Improving the climate footprint of cement: a modelling-based approach integrating demand and supply

Kimon Keramidas[1,2], Silvana Mima[2], Adrien Bidaud[2]

15th International Conference on Society & Materials (SAM-15), virtual, 10-11 May 2021

[1] European Commission, Joint Research Centre, Seville, Spain
[2] Université de Grenoble-Alpes, Grenoble, France

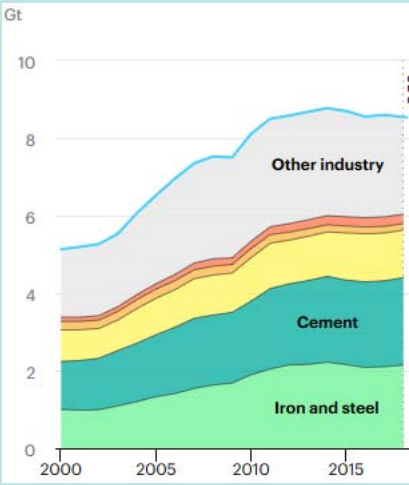
European Commission

Materials and industry: challenges

- UNEP International Resources Panel: The production of metal ores and non-metallic minerals (and associated emissions) is projected to more than double over the next 40 years
  - 49 Gt in 2015 to 104-126 Gt in 2060
- IEA: Non-energy materials production is responsible for a sizeable share of global CO2 emissions:
  - Cement 2017: 2.2 GtCO2 (6.7% of global CO2)

UNEP IRP

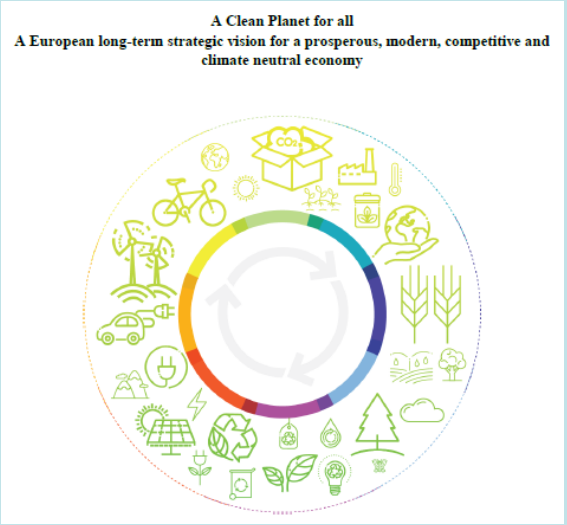
IEA Tracking Industry 2020



European Commission

Materials and industry in the context of climate change

- How to reconcile with climate change mitigation strategies?
  - EU, USA: net-zero GHG in 2050
  - China: net-zero CO2 in 2060
- We propose to represent both material demand and production in an energy model
  - Physical quantities as driver to industry demand
  - Techno-economic options in industry mitigation
  - Industry emissions pathway/budget as a result of overall economy pathway (relative costs vs other sectors)



European Commission

POLES-JRC: Prospective Outlook on Long-term Energy Systems

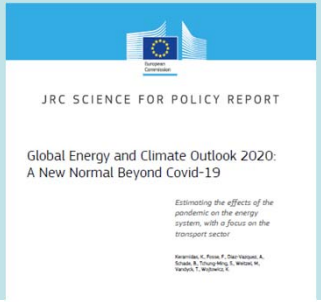
Simulating the evolution of the world energy system

- Annual steps until 2050-2100
- EU28 + 38 countries / regions (OECD, G20)

