Carbon Giants: Exploring the top 100 industrial CO_2 emitters in the EU

Simon Sturn, joint with Xenia Miklin, Thomas Neier, Klara Zwickl

All: WU – Vienna University of Economics and Business, Department of Socio-Economics

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Highlights

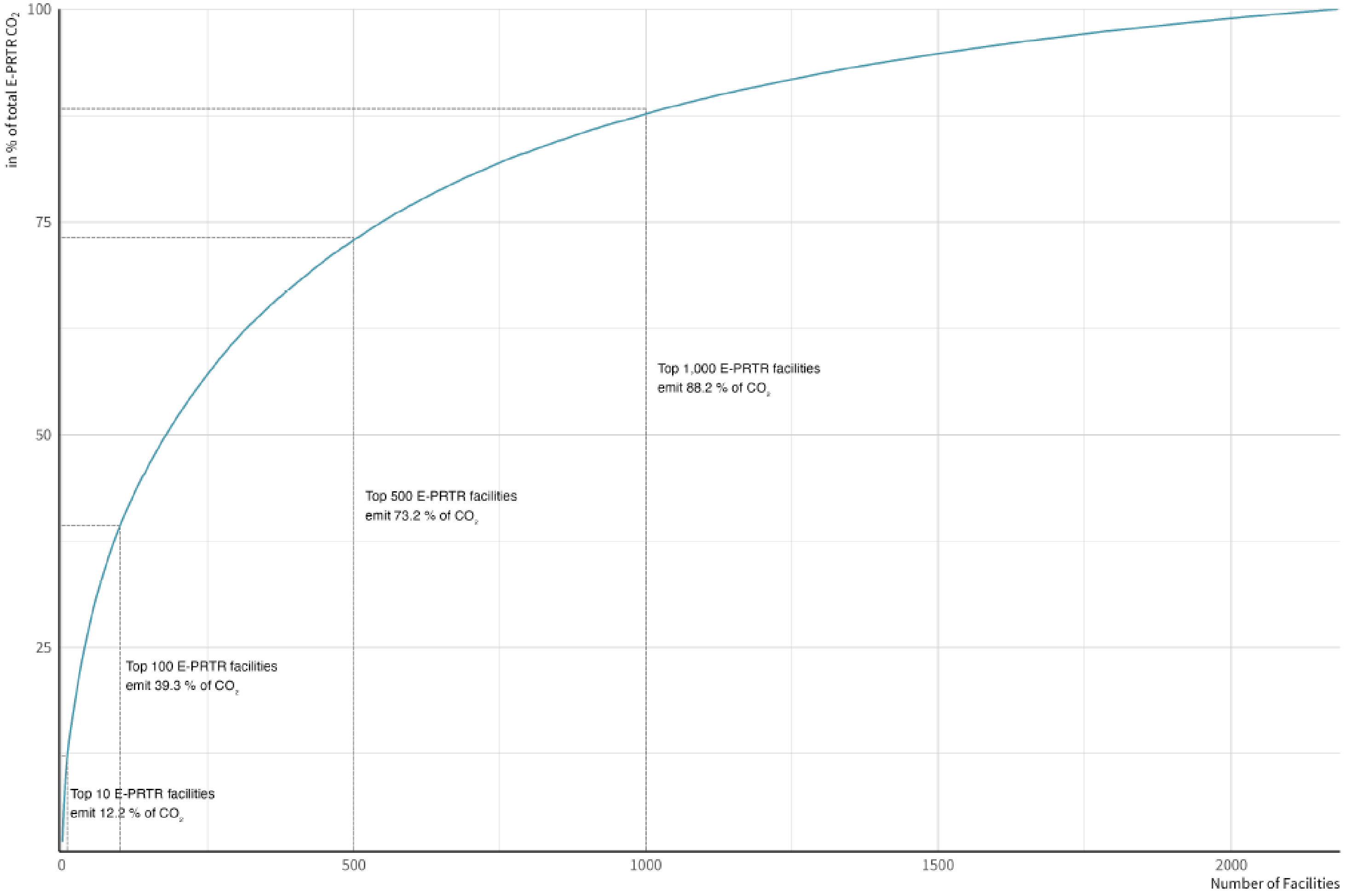
- We assess the top 100 industrial carbon emitting facilities in the EU.
- They account for 39% of industrial and 19% of total EU CO_2 emissions. They also emit a massive amount of co-pollutants, like PM, NO_x, SO_x, that negatively affect health of local population.
- We use climate avoidance and co-pollutant damage cost estimates to quantify the harm they are doing. Carbon and co-pollutant damages of top 100 often exceed regional industry value added. This indicates substantial underregulation.
- Yet, the top 100 received free EU ETS permits for 27% of their carbon emissions.
- Regions with top 100 facility face higher particulate matter exposure and lower life expectancy than remaining or neighboring regions.

