CLIMATE CHANGE AND THE GLOBAL INEQUALITY OF CARBON EMISSIONS 1990-2020

SUMMARY

OCTOBER 2021

LUCAS CHANCEL

WORLD INEQUALITY LAB

Climate change & the global inequality of carbon emissions, 1990-2020

Lucas Chancel[1]

Publication date: 18 October 18 2021
This version: 22 December 2021

[1] World Inequality Lab, Paris School of Economics and Sciences Po

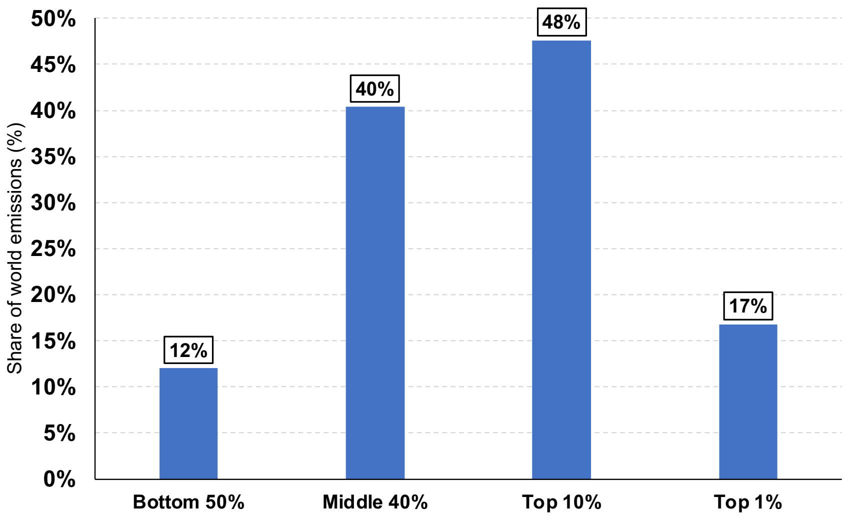
Summary

- This study provides novel findings on carbon emissions of individuals, based on a newly assembled set of economic inequality and environmental data available on the World Inequality Database (www.wid.world).

- Global emissions of greenhouse gases reached 50 billion tonnes of carbon dioxide equivalents (CO2) in 2019, i.e. around 6.6 tonnes of CO2 per capita. In 2021, global emissions have almost recovered their pre-pandemic peak.

- At the global level, the top 10% of global emitters (771 million individuals) create on average 31 tonnes of CO2 per person per year and are responsible for about 48% of global CO2 emissions. The bottom 50% (3.8 billion individuals) emit on average 1.6 tonnes and are responsible for around 12% of all emissions in 2019. The global top 1% emits on average 110 tonnes and contributes 17% of all emissions in a year.

Figure A. Global carbon inequality in 2019
(Contributions of each group to global emissions)



Interpretation: See figure 5A. **Sources and series:** Chancel (2021)

- Global inequality in per capita emissions is due to large inequalities in average emissions between countries and to even larger inequalities in emissions within each country. Currently, average emissions in Europe are close to 10 tonnes CO2 per person per year. In North America, the average individual emits around 20 tonnes. This value is eight tonnes in China, 2.6 tonnes in South and South-East Asia and 1.6 tonnes in Sub-Saharan Africa.

- Historical emissions inequality between regions is very great: North America and Europe are responsible for around half of all emissions since the Industrial Revolution. China represents about 11% of the historical total and Sub-Saharan Africa just 4%.

- Since 1990, emissions from the top 1% have risen faster than those of any other group because of the rise in economic inequalities within countries and because of the carbon content of their investments.

- The per capita emissions of the poorest half of the world population have only moderately increased since 1990, from 1.2 tonnes to 1.6 tonnes. The average emissions of the global bottom 50% remain about four times lower than the global average, and the poorest one billion people on earth emit less than one tonne CO2 per capita per annum.

- In many rich countries, per capita emissions among the poorest half of the population have declined since 1990, contrary to that of wealthier groups. Their current emissions levels are close to the per capita 2030 climate targets set by the US, the UK, Germany and France. In these countries then, policy efforts should be focused mainly on reducing the emissions of the top half of the population, and particularly the top 10%. In low-income and emerging countries, while certain groups will see their emissions levels rise in the coming decades, urgent action is needed to curb the emissions of the wealthy.

- While governments officially report greenhouse gases (GHG) emitted within their own territories, they do not produce systematic data on the carbon created by the goods and services imported to sustain their national living standards. When we factor in these emissions (as we do in this study), European emission levels increase by around 25%, while Chinese and Sub-Saharan African emissions are reduced by around 10% and 20%, respectively.

- Since the industrial revolution, humankind has emitted around 2,500 billion tonnes of CO2. Based on current emissions rates, the remaining carbon budget calculated to limit global warming to 2°C above preindustrial levels (that is, 900 billion tonnes of CO2) will be entirely depleted in 18 years. The budget remaining in order to limit planetary warming to 1.5°C (300 billion tCO2), will be depleted in six years.

The carbon inequality estimates developed in this study are available online on the World Inequality Database (WID.world).

Recommendations

• **Monitoring**. Countries do not currently possess basic, up-to-date information with which to track carbon emissions inequalities. It is now urgent that we develop public monitoring systems to measure the carbon emissions of individuals, with a particular focus on emissions embedded in consumption and in investment portfolios.

• **Reporting.** With better carbon inequality data, public deliberation could set clear targets in terms of emissions reductions per capita (not only in terms of national totals) and develop information systems to enable individuals to check the gap between their own emissions and national per capita targets. Public authorities should also conduct systematic assessments of the beneficiaries and losers of climate policies.

• **Taxing.** Climate policies have been disproportionately borne by low-income consumers in recent decades, in particular via carbon and energy taxes. More emphasis should be placed on wealthy polluters. This can be done via policy instruments that target investments in polluting and fossil fuel activities. Progressive wealth taxes on the ownership of polluting activities could accelerate divestment, reduce pollution levels of the wealthiest, and generate much-needed resources to increase investment in low-carbon infrastructure. Ultimately, the ownership and sale of assets associated with new fossil fuel projects should be prohibited.

• **Earmarking.** Public actors must significantly scale up their investments in low-carbon energy production infrastructure, transport and energy efficiency in order to ensure a fair transition. Overall, additional annual investments in the energy transition of around 2% of global GDP are needed (representing an additional USD1,800 bn in 2021). A relatively modest progressive global wealth with a pollution top-up, such as the one presented in this study, could generate 1.7% of global income. A significant part of these revenues could be earmarked for the green transition, to finance climate investments without additional financial cost for low- and middle-income groups.

Author: Lucas Chancel
Research assistants: Felix Bajard, François Burq, Aymeric Capitaine
Communication: Olivia Ronsain
This study benefitted from the support of the **United Nations Development Programme**.

Climate change & the global inequality of carbon emissions (1990-2020)

Bridging the gap between global data on carbon emissions and individual perceptions

To study global carbon emissions, we start with the same general assumption we make when we study income and wealth inequality: that looking at national averages and totals is important, but not sufficient. It is also necessary to navigate between different scales of analysis: the global level and the individual level. To do this, we investigate systematically the emissions levels of national and regional societies, and how emissions are distributed among different groups of individuals within these societies.

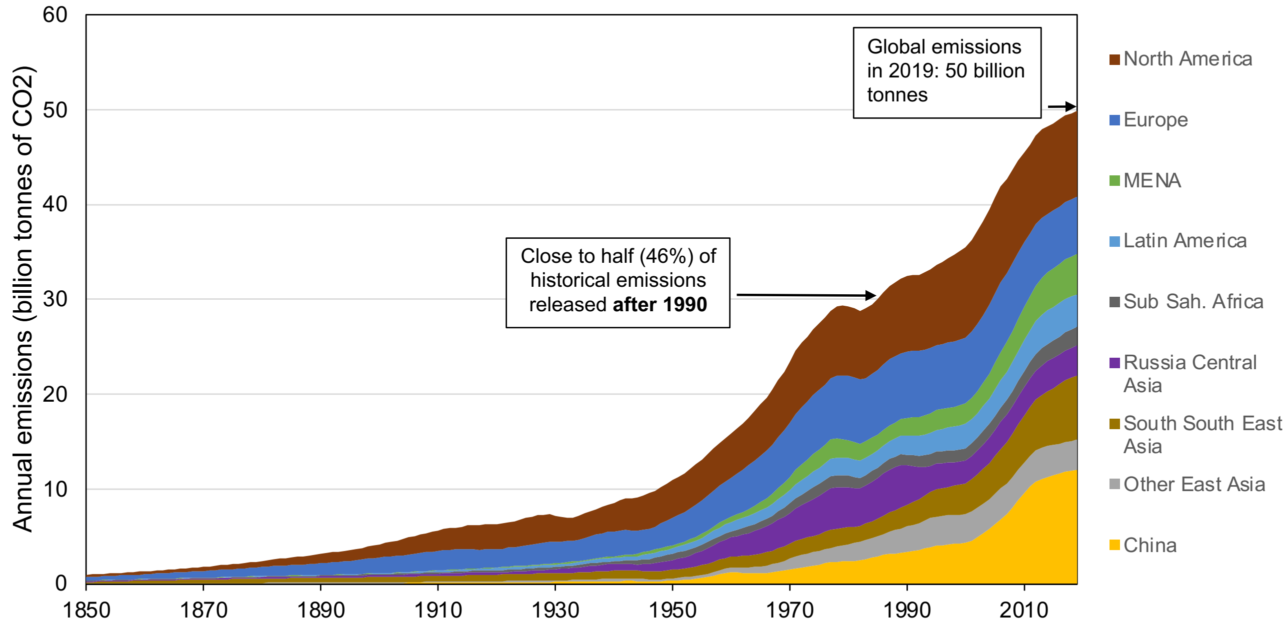
Global carbon inequality: initial insights

Carbon dioxide emissions are the result of the burning of fossil fuels, certain industrial processes (such as cement production), agricultural production (for example, cows emit a lot of greenhouse gases), waste management, and deforestation. These activities generate not only carbon dioxide (CO2), but also other greenhouse gases, including methane (CH4), and nitrous oxides (NOx). Each of these contributes differently to global warming: one tonne of methane is equivalent to 30 tonnes of CO2, and one tonne of nitrous oxide is equivalent to 280 tonnes of CO2. The numbers presented below refer to CO2 equivalents, i.e. they take into account all the different GHGs.[2]

In 2021, human beings released nearly 50 billion tonnes of CO2 into the atmosphere, reversing most of the decline that occurred during the 2020 Covid pandemic. Of these 50 billion tonnes, about three quarters were produced by the burning of fossil fuels for energy purposes, 12% by the agricultural sector, 9% by industry (in cement production among other things), and 4% came from waste.[3] On average, each individual emits just over 6.5 tonnes of CO2 per annum (see Figure 1). These averages mask considerable disparities between countries and within them, as we discuss below.