Output

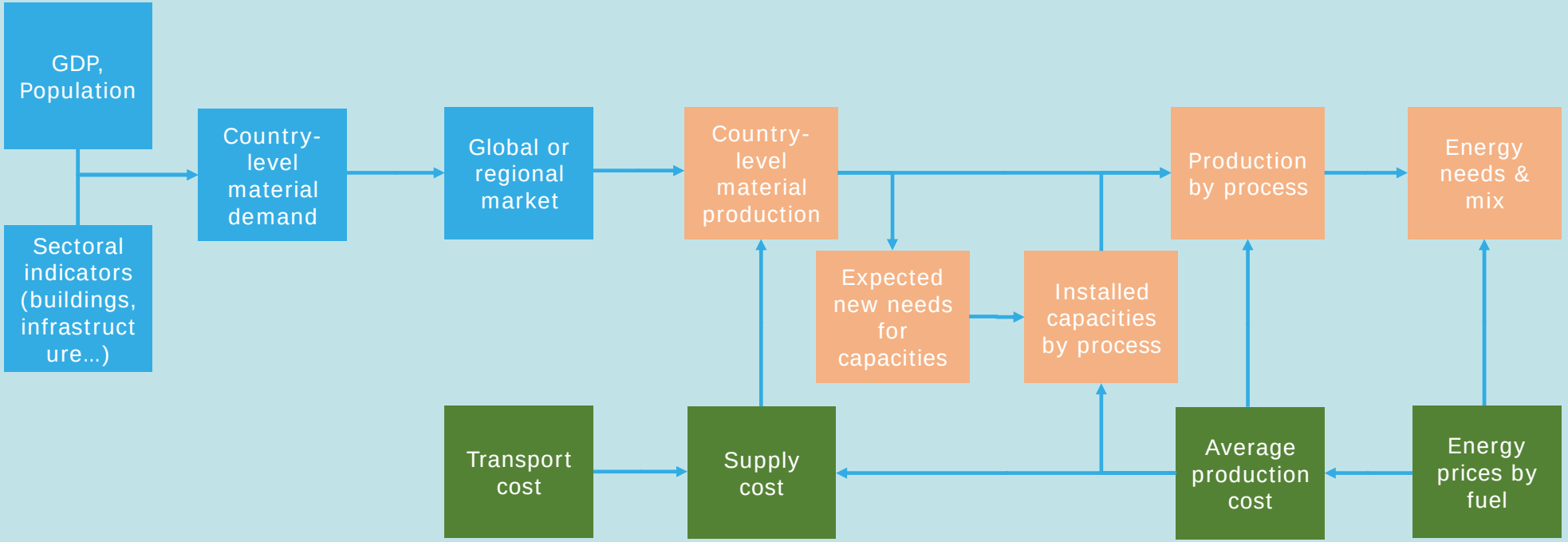
- International energy prices & trade
- All energy sources and vectors
- All GHG emissions (linkage with specialist tools for non-energy)

Policy context from JRC annual report GECO (Global Energy and Climate Outlook)



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

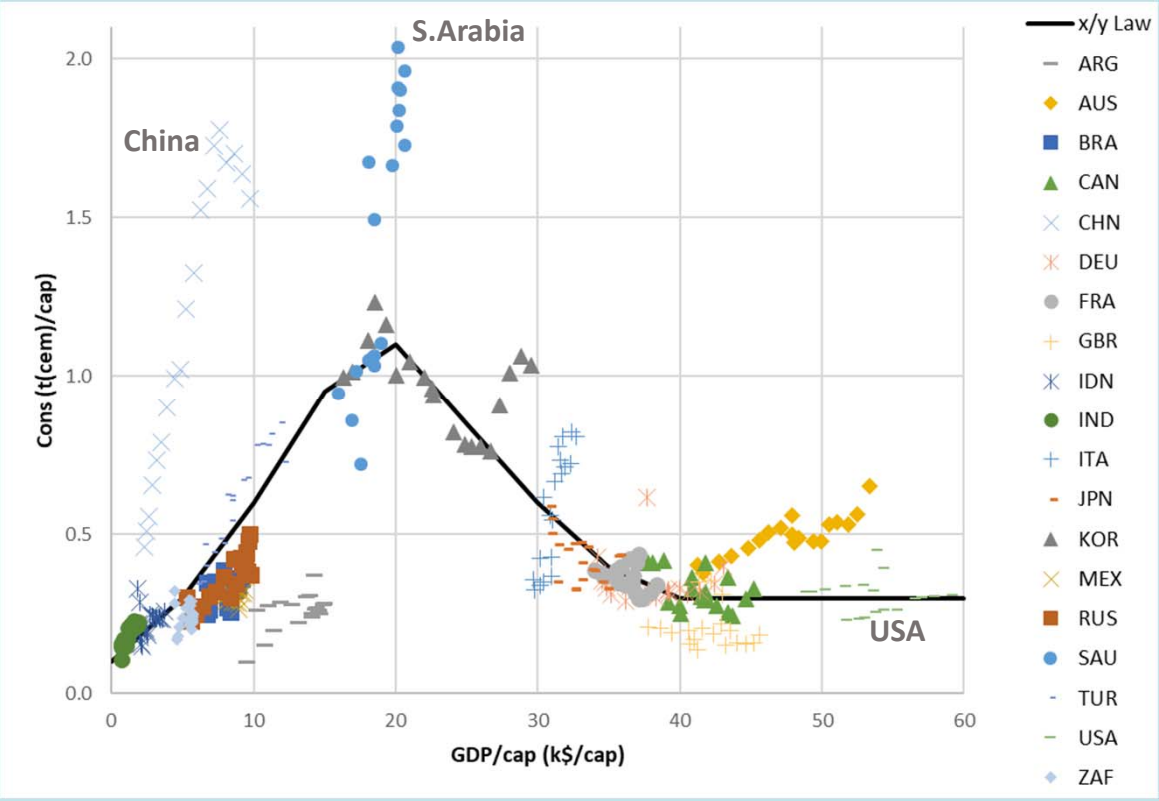
Cement Industry - POLES module: Methodology



