Public Health Co-benefits of Decarbonizing Industrial Production in Europe

Laure de Preux[1] Yixuan Gu[2] Daven K. Henze[3] Ulrich J. Wagner[2]

[1]Imperial College London

[2]University of Mannheim

[3]University of Colorado Boulder

The Economics of Decarbonizing Industrial Production: NBER Conference
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STILL PRELIMINARY

HEAL Project

Industrial GHG Emissions and Co-pollution

- 12 Gt of CO_2-equivalent annually emitted worldwide (20%)
- Public Health Benefits of Decarbonizing Industry:
  - Direct benefits of climate change mitigation
  - Health co-benefits of reducing air pollution due to
    - co-pollutants jointly emitted with CO_2 from fossil fuel use
    - co-pollutants of CO_2 process emissions
    - non-CO_2 GHGs (CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3)
- Goal of this paper is to **quantify**
  - health benefits of reduced $PM_{2.5}$ pollution due to industrial decarbonization (past and future)
  - contributions of different industries and pollutant species
  - distributional impacts
- Local nature of co-benefits provides a rationale for targeted subsidies to carbon intensive industries. How much? And where?

We focus on industrial activies regulated in the EU Emissions Trading Scheme (EU ETS)

Health co-benefits depend on

1. co-pollution intensity
2. location
3. atmospheric dispersion
4. population density

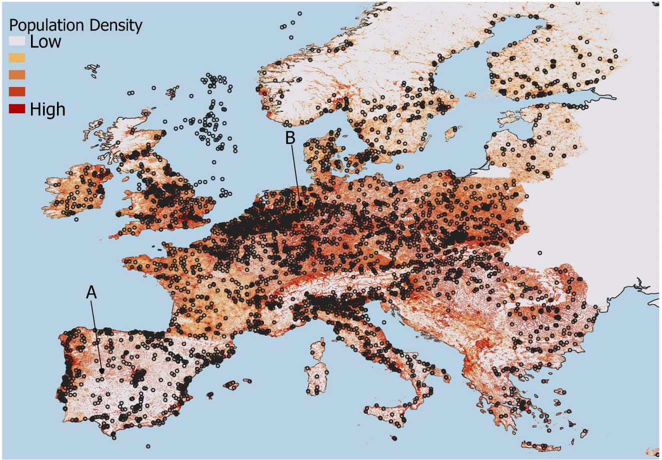


Figure: EU ETS Facilities and Population Density

Methods and Data

Research Design: Micro-founded Integrated Assessment

Summary:

1. Decarbonization Scenario
2. Facility-level Emissions of Air Pollutants: Location, Scale, Mix
   De Preux, Kassem and Wagner (*Mimeo*). Air Pollution Trading on the European Carbon Market.
3. Atmospheric Pollution Dispersion and Population Exposure
   Gu, Henze, Nawaz, Cao and Wagner (2023). Sources of PM2.5-associated health risks in Europe and corresponding emission-induced changes during 2005-2015. **GeoHealth**
4. Public Health Burden in terms of Mortality Impacts
   Murray, C. J. L *et al* (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. **The Lancet**

Steps 3 & 4: New Chemical Transport Model for Europe

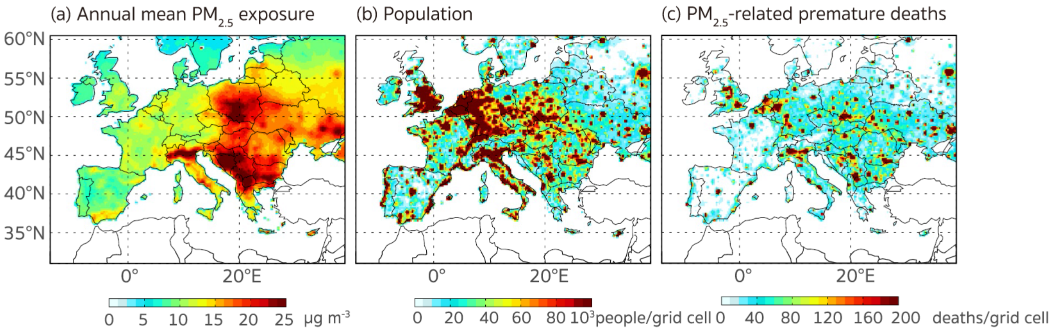
- Nested GEOS-Chem adjoint model (Gu *et al*, 2023)
- Model input:
  Primary pollutants NO_x, SO_2, NH_3, OC, BC, SOAP
- Model outputs
  - Population exposure to $PM_{2.5}$ on a $0.25^\circ \times 0.3125^\circ$-grid
  - $PM_{2.5}$ related premature deaths using dose-response from *Global Burden of Disease Study 2019* (Murray *et al*, 2020):

