

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

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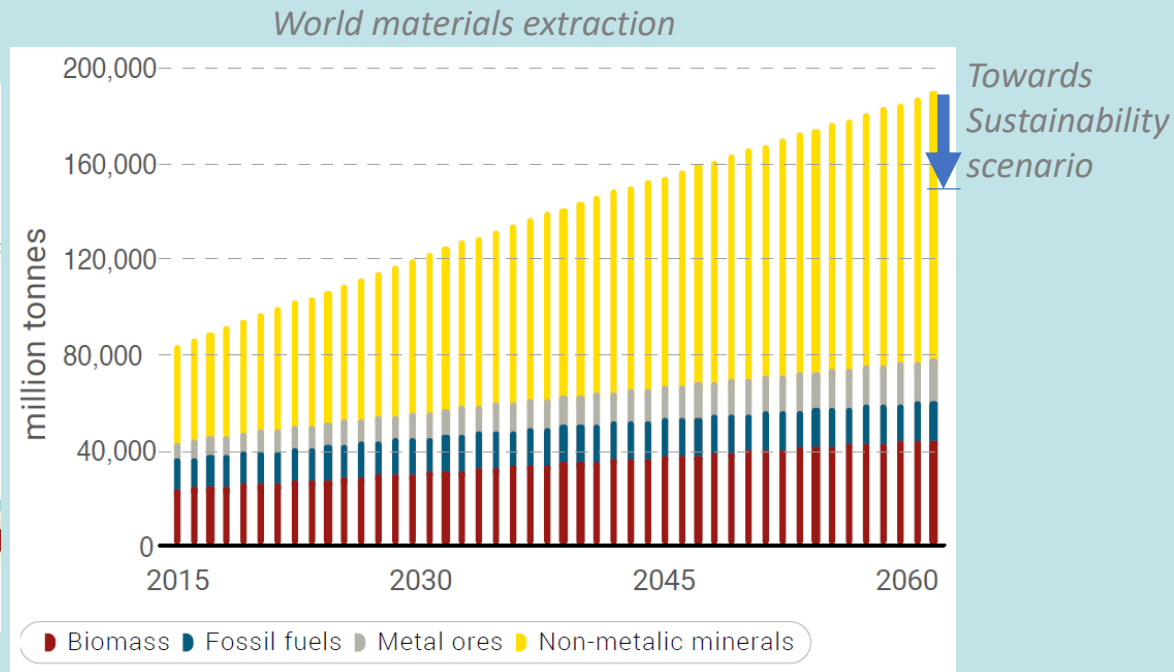
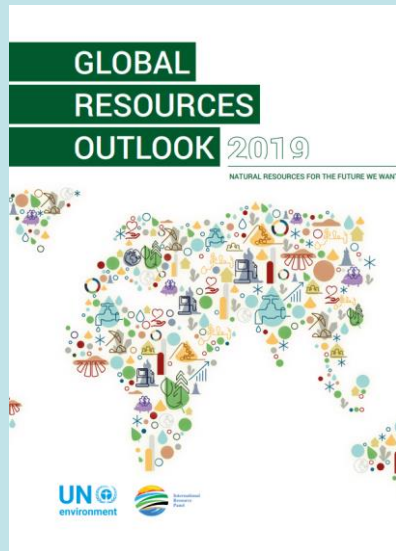
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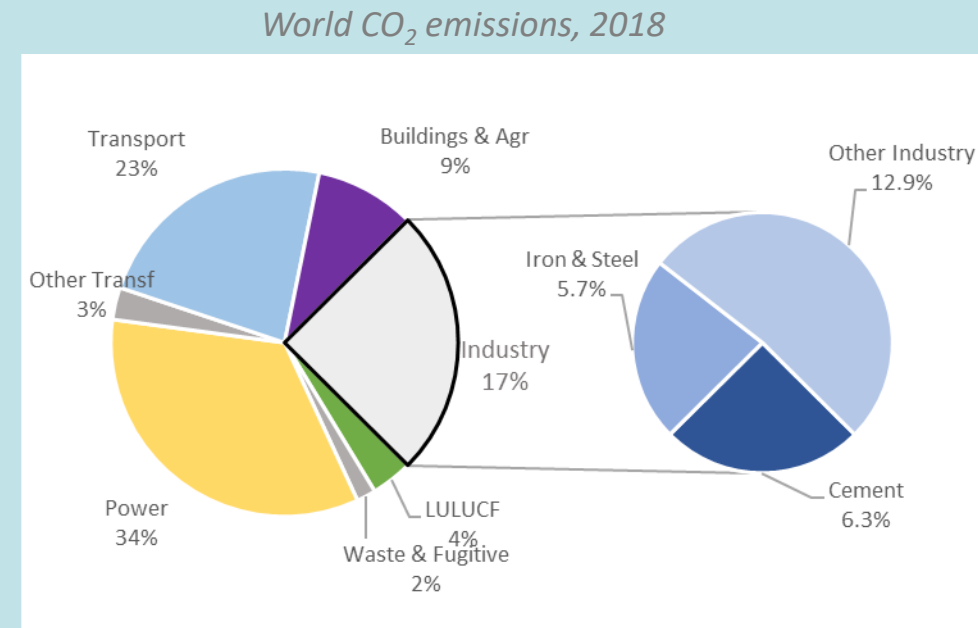
Agenda