+ Imported from complete model: energy prices, transport cost, climate policies (carbon price)

European Commission

Cement demand projection: Intensity of use



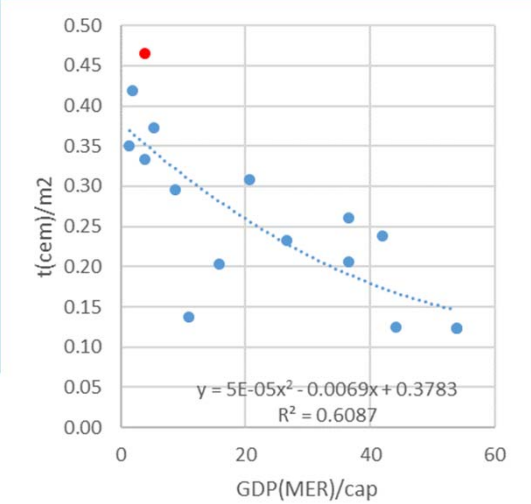
- 2000-2018 for G20 countries
- General shape of growth-peak-decrease
- Follows changing structure of economy from industrialization to services
- Rich countries: apparent plateau at non-zero level
- Outliers: fast growth, resources-intensive construction

European Commission

Cement demand projection: Specific uses

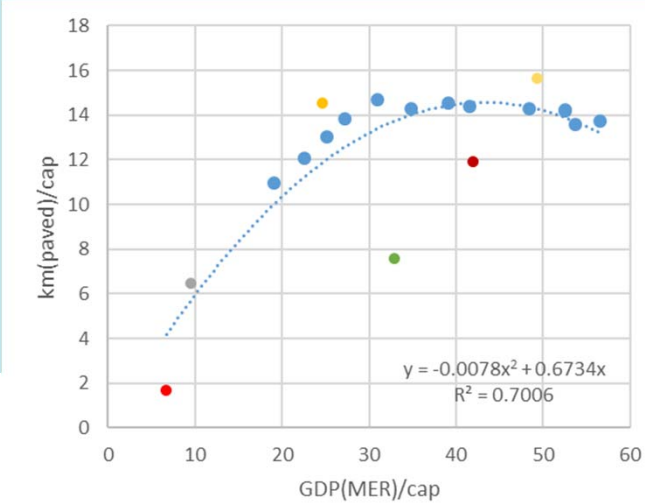
Buildings

- Demand per new & renovated surfaces
- Urbanization
- Materials used by country
- Material substitution



Road infrastructure

- Length of network per cap
- % of network that is paved



Power generation

- Power technologies: Specific material need per unit of capacity installed (constant)
- Power network: Specific material need per unit of additional electricity delivered (constant)

→ Specific uses calibrated to fit within total demand from Intensity of Use law

European Commission

Cement production mitigation options

Energy efficiency: new processes or retrofit capacities

- 2018: % of capacities use the most efficient process (dry kiln with pre-heater and/or pre-calciner)
- Electric kiln (indirect heating): emergent process

Carbon capture, use and storage (CCUS)

- CO2 injection/curing: possible for market segments (prefabricated blocks)
- CCS: possible leading role of cement industry (concentrated CO2 flow)

Carbon content of mix

- Biomass & waste: possible with current infrastructure (air pollutants)
- Synthetic fuels (H2, e-fuels): higher cost, for high mitigation

