Paris School of Economics
Center for Economic and Policy Research

Global carbon inequality
New findings & research perspectives

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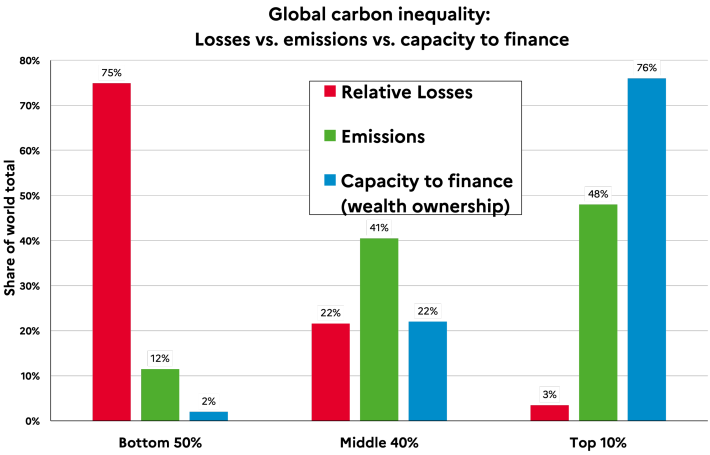
Who are the winners and losers of the environmental transition?

- Knowledge of the environmental crisis is necessary but not sufficient for change.
- Knowledge of technical solutions is necessary but not sufficient either.
- Better understanding distributional environmental conflicts (past & present) and their resolution is required.

Many dimensions to distributional environmental conflicts

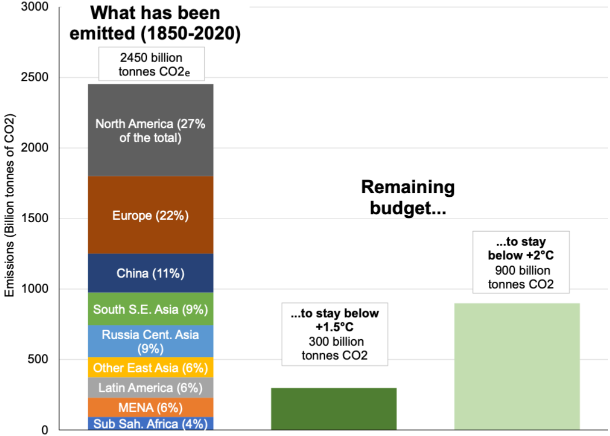


Global carbon inequality
Source: Chancel, Bothe, and Voituriez, 2023

Many dimensions to distributional environmental conflicts

- Variety of dimensions: impacts, contributions, capacity to act.
- Variety of scales: global, national, local.
- Variety of metrics: monetary, physical, socio-demographic.
- Burgeoning field in quantitative social sciences.

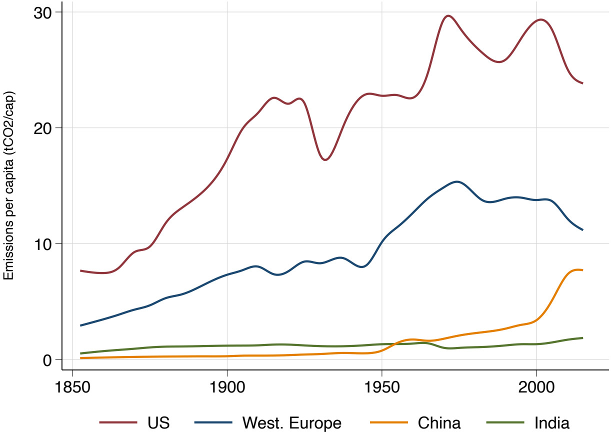
Unequal emissions between countries



Interpretation: The graph shows historical emissions by region (left bar) and the remaining global carbon budget (center and right bars) to have 83% chances to stay under 1.5°C and 2°C, according to IPCC AR6 (2021). Regional emissions are net of carbon embedded in imports of goods and services from other regions. **Source and series:** Chancel (2021). Historical data from the PRIMAP-hist dataset.

Historical emissions vs. remaining carbon budget

The global North reached per capita emissions levels the South will never reach



Per capita emissions across the world, 1850-2020

The "Great overshoot": global North emitted 3x more than its population share

- Global North emitted nearly 3x more than its population share over 1850-2050 assuming net zero in 2050 (4x more in Business-as-Usual scenario)
- Global South emitted 2x less than its population share (under BaU: South emits its population share by 2050) (Fanning and Hickel, 2023)

What are the implications of the "Great overshoot"?

- Historical development debate: Could the global North have developed with less carbon? [More]
- Contemporary debate: how much should the global North compensate global South for emissions overshoot?
  - At $200/tonne CO2, compensation = $100-250tn. Equivalent of a wealth tax on global North's net wealth of 1-2.5% (or 6-15% of income), every year over 2020-2050.

Next slides: Current work on carbon inequality over 1990-2050, with a focus on capital ownership

- "The Carbon Footprint of Capital" *Working paper* with Y. Rehm
  $\Rightarrow$ Measure the carbon content of capital ownership and its distribution

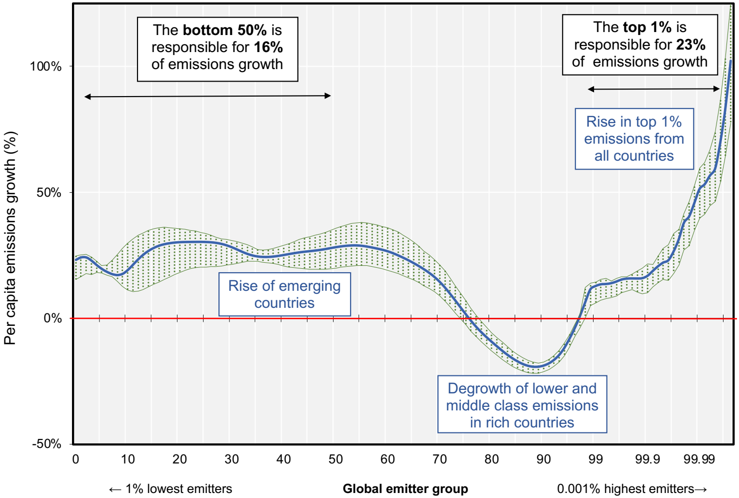
- "Global Carbon Inequality" *Nature sustainability*
  $\Rightarrow$ New estimates on the global inequality of carbon emissions

- "Potential pension fund losses should not deter high-income countries from bold climate action" *Joule* with G. Semieniuk, E. Saïsset, P. Holden, J.-F. Mercure, N. Edwards
  $\Rightarrow$ Distribution of financial losses due to stranded carbon assets

Key findings: Emissions from capital ownership are significant at the top

- Taking into account emissions from capital ownership increases the carbon footprint of the top 10% of individuals by 30%-90%, as compared to estimates measuring consumption emissions only.
- Emissions from capital ownership are at least as concentrated as capital (if anything: appear to be even more concentrated than capital).
- Ownership approach: 80-90% of emissions of the top 1% stems from the assets they own rather than from their consumption (rest is direct emissions).

Key findings: unequal emissions dynamics between countries and within them since 1990



Growth in per capita emissions by group, 1990-2019

Methodology

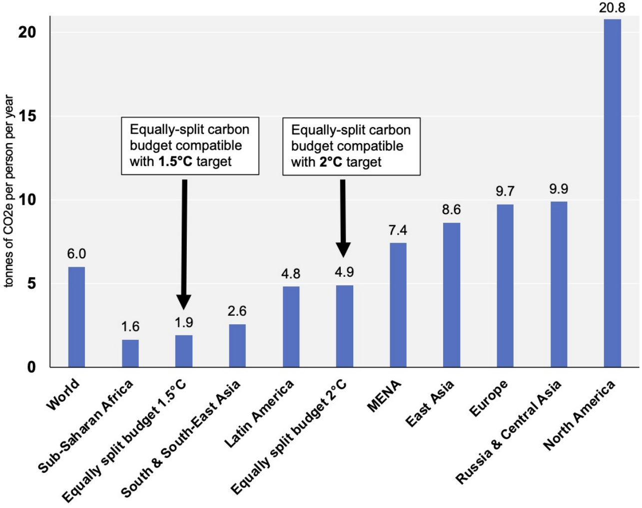
"Individuals with high socio-economic status contribute disproportionately to emissions and have the highest potential for emissions reductions, e.g., as citizens, investors, consumers, role models, and professionals."