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

Materials and industry: challenges



Source: Global Resources Outlook 2019, UNEP International Resources Panel



Source: GECO 2020, JRC

Materials and industry in the context of climate change

- Increasingly ambitious climate change mitigation strategies

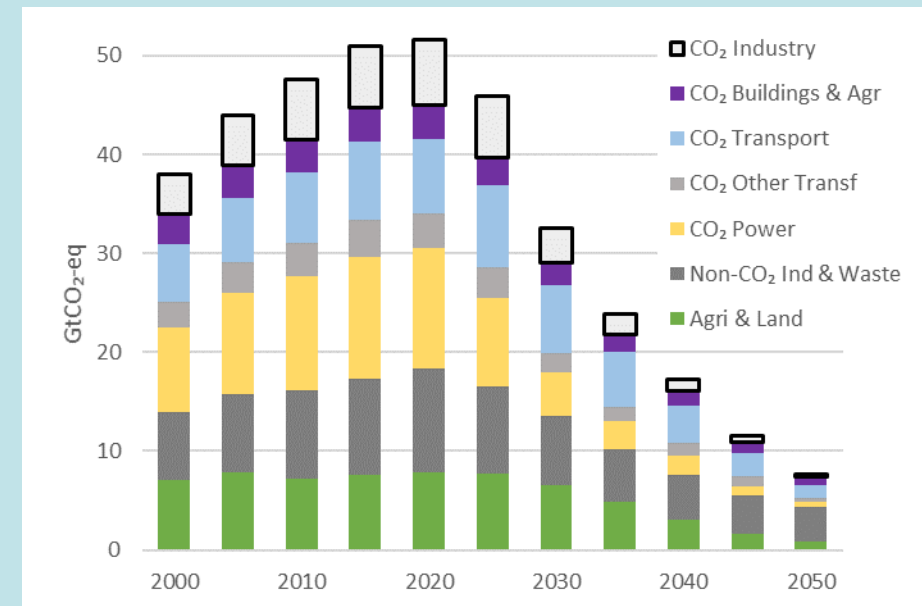
- EU, USA: net-zero GHG in 2050
- China: net-zero CO₂ in 2060

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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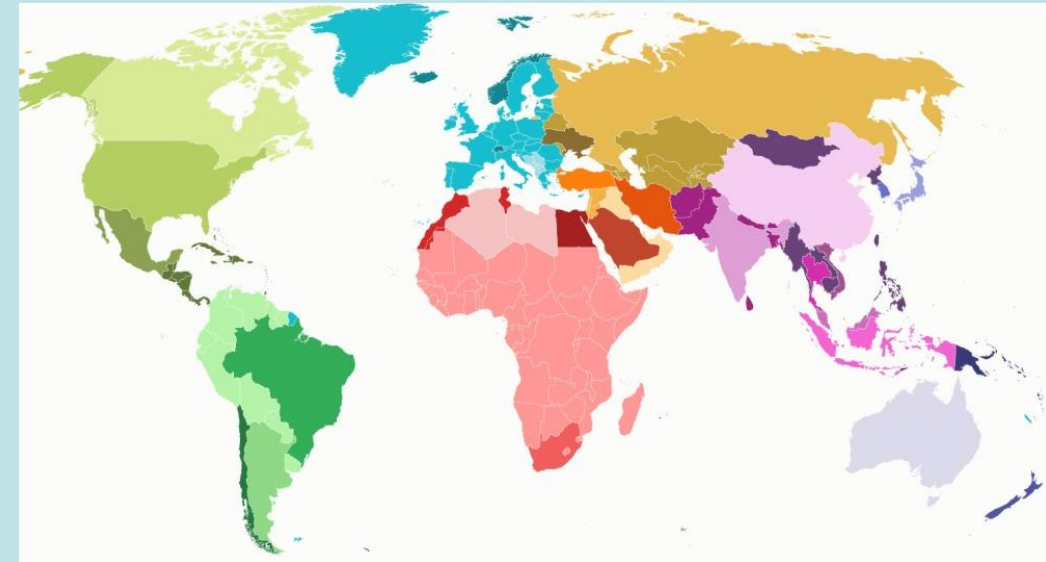
POLES: Prospective Outlook on Long-term Energy Systems