Data

- Most important sources are: European Pollutant Release and Transfer Register (E-PRTR) at the facility level.
  - A “**facility**” is characterized as one or multiple installations located on the same site that are operated by the same natural or legal person. An “installation” refers to a stationary technical unit where one or more industrial activities are carried out, along with directly related activities that have a technical link to these operations and could influence emissions and pollution.
  - This source has information on CO2 and **co-pollutants** (i.e. pollutants that are co-emitted to the air when burning carbon, like particulate matter, NOx, SOx).
  - Most recent year available for all European countries is **2017**.
- Installations level data from the European Union Transaction Log (EUTL) from the EU ETS.
  - 93 facilities in the E-PRTR top 100 list can be matched with the EUTL-installations data.
  - This source allows us to track top emitters over time, and calculate share of free permits.
- Additionally, country-level data from the European Monitoring and Evaluation Programme (EMEP), grid-cell population density data from the Global Human Settlement Layer by the European Commission’s Joint Research Center (GHS-POP), and NUTS3 regional data from the European Commission’s Knowledge Centre for Territorial Policies (ARDECO).

Stylized facts

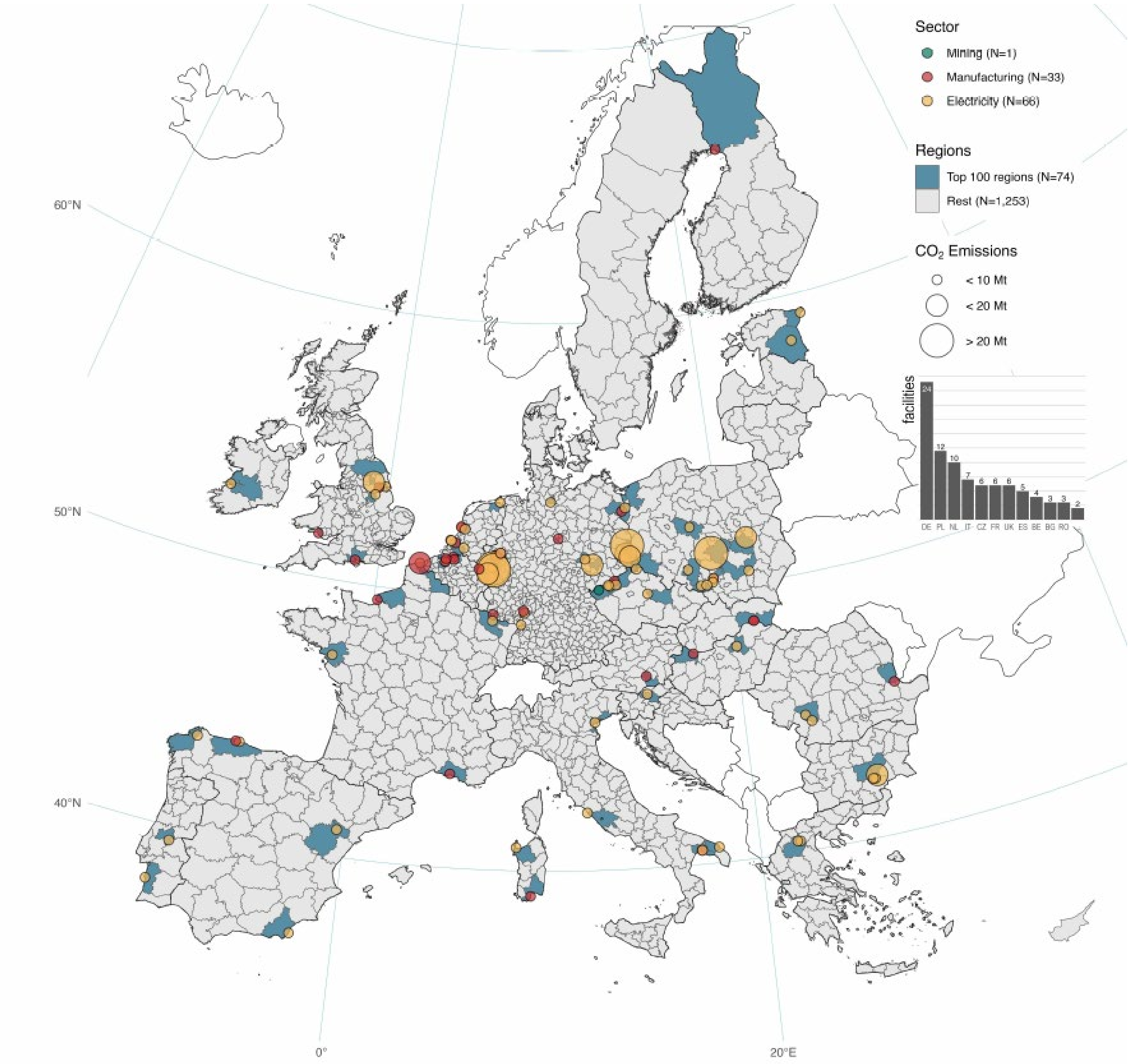
Cumulative distribution of CO2 emissions of E-PRTR facilities in EU-28 countries



- Top 10 = 12.2%
- Top 100 = 39.3%
- Top 500 = 73.2%
- Top 1000 = 88.2%
- Bottom 1082 = 11.8%

- Note: Not included are over 36,000 emitters that only report emissions of one or a few of the 91 pollutants listed in the E-PRTR data, but do not report CO2 emissions.

