):
  New Suspension Pre-heater (NSP)
  and with Pre-calciner (NSP+)

Climate policies accelerate the penetration of electric process

Reference *1.5C* *Energy intensity*



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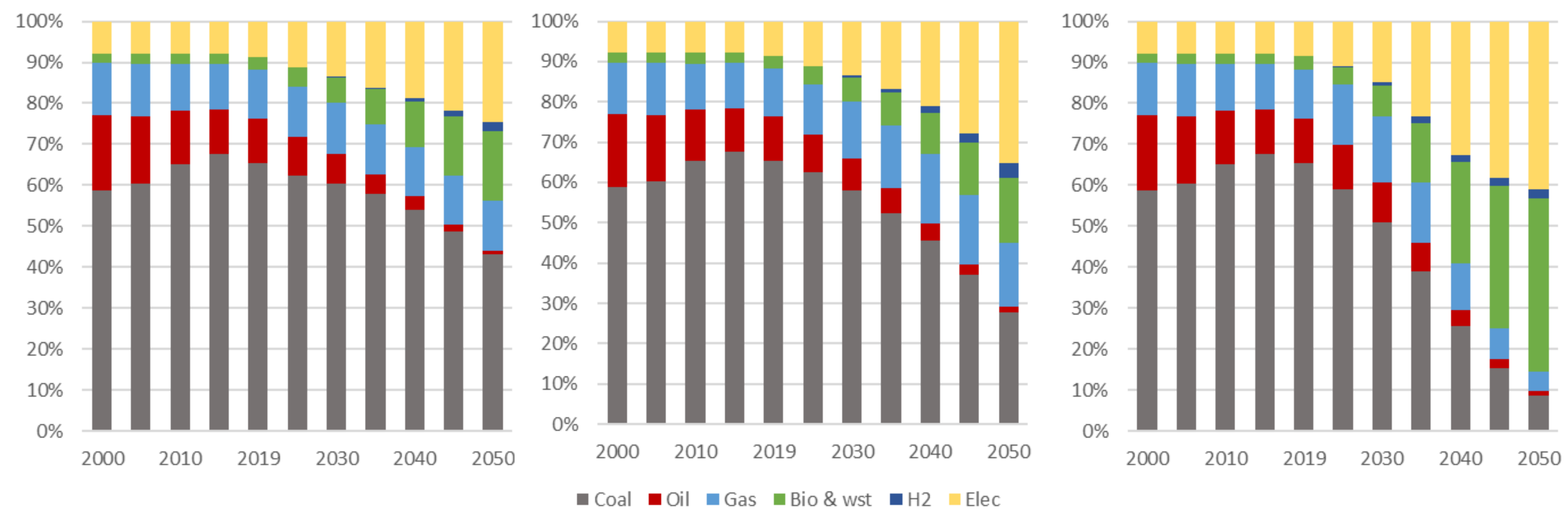
Projections: Cement production: Energy mix

- Historical predominance of coal
- Electricity in all processes for grinding

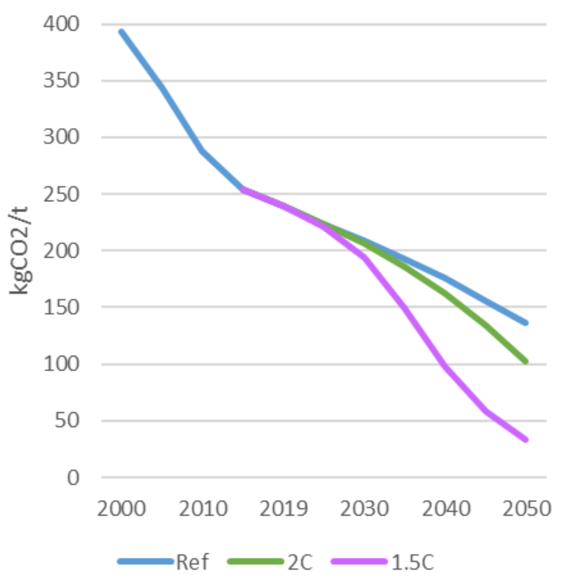
- 2C policies → fuel switch, electrification
- 1.5C policies → complete coal phase-out
- Synthetic fuels (H2, e-fuels): higher cost
- *…but impacts of biomass use: land use, biodiversity, air pollutants*