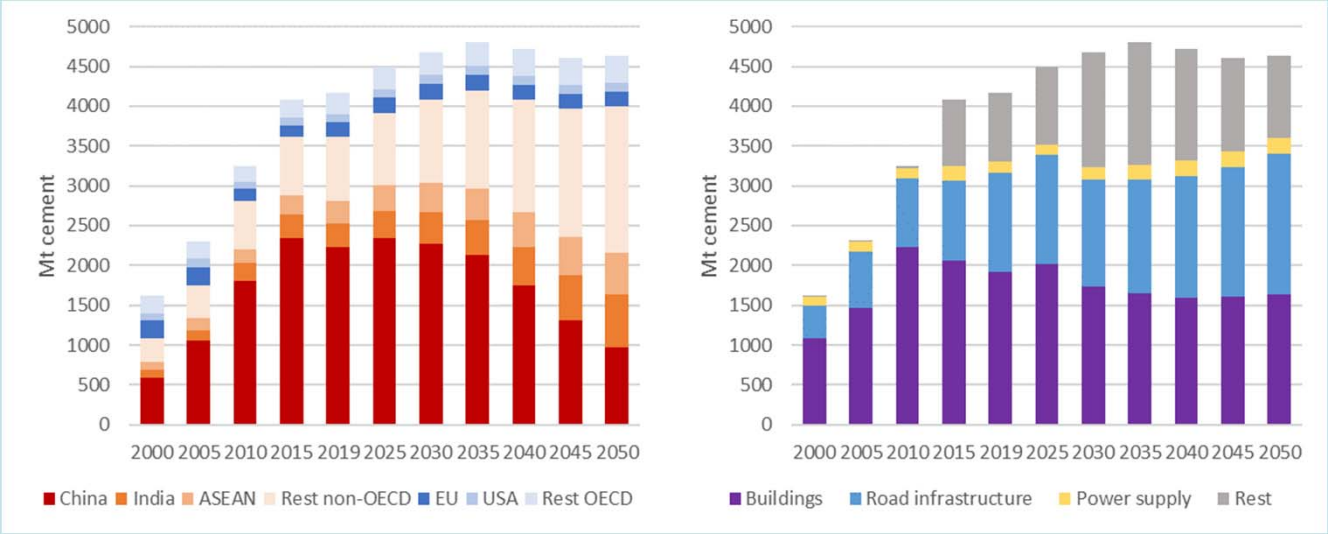
Other options

- Clinker/cement ratio: dependent on availability of substitutes (fly ash)
- New binder formulas: emergent technologies

European Commission

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 for buildings construction stabilizes (decrease in China, increase elsewhere non-OECD)
- Demand for other uses (other construction, public works) still increases in the medium term

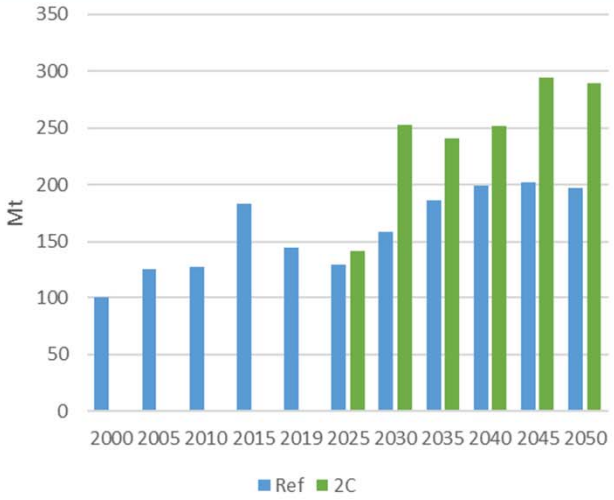
European Commission

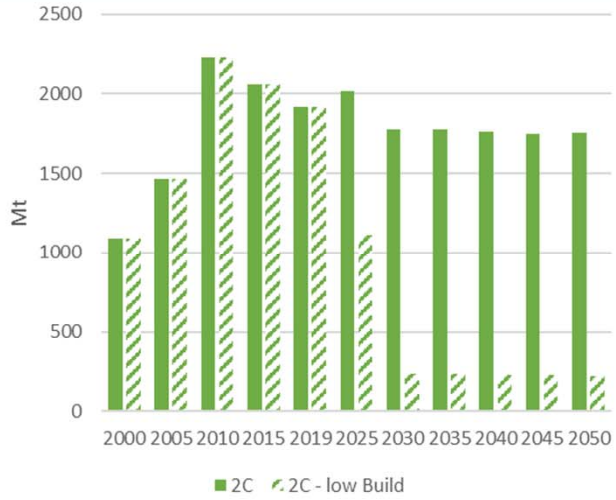
Projections: Cement demand: Changes in material uses