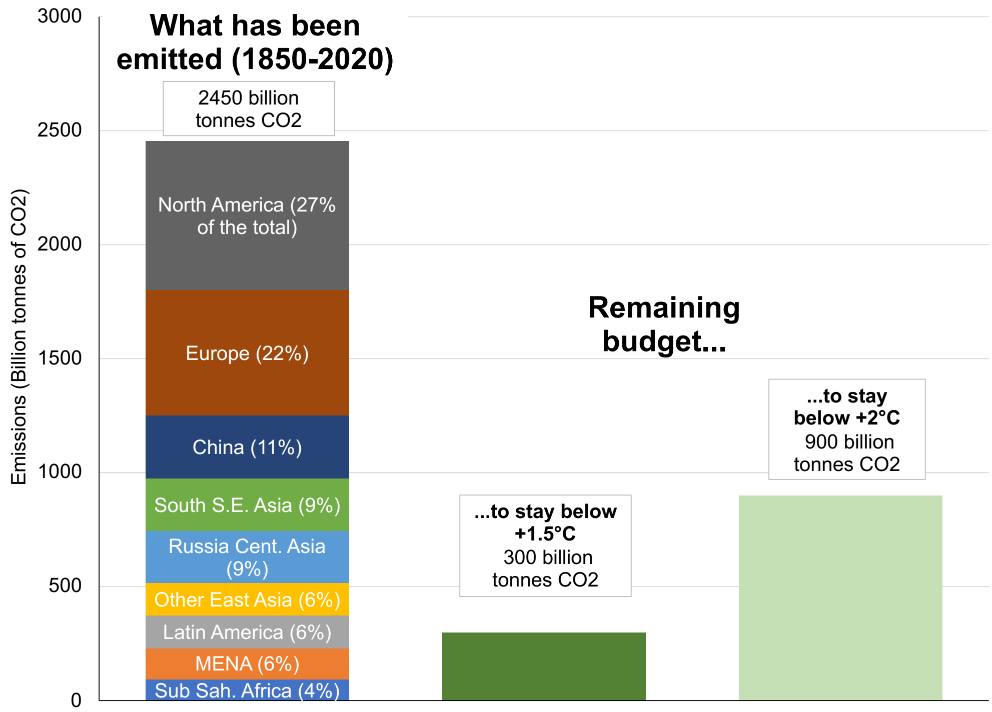
Global emissions have been rising almost continuously since the industrial revolution (Figure 1).[4] In 1850, one billion tonnes of carbon dioxide equivalents were emitted.[5] By 1900, the number had risen to 4.2 billion tonnes, it reached 11 billion tonnes by 1950, 35 billion tonnes in 2000, and about 50 billion today. Close to half of all emissions since the industrial revolution have been produced since 1990, the year of the first report by the Intergovernmental Panel on Climate Change (IPCC).

Figure 1. Global annual CO2 emissions by world regions, 1850-2019



Interpretation: The graph shows annual global emissions by world regions. After 1990, emissions include carbon and other greenhouse gases embedded in imports/exports of goods and services from/to other regions. **Source and series:** Chancel (2021). Historical data from the PRIMAP-hist dataset. Post-1990 data from Global Carbon Budget.

Figure 2. Historical emissions vs. remaining carbon budget



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.

Table 1. Global carbon emissions, 1850-2019

	Global emissions (billion tonnes)	Emissions per capita (tonnes per person)
1850	1.0	0.8
1880	2.5	1.8
1900	4.2	2.7
1920	6.6	3.5
1950	10.9	4.3
1980	30.2	6.8
2000	35.3	5.8
2020	50.1	6.6

Interpretation: emissions of carbon dioxyde equivalent (including all gases) from human activites (including deforestation and land-use change). **Sources and series:** Chancel (2021)

Table 2. Global per capita carbon budget

Sustainable emissions level...
(tonnes CO2 per person per year)

… to stay below +1.5°C	… to stay below +2°C	*Carbon budget shared before*
1.1	**3.4**	**2050**
0.4	**1.1**	**2100**

Interpretation: Sharing the remaining carbon budget to have an 83% chance of staying below a 1.5% temperature increase would require keeping annual emissions down to 1.1 tonnes per capita per annum between 2021 and 2050 (and zero afterwards). Sharing the same carbon allocation between now and 2100 would require keeping emissions down to 0.4 tonnes per capita per annum. Global carbon budget values from IPCC AR6, 83% confidence. **Sources and series:** Chancel (2021)

Of the total 2,450 billion tonnes of carbon released since 1850 (Figure 2), North America is responsible for 27%, Europe 22%, China 11%, South and South-East Asia 9%, Russia and Central Asia 9%, East Asia (including Japan) 6%, Latin America 6%, MENA 6%, and Sub-Saharan Africa 6%. Figure 2 compares historical emissions with the available carbon budgets intended to limit planetary warming. According to the latest IPCC report, there are 300 billion tonnes of CO2 left to be emitted if we are to stay below 1.5°C (with an 83% confidence rating) and 900 billion tonnes of CO2 left to stay below 2°C (with the same level of confidence). At current global emissions rates, the 1.5°C budget will be depleted in six years and the 2°C budget in 18 years.

Global emissions per capita rose from 0.8 tonnes of CO2 per annum in 1850, to 2.7 tonnes in 1900, 4.3 tonnes in 1950, and 6.8 tonnes in 1980s, before dropping back to 5.8 in 2000, and then rising again to 6.6 tonnes today (Table 1). The reduction observed between 1975 and 1980 was the result of a combination of factors, including global population growth (the population increased faster in regions where emissions are below the global average), and some improvement in energy efficiency following the oil crises of the 1970s.

To understand better the size of the carbon reduction challenge, we begin by comparing current emissions levels with those required to stay below an average global warming of 1.5°C and 2°C. The Paris Climate Agreement seeks to stay at a level of warming *well below* 2°C. Table 2 presents the sustainable per capita global carbon budget, i.e. the volume of emissions per person living between now and 2050 were all remaining CO2 emissions to be shared equally over the period.

To obtain these numbers, we simply divide the remaining carbon emissions by the cumulative global population that will be emitting them in the coming decades. According to the United Nations, there will be 265 billion individual-years between now and 2050. This implies a sustainable per capita budget, compatible with the +2°C temperature limit, of 3.4 tonnes per person per annum between now and 2050. This is about half of the current global average. The per capita sustainable budget compatible with the 1.5°C limit is 1.1 tonne of CO2 per annum per person, i.e. about six times less than the current global average.[6] We stress at the onset that these numbers are derived for comparative purposes and should be interpreted with care. They do not take into account the historical responsibilities for climate change. Taking historical responsibilities into account would mean that high-income nations have no carbon budget left.[7] We should also note that scenarios consistent with the 2°C target show that overall emissions must decrease progressively to reach zero in 2050 – they cannot be maintained at a certain high level until this date then suddenly drop to zero.

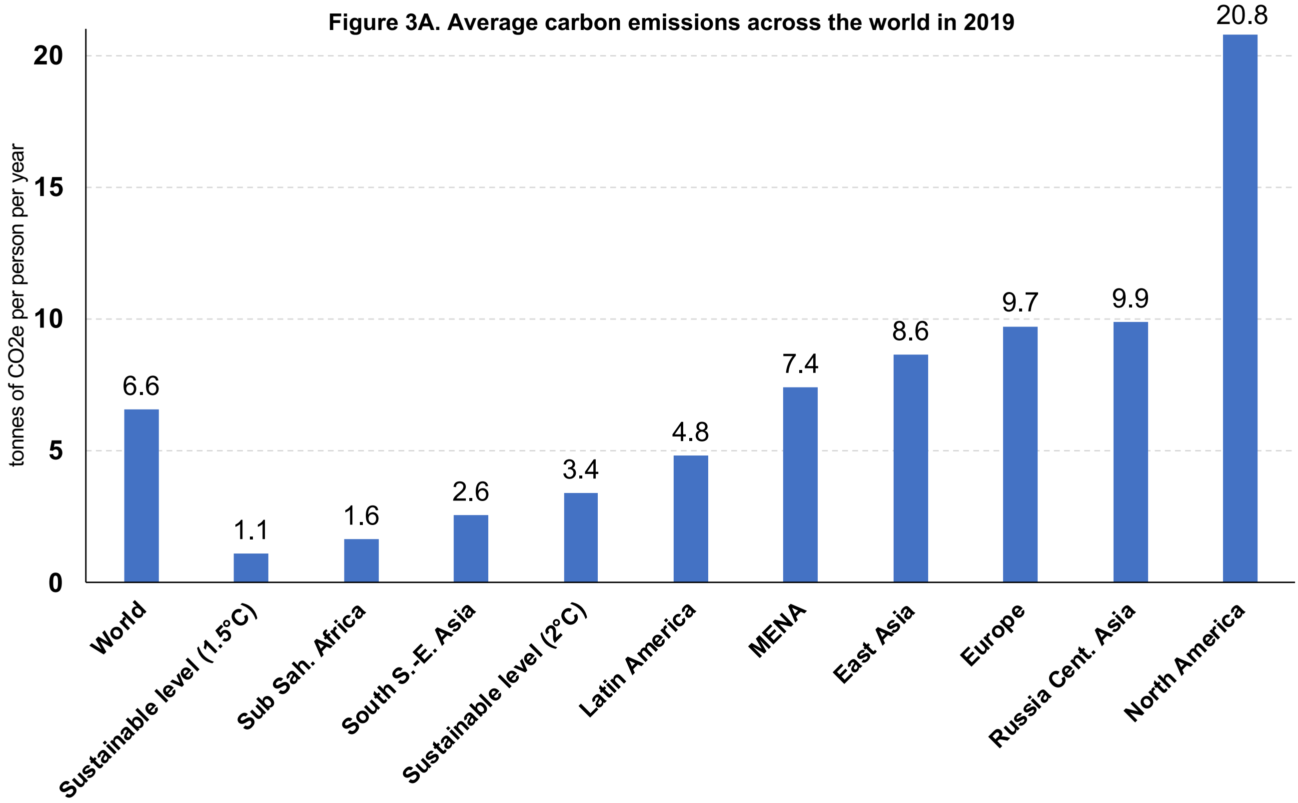
Carbon inequalities between regions are large and persistent

Figure 3A shows average emissions per capita for world regions, and Table 3 expresses these values as a percentage of the world average. Per capita emissions in Sub-Saharan Africa (1.6 tonnes per person per annum) represent just one quarter of the current average global per capita emissions. Thus, average emissions there are close to 50% above the 1.5°C sustainable level and about half of the 2°C budget. At the other end of the spectrum, per capita emissions in North America are 21 tonnes per capita (three times the world average and six times higher than the 2°C sustainable level). In between these two extremes stand South and South-East Asia, with 2.5 tonnes per capita (40% of the current world average and 80% of the 2°C budget), and Latin America with 4.8 tonnes (70% of world average, 1.4 times the 2°C budget), followed by the Middle East and North Africa, East Asia, Europe, and Russia and Central Asia, whose averages fall in the 7.5-10 tonnes range (between one and 1.5 times the world average, and two to three times more than the 2°C sustainable level).

Figure 3B compares historical emissions with current emissions of regional populations. The graph reveals that, while carbon inequalities between regions have declined recently (though China's share in current global emissions is significantly higher than its historical share), inequalities persist and are even more striking when compared with the population share of each region.

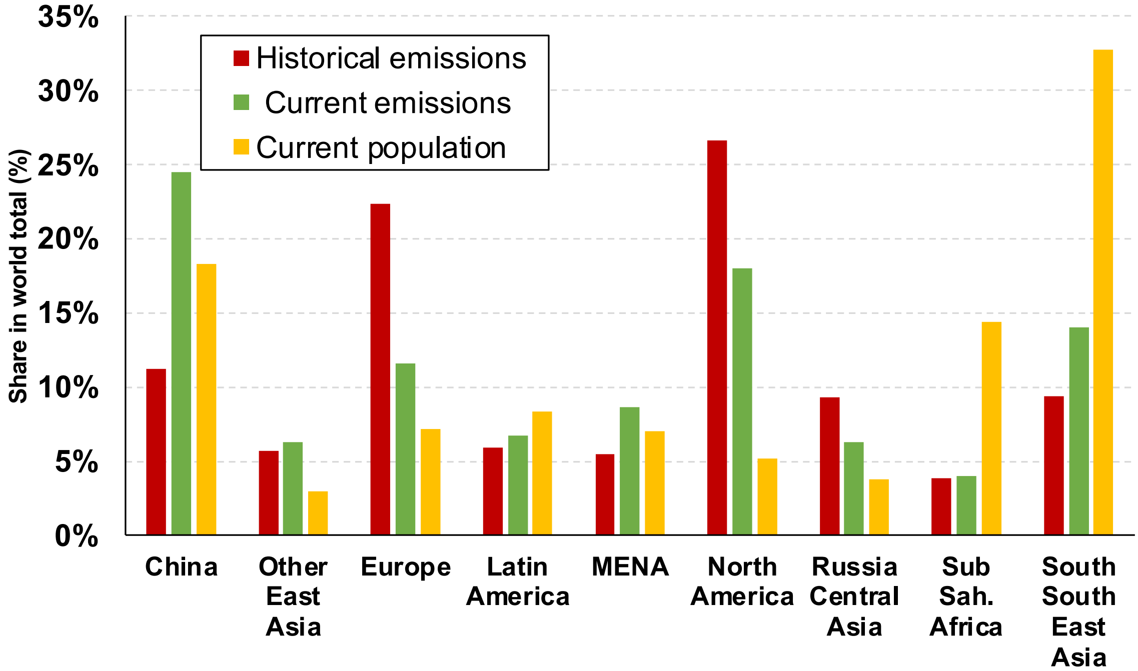
Inequalities in average carbon emissions between regions are quite close to the inequality in average incomes between regions, but with notable differences: US average emissions are 3.2 times the world average, while its average income is three times the world average, and Europe's emissions are 1.5 times the world average while the income figure is close to two. There is a close link between per capita income and emissions, but this link is not perfect: certain regions are more effective than others in limiting emissions associated with a given level of income