AR6 SPM, IPCC (2022)

Carbon inequality is everywhere apart from most govt. statistics

- National Statistical Organizations (NSOs) across the globe struggle to publish up-to-date, basic information on carbon emissions (i.e. imports/export).
- Most NSOs do not publish data on the distribution of emissions growth across the population.
- Data gap limits our ability to design, implement and review climate policy.
- Project makes contributions to close the gap. Disclaimer: a lot remains to be done. Reconstruction exercise & mapping of many gaps.

Large inequalities in average emissions between regions



Avg. per capita emissions across regions, 2019

- **Question:** how to measure the inequality of individual carbon footprints?

- A carbon footprint is a *"measure of the exclusive total amount of emissions of carbon dioxide that is directly and indirectly caused by an activity or is accumulated over the lifecycle stages of a product"*

  (IPCC, 2022), Working group III, Annex I p. 1796

- Two key criterion and associated challenges: *direct+indirect* attribution (all emissions) *exclusive* attribution (no double counting).

- **Standard answer**: Distribute emissions to consumers (Chakravarty et al., 2009; Hubacek et al., 2017; Lenzen et al., 2006).
- Relatively large body of work developing this approach at national and international level (see Chancel, 2022; Pottier, 2022).
- Issue 1: Studies typically underestimate top emissions because of under sampling / misreporting at the top (see Alvaredo et al., 2020; Atkinson and Piketty, 2007).
- Issue 2: What about constraints on consumers, lack of information, limited agency?

Origins of the carbon footprint concept

- One of the first references to the individual carbon footprint concept made by British Petroleum in 2003-4. [Figure]
- Developed a methodology and simulator to track personal carbon footprints + advertisement campaign centered on individual responsibility (Wiedmann and Minx, 2008).

Carbon footprints and the consumption framework

- Consumption-centric approach is relatively well aligned with interests of firms seeking to minimize their responsibility.
- Evidence that oil producers deliberately sought to downplay their role in global warming and engaged in climate denialism (Bonneuil, Choquet, and Franta, 2021; Supran and Oreskes, 2017).
- Yet, the consumer focus is also largely consistent with standard economics whereby satisfying consumption is the end goal of production (Smith, 1776) $\rightarrow$ pollution serves consumption.

Carbon footprints and the consumption framework (ctd.)

- Consumers lack information (Akerlof, 1970) $\Rightarrow$ Limited alternatives and agency to alter production processes.
- Contracts & markets are incomplete (Grossman and Hart, 1986; Hart, 2017) $\Rightarrow$ at least some utility associated with capital ownership, beyond consumption: residual decision rights.
- Consumption-centric perspective relies on extreme assumptions about the economy, not particularly consistent with developments in economics.

Alternatives to consumer-centric approach

- **Oil owners approach**: emissions attributed to a few investors in the oil, coal and gas industry (Griffin, 2017)
  - More than 50% of all CO_2 emissions since 1850 (and >70% of all *energy* emissions) due to 100 companies. 1/3 emissions since 1850 and over 1/2 energy emissions due to 25 companies.
- **Multinationals approach** (Zhang et al., 2020): carbon footprint of supply chains ("Coca-Cola's footprint is almost equivalent to Chinese food sector").
- **Rich list approach** (Oxfam, 2022): "Billionaires emit more than a million times average footprint of average individual"
- Issues: double counting or no individual consumption emissions at all.

Our approach to carbon inequality measurement

- Objective: a framework consistent with the principles of exclusivity and systematicity defined by the the IPCC, and consistent with Distributional National Accounts.
- We build Distributional Distributional Environmental accounts, along three approaches:
  - Consumption approach: all emissions to consumers.
  - Ownership approach: all indirect emissions to owners.
  - Mixed approach: combination of the above (similar to consumption except fixed capital formation emissions attributed to owners of the capital stock). [More]

Data sources

- Emissions
  - Eurostat FIGARO (Full International and Global Accounts for Research in input-Output) as well as EORA for non-CO2 gases and Global Carbon Project for global results (see *infra*).
  - Inter-country supply-use and input-output tables and flows of CO2 emissions by industry in 45 countries.
- Aggregate Wealth
  - Stock of fixed asset by industry and institutional sector Eurostat and OECD.
  - Carbon intensity of foreign investments EU-INFLOWS (OECD FDI, IMF PIS, Eurostat BoP). [More]
- Income, consumption & wealth inequality
  - Consumption: over 100+ country-level survey-based results on emissions vs. consumption/income.
  - Income and wealth: Distributional National Accounts + HFCS.

Input Output (IO) framework allocates all emissions to final demand: no double counting

Inter-industry transactions (”Z”) / **Final demand ("Y")** / **Gross output**

		Country 1		Country 2		Country 1		Country 2		Gross output
		Sector 1	Sector 2	Sector 1	Sector 2	HHs	Govt	HHs	Govt	
Country 1	Sector 1	340	150	100	154	150	150	300	160	1504
	Sector 2	354	200	200	600	200	400	300	200	2454
Country 2	Sector 1	300	200	300	60	100	200	290	500	1950
	Sector 2	50	250	427	200	35	400	300	200	1862

Country 1 sector 1 imported 354 from Country 1 Sector 2

Value Added = Sum of Final demands

Country 1	Value Added	460	1654		
Country 2	Value Added			923	848

Total input (x)

Input by country-sector	1504	2454	1950	1862

Carbon emissions ("Q")

Direct Emissions (CO2)	**200**	**300**	**200**	**400**

Figure: Input-Output: simplified representation

Input Output (IO) framework allocates all emissions to final demand: no double counting

Leontief's inverse (Leontief, 1970) (impact of final demand on sectors' output) given by:

$$L = (I - A)^{-1} \tag{1}$$

A is the technical coefficients matrix, each one given by:

$$a_{ij}^{rs} = z_{ij}^{rs} / x_j^s \tag{2}$$

The carbon intensity of production of sector s in country j is given by:

$$c_j^s = q_j^s / x_j^s \tag{3}$$

c is diagonalized into $\hat{c}$, the net carbon emissions associated (E) associated with final demand (Y) is given by:

$$E = \hat{c}LY \tag{4}$$

IO allocates all emissions to final demand: no double counting

Table 1.1
Global emissions, 1990-2019

Year	Total (GtCO2e)	HHs (GtCO2e)	Invest (GtCO2e)	Govt. (GtCO2e)	HHs (% total)	Invest (% total)	Govt (%total)
2014	44.1	23.2	13.8	5.7	52.6%	31.3%	12.9%
2015	44.3	23.1	14	5.7	52.1%	31.6%	12.9%
2016	44.3	23.2	14	5.7	52.4%	31.6%	12.9%
2017	44.9	23.5	14.2	5.7	52.3%	31.6%	12.7%
2018	45.8	23.9	14.6	5.8	52.2%	31.9%	12.7%
2019	45.8	23.9	14.6	5.8	52.2%	31.9%	12.7%
2020	43.4	22.5	14	5.5	51.8%	32.3%	12.7%

Interpretation: The table presents total GHG emissions from institutional sectors at the global level. Numbers include all emissions except from LULUCF. Sources and series: Author, see [16]