Notes: Data is based on the year 2017, the last year where this data is available for all EU-28 countries.
Source: E-PRTR, own calculations.

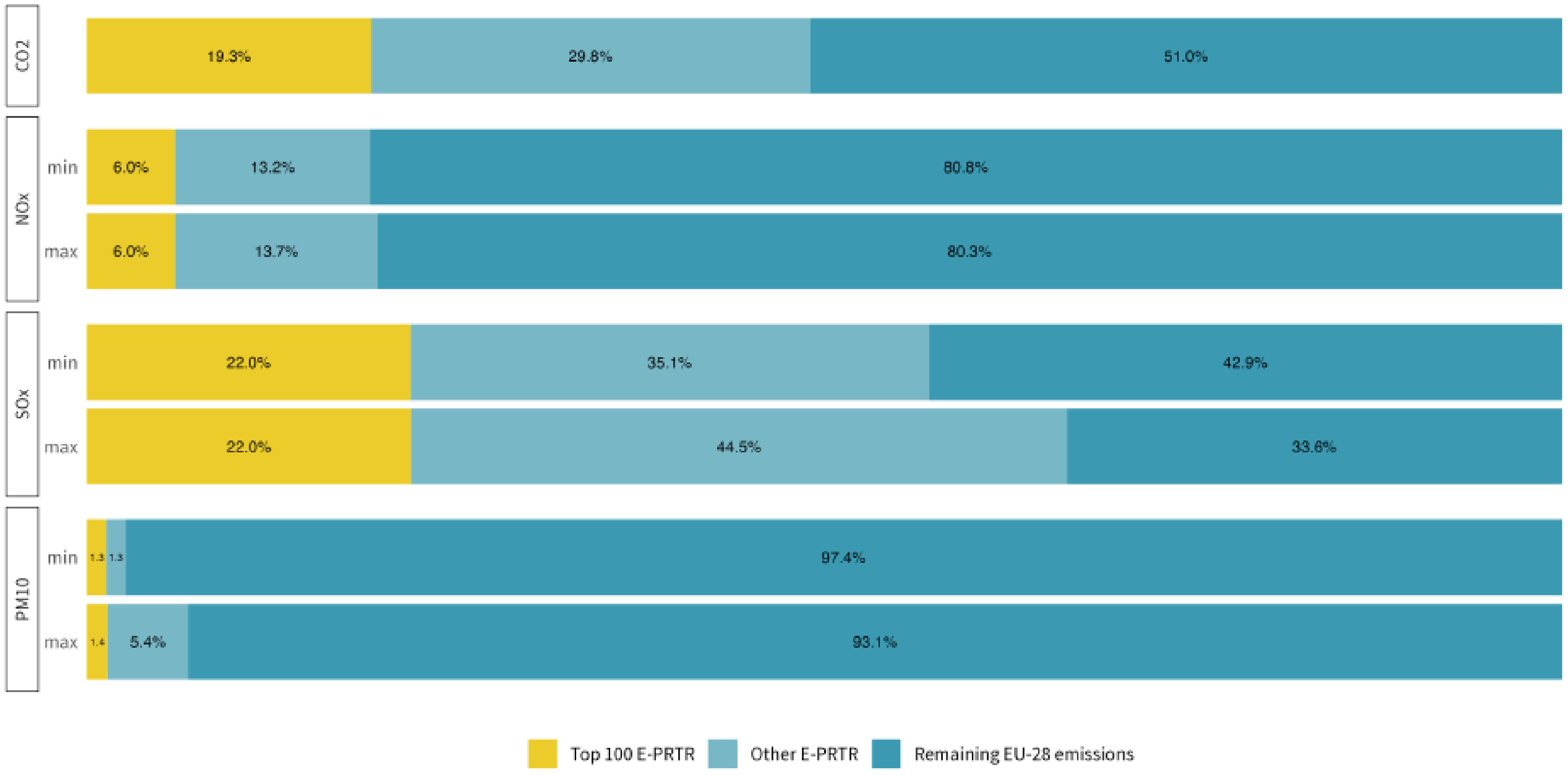


Notes: Data is based on the year 2017, the last year where this data is available for all EU-28 countries.
Sources: E-PRTR, own visualization.