Figure 3A. Average carbon emissions across the world in 2019



Interpretation: Values 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. The sustainable level correspond to an egalitarian distribution of the remaining carbon budget until 2050. **Source and series:** Chancel (2021)

Figure 3B. Historical and current emissions and population across world regions



Interpretation: China's share in world historical emissions since 1850 is 11% whereas its share in current emissions is 24%. Current emissions include carbon embedded in consumption. Current emissions and population refer to 2019. **Sources and series:** Chancel (2021)

Emissions embedded in goods and services increase carbon inequalities between regions

The emission levels cited above include emissions produced within a country as well as those embedded in goods and services imported from elsewhere. So, for example, when North Americans import smartphones from East Asia, the carbon emissions created in the production, transport and sale of those smartphones are attributed to North Americans and not to East Asians. This is the best way to measure emissions associated with the standard of living of individuals across the world. In this study, we refer to these emissions as "carbon footprints" rather than "territorial emissions", which correspond only to carbon emissions within territorial boundaries, and do not take into account the import and export of carbon embedded in goods and services. Territorial emissions are still used by authorities around the globe when they report progress on their emissions reduction and when they discuss international climate agreements. But referring only to territorial emissions obviously presents many problems: high-income countries can reduce their territorial emissions and use ecological dumping strategies to externalize their carbon-intensive industries to the rest of the world, then import back goods and services produced elsewhere. Factoring in the carbon embedded in goods and services also accounts for the climate change mitigation efforts of high-income countries, in particular in Europe, where imports represent a notable share of per capita emissions.

Table 3. Emissions per capita by world region, 2019

	Carbon footprint		
	(tonnes per capita)	**(x global average)**	**(x 2° budget)**
World	**6.6**	**1**	**1.9**
Sub Saharan Africa	1.6	0.3	0.5
South South-East Asia	2.6	0.4	0.8
Latin America	4.8	0.7	1.4
Middle East	7.4	1.1	2.2
East Asia	8.6	1.3	2.5
Europe	9.7	1.5	2.9
Central Asia / Russia	9.9	1.5	2.9
North America	20.8	3.2	6.1

Interpretation: Estimates takes into account emissions of all greenhouse gases from domestic consumption, public and private investments as well as net imports embedded in goods and services from the rest of the world. The +2°budget corresponds to an egalitarian distribution across the world population, between now and 2050, of all emissions left to limit temperature increase to +2°C. To stay below +1.5°C, the equitable per capita budget is 1.1 tonne per person per year. **Source and series**: Chancel (2021)

Table 4. Carbon footprints vs. territorial emissions across the world, 2019

	Footprint inc. consumption (tCO2/capita)	**Territorial** (tCO2/capita)	**% difference footprint vs. territorial**
World	*6.6*	*6.6*	*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%

Interpretation: 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. **Source and series:** Chancel (2021)

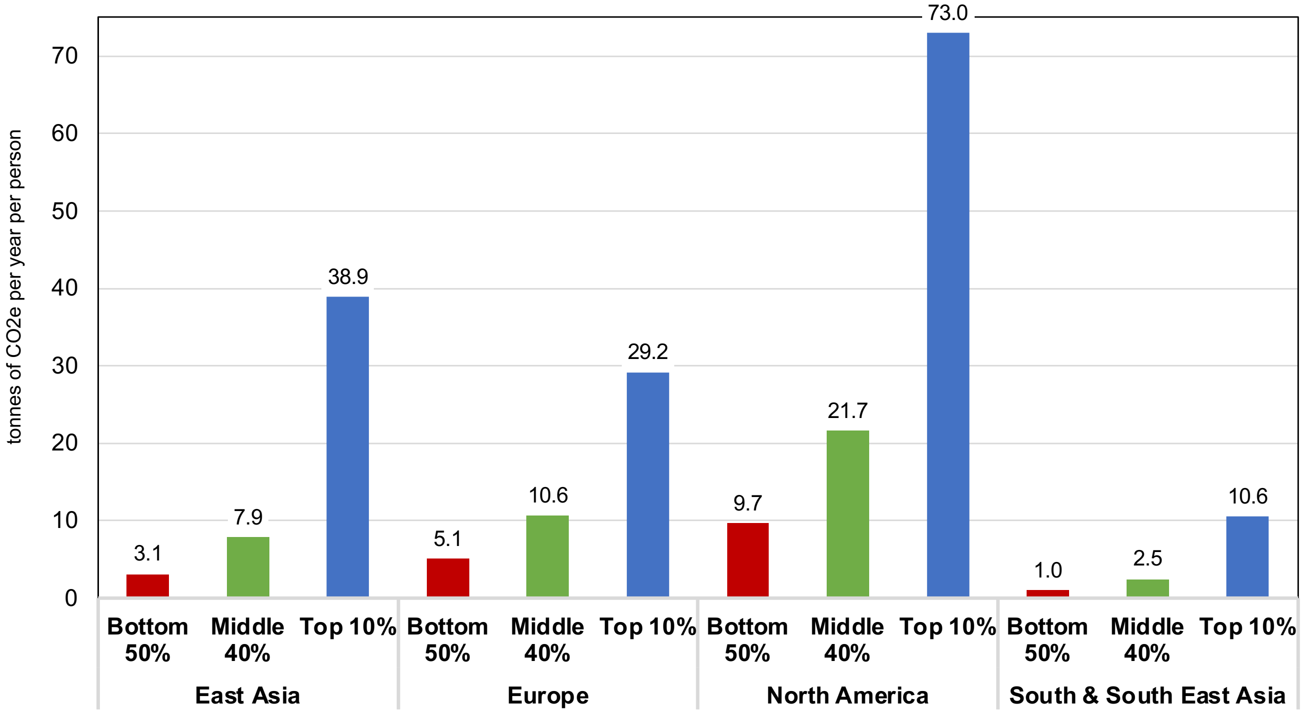
Table 4 shows the differences between carbon footprints and territorial emissions by region. In North America, the difference between footprints and territorial emissions expressed in percentage points is relatively low, because Americans import but also export carbon-intensive goods, and they consume significant quantities of carbon at home. In Europe, the carbon footprint is about 25% higher than territorial emissions. Nearly two tonnes of carbon per person per annum are imported from other regions of the world, mostly China. In East Asia, carbon emissions are 8% lower than territorial emissions: nearly one tonne of carbon per person is produced in East Asia to satisfy the needs of individuals in other parts of the world. Factoring in the carbon that is embedded in the consumption of goods and services increases the inequality between high- and middle-to-low-income regions, compared with when we count territorial emissions only.

Carbon inequalities within regions are even larger than carbon inequalities between them

Significant inequalities in carbon footprints are observed in every region of the world. Figures 4A and 4B present the carbon footprints of the poorest 50%, the middle 40% and the richest 10% of the population across the regions. In East Asia, the poorest 50% emit on average around three tonnes per annum, while the middle 40% emit nearly eight tonnes, and the top 10% almost 40 tonnes. This contrasts sharply with North America, where the bottom 50% emit fewer than 10 tonnes, the middle 40% around 22 tonnes, and the top 10% over 70 tonnes of carbon dioxide equivalent. This in turn can be contrasted with the emissions in Europe, where the bottom 50% emit nearly five tonnes, the middle 40% around 10.5 tonnes, and the top 10% around 30 tonnes. Emissions levels in South and South-East Asia are significantly lower, from one tonne for the bottom 50% to fewer than 11 tonnes on average for the top 10%.

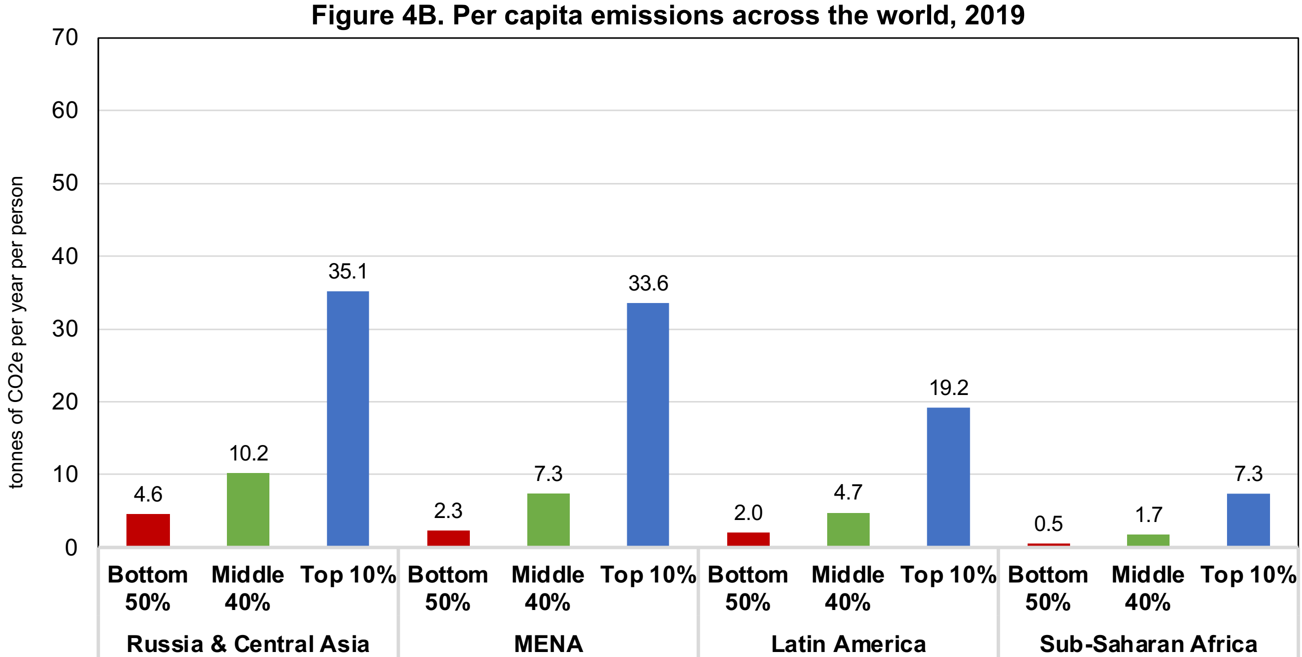
It is striking that the poorest half of the population in the US has emission levels comparable with the European middle 40%, despite being almost twice as poor.[8] This difference is largely due to the carbon-intensive energy mix in the US, where emissions from electricity are about twice as high as in the European Union. In the US, basic infrastructure consumes much more energy (because of the more widespread use of cars, for example), and devices tend to be less energy efficient (on average, cars are larger and less fuel efficient in the US than in Europe).