$$J_{PM_{2.5}} = \sum_{L} \sum_{A} \sum_{k \in D} \sum_{(I,J) \in k} \left(POP_{I,J,A} \times MOR_{I,J,A,L} \times AF_{I,J,A,L} \right)$$

where $AF_{I,J,A,L} = \frac{RR_{I,J,A,L} - 1}{RR_{I,J,A,L}}$ and L$\in${COPD, IHD, LRI, LC, T2D, stroke}

- Source appointment (adjoint):
  Compute sensitivity of premature deaths to specific pollution source without additional computational costs

$PM_{2.5}$ exposure, population, and health burden in Europe



Source: Gu et al. (2023a)

- 449,813 $PM_{2.5}$-related premature deaths in 2015 (relative to total pop. 598.97m)
- 59% due to anthropogenic NO_x, NH_3, SO_2, OC, BC, SOAP
- Between 2005-15, reduced industrial emissions avoided 4,000 premature deaths to industrial emissions

Step 2: Microdata on Emissions of CO_2 and Air Pollutants

1. European Union Transaction Log (EUTL)
   - Register of all ETS installations
   - Verified emissions and permit allocations
   -
2. European Pollutant Release and Transfer Register (E-PRTR)
   - Pollutant releases to air, water and land
   - 91 Pollutants, between 1 and 50 per facility (s.t. reporting thresholds)

Entity linked across data (De Preux, Kassem and Wagner, 2023)

- $>$8,000 EUTL installations (48.7 percent) matched to EPRTR facilities
- Matched installations account for 95.5 percent of EU ETS emissions
- Annual data from 2007-17

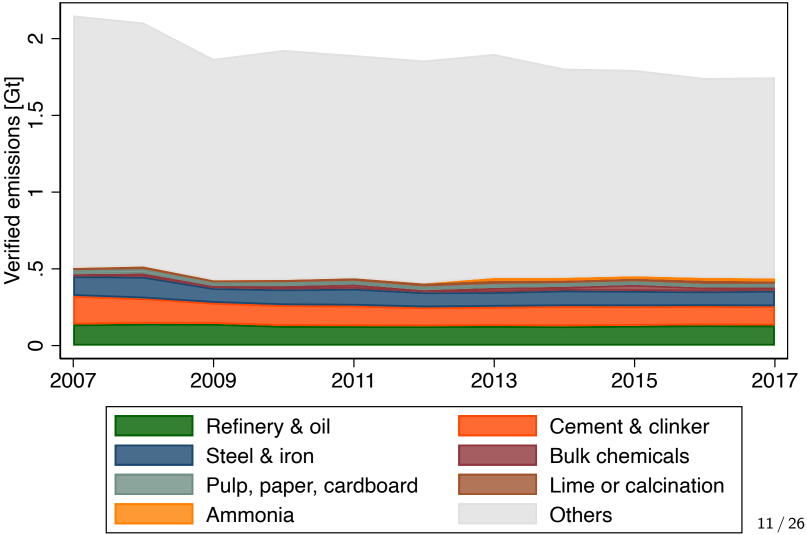
Step 1: Decarbonization Scenarios

1. Recent trends in CO_2 and co-pollution emissions 2008-2015
2. Naive decarbonization by 80%
3. Cost-effective (at current ETS prices) decarbonization of Portland cement

