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

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ABSTRACT

The aim of this paper is to analyse the potentials and challenges faced by the materials sector in the effort towards a low-carbon economy, with a focus on cement. We explicitly represent both the demand and production side of cement in a global energy system model. We look at multiple drivers of cement demand, including demand linked to low-carbon technologies and 'greening' options like clinker/cement ratio and material substitution; we represent materials supply industrial processes allowing investment in more energy-efficient capacities, alternative fuels use and other options such as carbon capture and storage, the development of novel cement formulations and possible reuse/recycling. This study presents on-going work using the POLES energy system model targeting a suitable reduction of cement-related greenhouse gas emissions.

Summary

Limiting climate change and reaching the Sustainable Development Goals (SDG) while at the same time increasing well-being poses multifaceted challenges to all aspects of human activities. Historically, higher income levels and well-being have been correlated with an increase in the demand of material goods, and more specifically of goods that are energy-intensive and CO_2-intensive in their production.

Non-energy materials production is responsible for a sizeable share of global CO_2 emissions: as of 2017, cement emitted 2.2 $GtCO_2$ (6.7% of global CO_2), iron and steel 2.1 Gt (6.4%), glass 0.1 Gt (0.4%), aluminium 0.2 Gt (0.6%) and copper 0.1 Gt (0.2%)[1][2][3]. The production of metal ores and non-metallic minerals is projected to more than double over the next 40 years, even in a sustainability scenario (49 Gt in 2015 to 104-126 Gt in 2060)[4], with associated emissions set to grow accordingly unless action is taken.

This work tackles these issues of demand and supply in an integrated way within an energy system model. The resulting projections of materials, energy and greenhouse gas emissions are more self-consistent; with a richer technological representation, they provide a more precise picture of investment needs and the effects of policy levers that are of interest to both

[1] IEA, Tracking Industry 2020. https://www.iea.org/reports/tracking-industry-2020

[2] Tost et al (2018). Metal Mining's Environmental Pressures: A Review and Updated Estimates on CO2 Emissions, Water Use, and Land Requirements. https://dx.doi.org/10.3390/su10082881

[3] https://www.gpi.org/news/glass-container-industry-releases-comprehensive-cradle-to-cradle-lca

[4] UNEP International Resource Panel, Global Resources Outlook 2019. https://www.resourcepanel.org/reports/global-resources-outlook

policymakers and investors.

We try to describe some improvements to better model the decarbonisation strategy of the cement sector. This work attempts to represent dynamically both demand and supply in a dynamic global energy system model, taking inspiration from:

- Dynamic materials demand: materials representation in energy system models or macroeconomic models have associated specific material demand to energy technologies or services[5] and have based materials demand projections on their modelling framework. Materials demand projections have also used the material intensity of use (IOU) concept[6], assuming the relation between material use and economic growth will continue in the future or "leapfrog" into more efficient use (or substitution).
- Dynamic materials supply (i.e. the processes in industries converting raw materials into finished goods): using physical materials demand as a basis for projections, modelling of the competition between multiple industrial processes (shift to dry kilns, retrofitting of preheater), new energy vectors (biomass and waste, hydrogen) and new paradigms (CCS, CCU), other options for reducing emissions (clinker/cement ratio, CO_2-curing).

The focus of this presentation will be the work done on cement demand and supply.

After comparisons of production by technology, energy consumption and CO_2 emissions for world, EU and major regions by scenario, we analyse the options of decarbonisation and their potential role in the future.

This work builds upon previous work in this field, namely: JRC work in steel[7], cement[8] and paper[9] supply; the EPE-IDDRI project work in steel, cement and aluminium demand and supply and glass demand[10]; Enerdata work on steel and copper demand[11]; IAMs work on cement supply[12].