Figure 4A. Per capita emissions across the world, 2019



Interpretation: 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 based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. **Source and series:** Chancel (2021)

Figure 4B. Per capita emissions across the world, 2019



Interpretation: 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 based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. **Source and series:** Chancel (2021)

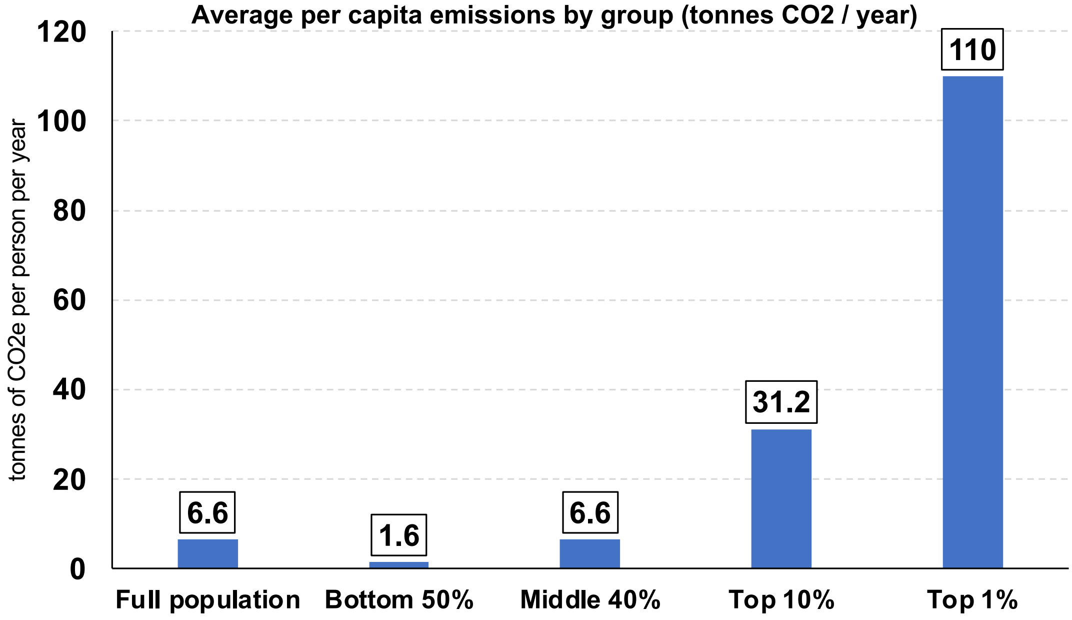
Nevertheless, European emissions remain very high by global standards. The European middle class emits significantly more than its counterparts in East Asia (around 10.5 tonnes compared with eight tonnes) and all other regions except North America. Yet it is also remarkable that the richest East Asians and the richest 10% in the Middle East emit more than the richest Europeans (39 tonnes, 34 tonnes, and 29 tonnes, respectively). This difference results from the higher income and wealth inequality levels in East Asia and the MENA region, and the fact that investments by wealthy Chinese are associated with significant emission volumes.

Turning to other regions, we find that Russia and Central Asia have an emissions profile close to that of Europe, but with higher top 10% emissions. Sub-Saharan Africa levels are lower, with the bottom 50% emissions around 0.5 tonnes and top 10% emissions around seven tonnes per person per annum. Overall, it stands out that only the poorest 50% of the population in Sub-Saharan Africa and South and South-East Asia come in under the 1.5°C per capita budget. Measuring levels against the 2°C per capita budget, we see that the bottom half of the population in each region is below or close to the threshold. In fact, it is striking that the bottom 50% in high- and middle-income regions such as Europe and Russia and Central Asia emit levels that fall within the 2°C budget. This shows that climate mitigation is largely a distributional issue, not only between countries but also within them.

Global carbon emissions inequality: one tenth of the population is responsible for close to half of all emissions

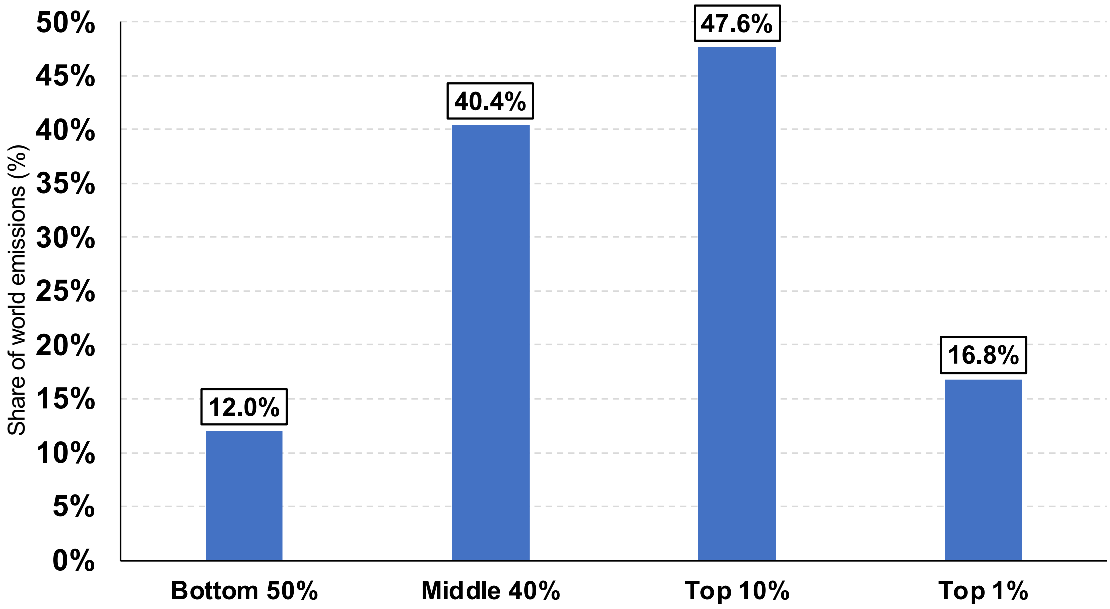
Figures 5AB show the inequality of carbon emissions between individuals at the world level. The global bottom 50% emit on average 1.6 tonnes per annum and contribute 12% of the total. The middle 40% emit 6.6 tonnes on average, making up 40.4% of the total. The top 10% emit 31 tonnes (47.6% of the total). The top 1% emits 110 tonnes (16.8% of the total). Global carbon emissions inequality thus appears to be very great: close to half of all emissions are created by just one tenth of the global population, and just one hundredth of the world population (77 million individuals) emits about 50% more than the entire bottom half of the population (3.8 billion individuals).

Figure 5A. Global carbon inequality 2019
Average per capita emissions by group (tonnes CO2 / year)



Interpretation: 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 based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. **Source and series:** Chancel (2021)

Figure 5B. Global carbon inequality, 2019: group shares



Interpretation: 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 based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. **Source and series:** Chancel (2021)

Table 5 presents more details on the global distribution of carbon emissions. The bottom 20% of the world population (1.5 billion individuals) emit fewer than 1.8 tonnes per capita per annum. Indeed, about one billion individuals emit less than a tonne per capita. The entry threshold to get in the middle 40% is 3.1 tonnes, and it takes 13 tonnes per capita per annum to get in the top 10%. It takes 130 tonnes to break into the global top 0.1% group of emitters (7.7 million individuals). (Figures 9AB, discussed below, show how each region contributes to these different groups of emitters.)

Per capita emissions have risen substantially among the global top 1% since 1990 but decreased among poorer groups in rich countries

How has global emissions inequality changed over the past few decades? A simple way to represent the change is to plot average emissions growth rate by percentile of the global income distribution. Global polluters are ranked from the lowest emitters to the highest on the horizontal axis of Figure 6, and their per capita emissions growth rate is presented on the vertical axis. Since 1990, average global emissions per capita grew by about 7% (and overall emissions grew by 58%). The per capita emissions of the bottom 50% grew faster than the average (32%), while those of the middle 40% grew more slowly than the average (4%), and some percentiles of the distribution actually saw a reduction in their emissions, of between five and 25%. Per capita emissions of the top 1% emissions grew by 26%, and top 0.01% emissions by more than 110%.

Per capita emissions matter but understanding the contribution of each group to the overall share of total emissions growth is crucial. Groups starting with very low per capita emissions levels can increase their emissions substantially over a given period yet still contribute very little to the overall growth in global emissions. This is in effect what has happened since 1990 (see Table 6, last column). The bottom half of the global population contributed only 16% of the growth in emissions observed since then, while the top 1% (77 million individuals) was responsible for 21% of emissions growth. These values are reported in the two boxes of Figure 6.

Table 5. Global inequality of individual carbon emissions, 2019

	Number of individuals (million)	Average (tonne CO2 per capita)	Threshold (tonne CO2 per capita)	Share (% total)
Full population	**7710**	**6.6**	**<0.1**	**100%**
Bottom 50%	**3855**	**1.6**	**<0.1**	**12.0%**
incl. Bottom 20%	*1542*	*0.8*	*<0.1*	*2.5%*
incl. Bottom 30%	*2313*	*2.1*	*1.8*	*9.5%*
Middle 40%	**3084**	**6.6**	**3.1**	**40.4%**
Top 10%	**771**	**31**	**13**	**47.6%**
incl. Top 1%	*77.1*	*110*	*46*	*16.8%*
incl. Top 0.1%	*7.71*	*467*	*130*	*7.1%*
incl. Top 0.01%	*0.771*	*2531*	*569*	*3.9%*

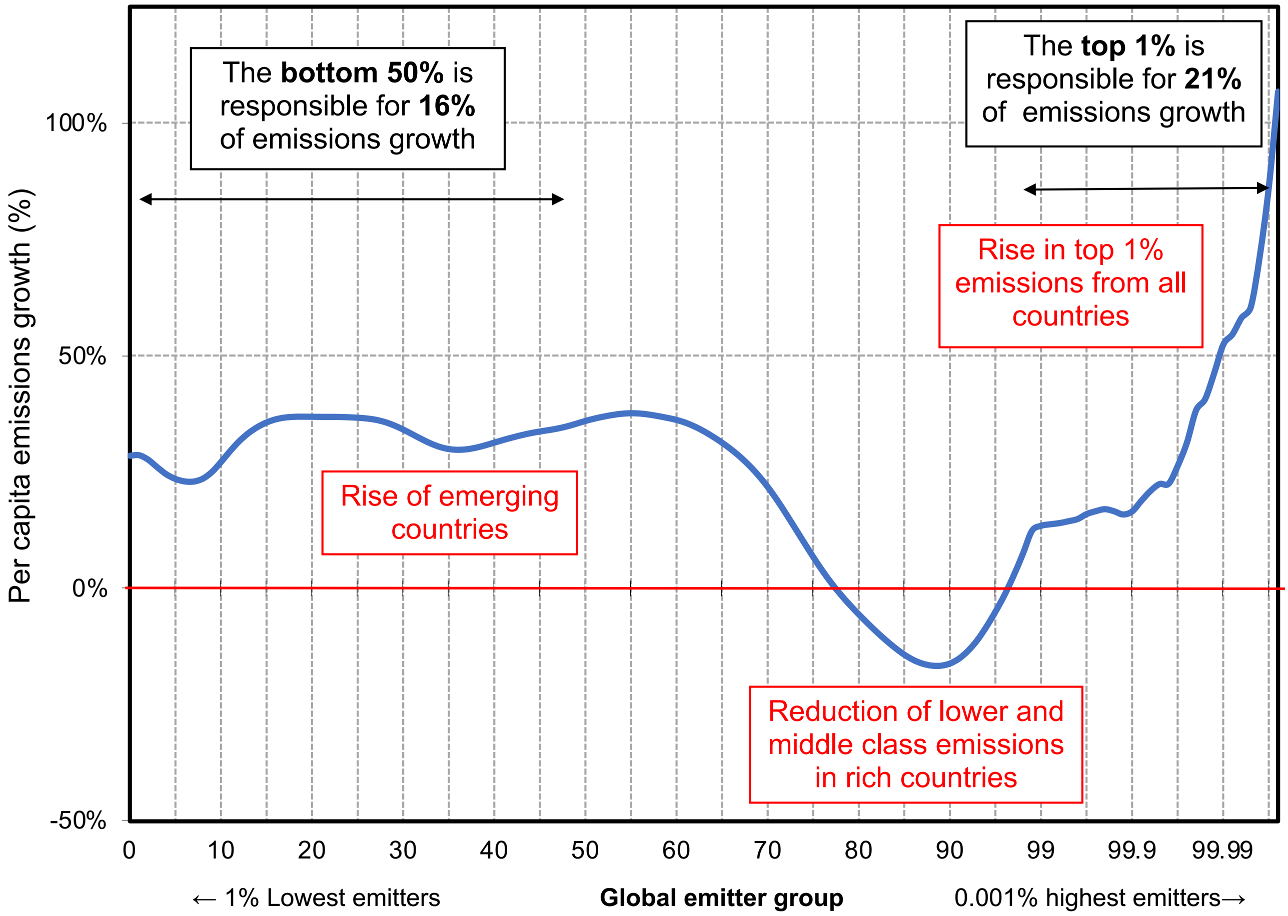
Interpretation: Individual carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. **Source and series:** Chancel (2021)

