CARBON EMISSIONS AND INCOME INEQUALITY

Technical note

This note explains the data and calculations used to produce the emissions distributions used in Oxfam's **Extreme Carbon Inequality briefing**. Owing to limitations with the data, and certain assumptions made in the analysis, all figures should be regarded as indicative of orders of magnitude, rather than exact reflections of reality. This analysis is intended to contribute to a discussion about the links between income and emissions and the associated inequities of intra-national greenhouse gas pollution; it is not intended to be a definitive international account of emissions produced by populations with different income levels. It is hoped that future work may build on the first steps taken here.

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DATA

The approach adopted in Oxfam's research assumes an elastic relationship between income distributions and emissions distributions. Put simply, it takes data on income shares of different percentiles at the national level and uses these shares as a starting point to distribute aggregate national emissions between income percentiles. It is faithful to the national emissions data provided and is unconcerned with the absolute income of each percentile.

There are two principle datasets used: one provides the intra-national income distributions and population totals, and the other provides national-level estimates of CO_2 emissions associated with household consumption.

[Square brackets below indicate the worksheet in the accompanying data file where the relevant data can be found]

Income distribution data ('WYD08') [A]

National income distribution data are obtained from analysis by Branko Milanovic.[1] This provides percentile-level estimates of income (and consumption – the two are treated interchangeably) for 118 countries in the benchmark year 2008, based on household surveys. Actual surveys years differ but are inflated/deflated to the benchmark year for cross-country comparability. For each percentile, income data are real 2008 per capita annual incomes in 2005 PPP $ values (**inc**). Each percentile's population (**pop**) is also given. The total population of these 118 countries is 6,142 million. This dataset represents the most recent data publically available on income distributions at this level of granularity.

Limitations

- Typically, household surveys don't capture the extreme right tails of income distributions as the tails are likely under-sampled.
- Consumption/expenditure, rather than income, is more likely to be the real driver of emissions (and different countries likely have different savings rates, which will also differ across the income distribution). This dataset, however, uses a combination of consumption and income surveys, depending on the country in question. Income and consumption are treated interchangeably.
- We might expect some changes to these national distributions, and the resultant global distribution, in future updates of this dataset owing to both more recent national household surveys and the release of the International Comparison Program (ICP) 2011 Purchasing Power Parities,[2] which change our understanding of relative income across countries.

Emissions data ('MRIO07') [B]

Data are based on estimates of CO_2 emissions for 2007 associated with household consumption provided by Glen Peters of the Center for International Climate and Environmental Research – Oslo. This analysis employs a Multi-Regional Input-Output (MRIO) model based on the trade model from the Global Trade Analysis Project (GTAP) 8.1.[3] Data are based on Le Quéré *et al.* (2014)[4] and territorial emissions are scaled to CDIAC values. The dataset covers 121 countries.

The values used in this analysis represent emissions from consumption rather than production. The underlying trade model allocates emissions associated with goods/services to the territory in which the consumption takes place, rather than the country in which the production process occurs. Estimates of consumption-based emissions are used in preference to standard national accounts of production (territorial) emissions because this analysis is focused on the behaviour of individuals rather than nations. Using an income distribution to construct an emissions distribution implicitly assumes all emissions can be assigned to domestic individuals (i.e. on an individual consumption basis). Similarly, therefore, emissions associated with consumption by governments, capital, and international transport sectors of the economy are excluded; data refer only to emissions resulting from direct consumption by households. The proportion of total consumption emissions that the household sector represents varies by country, but globally it represents around 64 percent of the total.

Combining the datasets

Only countries that are included (and have associated data) in both WYD08 and MRIO07 are included in this analysis. This equates to 93 countries with a combined population of 5,913.75 million people (approximately 87 percent of the global population in 2008). The countries included are listed in the Annex.

CALCULATIONS: EXPLANATION OF PROCESS AND ASSUMPTIONS FOR PRODUCING EMISSIONS DISTRIBUTIONS

Produce a global income distribution from national distribution data [A, C]:

1. Using WYD08, all national percentiles (**N%**) are sorted globally by income per capita.
2. For this global distribution we then calculate for each N% the cumulative population, the cumulative proportion of global population (to derive global percentiles), the total income of N% (inc.pop), and the cumulative income.
3. For each global percentile (**G%**) the population (59.14m), income and average income per capita are calculated.