Recent Trends in Industrial Emissions

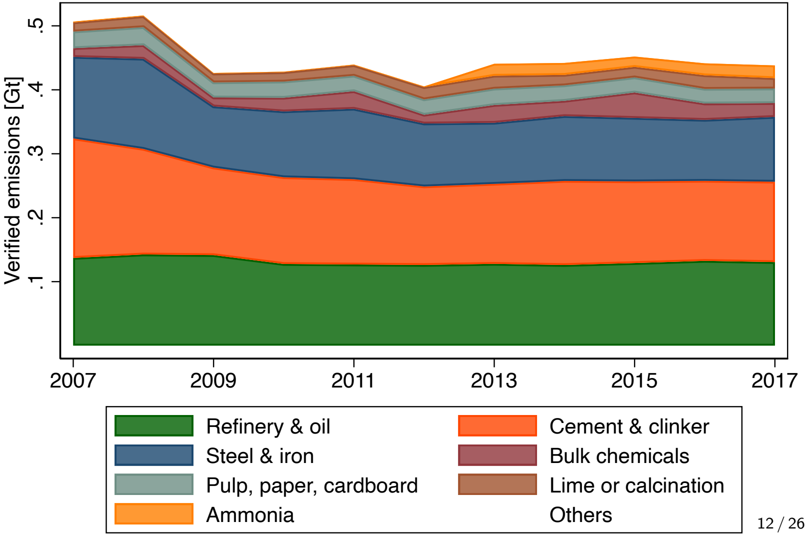
Carbon Emissions from Energy and Industry in the EU ETS 2007-17

- Emissions reductions under the cap were mostly driven by combustion activities (main part of 'other')
- Note: Combustion activities includes many industrial boilers

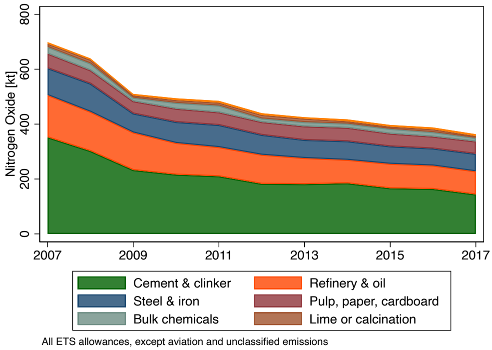


Industrial Carbon Emissions in the EU ETS 2007-17

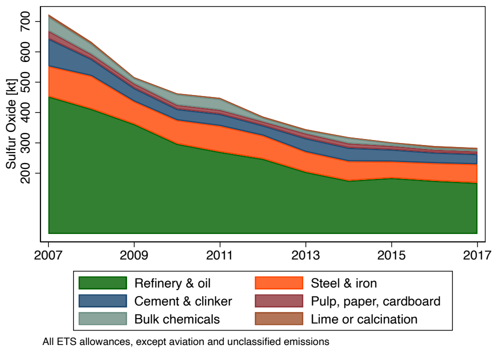
- Three largest industries have reduced emissions by about 15%
- In line with causal effect of ETS price on energy related emissions (Colmer, Martin, Muuls, Wagner, 2023)
- Note: Increased emissions from bulk chemicals, ammonia due to 2013 ETS changes