Pre-calciner electrification retrofit and higher use of solid waste & biomass

Reference *2C* *1.5C*



Emissions intensity of energy mix



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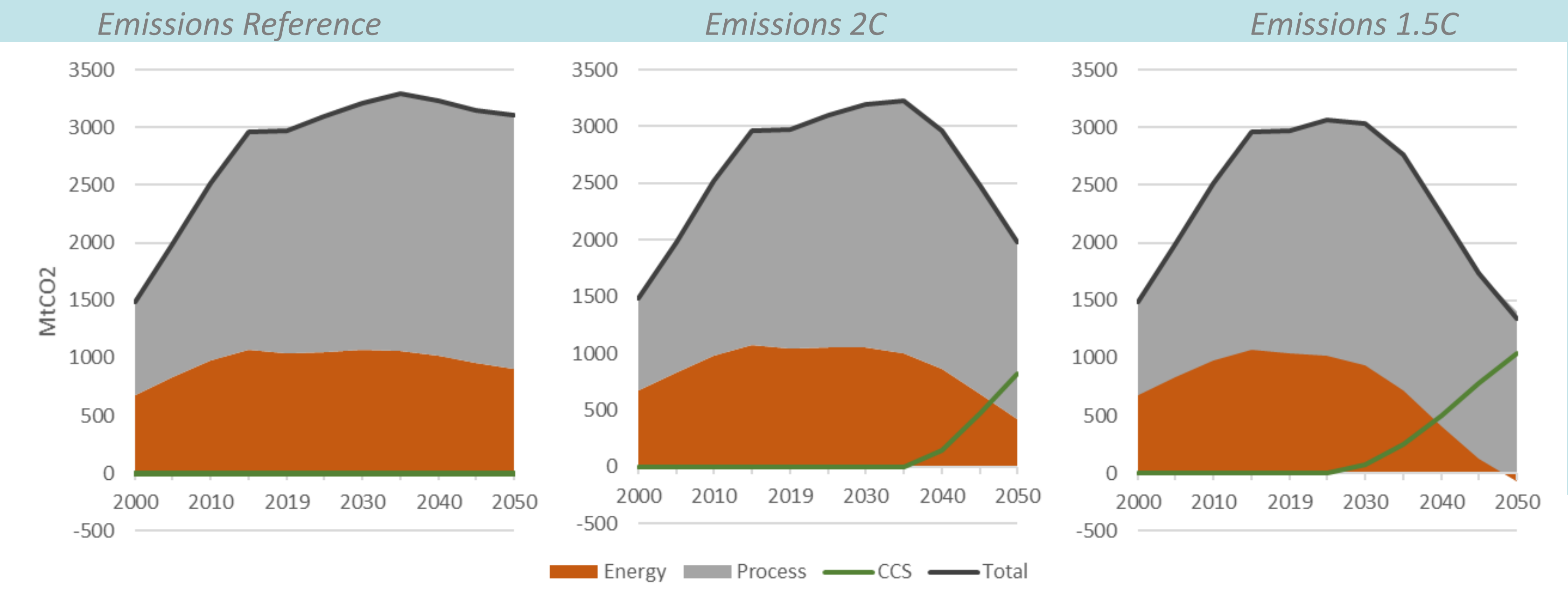
Projections: Cement production: Carbon capture and storage (CCS)

- ~ 60% of emissions come from process (clinker production)
- Calcination + energy combustion in the same space → CO_2-rich flue gas → possible leading role of cement industry in CCS
- Bioenergy + CCS: possibility to become net-negative
- *...but significant reliance on this single-solution*

- 2020s: bring CCS concept from pilot to large-scale solution
- World: ~ 3000 cement plants → 60 plants CCS-ready in 2030 in 1.5C scenario

CCS necessary for significant emission reductions



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Prioritising actions in the next decade

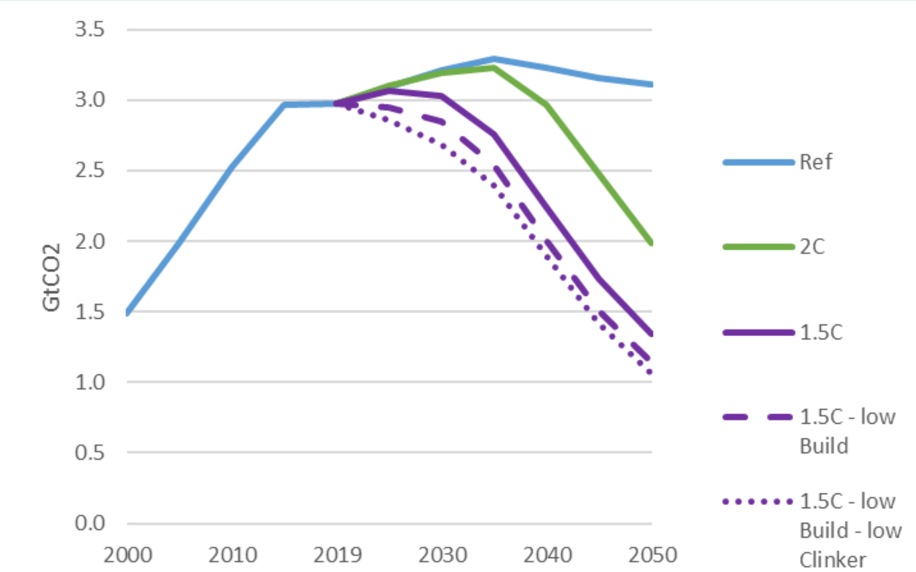
Ranking of reduction options **by 2030**:

1. **Material efficiency**: revise construction codes in buildings (lower-clinker cement, substitution by wood/steel/glass)
2. **CCS**: start adding carbon capture to existing cement plants, start building associated storage infrastructure
3. **Electrify** part of existing process (pre-calcination)
4. **Biomass** and waste: extend use to replace coal

Considerations **towards 2050**:

- Gaseous fuels (NG, H2): minor role in 1.5C scenario
- Beware of trade-offs! Biomass use and sustainability limits
- R&D: investigate low-TRL options: CO2-curing(for prefabricated blocks), new binder formulas
- Rebound effect on materials demand for power generation: relatively small effect for overall cement demand
- Attainment of net-zero relies on speed of deployment of CCS

Cement industry emissions



Conclusions

<u>Future work</u>

- Demand: explore different laws: strategies of development, urban forms, land use
- Trade: carbon leakage & carbon tax border adjustment
- Production: consider emergent technologies with low TRL
- End-of-life/recycling

<u>Integrated demand/supply assessment</u>

- Consider cement projections together with other materials modules:
  - Steel
  - Hydrogen

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Thank you!

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