Top 100 industrial CO2 emitters mapped in NUTS3 regions by NACE industry classification

- Germany hosts 24 facilities, Poland 12, the Netherlands 10, Italy 7, the Czech Republic, France, and the United Kingdom each 6, Spain 5, Belgium 4, Bulgaria and Romania 3, Estonia, Greece, Hungary, Portugal, and Slovakia each 2, Austria, Finland, Ireland, and Slovenia each 1.
- **Germany, Poland, and the Netherlands host 46 of the top 100 facilities.**
- They are located in 74 distinct NUTS3 regions and in 62 NUTS2 regions.
    - The NUTS2 region with the most top 100 facilities (8) is Düsseldorf, Germany.
- **33 are active in manufacturing** (mostly in the production of steel), while one is in mining, and **the remaining two-thirds are in the electricity sector** (mostly coal-fired power plants).
- **16 million people or 3.12% of Europe's population lives within 10km** of a top 100 facility.

CO_2 and co-pollutant share in percent of total for top 100 industrial CO_2 emitters, other CO_2 emitting E-PRTR facilities, and remaining EU-28 emissions



Notes: Some facilities fall under the reporting threshold for one or more co-pollutants. In these cases, we calculate two scenarios, one where we assume the facility does not emit the respective co-pollutant at all (min), and one where we assume the facility emits 1kg below the emission threshold (max). Data is based on the year 2017.
Sources: E-PRTR, EMEP, own calculations.

- Top 100 facilities contribute a significant share to industrial and overall carbon and co-pollutant emissions.

Monetizing climate and co-pollutant (PM, SOx, NOx) damages

- How much do these carbon and co-pollutant emissions cost (in €) society?
- EEA (2021) surveys the literature and provides central **climate change avoidance costs** and country-specific **co-pollutant damage costs**.
  - Central short and medium term estimate (of 105€ per ton of CO_2).
  - Central long term estimate (of 283€ per ton of CO_2).
    - What is the difference? In the short run, CO_2 emissions can be reduced by e.g. by switching from coal to gas. For more substantial reductions, much higher investments are necessary.
  - VOLY: The value of a life year considers the age at which deaths occur and calculates the and calculates the damage costs by measuring the loss of life expectancy as potential years of life lost.
  - VSL: The value of a statistical life quantifies the damage costs by gauging the amount individuals are willing to pay to reduce their risk of death from adverse health conditions.
    - VOLY is the lower and VSL the higher estimate, both are expressed in Euros
- So there are 4 versions of this calculation, with 2 different climate avoidance costs and 2 different co-pollutant damage costs.
- The joint magnitude of these damages ranges between **92 and 260 billion Euros**. This exceeds the GDP of 10 to 16 single European countries.

Pollution damages compared to value added

- Muller et al. (2011) introduce a framework for **integrating environmental externalities** into national accounts.
- Their findings reveal that certain industries – such as solid waste combustion, petroleum- and coal-fired electric power generation, etc. – generate air pollution damages that exceed their value added.
    - Coal-fired electric power generation emerges as the by far largest absolute contributor to external costs.
- The fact that external damages surpass the value added in these industries implies that if the national accounts incorporated the external costs, value added for these industries would be negative.
- We would like to do something similar. But we are unable to match facilities to firms. We use a bold alternative to facility-level value added. **Regional (NUTS3) industry (excluding construction) value added**.
    - Note: **Top 100-hosting NUTS3 regions are strongly populated industrial areas**. Average per capita gross value added 35.3% higher, average population in NUTS3 regions with top 100 facilities 612,000 inhabitants, compared to 337,000 inhabitants in the remaining regions. 74 NUTS3 regions with a top 100 facility, so many host more than one.

Co-pollutant damage and climate avoidance costs, with the central longer term estimate, relative to regional (NUTS3) industry value added, of top 100 industrial CO2 emitters

		Climate change avoidance and damage costs (in Mio. €)		GVA Share (%)	
		VOLY	VSL	VOLY	VSL
1	PGE - Elektrownia Bełchatów	11,471	13,165	442.33	507.65
2	RWE Power AG - Kraftwerk Neurath	9,090	10,696	166.97	196.47
3	RWE Power AG - Kraftwerk Niederaussem	8,451	10,340	174.54	213.55
4	LEAG - Kraftwerk Jaenschwalde	7,730	10,061	383.35	498.96
5	RWE Power AG - Kraftwerk Weisweiler	5,804	6,826	121.61	143.02
6	LEAG - Kraftwerk Boxberg	6,100	7,824	293.79	376.83
7	Drax Power Station	5,806	7,375	206.28	262.01
8	ArcelorMittal Atlantique et Lorraine - Site de Dunkerque	3,884	4,598	35.44	41.95
9	Enea Wytwarzanie SP.z oo - Koziencie Power Station	3,673	4,188	285.91	325.97
10	LEAG - Kraftwerk Schwarze Pumpe	3,626	4,538	179.84	225.09
	Top 10	65,636	79,611	178.34	216.31
	Top 50	151,878	183,825	92.01	111.37
	Top 100	212,482	259,565	75.03	91.66