Industrial Co-emissions 2007-17



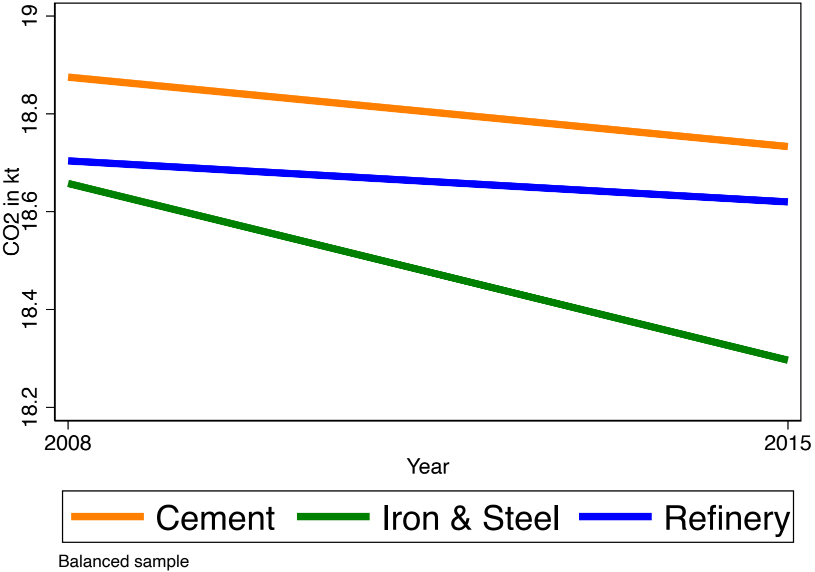
(a) NO_x



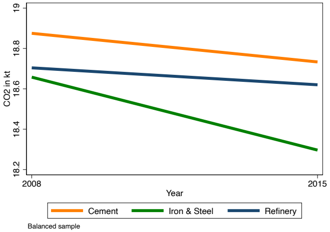
(b) SO_x

- Cement and refining reduced NO_x and SO_x emissions by almost 40%, respectively
- Not entirely driven by decarbonization

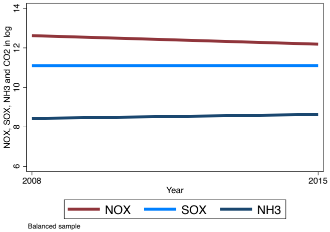
Changes in Carbon Emissions, 2008-15 (log scale, balanced sample)



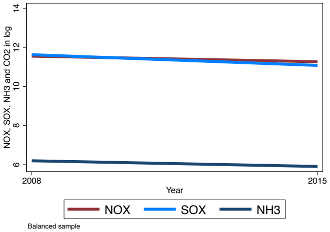
Changes in $PM_{2.5}$ precursor emissions, 2008-15 (logs, balanced)



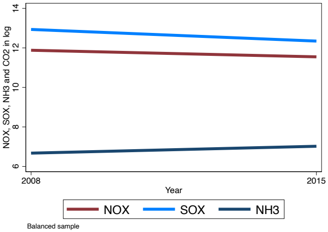
(a) Carbon emissions



(b) Cement



(c) Iron & Steel



(d) Refining

Health Impacts of Decarbonization Scenarios

Scenario 1: Avoided mortality due to recent emissions reductions

Associated $PM_{2.5}$ related premature deaths 2008-15

	Premature deaths				
	Level in 2008	Change 2008 to 2015	Imputed Change 2008-15 w/ pollution intensity from 2008	2015	median
Industry					
Cement	2,205	-738	-370	-347	-335
Steel	946	-237	-156	-264	-163
Refining	1,889	-741	-205	-180	-198
Total	**5,040**	**-1,715**	**-732**	**-791**	**-696**

- Significant health effects. Cement is most harmful industry
- Imputation: Scales co-emissions in proportion to observed carbon abatement

⇒ Observed mortality reductions in mortality only partially due to decarbonization

Decomposing Change in $PM_{2.5}$ related premature deaths, 2008-15

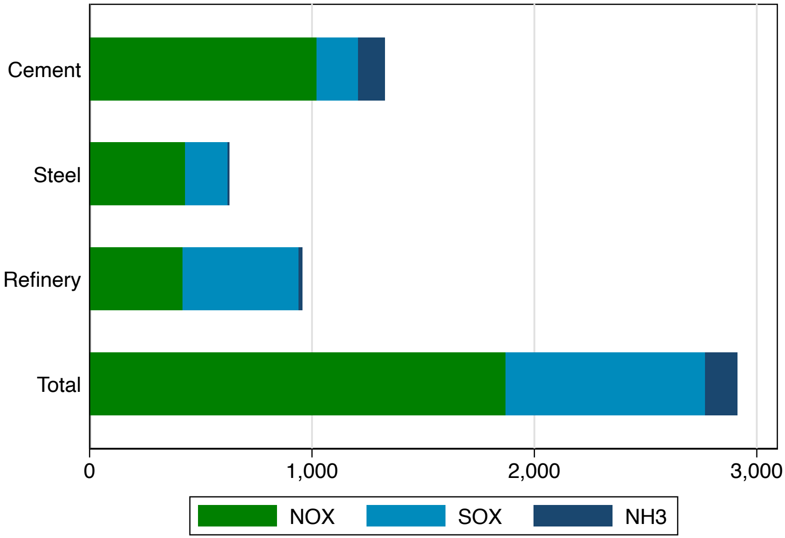
	Premature deaths			
	Level in 2008	Change 2008-15 observed	imputed (2008)	Decarbonization Contribution
Industry				
Cement	2,205	-33%	-17%	51%
Steel	946	-25%	-17%	68%
Refining	1,889	-39%	-11%	28%
Total	**5,040**	**-34%**	**-15%**	**44%**