Table 6. Emissions growth and inequality, 1990-2019

	Per capita emissions (tonnes CO2e per capita)		Total emissions (billion tonnes CO2e)		Growth in per capita emissions (1990-2019)	Growth in total emissions (1990-2019)	Share in emissions growth (1990-2019)
	1990	2019	1990	2019			
Full population	6.2	6.6	32.0	50.5	7%	58%	100%
Bottom 50%	1.2	1.6	3.1	6.1	32%	96%	16%
Middle 40%	6	6.6	13.3	20.4	4%	54%	39%
Top 10%	30	31	15.7	24.0	4%	54%	45%
Top 1%	87	110	4.5	8.5	26%	87%	21%
Top 0.1%	323	467	1.7	3.6	45%	114%	10%
Top 0.01%	1397	2531	0.7	2.0	81%	168%	7%

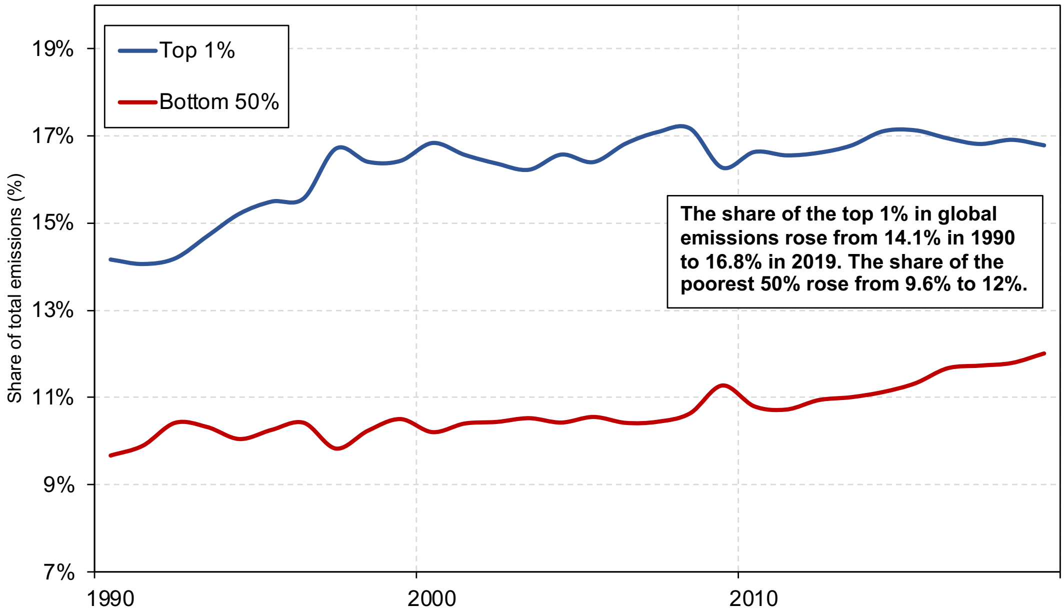
Interpretation: Personal carbon footprints include emissions from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. *Growth in total group emissions are different to growth in per capita emissions, due to population growth. Modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. **Source and series:** Chancel (2021)

Figure 6. Global inequality and carbon emissions, 1990-2019



Interpretation. Emissions of the global bottom 50% rose by around 20-40% between 1990 and 2019. Emissions notably declined among groups above the bottom 80% and below the top 5% of the global distribution, these groups mainly correspond to lower and middle income groups in rich countries. Emissions of the global top 1% and richer groups rose substantially. 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 based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households. **Source and series:** Chancel (2021)

Figure 7. Top 1% and bottom 50% shares in global carbon emissions, 1990-2019



Interpretation: This figure presents the share of global GHG emissions by the top 1% and bottom 50% of the global population between 1990 and 2019. GHG emissions measured correspond to individual footprints, i.e. they include indirect emissions produced abroad and embedded in individual consumption. Modeled estimates based on the systematic combination of tax data, household surveys and input-output tables. Emissions split equally within households **Sources and series:** Chancel (2021)

One of the most striking results shown in Figure 6 is the reduction in the emissions of about 15-20% of the world population, which largely corresponds to the lower- and middle-income groups of the rich countries. In these countries, the working and middle classes have reduced their emissions over the past 30 years. To be sure, these reductions are insufficient to meet the goals of the Paris Climate Agreement to limit global warming to 1.5°C or 2°C, but they contrast nevertheless with the emissions of the top 1% in these countries (and at the global level), which have significantly increased. Such a gap in carbon mitigation efforts between the rich and the less well-off in rich countries raises important questions about climate policies. In societies where the standards of living of the wealthy also shape the emissions of other social groups, this can have consequences for future emissions patterns. These dynamics also fuel criticisms of such environmental policies as carbon taxes, which have been shown to affect working and middle classes disproportionately in several countries (more on this below).

Figure 7 presents the evolution of the top 1% and the bottom 50% shares in total emissions between 1980 and 2019. Between 1990 and 2019, the global bottom 50% increased its share of the total, from around 9.5% to 12%, but at the same time, the top 1% share rose from 14% to close to 17%. Put differently, the gap in emissions between the top of the distribution and the bottom remained substantial over the entire period.

The rise in top 1% emissions is due to the increase in income and wealth inequalities within countries and to the rising share of emissions coming from the assets they own. We find that around half of emissions from the global top 1% stemmed from asset ownership in 1990, and this value rose over 70% in 2019.

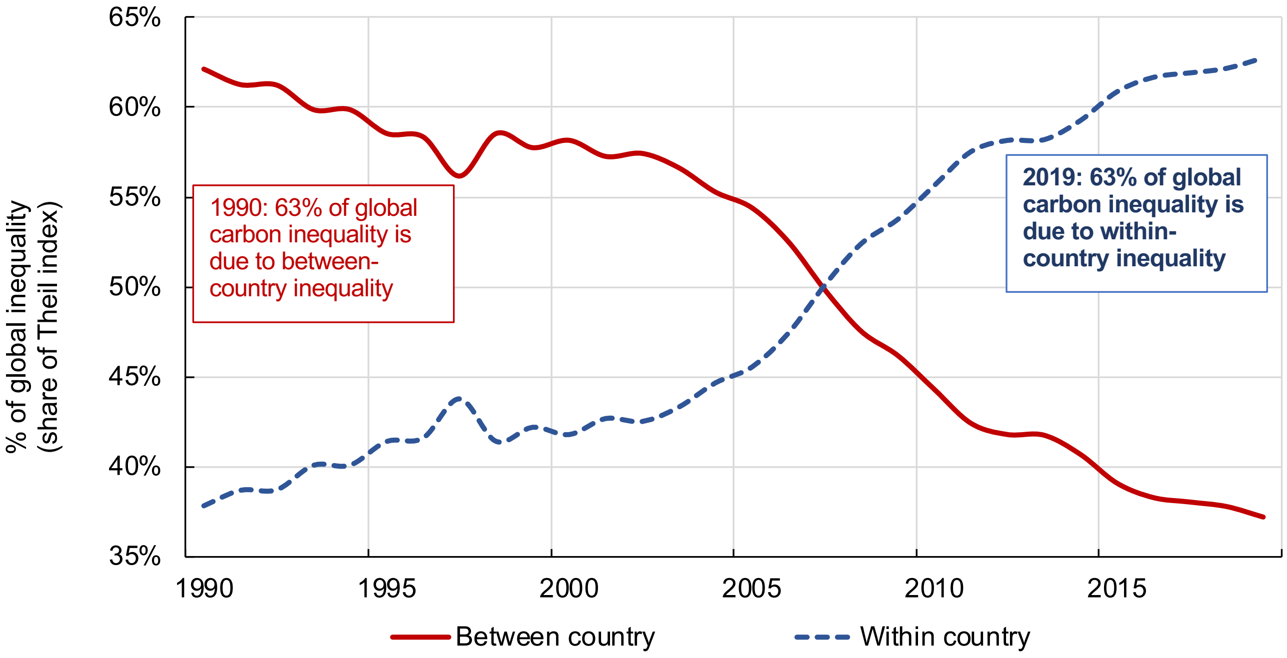
Inequalities within countries now represent the bulk of global emissions inequality

What has been driving the dynamics of global carbon inequality over the past decades: the average emission differential between countries, or inequalities within them? Figure 8 compares the share of global emissions that is due to intra-country differences with the inter-country differences. In 1990, most global carbon inequality (63%) was due to differences between countries: then, the average citizen of a rich country polluted unequivocally more than the rest of the world's citizens, and social inequalities within countries were on average lower across the globe than they are today. The situation has almost entirely reversed in 30 years. Domestic emissions inequalities now account for nearly two thirds of global emissions inequality. As for income, there remain significant (often huge) inequalities in emissions between countries and world regions (see Figure 1). This means that on top of the great inter-national inequality in carbon emissions, there also exist even greater inequalities in emissions between individuals. This has major implications for global debate on climate policies.

Figure 9A shows the geographical breakdown of each group of emitters. More precisely, the graph tells us about the share of population of each region in each percentile of the global carbon distribution. It shows, for example, that China, Latin America, and MENA are well represented among both the low emitters and the high emitter groups. This reflects the dual nature of these societies, where extreme polluters live close to very low polluters. Europe and North America are essentially represented in the top half of the global distribution (right hand side of the graph). The representation gap between Europe and North America among the very top of the distribution is clear in this graph, as is the large representation of Chinese among the highest polluters.

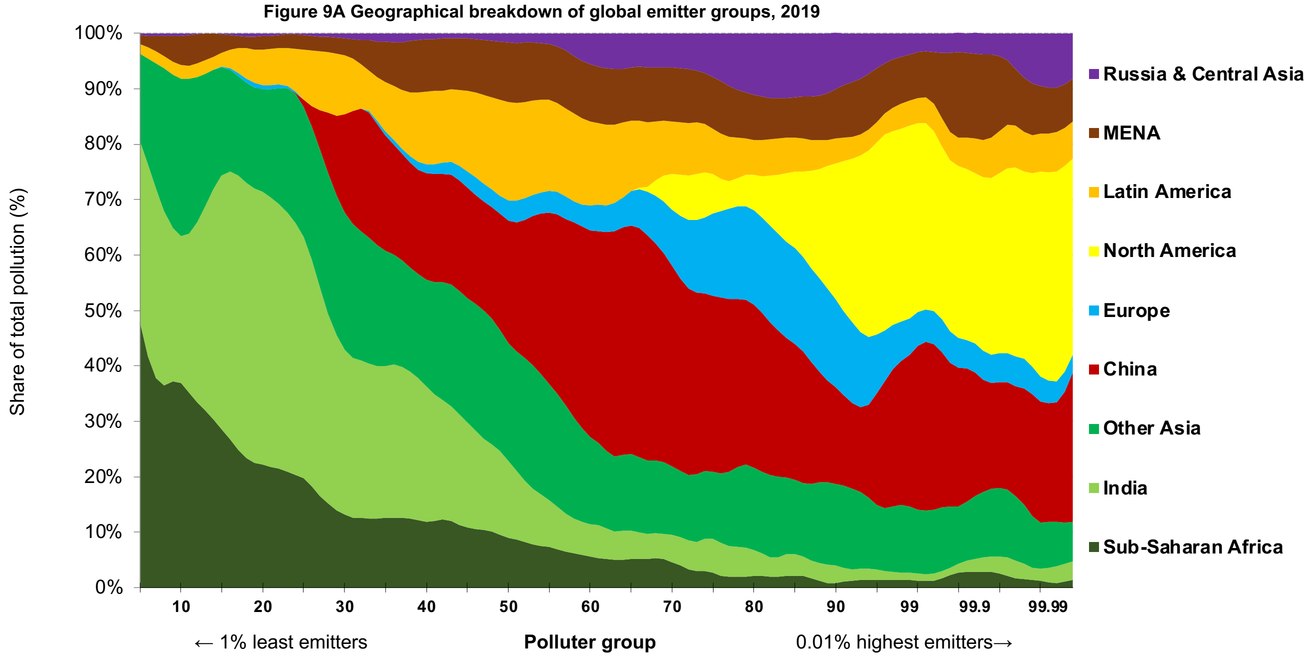
Figure 9B provides another representation of the global carbon distribution. Each color wedge is proportional to the population of a region, and the total colored area represents the world population. The graph summarizes the key insights into the global distribution of carbon emissions presented above.