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

Scenarios: policy context

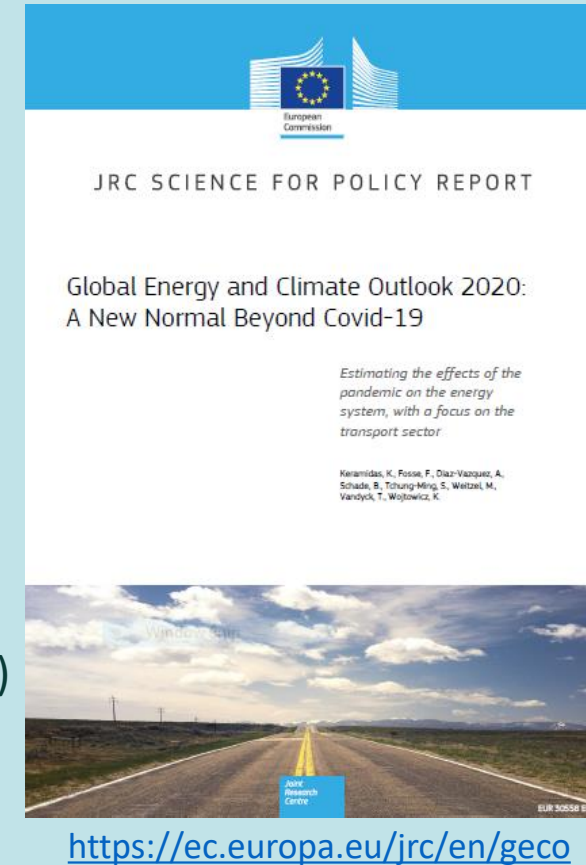
New/updated work

- 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)