- Largest decarbonization contribution from steel where health impact is smallest
- Largest health benefit in refining where the contribution of decarbonization is smallest.
- Next: Use 2015 pollution intensities to abstract from such other impacts.

Scenario 2: 80% Reduction in Emissions and Co-emissions

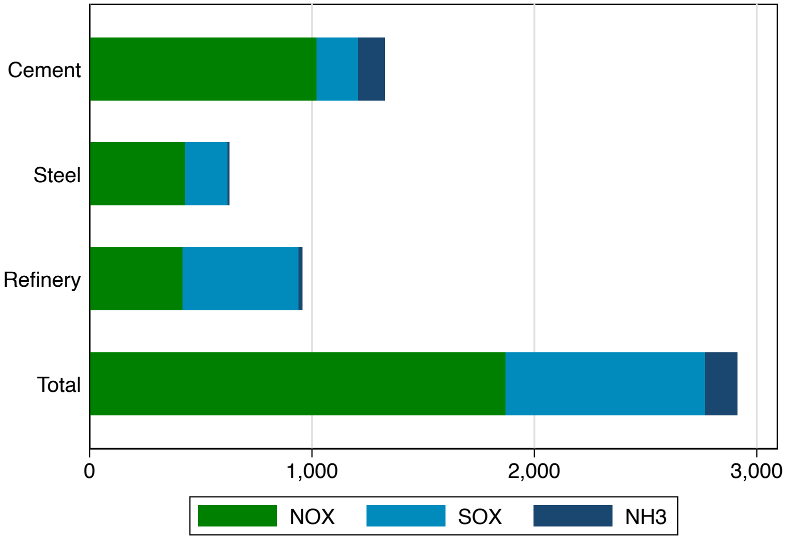
- Naive approach: Scale co-emissions in proportion to large decarbonization.
- Useful to gauge *potential* magnitude of health benefits different industries
- Likely consistent with:
  - output change
  - (large) energy efficiency improvements
  - electrification or
  - hydrogen-based production
- Not necessarily consistent with:
  - Carbon Capture and Storage
  - fuel substitution,
  - major process innovations

80% Decarbonization: Avoided Premature Deaths due to $PM_{2.5}$



Associated deaths with an 80% reduction in emissions in 2015

80% Decarbonization: Avoided Premature Deaths due to $PM_{2.5}$



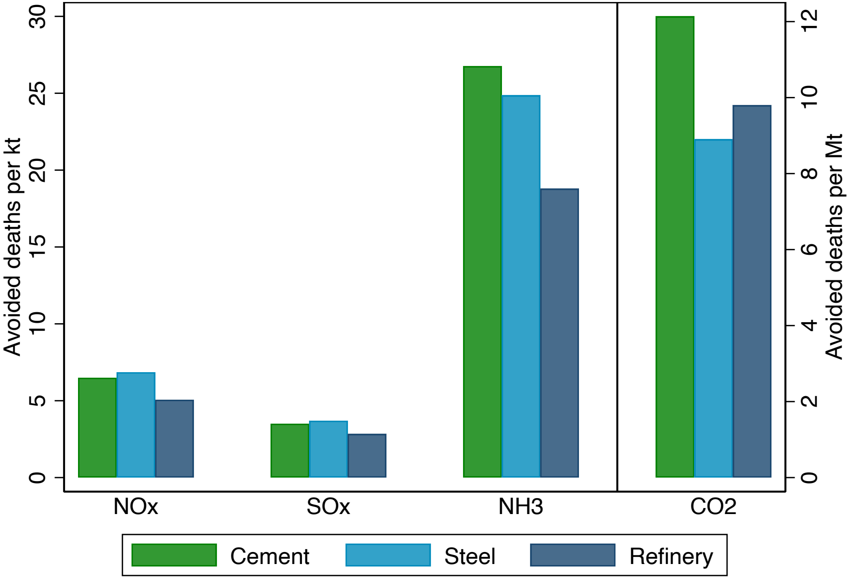
Associated deaths with an 80% reduction in emissions in 2015