Figure 8. Global carbon inequalities are mainly due to inequality within countries, 1990-2019
(Theil index decomposition of global carbon inequality)



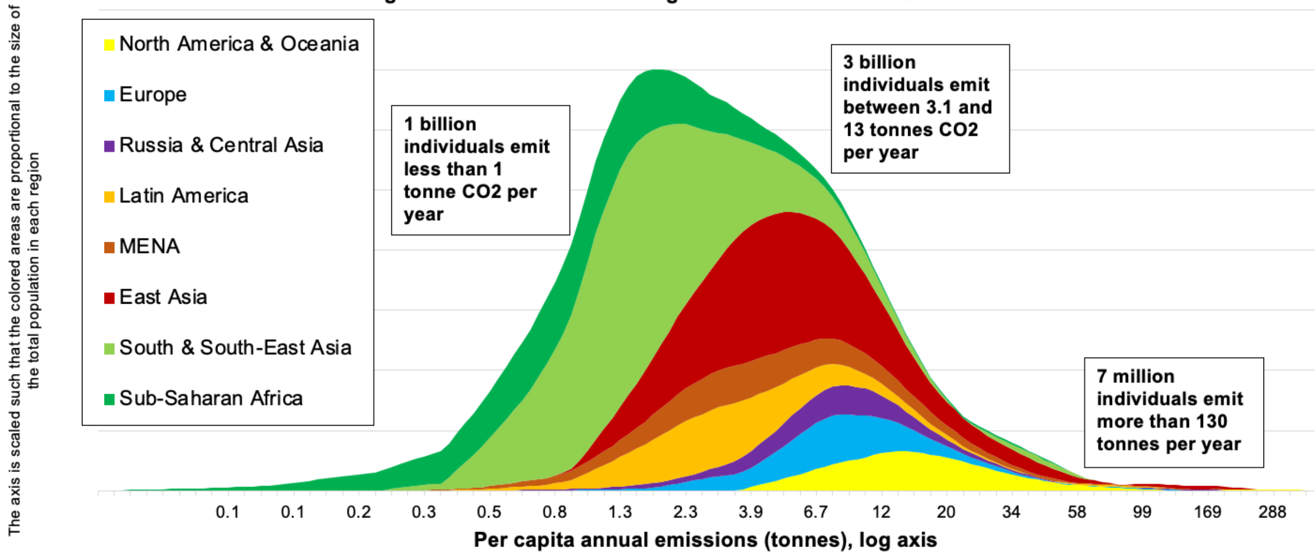
Interpretation: 37% of global carbon inequality between individuals is due to differences in emissions levels between countries while 63% is explained by inequality within countries in 2019.
Sources and series: Chancel (2021)

Figure 9A Geographical breakdown of global emitter groups, 2019



Interpretation: The graph shows the share of world regions in each group of global emitters, from the lowest 1% to the highest 0.1%. **Sources and series:** Chancel (2021)

Figure 9B. The distribution of global carbon emissions in 2019



Interpretation: The graph shows the global distribution of emitters in 2019. GHG emissions measured correspond to individual footprints, i.e. they include indirect emissions produced abroad and embedded in individual consumption.
Sources and series: Chancel (2021)

Addressing the climate challenge in unequal societies

Social movements in rich and emerging countries in 2018-2019 (including waves of protests against hikes in fuel and transport prices in Ecuador or Chile in 2019, and the Yellow Vest movements in Europe one year earlier) showed that policy reforms which do not properly assess the degree of inequality in a country and who will be the winners and losers in these reforms, are unlikely to be publicly supported and are likely to fail. This is particularly so for environmental policies. A clear illustration of this is the so-called Yellow Vest movement in France. In 2018, the French government implemented a hike in the carbon tax (which projected about four billion euros in additional tax revenues). While the tax was presented as a way of reducing carbon emissions, it was not accompanied by significant compensatory measures for low- and middle-income households.

The reform was introduced at the same time as a suppression of the progressive wealth tax on financial assets and capital incomes (which would have created around 3-4 billion euros of tax cuts, essentially concentrated among the top 1-2% of the wealth distribution). This reform was immediately opposed by the majority of the population. Many low- and middle-income households had to pay the carbon tax every day in order to go to work, having no alternative but to use their cars, while tax cuts were given to the very rich, living in cities, with low-carbon transport options, who also benefit from very low energy tax rates when they travel by plane. This situation triggered a wave of social protests (which spread to other European countries) and eventually led to the abandonment of the carbon tax.

In principle, a carbon tax can be a powerful tool to reduce emissions. In some countries, it has been implemented successfully and has contributed to limiting carbon emissions. However, the French example shows that when carbon policies are improperly designed and do not consider the socio-economic context in which they are implemented, they can easily fail and generate mistrust, making environmental policies look unfair. Let us be clear: the scale of transformation required to cut greenhouse gas emissions drastically in rich countries cannot be attained if environmental and social inequalities are not integrated into the very design of environmental policies. Below, we discuss options to address carbon inequalities seriously within and between countries.

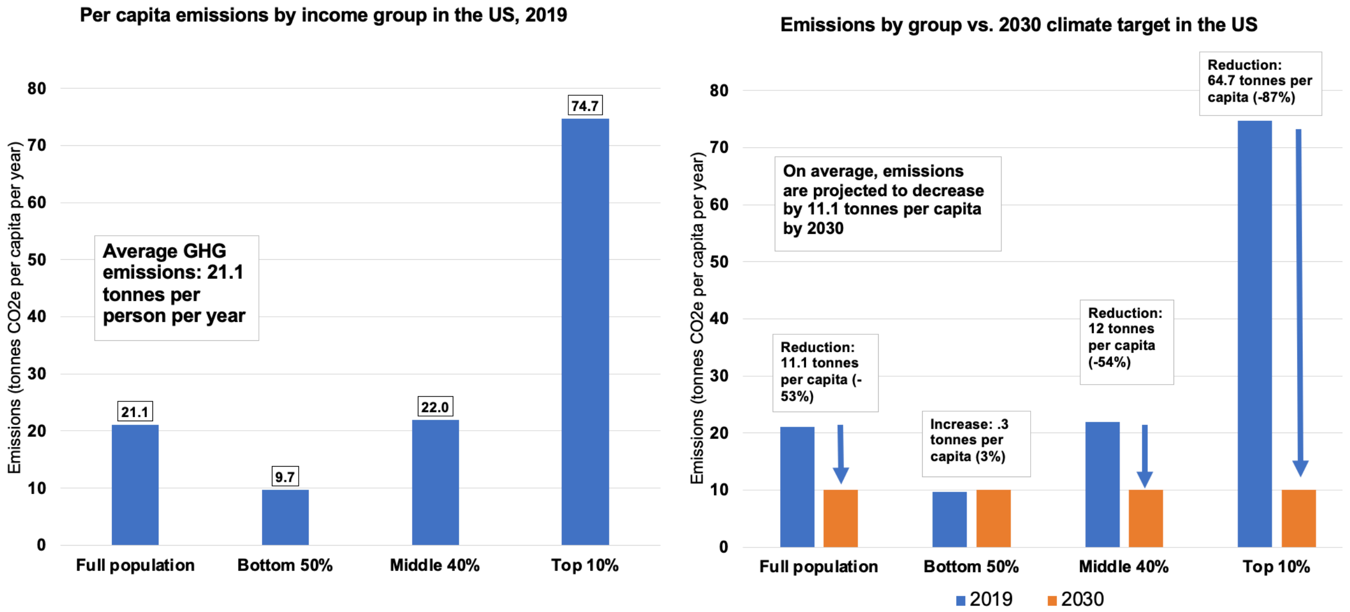
The first way to address carbon inequality is to track individual emissions within countries. Most governments do not publish aggregate carbon footprint estimates (they publish territorial emissions but, as discussed earlier, this is not sufficient to assess the actual environmental impact of policies). Governments also fail to track and publish reliable estimates of the inequality in carbon footprints, meaning that they cannot clearly foresee the distributional consequences of their climate policies. The estimates presented in this study provide a sound basis for these discussions. But governments still need to make a lot of progress if they are to account for individual emissions levels in a timely and systematic manner.

Figures 10ABCD present our best estimates of the carbon emissions of different population groups in the US, India, China, and France. The figures also present certain countries' climate targets for 2030. These countries were chosen as representatives of a wider set of countries: the US for Canada, Australia, and New Zealand, which have similar carbon inequality levels, France for European countries, and India and China for low income and emerging countries.[9]

The carbon emission commitments displayed in Figures 10ABCD are the pledges that states made at the Paris Agreement (or have made since then).[10] Pledges are typically expressed in aggregate emissions percentage reductions from a base year. Using population growth forecasts, these pledges can be expressed in terms of emissions per capita at a certain time, to make better sense of what they imply. In emerging countries (India and China, for example), targets are set on the basis of the carbon intensity of GDP. In these cases, it is possible to estimate the actual number of aggregate emissions implied by an estimated GDP level for 2030, and to express this number in per capita values.

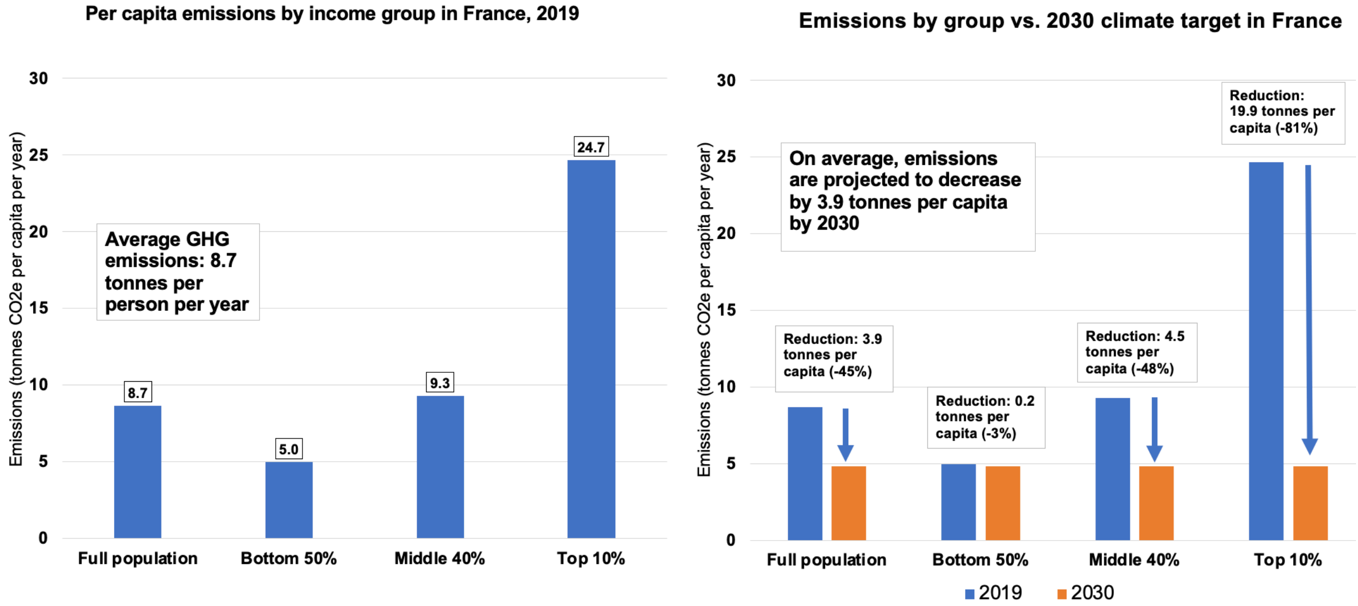
However, these targets do not represent what must be done in order to keep emissions below 1.5 or 2°C. So far, the official commitments do not add up to meeting the 2°C objective, much less to meeting the 1.5°C target. Rather, these numbers represent our best knowledge of what countries have pledged to achieve. For the US, pledges amount to a 53% reduction by 2030 of the late 2019 per capita emissions (which are close to mid-2021 emissions levels). In France, the pledge amounts to a 45% reduction. In India and China, emissions per capita are projected to increase, by 70% and 25% respectively between now and 2030.