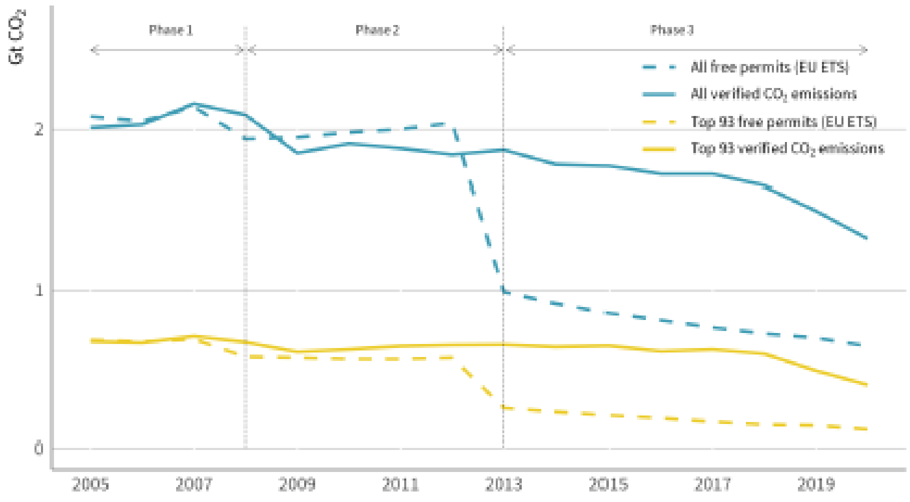
Notes: Country-specific damage costs and the central estimate of the climate change avoidance costs over the longer term (2040-2060) per ton of CO_2 equivalent in 2019 prices, amounting to 283€, are taken from EEA (2021, Table 33, p.88). Co-pollutants include PM_{10}, NO_x and SO_x. Co-pollutant damage costs are zero for facilities that do not report co-pollutants in a specific year, see minimum scenario in Figure 5. Gross value added (GVA) for industry (sectors B-E, excluding Construction) is measured at the NUTS3 level for the year 2017 in 2019 prices. Sources: E-PRTR, ARDECO, EEA, own calculations.

- **Damages exceed regional industrial value added for 11 to 39 facilities**, depending on the climate and damage costs applied.
- For long run climate avoidance costs, damages of the top 10 significantly exceed the local industry value added under both damage cost estimates considerably, ranging from 178% to 216%.
- These findings strongly indicate the need for regulation or taxation measures to ensure that the true costs of production are reflected in market prices.

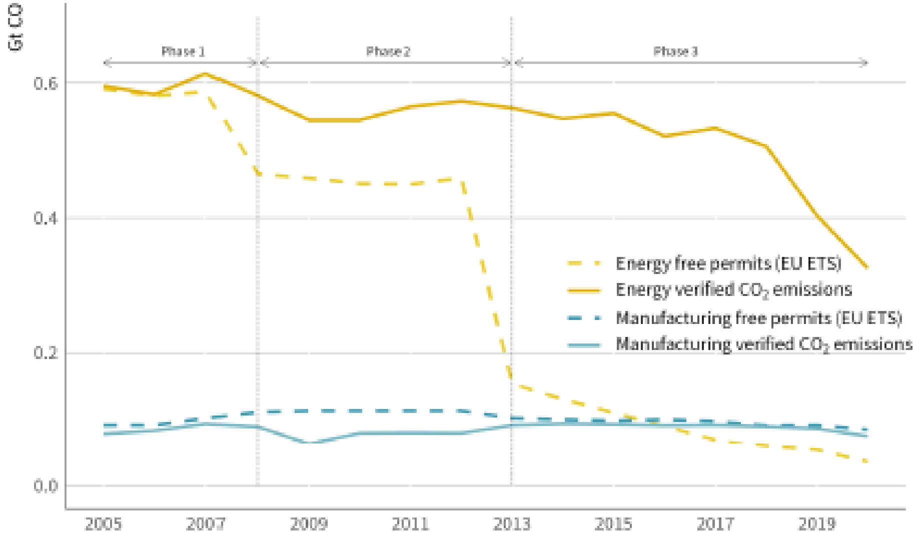
Free permits in the EU ETS

- They should be regulated more strongly. How many free carbon emission permits do they get?
- In the first (2005-2007) and second (2008–2012) phase of the EU ETS (2005-2007) over 90% of permits were allocated for free.
- In the third phase (2013-2020) there was a significant reduction in free allocation, with 57% of permits being transitioned to auctioning. Free allocation was supposed to become an exception, primarily for reasons related to competitiveness and concerns over 'carbon leakage,' particularly within the manufacturing sector.
  - "[P]ower generators since 2013 in principle do not receive any free allowances, but have to buy them. However, some free allowances are available to modernise the power sector in some [EU] Member States." (https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/free-allocation_en)

Free permits and verified CO2 emissions (in Gt) of (a) all installations and top 93 facilities and (b) top 93 facilities by sector



(a)



(b)

Notes: Freely allocated permits (in Gt) under the EU ETS, verified CO_2 emissions (in Gt) of (a) the top 93 E-PRTR facilities and the total sample of EU ETS installations (N_{2005}= 10,849; N_{2006}= 11,005; N_{2007}= 11,570; N_{2008}= 11,699; N_{2009}= 12,348; N_{2010}= 12,687; N_{2011}= 11,724; N_{2012}= 11,815; N_{2013}= 11,928; N_{2014}= 11,854; N_{2015}= 11,869; N_{2016}= 11,923; N_{2017}= 12,054; N_{2018}= 12,209; N_{2019}=12,268; N_{2020}=12,318) (b) the top 93 facilities by energy and manufacturing sector.
Sources: EUTL, own calculations.