IO allocates all emissions to final demand: emissions net of trade

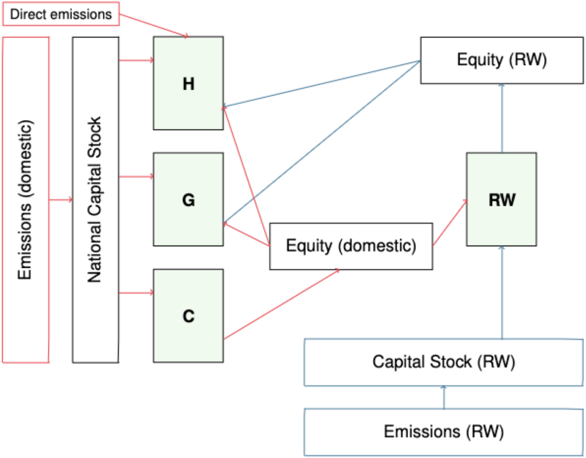
	Footprint inc. consumption (tCO2/capita)	Territorial (tCO2/capita)	% difference footprint vs. territorial
World	*6.0*	*6.0*	*0%*
Sub Saharan Africa	1.6	2.1	-22%
South South-East Asia	2.6	2.7	-5%
Latin America	4.8	4.9	-2%
Middle East	7.4	8.0	-7%
East Asia	8.6	9.4	-8%
Europe	9.7	7.9	23%
Central Asia / Russia	9.9	11.9	-17%
North America	20.8	19.8	5%

Notes: Carbon footprints include emissions from domestic consumption, public and private investments as well as net imports embedded in goods and services from the rest of the world. **Sources and series:** Author, see Methods and Supplementary Information.

Figure: Territorial vs. footprint emissions, 2019

Source: Chancel (2022)

Ownership approach: no double-counting

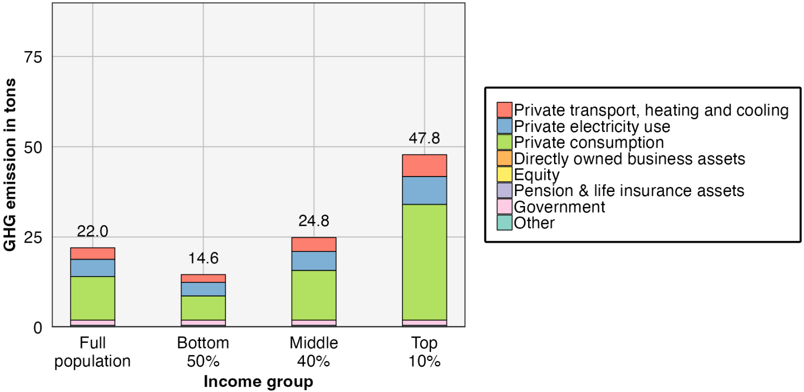


General method to attribute emissions to assets
Source: Chancel and Rehm (2023)

Results

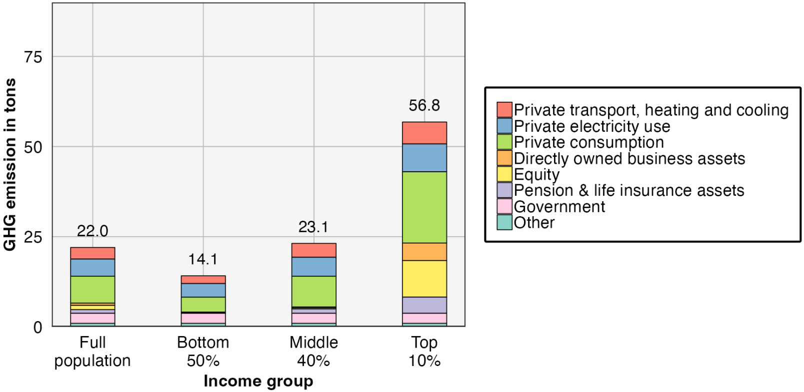
Consumption approach: US top 10% = 48tCO2e/cap,

Top 10% to Bottom 50% (T10/B50) avg. emissions gap: x3



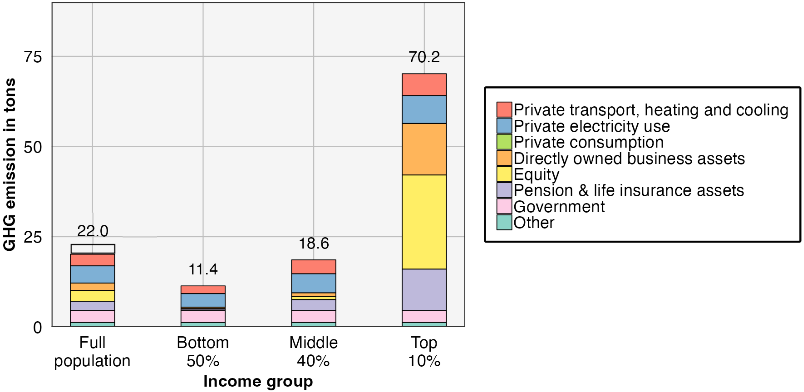
Per capita emissions by group in the US (consumption approach), 2019
Source: Chancel and Rehm 2023

Mixed approach: US top 10% = 57tCO2e/cap, T10/B50 gap: x4



Per capita emissions by group in the US (mixed approach), 2019
Source: Chancel and Rehm 2023

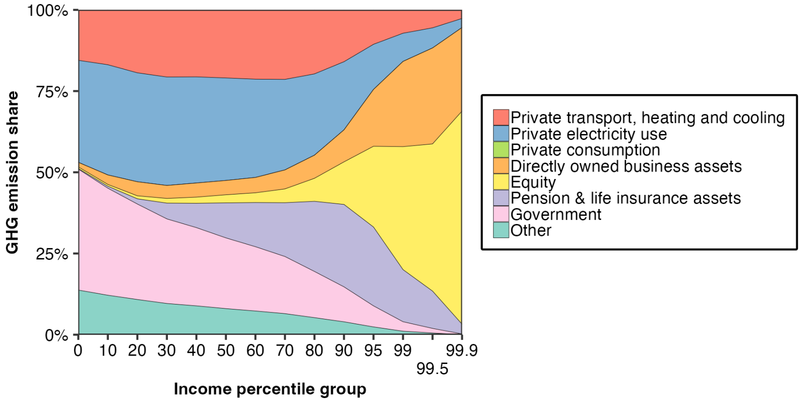
Ownership approach: US top 10% = 70tCO2e/cap, T10/B50 gap: x6.5



Per capita emissions by group in the US (ownership approach), 2019

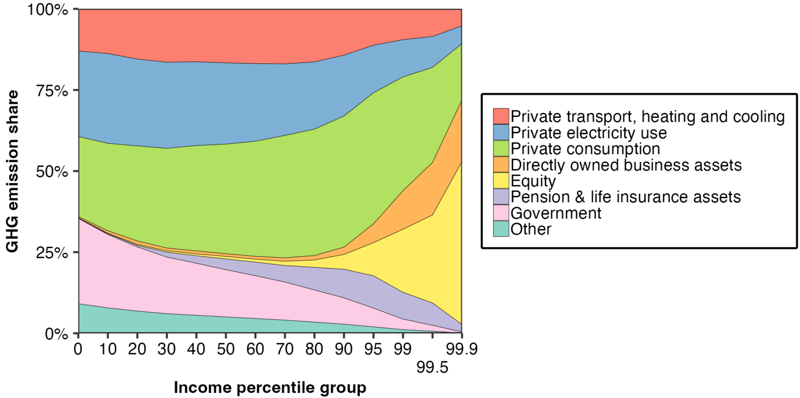
Source: Chancel and Rehm 2023

Ownership approach: over 80% of top 1% emissions from their assets



Breakdown of emissions by income group in the US (ownerhsip), 2019 **Source:** Chancel and Rehm 2023

Mixed approach: 50% of top 1% emissions from their assets



Breakdown of emissions by income group in the US (mixed), 2019

Source: Chancel and Rehm 2023

Results

- Taking into account emissions from capital ownership increases the carbon footprint of the top 10% of individuals by 30%-90%, as compared to estimates measuring consumption emissions only.
- Emissions from capital ownership are at least as concentrated as capital (if anything: appear to be even more concentrated than capital itself).
- Ownership approach: 80-90% of emissions of the top 1% stems from the assets they own rather than from their consumption (rest is direct emissions).