Figure 10A. Emissions inequality and per capita emissions target in the US, 2019-2030



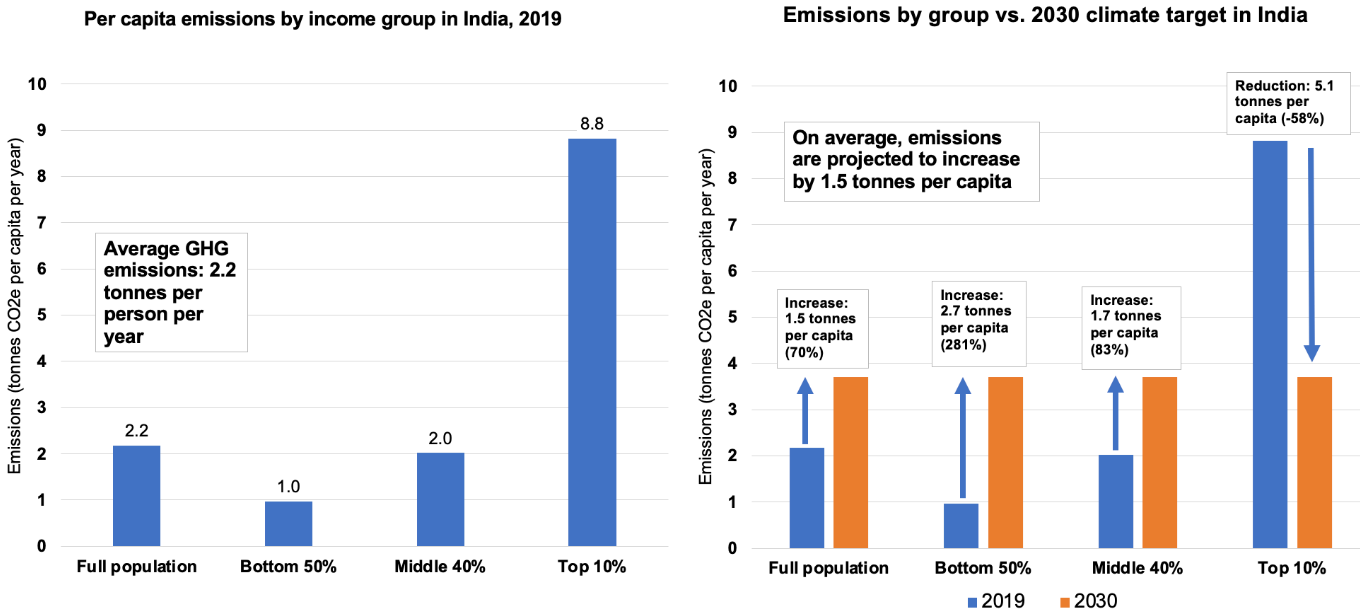
Interpretation: Individual carbon footprints include emissions from all greenhouse gases stemming from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates are based on the combination of national accounts, tax and survey data, input-output models and energy datasets. Emissions are split equally within households. The 2030 target corresponds to the overal emissions budget annouced by governments for 2030, divided by the total population of the country in 2030. **Source and series:** Chancel (2021)

Figure 10B. Emissions inequality and per capita emissions target in France, 2019-2030



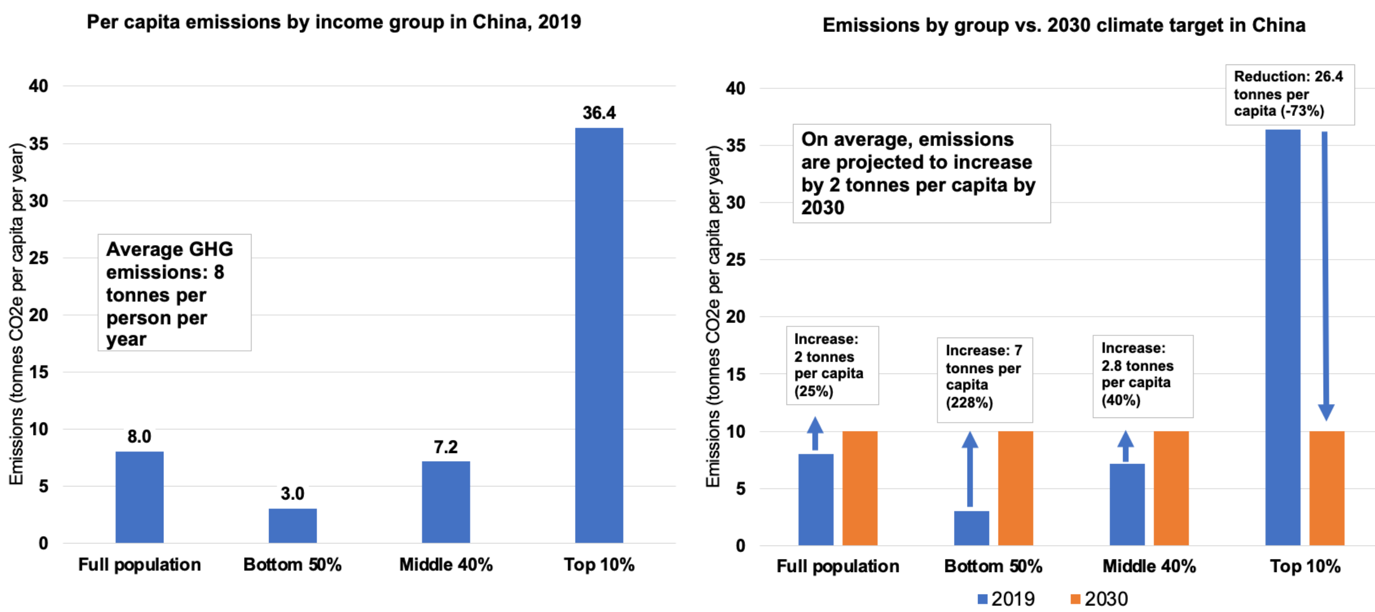
Interpretation: Individual carbon footprints include emissions from all greenhouse gases stemming from domestic consumption, public and private investments as well as imports and exports of carbon embedded in goods and services traded with the rest of the world. Modeled estimates based on the systematic combination of national accounts, tax and survey data, input-output models and energy datasets. Emissions are split equally within households. The 2030 target corresponds to the overal emissions budget annouced by governments for 2030, divided by the total population of the country in 2030. **Source and series**: Chancel (2021)

Figure 10C. Emissions inequality and per capita emissions target in India, 2019-2030



Interpretation: Individual carbon footprints include emissions from all greenhouse gases stemming 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 based on the systematic combination of national accounts, tax and survey data, input-output models and energy datasets. Emissions are split equally within households. The 2030 target corresponds to the overal emissions budget annouced by governments for 2030, divided by the total population of the country in 2030. **Source and series**: Chancel (2021)

Figure 10D. Emissions inequality and per capita emissions target in China, 2019-2030



Interpretation: Individual carbon footprints include emissions from all greenhouse gases stemming 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 national accounts, tax and survey data, input-output models and energy datasets. Emissions are split equally within households. The 2030 target corresponds to the overal emissions budget annouced by governments for 2030, divided by the total population of the country in 2030. **Source and series:** wir2022.wid.world/methodology and Chancel (2021)

The bottom half of the population in rich countries already near 2030 targets

Two main results stand out from these figures. First, in rich countries, the bottom 50% is already below the 2030 per capita target (in the US, for example), or very close to it (France). It follows that all emissions reductions efforts should be made by the top half of the distribution. In the US, the top 10% must cut its emissions by close to 90% in order to reach the 2030 per capita target, and the middle 40% by around 50%. The degree of effort required from the top 10% and middle 40% in France is similar.

Second, it appears that in emerging countries, not all groups should be permitted to increase their emissions levels. While the bottom and middle of the distribution are currently below the 2030 target, the top 10% is significantly above it. Indeed, in China, the top 10% must cut its emissions by more than 70% to meet the sustainable target. The value is also significant in India (-58%).

A new approach to climate policymaking

There are many ways to meet the 2030 pledges and there is no single ready-made solution or magic formula for implementing just carbon policies. What is paramount is to factor the large levels of carbon inequalities into the design of climate policy. In reality, different policy instruments (whether regulations, taxes, incentives or investments) have different impacts on different socio-economic groups.

One of the key conclusions of this study is that if countries do not take the egalitarian approach presented above (e.g. by demanding relatively fewer emissions reduction efforts from richer groups), then this will inevitably mean demanding more reductions from low-income groups, who have fewer resources with which to reduce their carbon footprints. Such strategies raise the question of financial compensation for low-income groups and of the just financing of these efforts.

Table 7 presents a schematic framework of climate policies and their potential impacts on income distribution (in the bottom, middle and top income groups).[11] The policies are broken down into three categories: decarbonizing the energy supply, decarbonizing energy access, and decarbonizing existing energy end-uses (such as existing transport systems). The table is non-exhaustive and illustrates the variety of climate/energy policies available to policymakers and the set of possible impacts on different social groups. We argue that an inequality "reality check" of climate policies should take center stage in climate policymaking.

Table 7. An inequality reality check for climate policies

		What kind of climate policy?		
		Decarbonize energy supply	**Decarbonize 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 + tricter 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

Interpretation: The table presents different climate policies and their potential impact on social groups. The types of measures and their impact are non-exhaustive. *Fossil fuel subsidies typically benefit wealthy groups more than poorer ones in both rich and developing countries. Table adapted from Voituriez and Chancel (2020) and Rodrik and Stantcheva (2021).

Table 8. Revenues from a progressive wealth tax with a pollution top-up

Wealth group ($)	Number of adults (million)	Total group wealth ($ bn)	Avg. group wealth ($ m)	Wealth tax revenues from group ($bn)	Revenues from fossil assets top-up ($bn)	Total tax revenues (% global income)
All above 1m	62.2	174 200	2.8	1695	100	1.7%
1m - 10m	60.3	111 100	1.8	684	64	0.7%
10m - 100m	1.8	33 600	19	432	19	0.5%
+100m	0.1	29 570	387	579	17	0.6%

Interpretation: The table presents revenues to be expected from a global progressive wealth tax with a pollution top-up. The wealth tax rates range from 1% for individuals with net wealth between USD1m and USD10m, 1.5% for net wealth between 10 and 100m USD, 2% for between USD1b and USD10b, 3% for between 10 and 100b USD, and 3.5% above USD100b. On top of this wealth tax, we apply a tax on assets in major oil, gas and coal companies, whose rate ranges from 10 to 15%, with a discount proportional to these firms' green energy production (which is extremely low for the major oil companies, representing around just 2% of capital investments in renewables). **Sources**: Chancel (2021)

Examples of climate policies that effectively address inequality exist. In British Colombia (Canada), a carbon tax was introduced along with a significant package of transfers to low- and middle-income households, which ensured the social viability of the reform.[12] In Indonesia, energy subsidies reforms were coupled with substantial investments in the public health system, largely financed by increased revenues from energy taxes. In Sweden, decades of large-scale public investments in low-carbon infrastructure made it possible for low-income groups to access affordable, clean energy sources. When a carbon tax was eventually introduced, low-income groups had the choice between green(er) or fossil fuel options.[13]

One dimension which has been largely left out of climate policies around the world is the large carbon footprints of the very wealthy. Given the inordinate responsibility of wealthy groups for overall emissions levels (within countries and at the global level), lack of focus on this question is unfortunate. So far, the standard form of carbon taxation has been a uniform tax rate for all, i.e. whether rich or poor, individuals should pay the same carbon tax rate. In unequal societies, this *de facto* means giving more polluting rights to wealthy individuals, who are less affected by an increase in carbon prices than low-income individuals. To accelerate carbon emissions reductions among the wealthiest, progressive carbon taxes can be a useful instrument. Progressive carbon taxation means that the rate of a carbon tax increases with the level of emissions or the level of wealth of individuals. Chancel and Piketty made proposals along these lines, and also proposed specific taxes on carbon-intensive luxury consumption items.[14] These can include business class airline tickets, yachts, etc. Indeed, progressive carbon taxes will not suffice: stricter regulations (including bans) on the consumption of expensive carbon goods or services must also be implemented, for example on the purchase of SUVs.