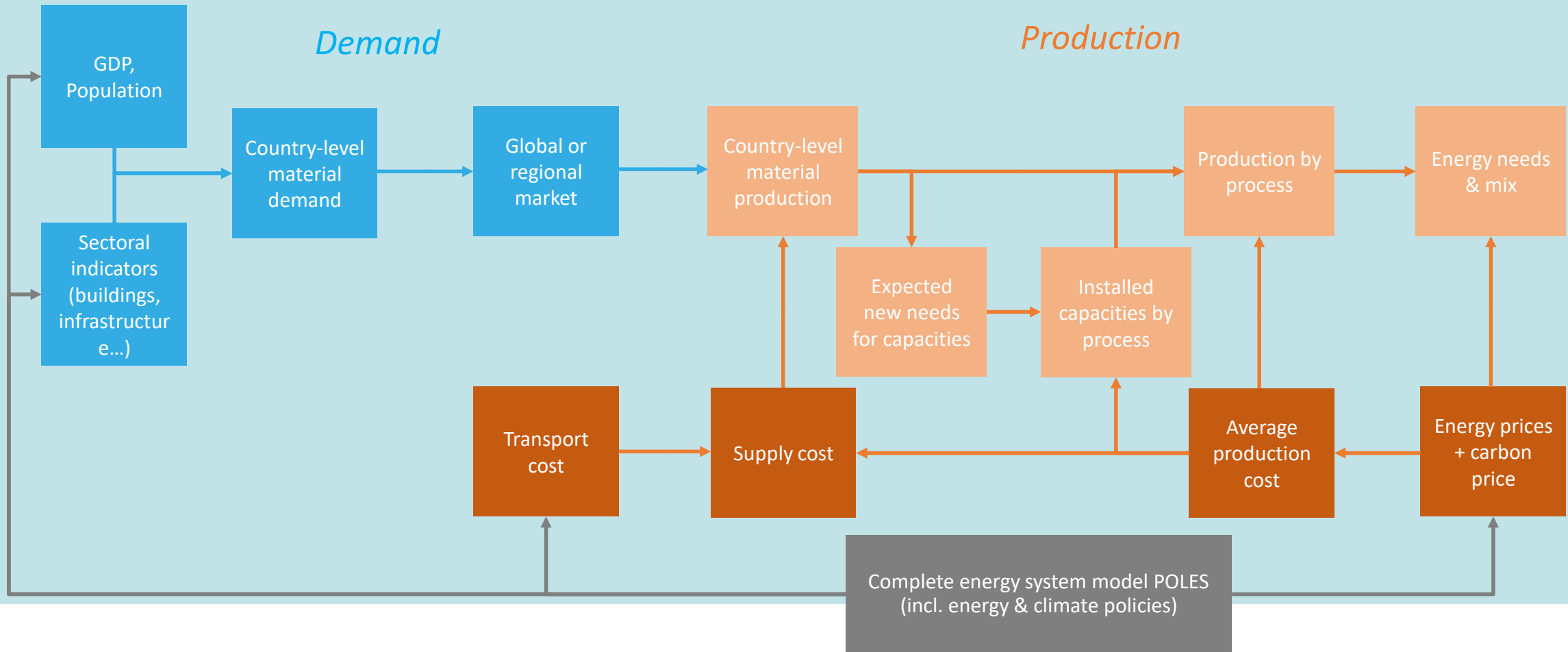


Policy context from JRC annual report GECO

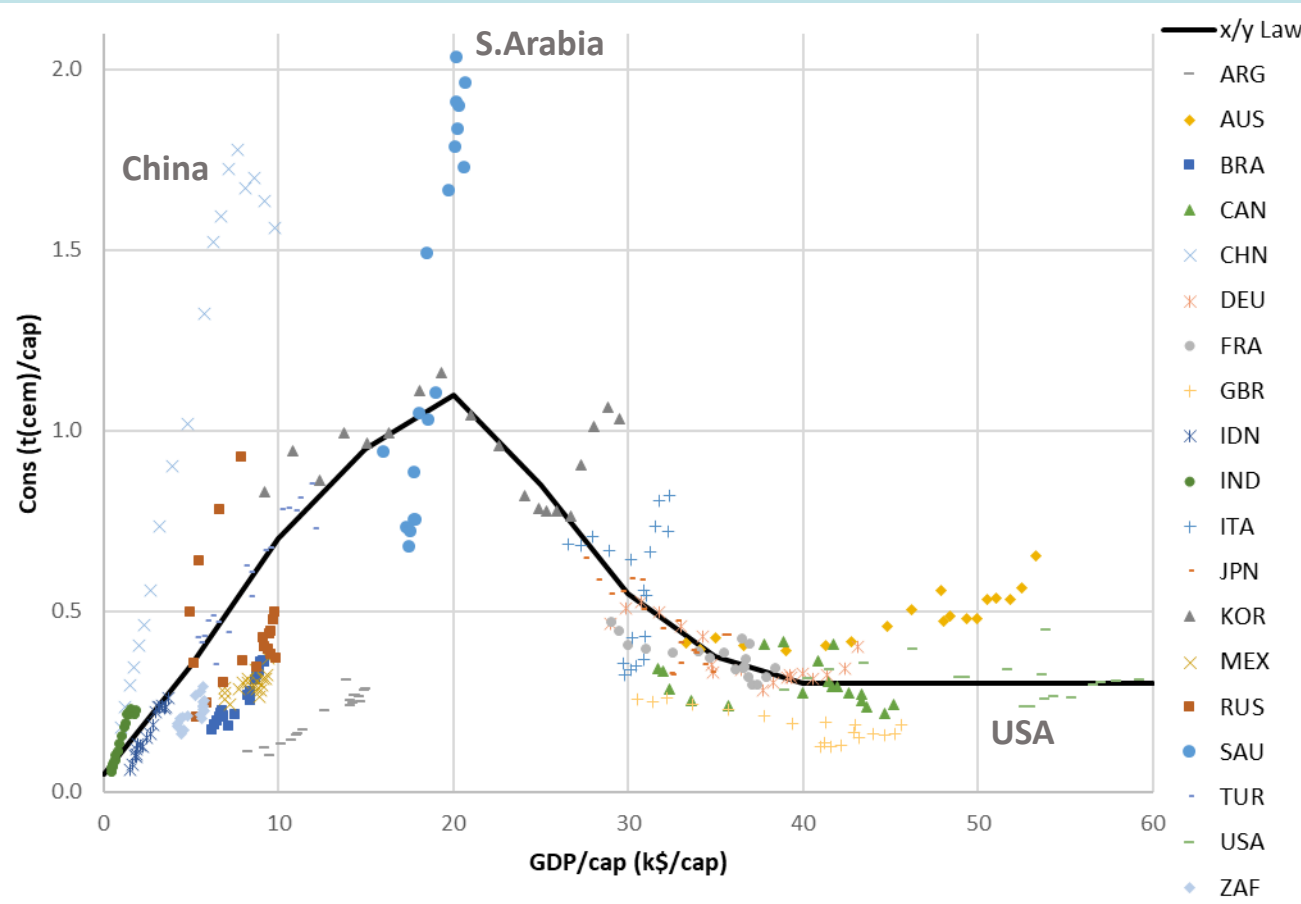
- Reference scenario (current policies)
- 2°C climate change scenario
- 1.5°C climate change scenario