Avoided Deaths per kilo ton:

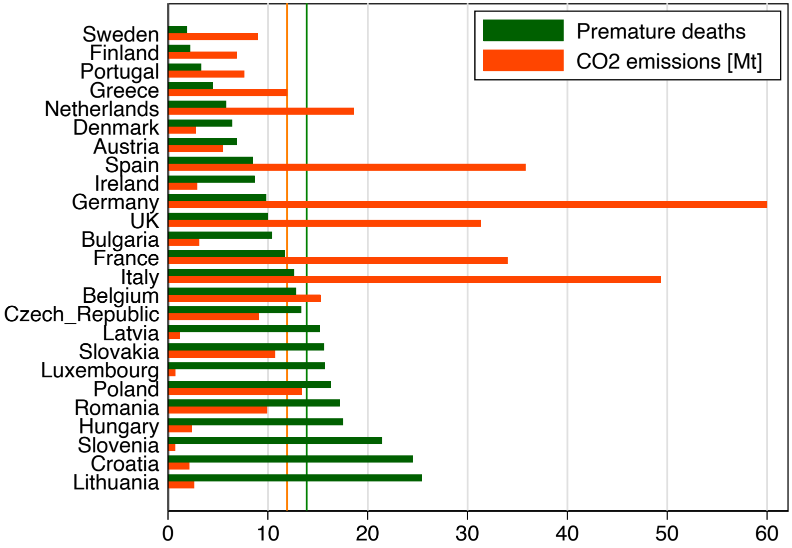
- NH_3: 20.3
- NO_x: 4.9
- SO_x: 2.5

Emissions-weighted average of marginal impacts across industries

Marginal Mortality Impacts of Pollutants by Industry



Marginal Health Impacts per Mt of CO_2e by Source Country



Emissions from cement, steel and refining in 2015. Vertical lines are means.

Scenario 3: Decarbonizing Cement Production

Levers for decarbonizing Portland Cement that are profitable at 80 Euros per tCO2e or less: (Glenk et al., 2023)

1. Reducing Clinker to Cement ratio:
   - optimized grinding of cement
   - addition of new supplementary cementitious materials (SCMs) and of recycled cement
   - Air quality (AQ) impact is positive (lower fossil fuel use)

2. Fuel Switching:
   - Biomass: AQ impact depends on specific fuel and pollution control equipment
   - Waste: AQ impact depends on alternative disposal (incineration vs. land fill)

3. Carbon Capture and Storage with LEILAC.
   - We disregard LEILAC and other CCS technologies (likely no AQ benefit).

Cost-effective Decarbonization of Portland Cement Production

Compute pollution reduction factor following Fenell et al. (2021, *Joule*)

$$\frac{CO_2}{CO_{2\ base}} = \frac{Clinker}{Clinker_{base}}(1 - Digitization)(1 - EnEff)(1 - Hydrogen)(1 - AltFuel) \quad (1)$$

We follow their assumptions and assume:

- Lower clinker requirement: from 0.7 to 0.6 (low) or 0.5 (high)
- Digitization improves efficiency by 10%
- Energy efficiency improvements of 5%
- Hydrogen share=0
- Alternative fuel share: low 10%, high 50%

Back-of-Envelope Calculation

- Reduction in fuel based emissions reduction by 33% (low) or 69% (high)
- Avoided premature deaths from cement production 547 (low) or 1,145 (high) p.a.
- Monetized benefits (VSL at €2.7 m) of €1.5 bn and €3.1 bn

Conclusion and Outlook

- Industrial decarbonization offers sizable $PM_{2.5}$ related health co-benefits in Europe
- Magnitude depends on which industries decarbonize, and where
- Cement & clinker production is a prime candidate, given size, pollution intensity, and economics of readily available decarbonization levers
- Analysis *still preliminary*
- Distributional analysis of health burden is feasible but computationally expensive.

Thank You!