Produce index values for each national and global distribution [D]:

For distribution X, the index value for percentile n (Pn) = 100(inc of Pn / inc of P1)*

Add an optional elasticity function to each distribution index. This allows elastic relationships between income and emissions to be specified globally or individually for each country. By default unitary elasticity is used for all distributions **[E].**

*E*100*(iPn/100), where E is the elasticity value and iPn is the index value for percentile n.*

Chakravarty *et al.* (2009)[5] make the case for a unitary elasticity (1) between incomes and emissions, but their approach has been criticized by Grubler & Pachauri (2009).[6] EcoEquity and the Stockholm Environment Institute also adopt this unitary approach in their Greenhouse Development Rights Climate Equity Reference Calculator.[7] There is certainly a debate to be had about the appropriateness of employing different elasticity values in different countries, but for simplicity, and because generally results are not very sensitive to the elasticity value selected, a unitary elasticity of 1 is employed globally by default. This can easily be changed nationally or globally.

Each (elastic) distribution index is then converted into a synthetic emissions distribution (giving the emissions associated with each income percentile) by multiplying the average national (or global) per capita emissions by each percentile's index value divided by the distribution's average index values **[A, F]:**

$$CO_2pc \times \left(iP_n \div \overline{iP_i} \right)$$

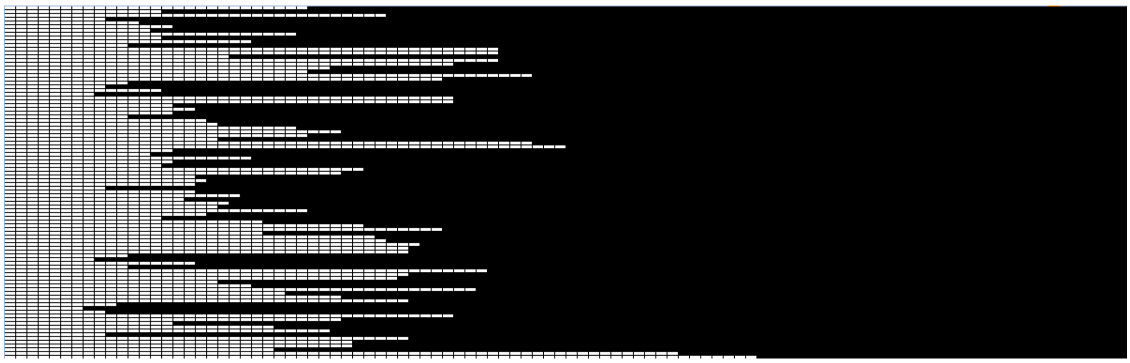
The resulting emissions distributions, while faithful to the underlying income distributions, in many cases produce per capita emissions values at the lower end of the distribution (i.e. associated with the poorest segments of the population) that are lower than might be considered plausible. For example, unless living a subsistence life completely off-grid using only renewable energy, each person will have a base level of emissions resulting from their energy use that, in some cases, may be higher than suggested by the distribution. The lower bound of plausibility will differ by country and will be dependent on the structure of that nation's economy and fuel mix used for energy provision. As a result, for these indicative calculations, a nationally determined threshold of minimally plausible emissions is applied, below which no percentile's per capita emissions can fall. Ideally this threshold would be determined relative to the median per capita emissions in each country (in the same way that relative poverty is calculated relative to the median income of the population), but as the median is dependent on the shape of the distribution produced, a second-best, but reasonable, option is employed, expressing the threshold relative to the mean per capita emissions in each country. A simple, arbitrary, threshold used as default for the purpose of this exercise is 50 percent of the mean (this can easily be adjusted). Although arbitrary, reference to Ummel (2014),[8] which estimates emissions footprints for six million US households over the period 2008–2012 (including analysis relating per-person GHG footprints and per-person income), suggests this is not unreasonable. Comparing Ummel's results with those for the US from this exercise confirm that the results obtained here are of the right order of magnitude.

The nationally determined lower bound per capita emission threshold is applied by redistributing per capita emissions from those percentiles with emissions above the threshold to those below the threshold.