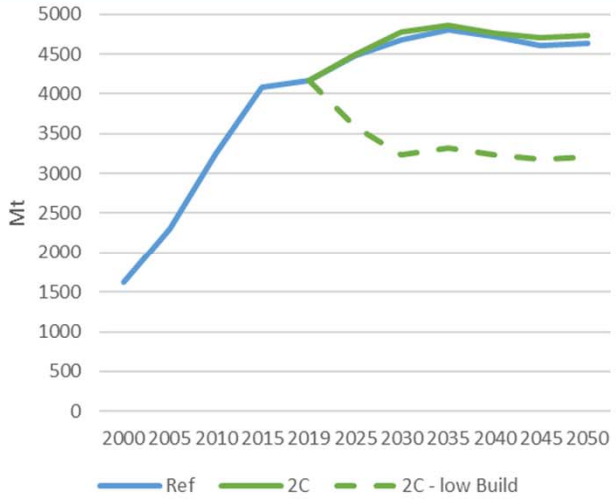
- Shift to low-carbon power system and electrification of demand pushes cement demand for **power** upwards
- Cumulated 2020-2050: +35%

- Shift to construction using different materials (more steel and wood) pushes cement demand for **buildings** downwards
- Extreme scenario: global average building standard in 2030 is technical minimum of 80% of concrete substituted with wood & steel
- Cumulated 2020-2050: -72%

- Total effect on demand of changes in material uses: mainly driven by changes in construction



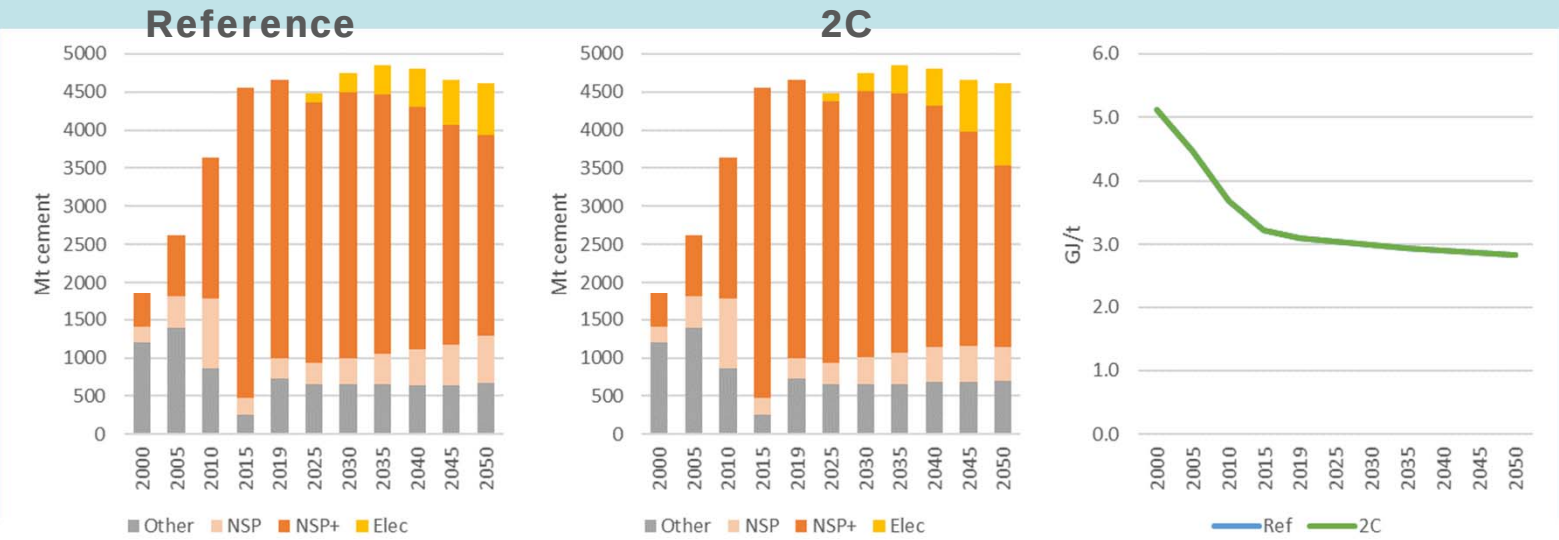




opean
nmission

Projections: Cement production: Production capacities

- Recent past: major shift to most energy-efficient (and costlier) process of New Suspension Pre-heater (NSP) and with Pre-calciner (NSP+), especially in China
- With effect of market forces, diversification of production capacities
- Climate policies foster the penetration of electric process
- Small difference in overall energy-efficiency