[5] GENERATE project, IFPEN and others, 2018-ongoing. https://www.researchgate.net/project/GENERATE

[6] Labys (2004). Dematerialization and Transmaterialization: What Have We Learned? https://researchrepository.wvu.edu/rri_pubs/132/

[7] Hidalgo et al (2005). Technological prospects and CO2 emission trading analyses in the iron and steel industry: A global model. https://doi.org/10.1016/j.energy.2004.05.022

[8] Szabó et al (2006). CO2 emission trading within the European Union and Annex B countries: the cement industry case. https://doi.org/10.1016/j.enpol.2004.06.003

[9] Szabó et al (2009). A world model of the pulp and paper industry: Demand, energy consumption and emission scenarios to 2030. https://doi.org/10.1016/j.envsci.2009.01.011

[10] http://www.epe-asso.org/etude-fonddri-epe-iddri-scenarios-sous-contrainte-carbone-2007/

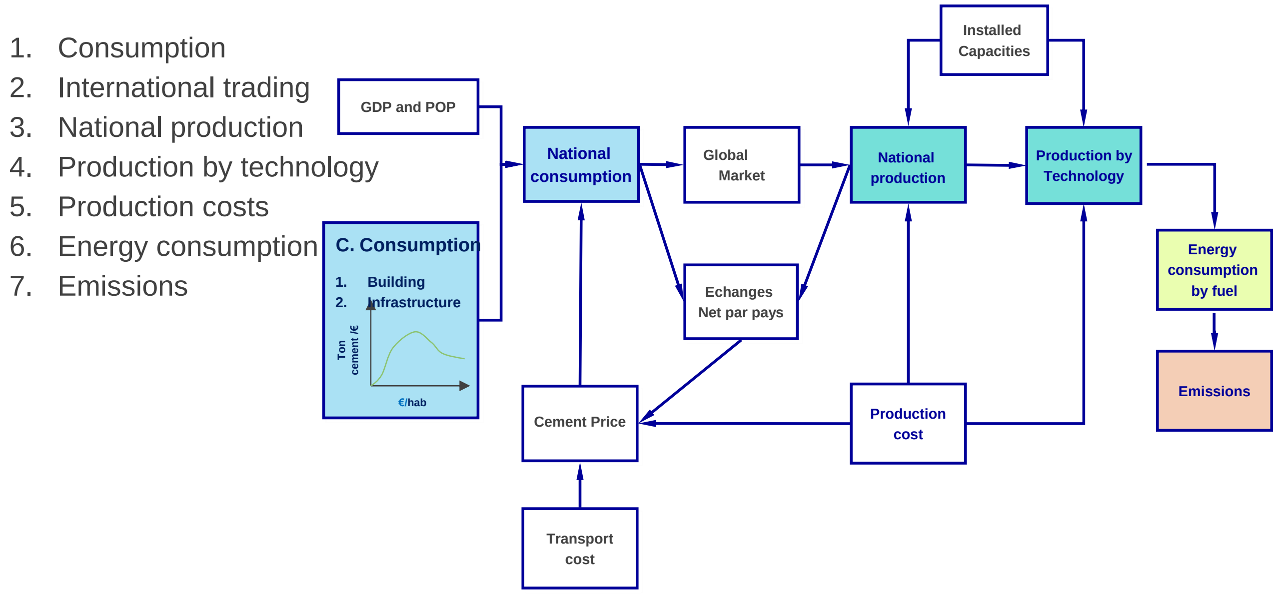
[11] http://pratclif.com/2015/mines-ressources/polinares/chapter18.pdf

[12] ADVANCE project, Utrecht University and others, 2016. Enhancing the representation of energy demand developments in IAM models – A Modeling Guide for the Cement Industry. http://www.fp7-advance.eu/?q=content/industrial-sector-cement-guideline

Methodology

The long-term POLES model[13] provides projections of energy use and CO_2 emissions for 66 world regions. This study develops the cement industry within the POLES model, showing the emissions reduction options under a current policies scenario and a 2°C-compatible climate policy scenario.

Regional demand is derived from indicators from the rest of the model (buildings, road network, power generation). Certain emissions reduction options are driven by economic considerations (fuel mix, energy efficiency retrofit, CCS) while others are, currently, considered as exogenous scenario parameters (clinker/cement ratio, demand-side material substitution).



Conclusion and further work

Improvements foreseen include the representation of new low-carbon types of cement, substitution with other materials and the possible impacts of decarbonization strategies on international trade of cement. The prospective role and associated costs of co-processing of biomass and waste in cement plants, as well as of options with low Technology Readiness Levels such as new binder types, have to be assessed further. The competitors of cement have to be studied in order to assess how the cement industry can be impacted by a wider adoption of other construction materials (wood, glass, steel ...) and policy choices (construction codes, urbanisation and vertical housing, housing renovation rates).

[13] https://ec.europa.eu/jrc/en/poles