Below-threshold values are all inflated to the threshold value and the sum of the marginal increase is subtracted equally from all above threshold percentiles. For some countries, this simplistic adjustment does result in national-level emissions that differ slightly from the original MRIO07 data. These are generally within one percent of the original values. This is a result of some slightly crude results for percentiles around the threshold level (those with pre-adjustment values above the threshold may fall slightly below the threshold when the adjustment subtraction is made. As this exercise is only intended to be indicative, further adjustments to correct this have not been made **[A, F]**.

The proportion of the distribution that requires adjustment to bring values up to threshold values varies considerably by country. Figure 1 gives a quick visual indication: each row represents a country, each column is a percentile and shaded cells are above the threshold.

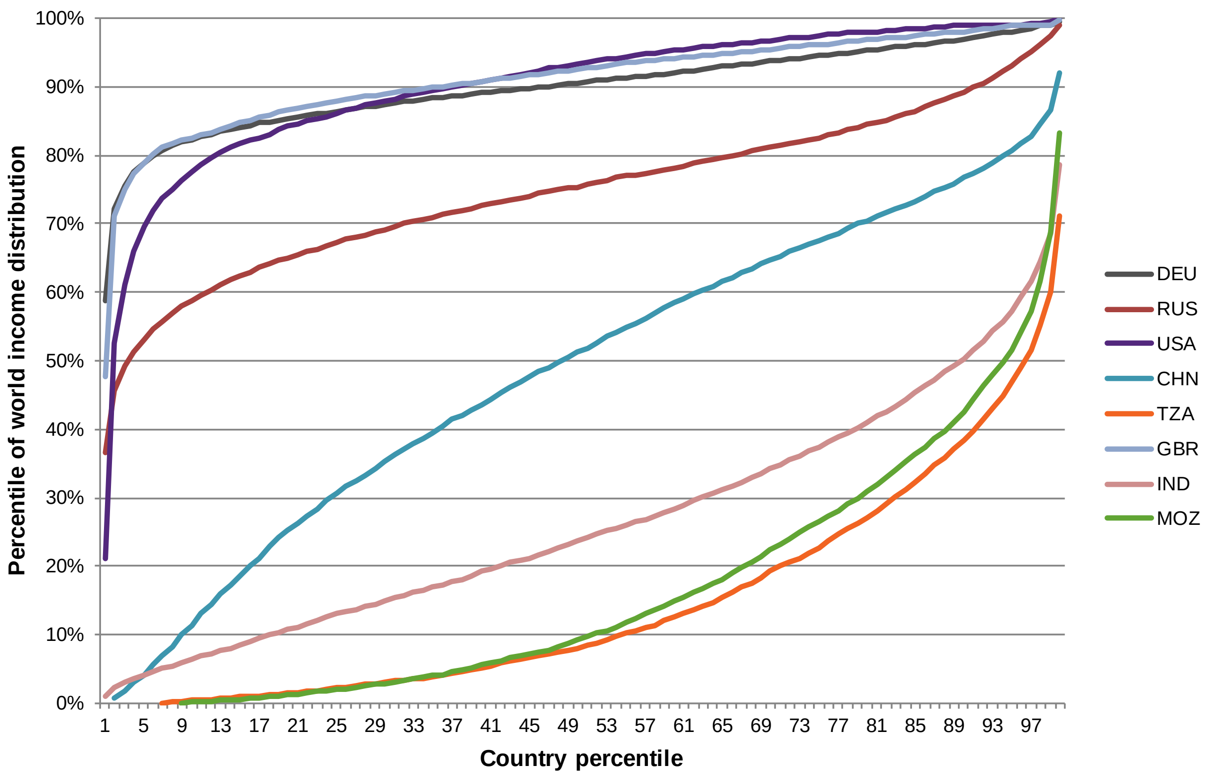
Figure 1: Incidence of country-by-country minimum threshold levels



SUMMARY RESULTS

By comparing different countries' income distributions with the global distribution, it is easy to understand how the incomes of different groups in different countries relate to one another (Figure 2). For example, the 90th percentile in Russia has approximately the same per capita income as the 50th percentile in Germany and the 90th percentile globally.

Figure 2: National income distributions in the context of the global income distribution [g1]



All results presented here are based on unitary elasticity and the application of a national minimum threshold for per capita emissions. The associated data workbook contains calculations for both adjusted and unadjusted data, and the possibility to adjust both of these parameters [on sheets E and F respectively].