- Following results from "Global Carbon Inequality over 1990-2019", *Nature Sustainability*. See more [methods].

- Extension of the mixed approach to the global level.

Carbon inequality is not just a poor vs. rich country issue

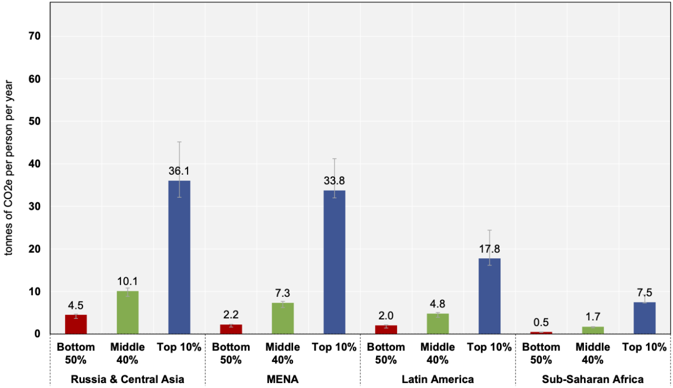


Figure 2B. Per capita GHG footprints by group, 2019

Notes: Individual carbon footprints include emissions from domestic consumption, public and private investments, and imports and exports of carbon embedded in goods and services traded with the rest of the world. Benchmark scenario with modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. Error bars show estimates for extreme scenarios (with alpha=0.4 and alpha=0.8 in the other). **Source and series**: Author, see Methods and Supplementary Information

Benchmark results: Bottom 50% emits 1.4tCO2/cap vs. top 1% ∼100tCO2cap

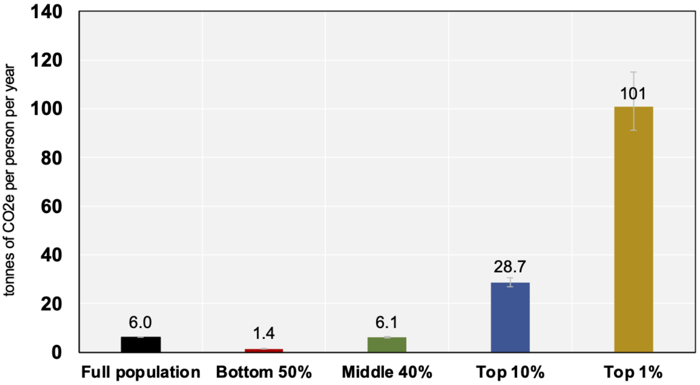


Figure 3A. GHG footprints by global emitter group, 2019
(tCO_2e per capita)

Notes: Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates are based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. Benchmark scenario. Error bars show estimates for extreme scenarios (with alpha=0.4 in one case and alpha=0.8 in the other).
Source and series: Author, see Methods and Supplementary Information.

Benchmark results: Top 10% = 48% of emissions, bottom 50% <12%

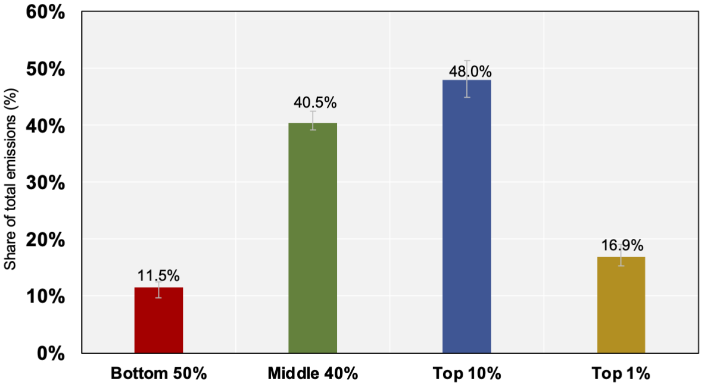


Figure 2B. GHG footprints by global emitter group, 2019
(% world total)

Notes: Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates are based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. Benchmark scenario. Error bars show estimates for extreme scenarios (with alpha=0.4 in one case and alpha=0.8 in the other).
Source and series: Author, see Methods and Supplementary Information.

Per capita emissions dropped for some since 1990

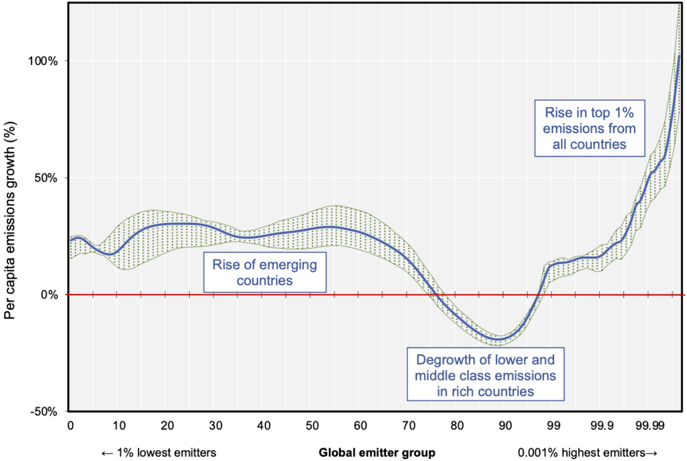


Figure 4. Emissions growth by global emitter group, 1990-2019

Notes: Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates are based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. Benchmark scenario. Shaded area shows estimates for extreme scenarios values. **Source and series**: Author, see Methods and Supplementary Information.

Does it really matter to focus on the top 1%?

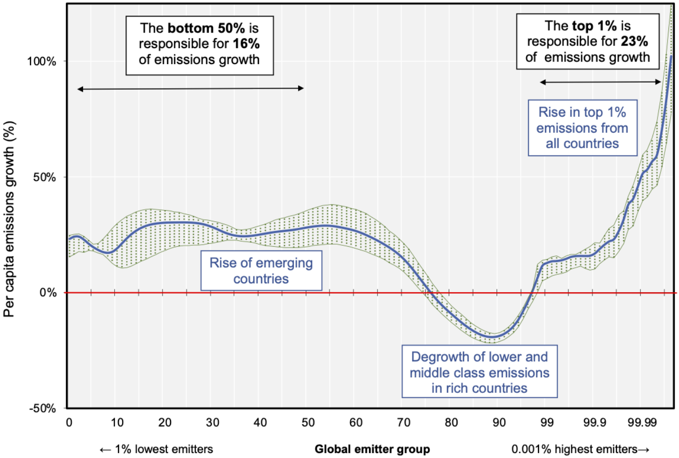


Figure 4. Emissions growth by global emitter group, 1990-2019

Notes: Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates are based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. Benchmark scenario. Shaded area shows estimates for extreme scenarios values. **Source and series**: Author, see Methods and Supplementary Information.

Global bottom 50% emissions: no real catch-up

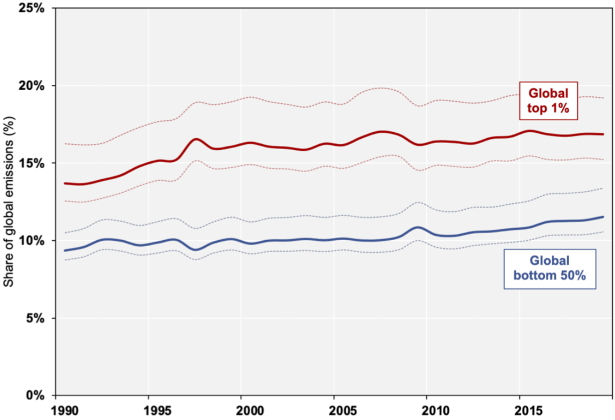


Figure 5. Global top 1% vs. bottom 50% emissions share, 1990-2019

Notes: Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates are based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. Benchmark scenario. Error bars show estimates for extreme scenarios values. **Source and series**: Author, see Methods and Supplementary Information.