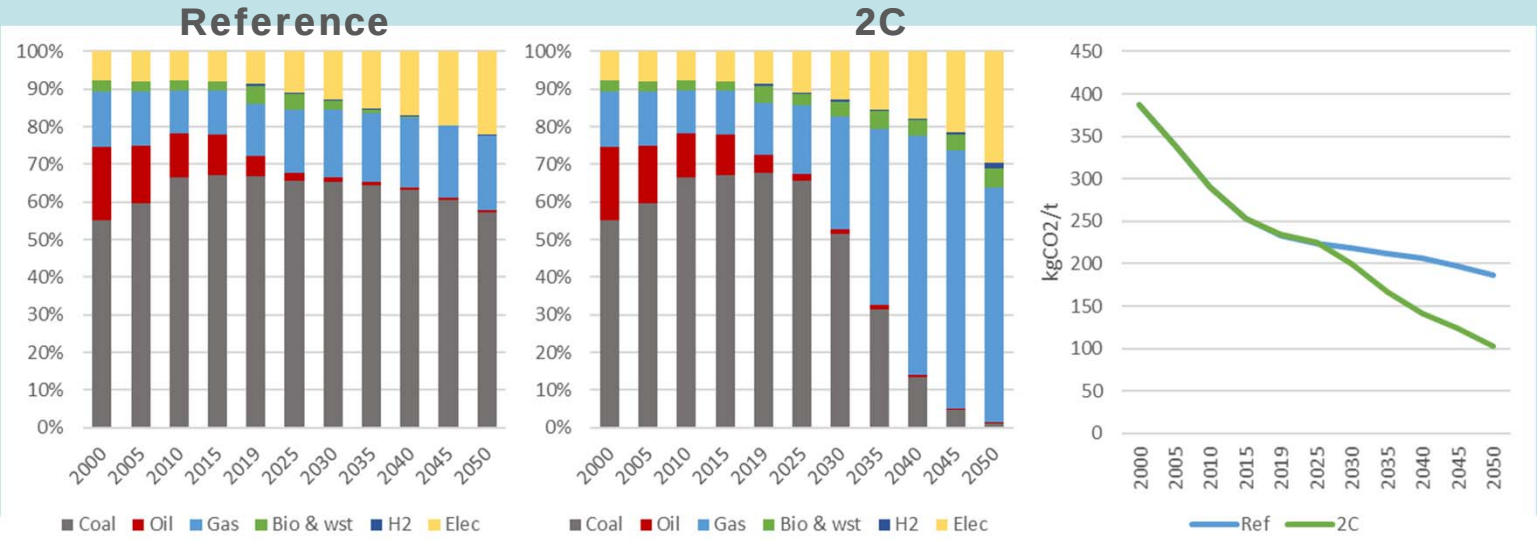
European Commission

Projections: Cement production: Energy mix

- Predominance of coal
- Electricity in all processes for grinding

- Climate policies foster substitution of coal with gas and the penetration of electric process
- Low biomass penetration related to land use and biodiversity concerns