Global summary

- Global average household consumption per capita emissions in 2007 were 3.42 tCO_2 [1].
- Global total household consumption emissions in 2007 were 17,187,821,112 tCO_2 [1].
- The emissions of the top 10 percent richest people globally are 49 percent of the global total [1].
- The emissions of the bottom 50 percent poorest people globally are 10 percent of the global total [1].
- The emissions of the bottom 40 percent poorest people globally are 7 percent of the global total [1].
- The top 10 percent richest people globally have per capita emissions of 17.60 tCO_2 and total emissions of 8,431,448,890 tCO_2 [1].
- The bottom 50 percent poorest people globally have per capita emissions of 1.57 tCO_2 and total emissions of 2,870,765,609 tCO_2 [1].
- The bottom 40 percent poorest people globally have per capita emissions of 1.57 tCO_2 and total emissions of 1,965,838,004 tCO_2 [1].

- The average per capita emissions of the top 10 percent are 11 times higher than the average emissions of the poorest 50 percent [1].
- The total emissions of the top 10 percent are five times higher than the total emissions of the poorest 50 percent [1].
- The average per capita emissions of the top 10 percent are 11 times higher than the average emissions of the poorest 40 percent [1].
- The total emissions of the top 10 percent are seven times higher than the total emissions of the poorest 40 percent [1].

N.B. Per capita values for the bottom 40 and 50 percent of the global population are equal, as the minimum threshold for the global distribution falls in the 66th percentile, so the reported value for both the bottom 40 and 50 percent is half the global per capita mean.

Figure 3: Global income deciles and associated household emissions [g2]

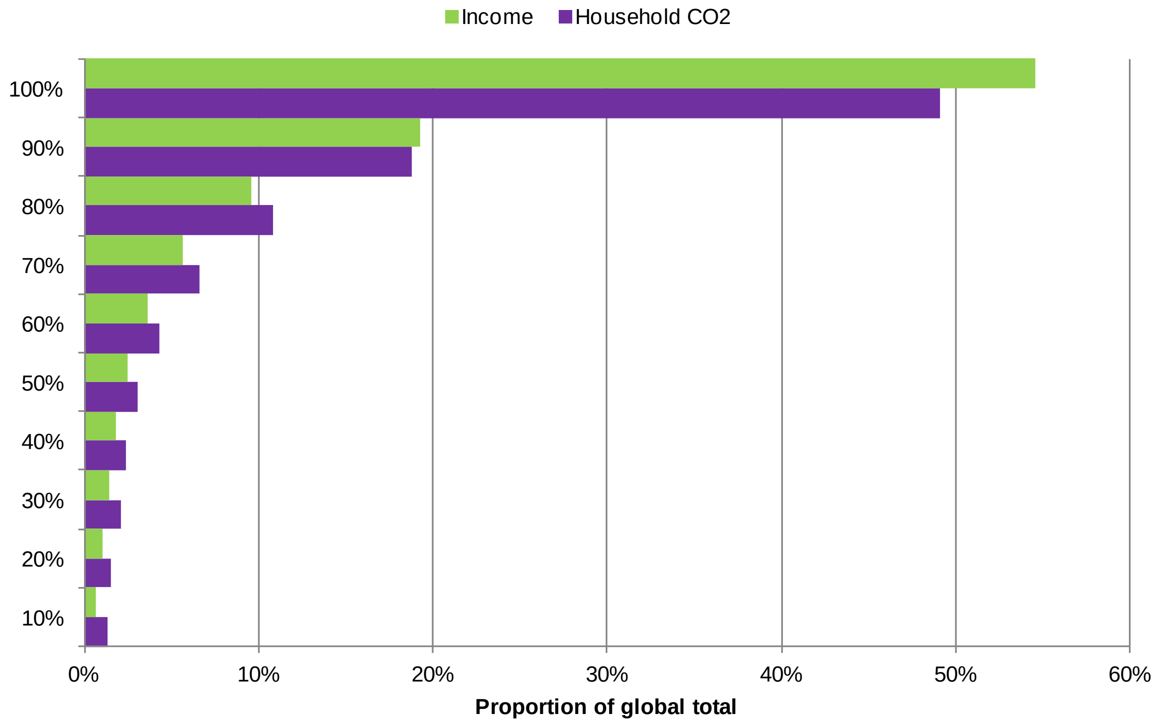


Figure 4: Per capita emissions from different income levels for the UK, China, India, US, and the world [g3]