Global carbon inequality broadly stable

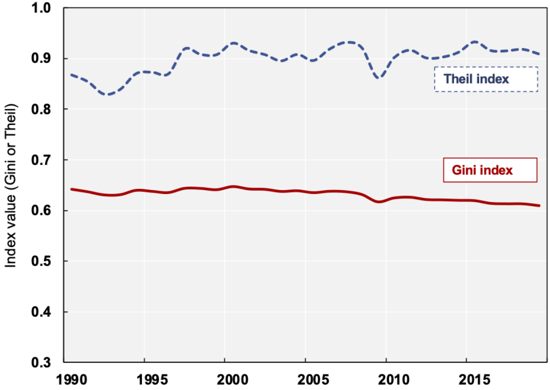


Figure 6B. Global carbon inequality: Theil vs. Gini index, 1990-2019

Notes: Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates are based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. Benchmark scenario. **Source and series**: Author, see Methods and Supplementary Information.

Large shift in between vs. within carbon inequality since 1990

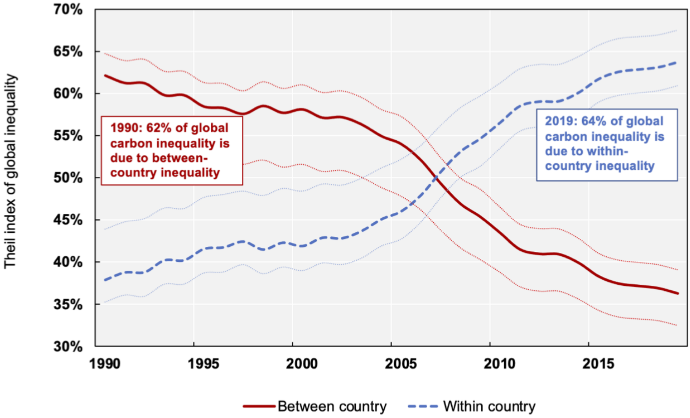


Figure 6A. Global carbon inequality: within vs. between Theil decomposition, 1990-2019

Notes: Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates are based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. Benchmark scenario. Error bars show estimates for extreme scenarios values. **Source and series**: Author, see Methods and Supplementary Information.

Discussion

Methdological discussion: Robustness

- Global distribution of emitters: close results with different approaches in the literature (cf. Bruckner et al., 2022; Chancel and Piketty, 2015; Kartha et al., 2020). [Figure]
- Ownership approach & better treatment of top income/wealth/emissions highlight dynamics at the very top.
- National level: In France, Top 10% to Bottom 50% avg. emissions gaps x2 in the consumption-centric view, rises to x3-x8 (or more) when wealth is included. [Figure]

Methodological discussion: inequality of constraints

- Many factors drive inequality of direct emissions: location, occupation, technology, generation, gender (see Chancel, 2014; Pottier et al., 2020). But direct emissions represent only about 35% of the total.
- Remaining emissions (and constraint associated with their mitigation) largely dependent on income and wealth level.
- Our framework: a step forward in integrating constraints, but still a long way to include them (cf. basic needs literature Rao, Min, and Mastrucci, 2019; Vogel et al., 2021).

Methodological perspectives

- Developments based on Norwegian admin data (full universe of tax payers & firms): more granular approaches + policy impacts.
- Current work with UN Stats to help produce satellite environmental accounts.

Substantive lessons: unequal pollution world order

- Global income and wealth inequality intertwined with carbon inequality.
- Top 10% contribute to nearly half of all emissions, while facing relatively little impacts.
- Global South needs $1.8tn/year in climate finance (Chancel, Bothe and Voituriez 2023).
- Top emitters from everywhere: need for policies addressing high carbon inequality in low emitting countries (regulations, taxes).

Substantive lessons: unequal decarbonization dynamics

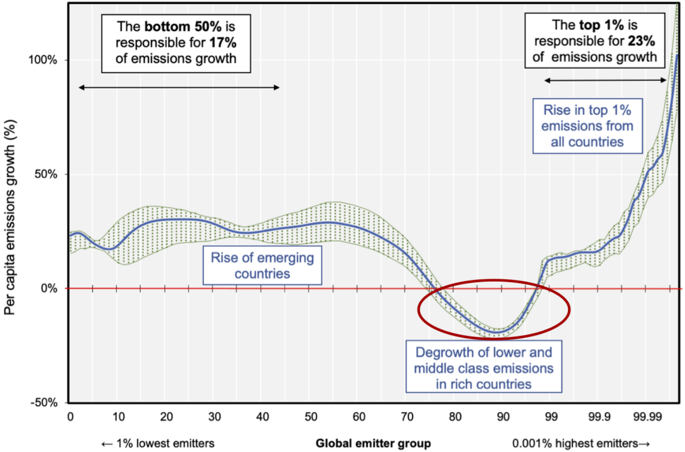


Figure 4. Emissions growth by global emitter group, 1990-2019

Substantive lessons: unequal decarbonization dynamics

- Differentiated emissions pathways: recent evidence of unequal consumption dynamics in the US (Starr et al., 2023) [Figure], and in most countries (Zheng et al., 2023). [Figure]
- Inequalities in emissions associated with capital ownership: the elephant in the room. Unequal emissions trends seem to be exacerbated when factoring-in ownership.
- Focusing solely on individual consumption-based emissions can be counter-productive, as "every little helps" policies do not add-up & leaves inequality of constraints aside.

Substantive perspectives: are we getting the losers right?

Financial losses due to climate change concentrated among top groups

- Stranded assets are the assets that lose value because of climate change induced constraints and policy.
- Wealthiest 10% concentrate 65% of all stranded assets in the US, 75% in Europe.
- See [Figure].

Substantive perspective: factoring-in inequality in climate policies

		What kind of climate policy?		
		Decarbonize:green energy supply	**Decarbonize:green energy access**	**Switch in energy end-uses (building, transport, industry)**
Which social group is targetted?	**Bottom 50%**	Industrial policy: public investments in renewables (off or on-gridd); Social protection: increase transfers to workers in industries affected by the transition	Public investments in green energy access (e.g. clean cookstoves; construction of new zero carbon social housing)	Develop public transport systems: low-carbon bus, rail, car-sharing strategies; energy retrofitting in social housing; cash-transfers to compensate increase in fossil energy prices
	Middle 40%	Same as above + Financial incentives to encourage middle-class investments in green energy. Bans on new fossil investments	Subsidies for green housing construction; Buildings regulations; penalty and bans on sales of inefficient housing	Same as above; Stricter regulations & taxes on polluting purchases (SUVs, air tickets); Subsidies on green alternatives (elec. vehicles)
	Top 10 % & Top 1%	Wealth or corporate taxes with pollution top-up to finance the above & accelerate divestment from fossils; Bans on new fossil investments	Wealth or corporate taxes with pollution top-up (see left); Fossil fuel subsidy removal*	Strict regulations on polluting purchases (SUVs, air tickets); Wealth or corporate taxes with pollution top-up (see left); Carbon cards to track high personal carbon footprints & cap them

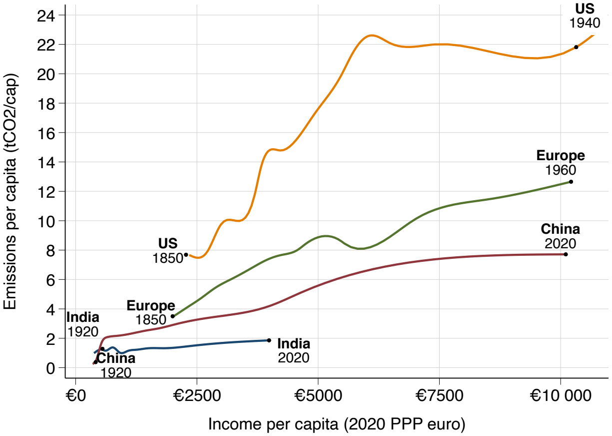
Substantive perspective: How to accelerate decarbonization in unequal societies?