Cement Industry - POLES module: Methodology



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

Cement production processes

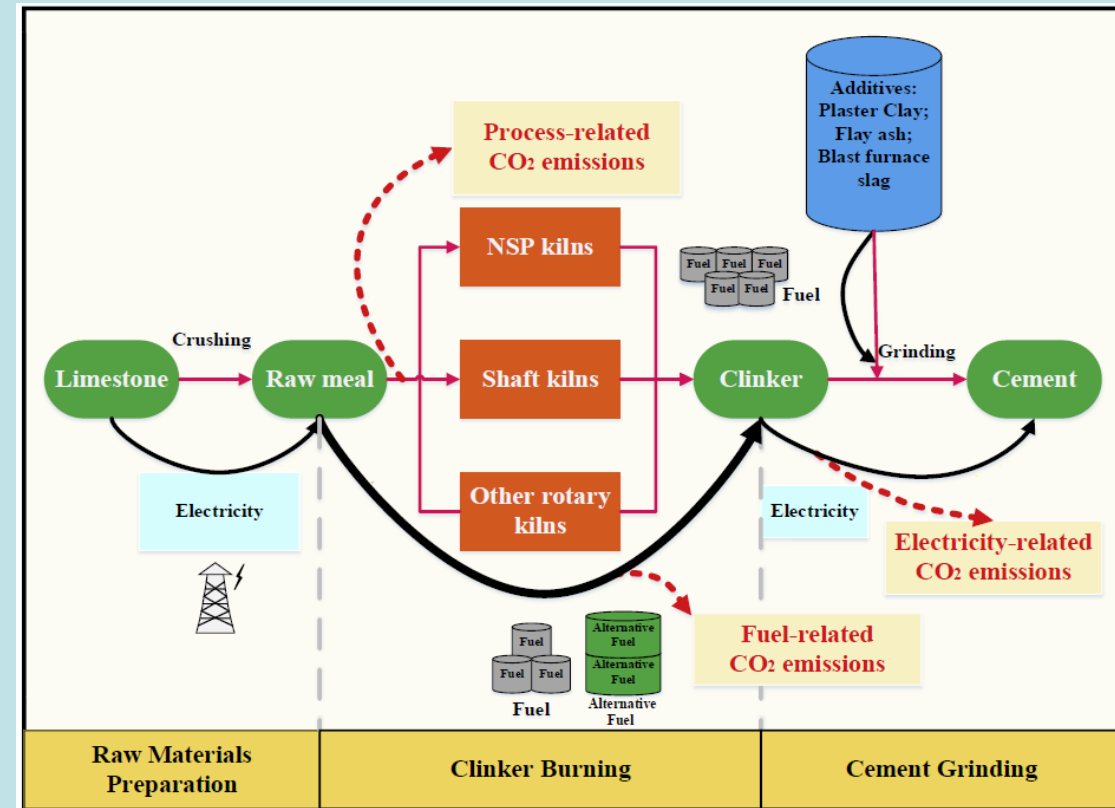
Which processes?

- 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)



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



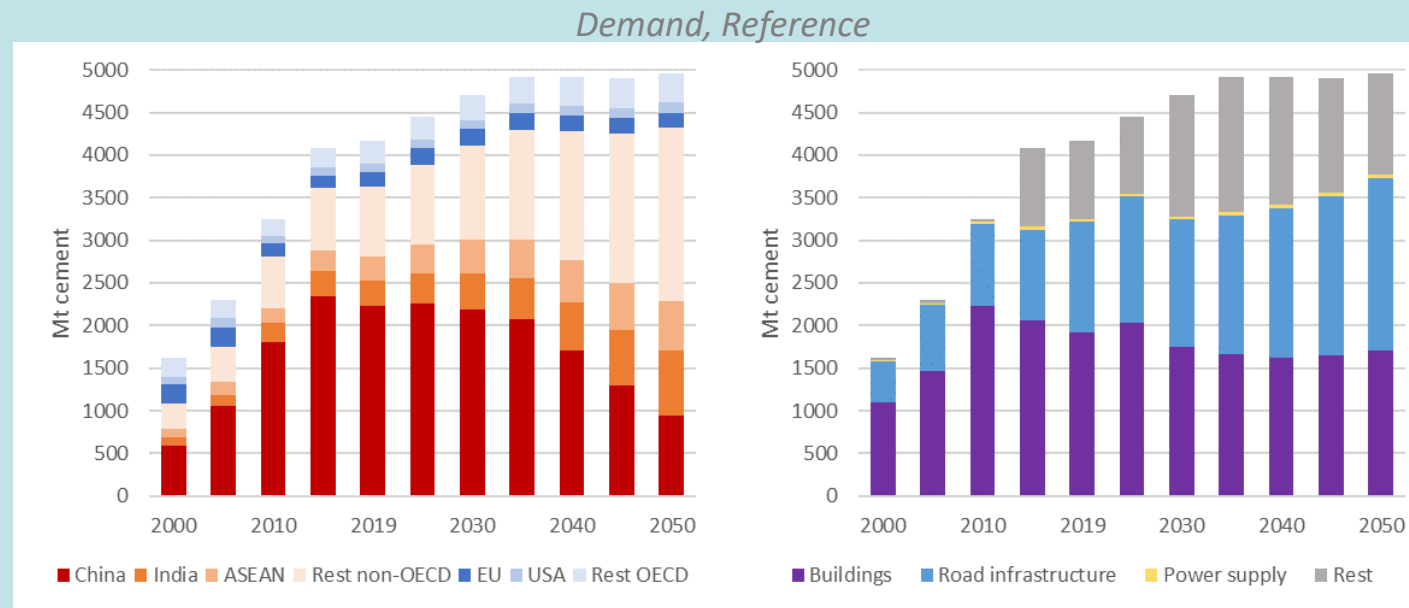
Source: Zhang et al, Journal of Cleaner Production, 2018