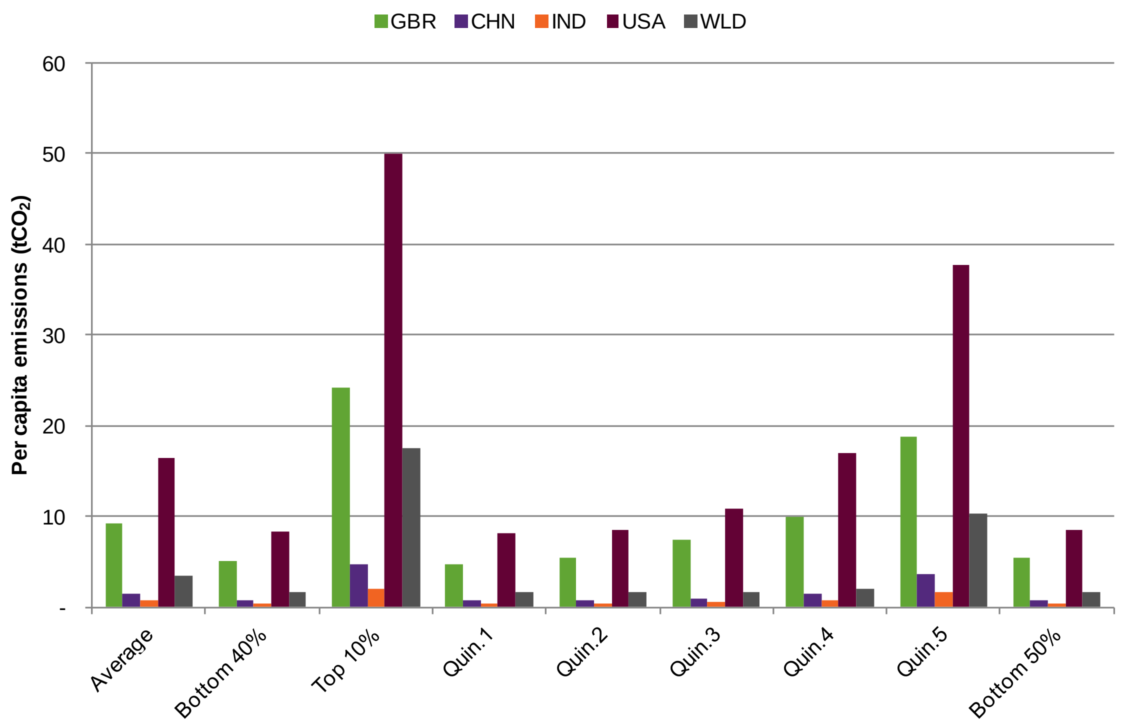


Table 1: Emissions, populations, and incomes of global top 10% (based on income) [A]

Global top 10%	CO_2 (mt)		Population (m)		Income ($m)	
	8431.45	100.0%	591.94	100.0%	16,624,606.79	100.0%
USA	4094.24	48.6%	194.60	32.9%	6835264.41	41.1%
JPN	588.99	7.0%	68.81	11.6%	1667262.41	10.0%
DEU	466.70	5.5%	45.25	7.6%	1107851.52	6.7%
GBR	463.98	5.5%	40.28	6.8%	1119749.31	6.7%
CAN	324.64	3.9%	23.65	4.0%	703892.94	4.2%
RUS	303.86	3.6%	14.18	2.4%	332665.83	2.0%
FRA	303.78	3.6%	34.66	5.9%	881863.23	5.3%
ITA	264.95	3.1%	24.94	4.2%	569980.28	3.4%
KOR	180.74	2.1%	20.41	3.4%	493077.64	3.0%
ESP	142.45	1.7%	15.26	2.6%	326032.38	2.0%
CHN	129.96	1.5%	13.26	2.2%	226570.49	1.4%
ZAF	95.98	1.1%	4.39	0.7%	142349.55	0.9%
NLD	93.43	1.1%	9.01	1.5%	212943.58	1.3%
TWN	89.75	1.1%	10.35	1.7%	253670.23	1.5%
BRA	85.62	1.0%	11.52	1.9%	309651.82	1.9%
IRN	79.69	0.9%	4.32	0.7%	101827.08	0.6%
MEX	71.55	0.8%	3.19	0.5%	86872.89	0.5%
GRC	63.59	0.8%	2.80	0.5%	61309.55	0.4%
BEL	60.62	0.7%	4.57	0.8%	100185.73	0.6%
TUR	51.84	0.6%	4.43	0.7%	103433.75	0.6%
AUT	43.95	0.5%	4.33	0.7%	97856.56	0.6%