- In 2017, 13.2% of permits allocated to energy producers were still granted for free. By 2020, this share decreased slightly to 11%.
- For manufacturing, free allowances consistently exceed verified emissions in every year from 2005 to 2020.

Socio-demographic characteristics of regions with a top 100 facility

- We gather regional information for NUTS2 regions (cross-sectional for 2017).
- In the first part of this analysis, we compare NUTS2 regions hosting a top 100 facility to those without.

$$Y_{ic} = \beta \cdot D_{ic}^{top100} + \gamma \cdot X_{ic} + \delta_c + \varepsilon_{ic}$$

  - With region i in country c
- In the second part, we limit the set of control regions to the neighbors of the top 100 hosting NUTS2 regions that do not host a top 100 facility themselves.

$$Y_{inc} = \beta \cdot D_{inc}^{top100} + \gamma \cdot X_{inc} + \alpha_n + \delta_c + \varepsilon_{inc}$$

  - With region i, neighboring region n, country c.
- We have 62 NUTS2 regions with a top 100 facility.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All NUTS2 regions				Top 100 and neighboring NUTS2 regions			
		= (1) + country fixed effects	= (2) + controlling for population density	= (3) weighted by population	With neighbors fixed effects	= (5) + country fixed effects	= (6) + controlling for population density	= (7) weighted by population
Panel A: PM_{10} exposure								
Top 100 dummy	1.740**	0.797*	1.020**	1.371**	0.910***	0.919***	0.854***	1.076***
	(0.035)	(0.064)	(0.017)	(0.026)	(0.006)	(0.002)	(0.003)	(0.001)
Observations	273	273	273	273	275	275	275	275
Adjusted R-squared	0.022	0.598	0.676	0.622	0.661	0.717	0.735	0.800
Panel B: $PM_{2.5}$ exposure								
Top 100 dummy	1.354*	0.450	0.597**	0.542	0.572**	0.571***	0.525***	0.577***
	(0.076)	(0.134)	(0.033)	(0.216)	(0.020)	(0.006)	(0.007)	(0.005)
Observations	273	273	273	273	275	275	275	275
Adjusted R-squared	0.022	0.678	0.732	0.697	0.756	0.797	0.811	0.863
Panel C: NO_x exposure								
Top 100 dummy	0.759	0.168	0.792**	0.413	0.570*	0.598*	0.414*	0.379
	(0.388)	(0.785)	(0.048)	(0.528)	(0.078)	(0.078)	(0.066)	(0.187)
Observations	273	273	273	273	275	275	275	275
Adjusted R-squared	-0.000	0.308	0.749	0.713	0.640	0.660	0.838	0.860

Notes: Regression results based on Equation (1) for Specifications 1-4, and Equation (2) for Specifications 5-8.
*** indicates statistically significant at the 1% level, *** at the 5% level, and ** at the 10% level.
P-values based on randomization inference in brackets.
Source: EEA, EUROSTAT, own calculations

- Across most specifications, we find that pollution levels are higher by about 20% of a SD in top 100 regions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All NUTS2 regions				Top 100 and neighboring NUTS2 regions			
		= (1) + country fixed effects	= (2) + controlling for population density	= (3) weighted by population	With neighbors fixed effects	= (5) + country fixed effects	= (6) + controlling for population density	= (7) weighted by population
Panel A: Crude death rate								
Top 100 dummy	51.936***	28.131***	27.868**	34.260***	20.832*	24.335***	25.304***	17.331*
	(0.004)	(0.016)	(0.017)	(0.009)	(0.083)	(0.009)	(0.007)	(0.086)
Observations	273	273	273	273	275	275	275	275
Adjusted R-squared	0.357	0.872	0.873	0.877	0.829	0.903	0.904	0.908
Panel B: Life expectancy in years								
Top 100 dummy	-0.636**	-0.334**	-0.318**	-0.488**	-0.259*	-0.269***	-0.273***	-0.221
	(0.013)	(0.015)	(0.018)	(0.011)	(0.075)	(0.007)	(0.007)	(0.110)
Observations	273	273	273	273	275	275	275	275
Adjusted R-squared	0.009	0.848	0.849	0.861	0.846	0.925	0.925	0.924
Panel C: GDP per capita								
Top 100 dummy	-2,820.566	-1,100.843	271.206	-1,625.678	1,030.304	1,751.739*	1,471.329	1,019.990
	(0.308)	(0.589)	(0.854)	(0.443)	(0.464)	(0.091)	(0.121)	(0.359)
Observations	273	273	273	273	275	275	275	275
Adjusted R-squared	0.001	0.401	0.597	0.595	0.578	0.801	0.832	0.830
Panel D: Unemployment rate								
Top 100 dummy	-0.391	0.631	0.755*	1.051	0.163	0.401	0.377	0.124
	(0.936)	(0.152)	(0.064)	(0.167)	(0.692)	(0.193)	(0.225)	(0.730)
Observations	272	272	272	272	275	275	275	275
Adjusted R-squared	-0.003	0.740	0.757	0.682	0.670	0.830	0.831	0.841
Panel E: Risk of poverty rate								
Top 100 dummy	-0.597	0.701	0.838	1.685	0.342	0.539	0.501	0.052
	(0.796)	(0.426)	(0.329)	(0.308)	(0.549)	(0.336)	(0.362)	(0.941)
Observations	273	273	273	273	275	275	275	275
Adjusted R-squared	-0.003	0.582	0.589	0.462	0.708	0.765	0.765	0.745
Panel F: Early leavers from education rate								
Top 100 dummy	0.717	1.282**	1.273**	1.325**	0.809*	0.429	0.422	0.134
	(0.294)	(0.021)	(0.024)	(0.040)	(0.077)	(0.309)	(0.320)	(0.754)
Observations	249	249	249	249	253	253	253	253
Adjusted R-squared	0.000	0.454	0.451	0.533	0.563	0.683	0.681	0.770