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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



- 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**

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 GtCO₂...to avoid >180 GtCO₂ with low-carbon power*

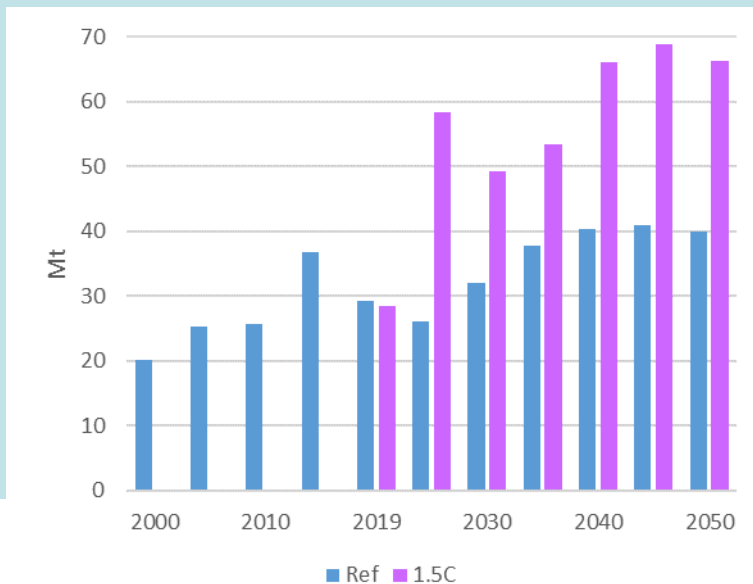


Coal: 250 t(concr)/MW
 Wind: 420 t(concr)/MW
 Source: IFPEN, 2019

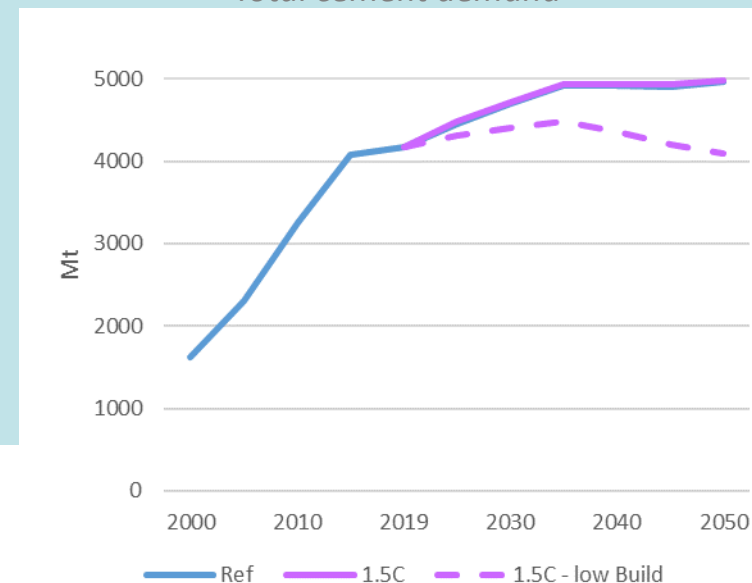


Rebound effect for power generation decarbonization relatively small on overall cement demand