- Carbon content of energy mix decreases significantly



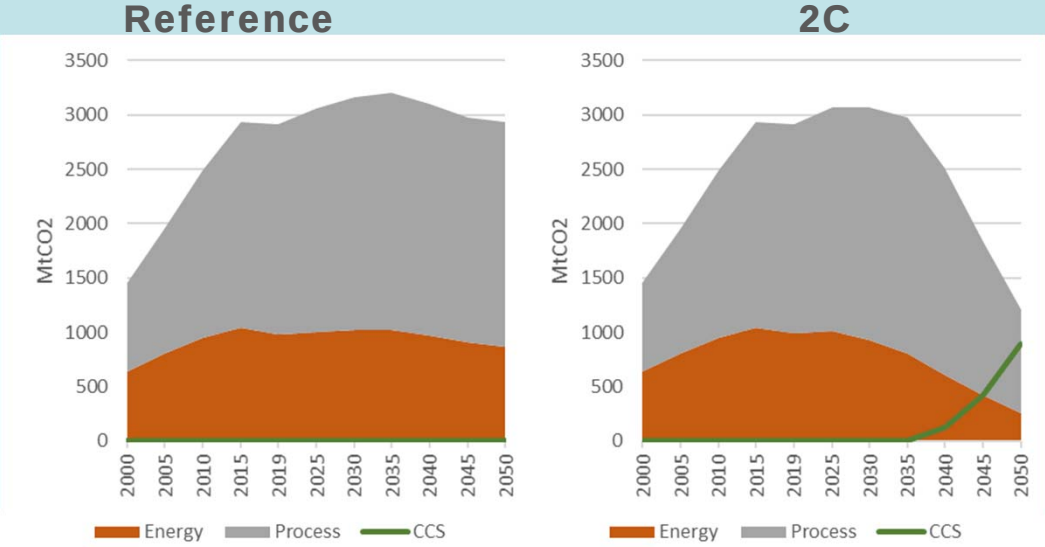
European Commission

Projections: Cement production: CCUS & Clinker substitutes

- Over half of emissions come from process (clinker production)
- Calcination and energy combustion in the same kiln result in a CO2-rich flue gas

- CCS emerges only with climate policies
- Large scale effect only after 2030
- 2C: CCS captures nearly half of emissions in 2050

- CCU: CO2 injection in prefabricated blocks
  → adapted for about a quarter of cement demand
- Clinker/cement ratio: dependent on availability of substitutes (fly ash)
  → a decrease globally of 5pp would correspondingly result in 5% less emissions



European Commission

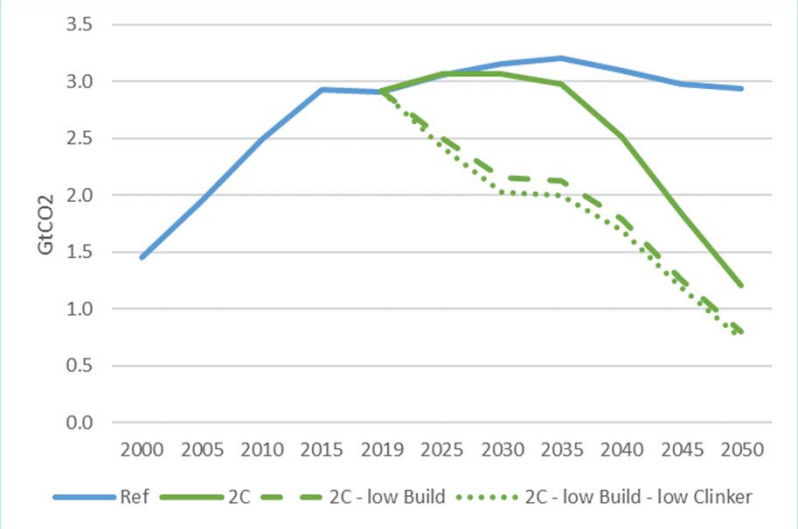
Conclusions

- Combined measures could reduced emissions of cement industry by as much as 75% in a 2C policy world
- Ranking of reduction options:

→Production-side: CCS; fuel mix (gas, biomass, electricity); cement/clinker ratio

→Demand-side: materials used in buildings; urbanization

→Low-carbon transition feedback on materials demand: small effect for cement (for power generation)



Future work

- Trade, carbon leakage & CBAM
- CCUS
- Material substitution
- Concrete end-of-life/recycling

European Commission

Thank you!

Kimon Keramidas
kimon.keramidas@ec.europa.eu

Thesis at I-MEP2
doctoral school of UGA

Sources used

- Cement production: USGS
- Clinker/cement ratio: GCC GNR
- Cement processes mix: GCC GNR (21% world coverage), literature
- Specific energy consumption by process: IEA ETSAP, JRC
- Energy mix by fuel: derived from non-metallic minerals balances of IEA
- Cement trade: Comtrade
- Apparent cement consumption: Production + Trade
- Cement consumption by sector & Specific material consumption: ADVANCE, IFPEN, DBS, literature…
- GDP: World Bank (2019), IMF (Jun-2020), EU Ageing Report (2020)
- Population: JRC-IIASA (2018), EU Ageing Report (2020)
- Energy & Climate Policies: JRC GECO 2020

European Commission