- Across most specifications, we find that the crude death rate is higher and life expectancy is lower by about 10% of a SD in top 100 regions.
- We also find some evidence, that school drop out rates are higher.
- No other discrepancies (GDP, unemployment, poverty).

Average CO2 and co-pollutant emissions (in tons) by E-PRTR and top 100 facilities in NUTS2 regions with top 100 facilities

- Our results are consistent with a substantial body of literature indicating adverse impacts of co-pollutant exposure on health, mortality, and school performance.
- We cannot show that this is caused by the top 100 facilities.
- But we can show, that the top 100 massively contribute to regional co-pollutant emissions.

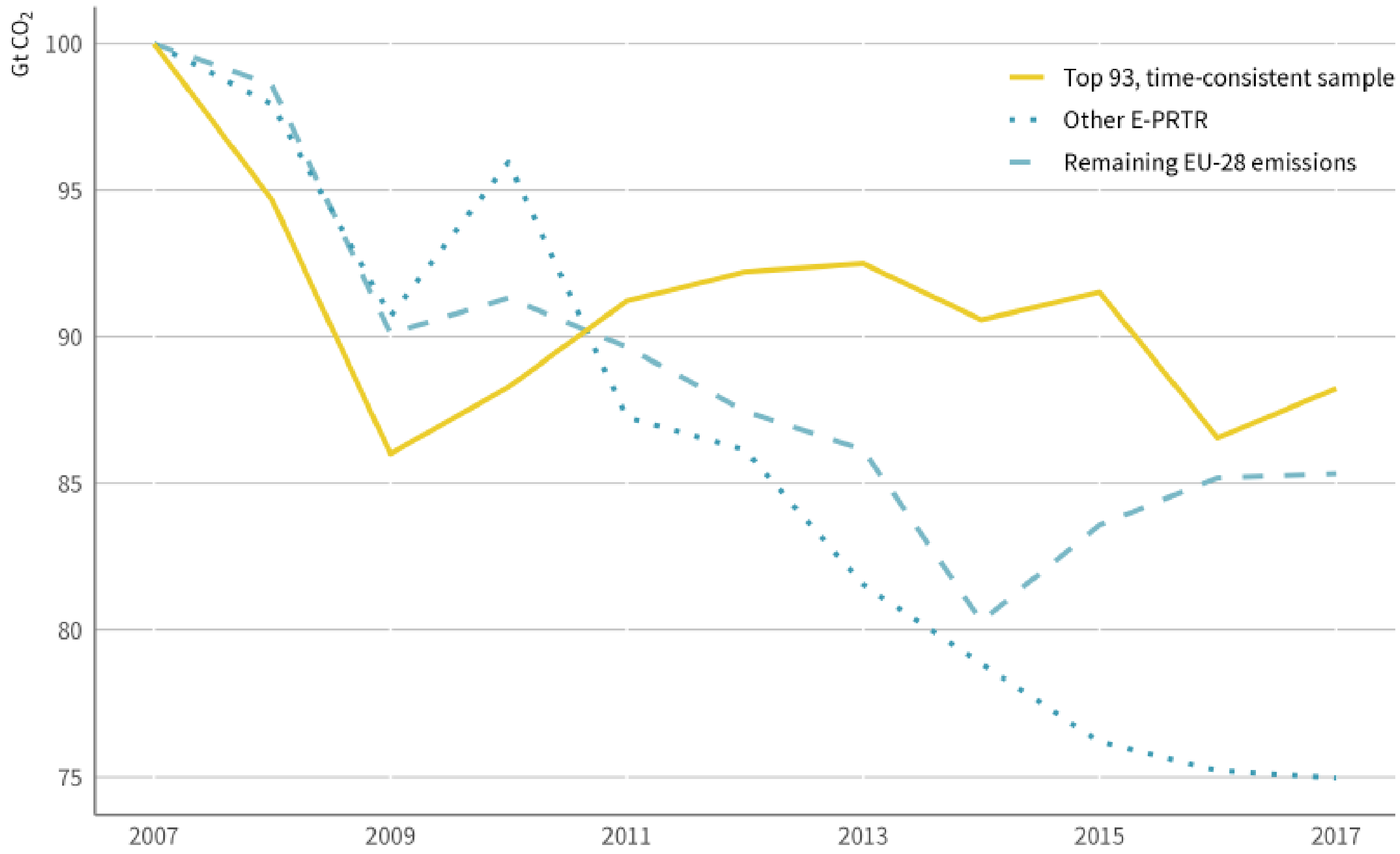
	E-PRTR emissions	Top 100 emissions	Average share of top 100 (in %)
CO_2	23,800,000	16,200,000	63.89
NO_x	16,700	10,800	59.83
SO_x	16,400	10,900	63.12
PM_{10}	906.43	711.80	74.20