Cement for Power



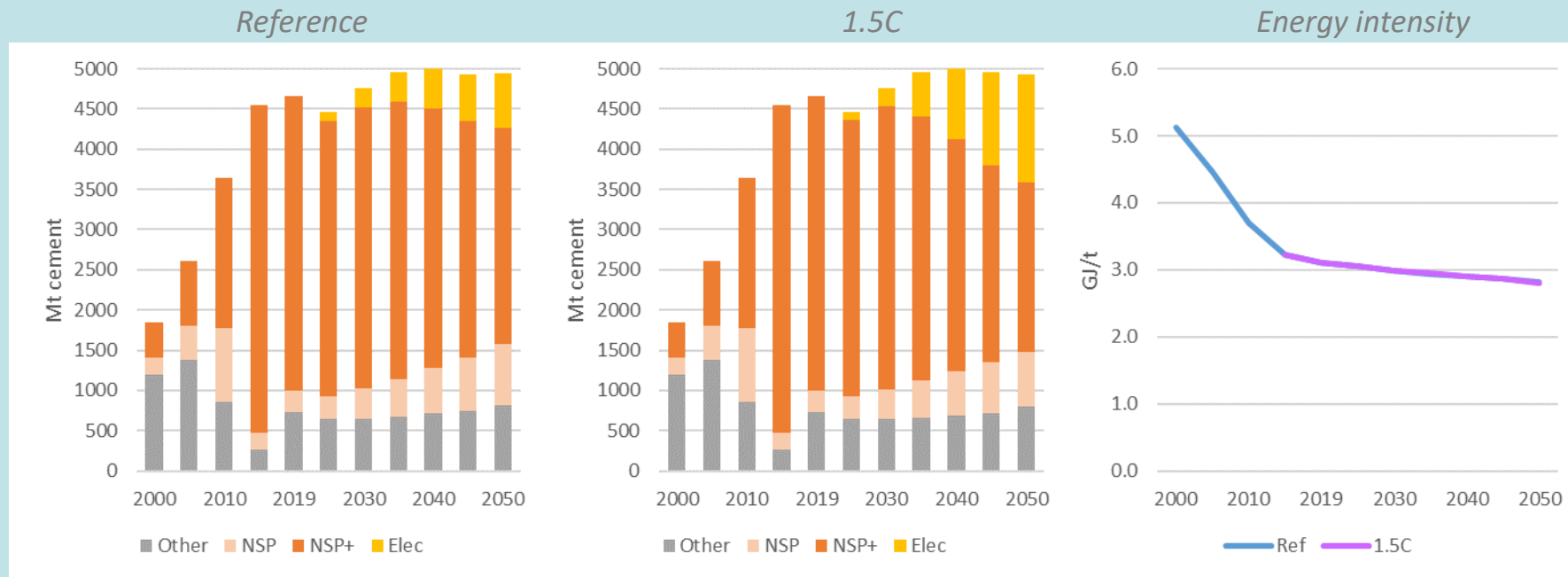
Total cement demand



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+)

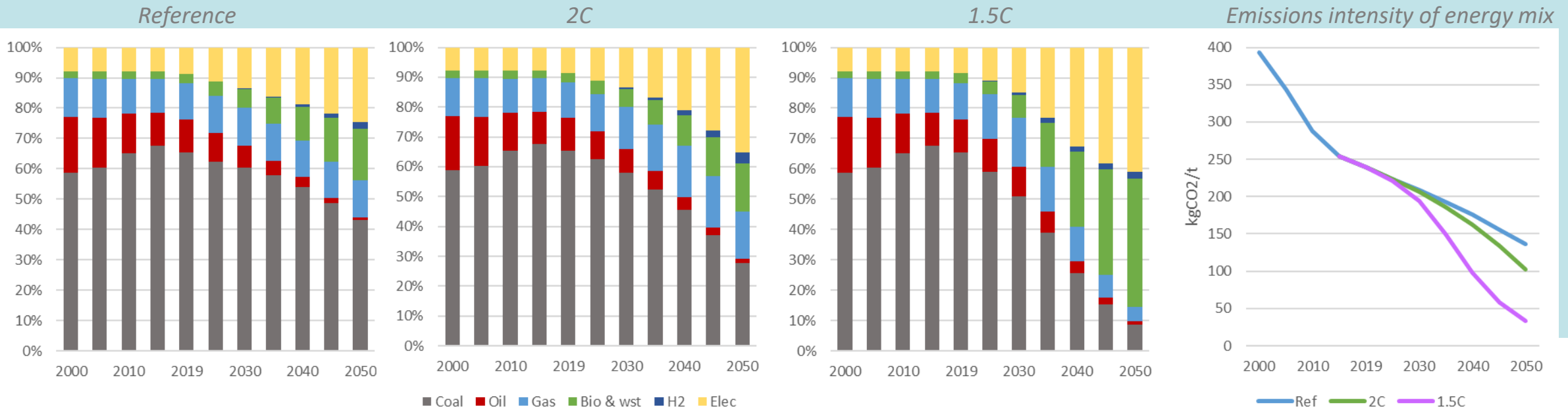
Climate policies accelerate the penetration of electric process