- Unequal decarbonization dynamics: wealthy groups do not decarbonize at the same pace as the rest of the population.
- Factoring-in ownership inequalities reveals a different picture of constraints and responsibilities, opening novel policy options & challenges.
- Lack of data? Historical examples show that data often comes with new policy (cf. progressive income tax).
- More research needed on brown/green capital investments: regulations, bans, taxes + measurement standards.

Research perspectives

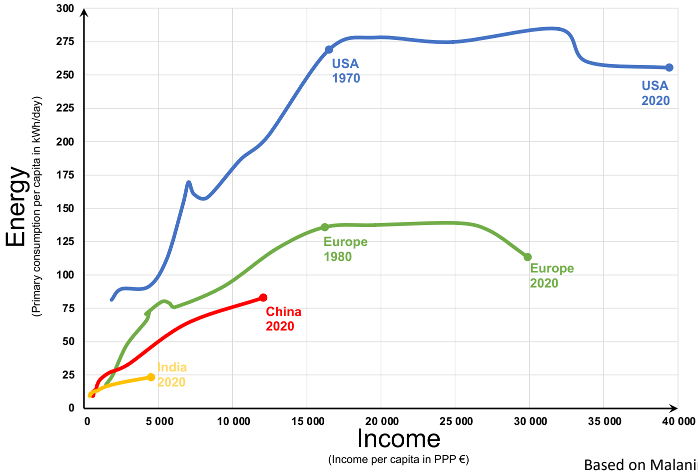
- Quantification is key to answer fundamental inequality research questions: "Who's big, who's small?".
- Yet, constant need to critically reflect upon the categories constructed to quantify $\Rightarrow$ fine line for social sciences, challenging but rewarding.
- Frontier environmental inequality research: inequality of constraints. These are financial, but also political, geopolitical, sociological $\Rightarrow$ bright days ahead for interdisciplinary research on inequality.

Need for a deeper understanding of variety of ecological/development regimes



Per capita emissions across the world, 1850-2020

Need for a deeper understanding of variety of energy / economy regimes

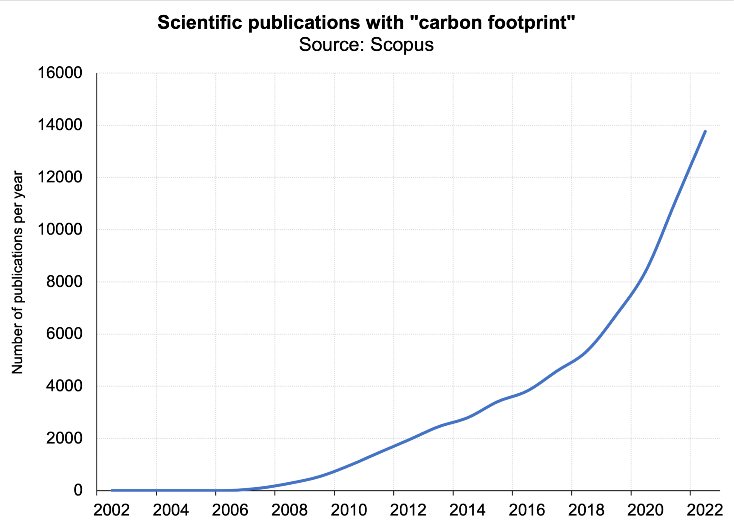


Based on Malanima :

Per capita energy consumption vs. income across the world, 1850-2020

[Back]

The rise of carbon footprints



"Carbon footprint" in the scientific literature

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Consumption approach

- Emissions from each productive sector are attributed to final consumers, based on their share of consumption from the various sectors.
- Pending issue in the literature: what to do of capital formation? Some studies entirely leave it aside. Relative quality effect as an issue.
- Assumption: consumers can change production processes by shifting their habits.

Mixed approach: median approach between ownership and consumption

- Similar to consumption approach: most of emissions are attributed to final consumers.
- Difference: investment emissions (capital formation, P.51 block of national accounts) are allocated to owners of the capital stock (about 15-30% total depending on countries)
- Assumption: owners of the capital stock have more agency than consumers on these emissions.

Ownership approach: combining financial accounts with air accounts

- Individuals are attributed their direct emissions and the emissions of the firms they own.
- Assumption: individuals have agency over their direct emissions and over the emissions of the capital they own. [Back]

Ownership approach: data requirements

- Stock of fixed assets by industry and institutional sector and year available from Eurostat and the US.
- Capital stock measured at market prices net of depreciation following national accounts.
- Attributing emissions of the corporate sector requires knowledge of who owns the corporate sector (households or govt., at home or abroad): Eurostat and OECD.

- Objective: match 21 industries (e.g. manufacturing, transport, etc.), for which data is available in national accounts and in the emission accounts with non-financial capital types.
- Non financial capital types: Dwellings, other buildings and structures, transport equipment, ICT equipment, other machinery, cultivated biological resources, research & development, computer software & databases, other intellectual property products.
- Matrix of capital stock by industry and asset [link].
- Carbon intensity of foreign investments from EU-INFLOWS database (bilateral financial investment stocks and flows for 80 economies) based on OECD Foreign Direct Investment database, IMF Portfolio Investment Survey and Eurostat Balance of Payment data.
  [Back]

Capital stock by industry

Table A.3: Capital stock and annual emissions in France (2017) – by industry and asset type

	Capital stock *in b euros*						Emissions *in m tons*
	Fixed Assets (total)	Dwellings	Other buildings and structures	Machinery and equipment	Cultivated biological resources	Intellectual property products	
Industry activities (total)	7648.6	4524.6	2033.9	662.4	22.1	405.6	348.1
Agriculture, forestry and fishing	113.4	0.0	37.2	51.7	22.1	2.4	89.4
Mining and quarrying	15.0	0.0	9.8	3.8	0.0	1.4	1.1
Manufacturing	336.8	0.0	61.7	124.2	0.0	150.9	94.6
Electricity, gas, steam and air conditioning supply	136.5	0.0	45.3	86.3	0.0	5.0	34.2
Water supply; sewerage, waste management and remediation activities	67.3	0.0	45.1	21.2	0.0	1.0	24.0
Construction	48.4	0.0	27.3	18.2	0.0	2.9	9.4
Wholesale and retail trade; repair of motor vehicles and motorcycles	109.9	0.0	64.8	36.5	0.0	8.6	15.1
Transportation and storage	165.7	0.0	72.2	88.3	0.0	5.2	44.4
Accommodation and food service activities	42.4	0.0	33.3	8.6	0.0	0.5	3.2
Information and communication	121.2	0.0	22.7	32.2	0.0	66.2	1.3
Financial and insurance activities	99.3	0.0	68.4	15.3	0.0	15.6	1.0
Real estate activities	5031.9	4524.6	499.8	6.6	0.0	0.9	0.5
Professional, scientific and technical activities	172.1	0.0	49.5	21.6	0.0	101.1	2.5
Administrative and support service activities	78.0	0.0	8.5	63.2	0.0	6.3	7.5
Public administration and defence; compulsory social security	737.1	0.0	664.1	47.8	0.0	25.1	3.4
Education	128.6	0.0	118.8	6.3	0.0	3.4	5.0
Human health and social work activities	134.0	0.0	107.3	22.8	0.0	3.9	7.2
Arts, entertainment and recreation	96.9	0.0	89.8	5.6	0.0	1.5	2.5
Other service activities	14.1	0.0	8.1	2.3	0.0	3.7	1.7

Note: Matrix used to calculate average asset-specific carbon intensities for France (2017) as presented in Table A.5. Annual greenhouse gas emissions in CO2 equivalents as recorded in air emission accounts. No emissions assigned to (i) the activities of households as employers and to (ii) the activities of international organizations because the non-financial capital stock of these two industries is zero. Capital stock refers to the net capital stock at year-end by asset type in each industry as recorded in national accounts. Capital stock excludes land, which is added in Table A.5. Sub-categories for machinery and intellectual property omitted for better visibility. Based on data from Eurostat and Insee.