Notes: Column 1 displays average total emissions in top 100 hosting NUTS2 regions from all E-PRTR facilities. Column 2 shows average emissions by the top 100 facilities in these regions. Column 3 represents the top 100 facilities' average share of all E-PRTR emissions in percentage.
Source: E-PRTR, own calculations

Conclusions

- Large carbon emitters cause more damage than they add value to the economy.
- They also create a health equity problem.
- Should be regulated more strictly.
- Yet, receive free permits.

Development of CO2 emissions (2007=100) for top 93 industrial CO2 emitters, other E-PRTR facilities, and remaining total EU-28



- Top 100/93 reduced emissions in Great Recession, but not afterwards.

Notes: Top 93 are among E-PRTR top 100 facilities from 2017 that could be identified in EUTL. This time-consistent sample includes the same facilities each year. The number of E-PRTR facilities varies by year: N_{2007}= 2,178; N_{2008}= 2,230 N_{2009}= 2,156; N_{2010}= 2,241; N_{2011}= 2,210; N_{2012}= 2,186; N_{2013}= 2,123; N_{2014}= 2,072; N_{2015}= 2,054; N_{2016}= 2,058; N_{2017}= 2,082. Sources: E-PRTR, EUTL, EMEP, own calculations.

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Co-pollutant damage and long run climate avoidance costs associated with free allowances, ranked by amount of received free allowances, and relative to regional (NUTS3) industry value added

		Climate change avoidance and damage costs (in Mio. €)		GVA Share (%)	
		VOLY	VSL	VOLY	VSL
1	ArcelorMittal Taranto Ilva S.P.A.	2,010	2,570	124.17	158.56
2	Tata Steel DBM	2,250	2,950	118.94	155.85
3	AcelorMittal Atlantique et Lorraine - Site de Dunkerque	2,640	3,350	24.04	30.56
4	PGE - Elektrownia Bełchatów	2,372	2,722	91.62	105.13
5	ArcelorMittal Asturias (Aviles)	1,760	2,340	41.23	54.77
6	BASF SE - Ludwigshafen	2,004	2,275	23.49	26.66
7	Hüttenwerke Krupp Mannesmann GmbH	1,730	2,410	41.44	57.67
8	Port Talbot Steel Works	2,268	3,210	79.22	112.22
9	ArcelorMittal Mediterranee	2,052	2,614	24.53	31.24
10	Liberty Galati Steel Works	1,190	1,410	145.55	172.23
	Top 10 receivers	20,300	25,900	43.99	56.12
	Top 50 receivers	47,800	61,100	34.81	44.49
	Top 93 receivers	48,000	61,400	19.82	25.35

Notes: Country-specific damage costs and the central estimate of the climate change avoidance costs over the longer term (2040-2060) per ton of CO_2 equivalent in 2019 prices, amounting to 283€, are taken from EEA (2021, Table 33, p.88). Co-pollutants include PM_{10}, NO_x, and SO_x. Data is based on the year 2017. Co-pollutant damage costs are zero for facilities that do not report co-pollutants in a specific year, see minimum scenario in Figure 5. Gross value added (GVA) for industry (sectors B-E, excluding Construction) is measured at the NUTS3 level for the year 2017 in 2019 prices.
Sources: E-PRTR, EUTL, ARDECO, EEA, own calculations.

- Damage costs of ArcelorMittal Taranto Ilva S.P.A. exceed the regional industry value added considerably (124.2% for VOLY and 158.6% for VSL).
- Yet, this facility received free permits amounting to 208% of its verified carbon emissions.
- Free damages also exceed VA for Tata Steel DBM and Liberty Galati Steel Works.
- And for the higher VSL estimate also for PGE - Elektrownia Bełchat.w, EU's largest industrial carbon emitter, Port Talbot Steel Works, and U.S. Steel Kosice.