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

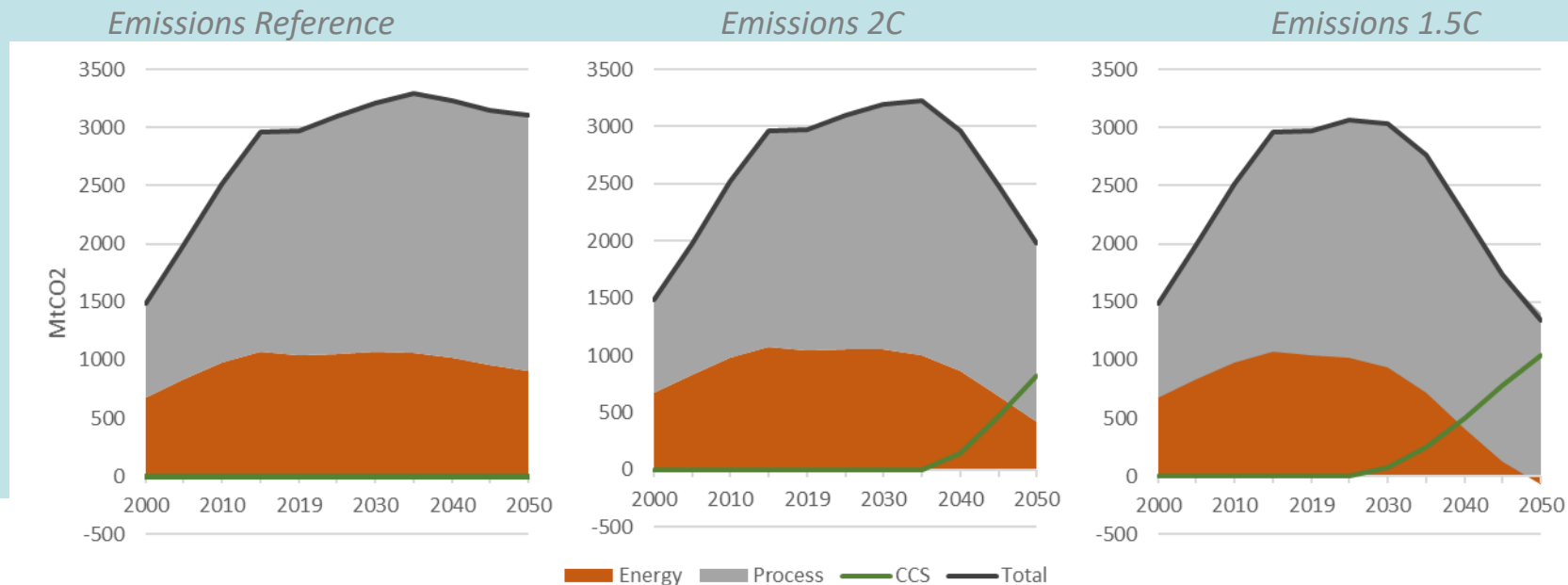
Pre-calcliner electrification retrofit and higher use of solid waste & biomass



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

- ~ 60% of emissions come from process (clinker production)
- Calcination + energy combustion in the same space → CO₂-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

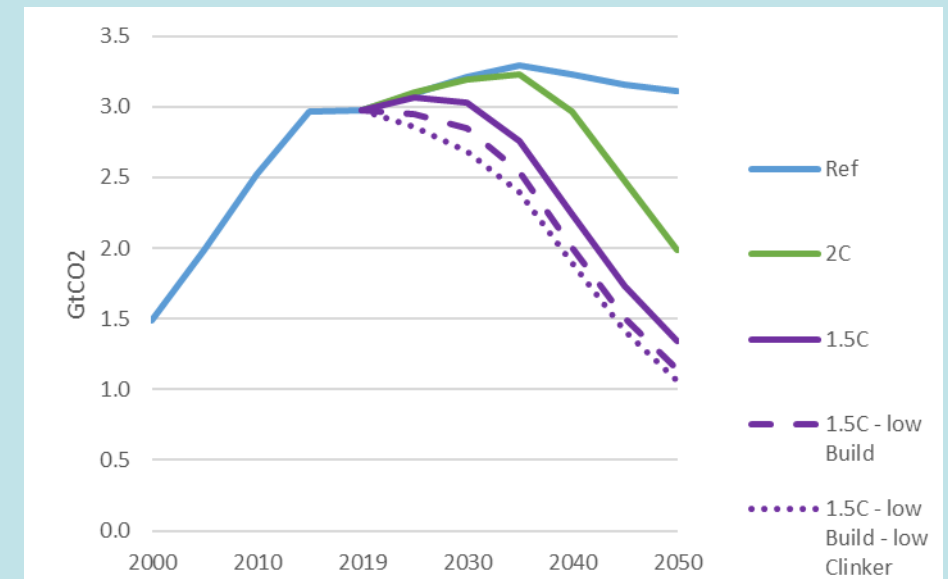
Ranking of reduction options **by 2030**:

- 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

Future work

- 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

Integrated demand/supply assessment

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



Thank you!



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