Capital stock by industry

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Extension to global dynamics

- Conceptually, we follow the mixed approach described above.
- Different data needs imply use of multi-regional IO tables from Global Carbon Project for CO_2 and from EORA for non-CO_2 GHGs (Friedlingstein et al., 2020; Manfred et al., 2013).
- We model individual emissions from consumption, based on the latest available micro-level household surveys (over 120+ countries) and distribute investment emissions as a function of individuals' wealth.
- Limits: modelled estimates. Strengths: method that can be fed with novel country-level data. Regional & global results robust to wide range of parametric assumptions at country-level. See more methods. Back to results.

Distributing emissions among individuals

Average per capita emissions at *percentile* p, in a given year and country are given by:

$$E_p^{tot} = E_p^{cons} + E_p^{inv} + E_p^{gov} \tag{5}$$

Where E_p^{cons}, E_p^{inv}, E_p^{gov} are individual average footprints at percentile p, associated with household consumption, private investment and public spending, respectively.

Emissions associated with individual consumption

$$E_p^{cons} = f(E^{cons}, y_p, \alpha) \quad (6)$$

- E^{cons} is the average carbon footprint associated with a unit of consumption in the country, y_p the average income level of individuals in percentile p, α the elasticity of household consumption carbon emissions to income in a model of the form $E_p^{cons} = kE^{cons} \times y_p^{\alpha}$.
- Available micro-level household surveys point show expenditure elasticity of carbon emissions around 0.9-1.1 and income-carbon elasticity around 0.5-0.7.
- The paper mobilizes country-level values from recent research (120+ countries)

Table 5.1
Income-emissions and consumption-emissions elasticities across the world, 1988-2019

Country	Period	Scope	Reference	Expenditure elasticity	Income elasticity
Afghanistan	2014	CO2	[16]	1.117	.7*
Albania	2014	CO2	[16]	1.101	.68*
Angola	2014	CO2	[16]	1.112	.69*
Armenia	2014	CO2	[16]	1.114	.69*
Australia	1993-1994	GHG	[17]	.7	.55
Austria	2014	CO2	[16]	1.087	.68*
Azerbaijan	2014	CO2	[16]	1.114	.69*
Bangladesh	2014	CO2	[16]	1.101	.68*
Belarus	2014	CO2	[16]	.845	.51*
Belgium	2014	CO2	[16]	1.005	.52*
Belgium	2014	GHG	see [15]	.8	.47
Belgium (Flanders)	2010	GHG	[15, 18]	.84	.52
Benin	2014	CO2	[16]	1.001	.61*
Bhutan	2014	CO2	[16]	1.074	.67*
Bolivia	2014	CO2	[16]	1.021	.63*
Bosnia and Herzegovina	2014	CO2	[16]	.896	.54*
Brazil	2014	CO2	[16]	.875	.53*
Bulgaria	2014	CO2	[16]	1.088	.68*
Burkina Faso	2014	CO2	[16]	1.154	.72*
Burundi	2014	CO2	[16]	1.198	.75*
Cabo Verde	2014	CO2	[16]	1.094	.68*
Cambodia	2014	CO2	[16]	1.155	.72*
Cameroon	2014	CO2	[16]	1.071	.66*
Chad	2014	CO2	[16]	.995	.61*
China	2005	CO2	[15, 19]	.83	.74

Table 5.1
Income-emissions and consumption-emissions elasticities across the world, 1988-2019

Country	Period	Scope	Reference	Expenditure elasticity	Income elasticity
Fiji	2014	CO2	[16]	1.154	.72*
Finland	2006	GHG	[15, 22]	.8	.61
Finland	2012	GHG	[15, 23]		.68
Finland	2014	CO2	[16]	1.017	.56*
Finland (Helsinki)	2006	GHG	[15, 24]	.93	.61
Finland (Helsinki)	2012	GHG	[15, 24]	.89	.56
France	2005	CO2	[15, 25]	.82	.62
France	2010	GHG	[15]		.54
France	2010	GHG	[15]	.86	.53
France	2014	CO2	[16]	1.038	.6*
Gabon	2014	CO2	[16]	1.037	.64*
Gambia	2014	CO2	[16]	.965	.59*
Georgia	2014	CO2	[16]	1.088	.68*
Germany	2013	GHG	[15, 26]		.56
Germany	2013	GHG	[15, 27]	1.04	.58
Germany	2014	CO2	[16]	1.011	
Germany (West)	1988	CO2	[15, 28]		.8
Ghana	2014	CO2	[16]	1.031	.64*
Greece	2014	CO2	[16]	.949	.58*
Guatemala	2014	CO2	[16]	.95	.58*
Guinea	2014	CO2	[16]	1.101	.68*
Haiti	2014	CO2	[16]	1.107	.69*
Honduras	2014	CO2	[16]	1.061	.66*
Hungary	2014	CO2	[16]	1.06	.66*
India	1989-1990	CO2	[15, 29]	1.1	
India	2003-2004	CO2	[15, 30]	1.04	.86
India	2014	CO2	[16]	1.143	.71*

Table 5.1
Income-emissions and consumption-emissions elasticities across the world, 1988-2019

Country	Period	Scope	Reference	Expenditure elasticity	Income elasticity
USA	2012-2014	CO2	see [15]	.82	.31
USA	2012-2014	CO2	[46]	.73	.5*
USA	2014	CO2	[16]	1.007	
Uganda	2014	CO2	[16]	1.08	.67*
Ukraine	2014	CO2	[16]	1.007	.62*
United Kingdom	2004	CO2	[47]		.7
United Kingdom	2004		[15, 48]		.34
United Kingdom	2006	GHG	[15, 49]		.34
United Kingdom	2006-2009	CO2	[50]		.6
United Kingdom	2014	CO2	[16]	1.072	
Viet Nam	2014	CO2	[16]	1.051	.65*
Yemen	2014	CO2	[16]	1.096	.68*
Zambia	2014	CO2	[16]	1.053	.65*

Note: The table presents elasticity values found in the literature for various countries, periods and concepts. Inc elasticity values followed by an asterisk are predicted from consumption elasticities available in the literature observed regularities between consumption and income elasticities. For a given country, when there are several inc elasticities available, the latest available year is used the benchmark. *Sources and series:* Author. Note that when source refers to both [15] and another paper, this means that estimates were calculated by [15] on the basis of data provided in the other source provided.

Emissions associated with investments

$$E_p^{inv} = f(E^{inv}, w_p, \gamma) \tag{7}$$

- E^{inv} is the average emissions level associated with fixed capital formation, w_p the average investment level of individuals in percentile p, γ the elasticity of wealth to investment emissions.
- (Rehm and Chancel, 2022) find an elasticity near 1 in Germany and France. Corroborated by other recent work (Lacharme et al., 2021).
- We take a value of 1 (and test wider bounds in all countries 0.8-1.2).

Income and wealth inequality data

- WID.world project: distributional income and wealth estimates based on surveys, tax data and national accounts, following (Alvaredo et al., 2020; Piketty and Saez, 2003); Blanchet, Chancel, Flores, Morgan et al., 2020.

- Global income and wealth inequality datasets on WID.world, available from the 1990s onwards: income and wealth thresholds, averages, shares for bottom 99 percentiles, top 0.1%, 0.01% within each country.