Shifting the focus from consumers to asset owners

Finally, we argue that climate policy instruments focusing on the regulation and taxation of asset portfolios (rather than on the consumption of goods and services) deserve more attention. Carbon consumers, especially from low- and middle-income groups are often constrained in their energy choices, because they are locked into carbon intensive infrastructure systems. On the contrary, investors who opt to invest in fossil fuel industries do so while they have many alternative options for investing their wealth. Therefore, the purchase of stock in fossil fuel companies that continue to develop new extraction projects should be highly regulated. Such moves can be accompanied, for a short period (before effective bans are introduced), by steeply progressive tax rates on polluting stock ownership.

In Table 8, we provide estimates of a global progressive wealth tax on multimillionaires, including a pollution top-up. Revenue estimates are based on the most recent data available on the World Inequality Database, and include an additional tax component, based on the ownership of stock in the world's leading oil and gas companies.[15] A discount is applied when fossil fuel companies invest in renewable energy. If companies shifted all their operations to renewable energy supplies, then their shareholders would no longer face the pollution wealth tax top-up. Currently, however, this is far from being the case: only 2% of oil company investments are made in renewable energy activities.[16] Radical investment decision changes would therefore need to be made in order to avoid the wealth tax pollution top-up.

Applying a 10% tax rate on the value of carbon assets owned by global multimillionaires would generate at least $100bn in one year. This is no neglible amount: it represents about 1.5 times the current estimated annual costs of adaptation to global warming for developing countries (about $70bn per year in 2020). Yet, compared with current additional investment requirements in energy systems globally, this value remains small. It is estimated that 2% of GDP in additional annual investment are required (i.e. about $2,000b). As a matter of fact, the very large additional investments in infrastructure necessary to meet the energy transition challenge will require considerable new sources of financing and these cannot be met by taxes on highly polluting assets alone. Progressive taxes on both carbon and non-carbon assets will be essential to ensuring that governments make sufficient investments in a timely manner.

Box 1 Measuring carbon inequality between individuals

Measuring carbon inequality between individuals across the globe is an even more challenging task than measuring it for income and wealth. In this report, our emissions estimates are based on observed national carbon footprints across different sectors of the economy, inequalities in private consumption, wealth inequality, and levels of government spending. The novelty of our approach is to combine systematically the new data sets on global income and wealth inequality produced by the WID.world project with international carbon data series, known as environment input–output tables.[17]

Environmental input–output (IO) tables are based on the pioneering work of Nobel prize winner Wassily Leontief, who systematized the work of one of the first economists of the 18th century, François Quesnay, and extended it, to study the relationship between production and the consumption of environmental inputs.[18] Environmental IO tables make it possible to measure the carbon content associated with the production of an economic sector, taking into account all the emissions used in the intermediary production process of the goods produced by this sector. Intermediary emissions include both those made on a territory and those made abroad by foreign suppliers. This is particularly useful for measuring carbon footprints rather than only territorial emissions (see above). The strength of Environmental IO methodology is also its systematicity: it ensures that one tonne of carbon used in the production of a good is never counted twice. The problem of double counting arises in other methods of measuring carbon footprints, known as Life Cycle Analyses, which allow more detailed estimates for a specific product, but cannot provide systematic and coherent macro-level statistics. The two approaches are complementary, but when we are investigating global emissions inequality, we prefer the IO approach.

From Environmental IO tables, we can reconstruct, country by country, and sector by sector, the volume of emissions associated with household consumption, the government sector, and private investments in an economy. With this information, we can distribute each component to income groups within countries. We distribute emissions to private consumption on the basis of observed regularities in the relationship between individual (carbon) consumption and income. Typically, micro-level household surveys find that carbon emissions increase with income, but less than proportionally.[19] We then add emissions associated with government spending. Our assumption is both simple and conservative (i.e. it uses a low limit to emission inequality), as we assume that emissions associated with government spending are distributed as a lump sum to individuals. We also take into account emissions associated with investments, based on the distribution of assets across the population. For instance, if a group is responsible for 25% of all private investments, then this group is attributed 25% of the emissions associated with those investments. Our method is adaptable: it will be refined as more elaborate data sources on carbon emissions associated with private consumption and wealth are developed.[20] While it is urgent to improve the quality of the public monitoring of carbon inequalities, we believe that we can already produce reliable statistics that are consistent with carbon inequality levels produced by more detailed micro-level studies. Methodological details can be found in the more technical study associated to this paper.[21]

Box 2 Carbon footprints of the very wealthy

How much CO2 do the wealthiest individuals on earth emit? Our estimates show that emissions can reach extreme levels: the global top 1% of individuals emits around 110 tonnes on average, the top 0.1% 467 tonnes, the top 0.01% 2,530 tonnes per person per annum. These emissions stem both from individual consumption and from the investments they make. There are variations within each group: certain very wealthy individuals invest in less carbon-intensive activities than others and consume fewer carbon-intensive goods. On average, however, the answer is quite clear: extreme wealth comes with extreme pollution.[22] Our estimates should be interpreted with care, given the difficulty of properly assessing the carbon content of wealth and the carbon embedded in consumption, but our approach is rather conservative: we tend to underestimate the carbon footprint associated with extreme wealth rather than overestimate it.

Perhaps the most conspicuous illustration of extreme pollution associated with wealth inequality in recent years is the development of space travel. Space travel is expected to cost from several thousand dollars to several dozen million dollars per trip. A single flight is estimated to emit no fewer than 75 tonnes of carbon per passenger once indirect emissions associated to the flight are considered.[23] At the other end of the distribution, about one billion individuals emit less than one tonne per person per year. Over their lifetime, this group of one billion individuals does not emit more than 75 tonnes of carbon per person. It therefore takes a few minutes in space travel to emit at least as much carbon as an individual from the bottom billion will emit in her entire lifetime.[24] This example shows that there is scarcely any limit to the carbon emissions of the ultra-wealthy.

---

[1] World Inequality Lab, Paris School of Economics, Sciences Po, Paris

2 Thus, the term CO2 is interchangeable with "CO2-equivalent" or "CO2e", but we use CO2 in this study for simplicity and readability.

3 It is estimated that an additional 5–7 billion tonnes are associated with deforestation and land use, changes to land use, and forestry (LULUCF). Because these emissions are harder to take into account country by country, we do not include them in the national and regional figures presented in this study. Including deforestation, per capita emissions could reach around seven tonnes CO2 per capita.

[4] Detailed methodology and data series are presented and discussed in the working paper: Chancel, L. 2021. "Global Carbon Inequality (1990-2019)." WID.world Working Paper

5 Estimates of deforestation indicate an additional 1.5 billion tonnes due to deforestation in 1850; see PRIMAP historical data set: https://www.pik-potsdam.de/paris-reality-check/primap-hist/.

6 Logically, these budgets would decrease should we decide to split them between now and 2100 (rather than between now and 2050). Doing so would reduce the 2°C sustainable level to 1.1 tonnes per person per annum. The equivalent figure for the 1.5°C compatible budget would drop to 0.4 tonne per person per annum.

[7] For discussions on climate justice principles and applications to different carbon budget sharing strategies, see Grasso, M. and T. Roberts. 2014. "A Compromise to Break the Climate Impasse." *Nature Climate Change* no. 4: 543–549; Fuglestvedt, J. S. and S. Kallbekken. 2015. "Climate Responsibility: Fair Shares?" *Nature Climate Change*; Matthews, H. D. 2015. "Quantifying Historical Carbon and Climate Debts among Nations." *Nature Climate Change*; Raupach, M. R. et al. 2014. "Sharing a Quota on Cumulative Carbon Emissions." *Nature Climate Change* no. 4: 873–879; Landis, F. and T. Bernauer. 2012. "Transfer Payments in Global Climate Policy." *Nature Climate Change* no. 2: 628–633.

8 The middle 40% of Europeans earn on average PPP €38,500 per annum per adult after all taxes and transfers, whereas the bottom 50% of the US distribution earn PPP €20,000 per annum per adult after all taxes and transfers are taken into account.

[9] There are variations in carbon emissions levels across European countries (France has a slightly lower carbon footprint than many of its neighbors), but these differences are minor compared with differences with the US on the one hand, and China and India on the other.

[10] We report pledges announced up to the last semester 2020.

[11] The table is adapted from Voituriez, T., and L. Chancel. 2020. "How do Governments' Responses to the Coronavirus Crisis Address Inequality and the Environment?", in *Human Development Report 2020*, United Nations Development Programme. For a version focusing on redistribution and predistribution policies, see Rodrik, D., and S. Stantcheva. 2021. "A Policy-matrix for Inclusive Prosperity." NBER Working Paper No. 28736, April.

[12] See Chancel, L. 2020. *Unsustainable Inequalities: Social Justice and the Environment*. Cambridge: Harvard University Press
[13] See Chancel, *Unsustainable Inequalities*.
[14] See Chancel, L. and T. Piketty. 2015. "Carbon and Inequality: From Kyoto to Paris." Paris School of Economics Study.
[15] See www.wid.world and Chancel, L., T. Piketty, E. Saez, and G. Zucman. 2021. *World Inequality Report 2022*, Chapter 7 (*forthcoming*).
[16] See *Financial Times*, https://www.ft.com/content/95efca74-4299-11ea-a43a-c4b328d9061c
[17] For more details, see Chancel, L. 2021. "Global Carbon Inequality, 1990-2019", WID.world Working Paper 2021/21. See also Chancel and Piketty (2015) and Kartha et al. 2020. "The Carbon Inequality Era, Joint Research Report." SEI and Oxfam, September 2020
[18] Leontief, W. 1966. *Input–Output Economics*. Oxford: Oxford University Press and Leontief, W. 1970.
[19] Using country-level micro studies, we assume a central elasticity of 0.6 between income and emissions from private consumption, meaning that when income increases by 10%, emissions rise by 6%.
[20] See Rehm, Y. 2021. "Measuring and Taxing the Carbon Content of Wealth." PSE dissertation.
[21] See Chancel, L. 2021. "Global Carbon Inequality (1990-2019)." WID.world Working Paper
22 See also DOI: 10.1038/s41558-019-0402-3, Gössling, S. 2019. "Celebrities, Air Travel, and Social Norms." *Annals of Tourism Research* vol. 79.
23 In our lower bound estimates, the launch of a liquid H2 O2 rocket requires about 10 tonnes CO2 to produce the fuel transported by the rocket and another circa 65 tonnes in indirect emissions, associated to the construction of the engine, the on-ground transportation of staff as well as the heating/cooling of employees' offices. These estimates are surrounded by large uncertainties and should be treated with care (our upper bound estimates suggest that a single flight could emit as much as several hundred tonnes of CO2). In order to get a more precise account of emissions associated to commercial space travel, it is critical that companies themselves produce detailed, systematic and transparent estimates associated to each flight. These estimates should not only refer to emissions at point of use (in the case of Liquid H2/O2 rockets, values are close to zero), but should also include indirect emissions (scope 3) associated to the launch.
24 One billion people emitting less than one tonne per annum and whose life expectancy is fewer than 75 years.