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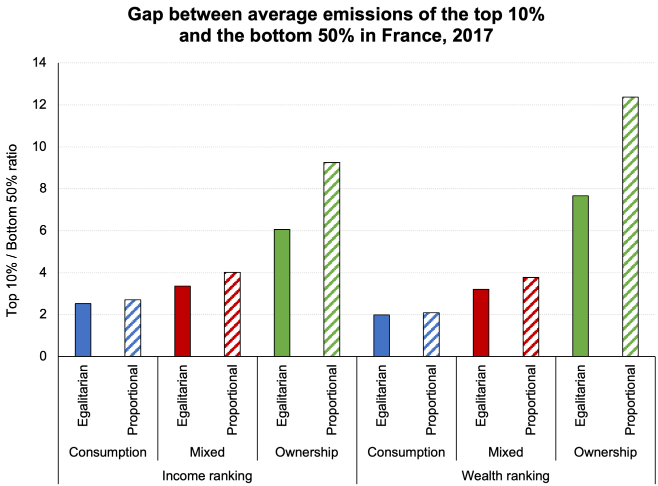
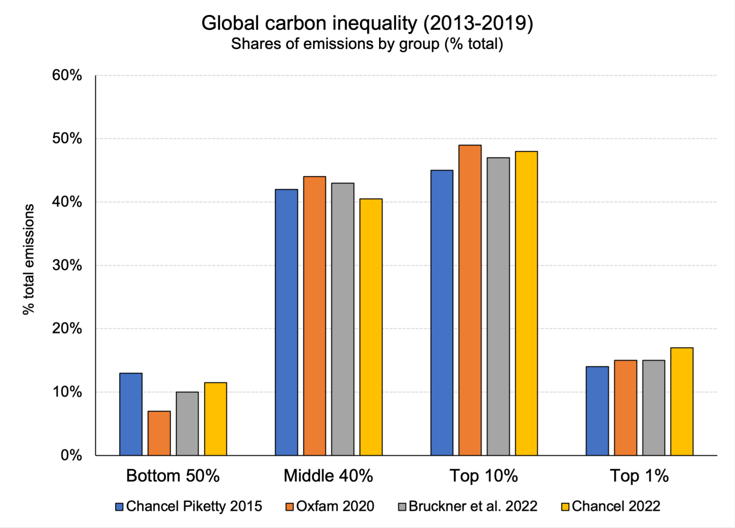
Significant carbon inequalities across all scenarios



Note: the graph shows the gap between the average per capita emission level of the top 10% of individuals and the bottom 50% of individuals in France in 2017 according to different scenarios and methods to rank individuals. The top 10% of individuals ranked by net wealth emit 7.7x more than the bottom 50% of individuals in the "ownership - egalitarian" scenario (second bar from the left). Consumption scenario: emissions allocated to final consumers. Ownership scenario: emissions allocated to owners of polluting technologies. Mixed secnario: emissions allocated to consumers and capital formation emissions to owners. Egalitarian variant: government emissions allocated as a lump-sum to individuals. Proportional variant: government emissions allocated proportionally to individual consumption.
Sources: Chancel and Rehm 2023

[Back]

Global carbon inequality: an emerging consensus



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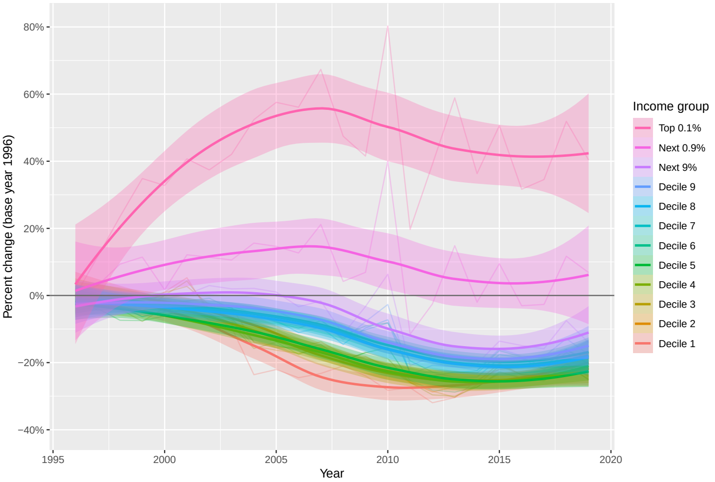
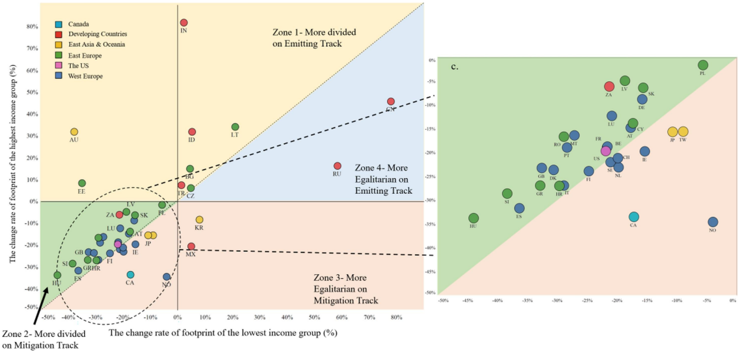
US: consumption emissions dropped at the bottom 99% & rose at the top



Consumption-based emissions growth by group, 1995-2019 [Back]
Starr et al., 2023

Top 20% reduced their emissions less than bottom 20%



Consumption-based emissions reduction of the top 20% (Y axis) vs. bottom 20% (X axis) over 2005-2015

Source: Zheng et al., 2023 [Back]

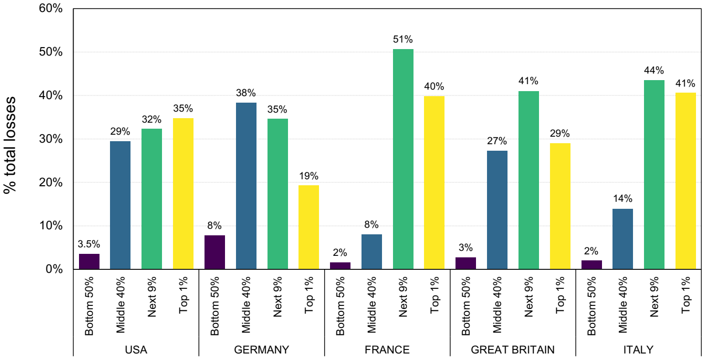
Stranded assets are highly concentrated among wealthy individuals in the US and Europe

- map financial geography of stranded oil and gas asset risk for equity ownership
- trace potential losses from extraction sites (through headquarters, banks, funds, govts., individuals)
- Calculate profits given expectations for each of 43,439 oil and gas extraction sites from Rystad ucube
- Expectations realignments modeled in 2022, combining two scenarios of E3ME-FTT-GENIE model

Stranded assets methodology

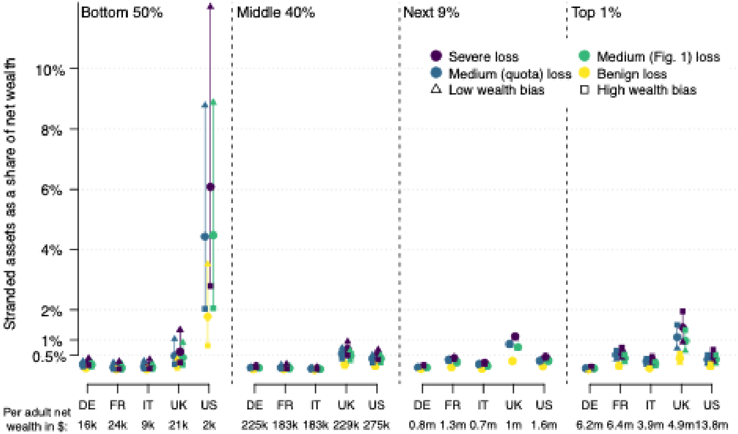
- Stage 1: determine the non-producing sites (stranded oil and gas assets)
- Stage 2: identify direct owners of expected lost profit streams: 69,900 ownership links to 1,759 oil and gas companies
- Stage 3: propagate losses to corporate shareholders (network of 1.8 million companies, 33,386 nodes affected, 16,171 ultimate corporate owners, including via funds) from Bureau van Dijk's ORBIS
- Stage 4: allocate to ultimate owners: persons and governments

Stranded assets are highly concentrated among wealthy individuals in the US and Europe



Share of stranded asset losses as a % total losses across countries
Sources: Semieniuk, Chancel et al. 2023
[Back].

This does not mean that poorest groups are not at risk, but can be compensated



Share of stranded asset losses as a % net wealth by group
Sources: Semieniuk, Chancel et al. 2023
[Back].

"The construction of a political space implies and makes possible the construction of a space of common measurement, within which things are comparable because the categories and coding procedures are identical."

Desrosières, 1993