NOR	38.07	0.5%	3.77	0.6%	95555.39	0.6%
DNK	34.46	0.4%	2.95	0.5%	65786.33	0.4%
FIN	33.74	0.4%	2.59	0.4%	58436.61	0.4%
SWE	33.23	0.4%	5.41	0.9%	117099.96	0.7%
IRL	30.53	0.4%	2.32	0.4%	56483.59	0.3%
ISR	25.61	0.3%	1.83	0.3%	42953.61	0.3%
POL	24.54	0.3%	1.14	0.2%	24794.89	0.1%
MYS	24.08	0.3%	1.89	0.3%	46315.97	0.3%
ARG	23.82	0.3%	2.39	0.4%	55385.60	0.3%
PRT	20.51	0.2%	1.80	0.3%	42373.66	0.3%
CHL	19.81	0.2%	1.51	0.3%	49380.40	0.3%
COL	11.60	0.1%	1.35	0.2%	40644.23	0.2%
EGY	9.48	0.1%	0.82	0.1%	12052.25	0.1%
CZE	9.43	0.1%	0.63	0.1%	12997.46	0.1%
LUX	8.80	0.1%	0.38	0.1%	11046.69	0.1%
THA	8.29	0.1%	0.68	0.1%	12860.15	0.1%
VEN	7.62	0.1%	0.28	0.0%	6946.13	0.0%
CYP	6.12	0.1%	0.65	0.1%	15022.60	0.1%
ECU	5.48	0.1%	0.40	0.1%	9395.28	0.1%
PER	4.99	0.1%	0.58	0.1%	13692.83	0.1%
SVN	4.72	0.1%	0.51	0.1%	9815.72	0.1%
DOM	4.17	0.0%	0.30	0.1%	7609.66	0.0%
HRV	4.13	0.0%	0.31	0.1%	6578.92	0.0%
ROM	3.54	0.0%	0.22	0.0%	3657.15	0.0%
HUN	3.49	0.0%	0.20	0.0%	4302.45	0.0%
BGR	3.43	0.0%	0.23	0.0%	4731.79	0.0%
MAR	2.71	0.0%	0.31	0.1%	6136.92	0.0%
CRI	2.37	0.0%	0.32	0.1%	8023.64	0.0%
PAN	2.37	0.0%	0.20	0.0%	5441.25	0.0%
GTM	2.22	0.0%	0.14	0.0%	5442.85	0.0%
EST	2.19	0.0%	0.09	0.0%	1841.36	0.0%
LVA	2.10	0.0%	0.16	0.0%	3339.51	0.0%
BOL	2.10	0.0%	0.19	0.0%	5977.10	0.0%
HND	2.00	0.0%	0.22	0.0%	6650.01	0.0%
LTU	1.90	0.0%	0.17	0.0%	3680.13	0.0%
SVK	1.54	0.0%	0.11	0.0%	2000.78	0.0%
LKA	1.31	0.0%	0.20	0.0%	3449.91	0.0%
URY	1.25	0.0%	0.17	0.0%	4125.64	0.0%
JOR	0.97	0.0%	0.06	0.0%	903.59	0.0%
PRY	0.92	0.0%	0.12	0.0%	3814.20	0.0%
SLV	0.74	0.0%	0.06	0.0%	1587.44	0.0%
NIC	0.41	0.0%	0.06	0.0%	1403.95	0.0%
ALB	0.33	0.0%	0.03	0.0%	558.02	0.0%

Global top 1 percent

While this analysis is not robust enough to interrogate the data at any resolution higher than the decile level, a crude inference may be made as to the approximate emissions that the global top one percent are responsible for by referring to other publications.

G20 summary

Figure 5: Per capita household emissions in G20 countries [g4]

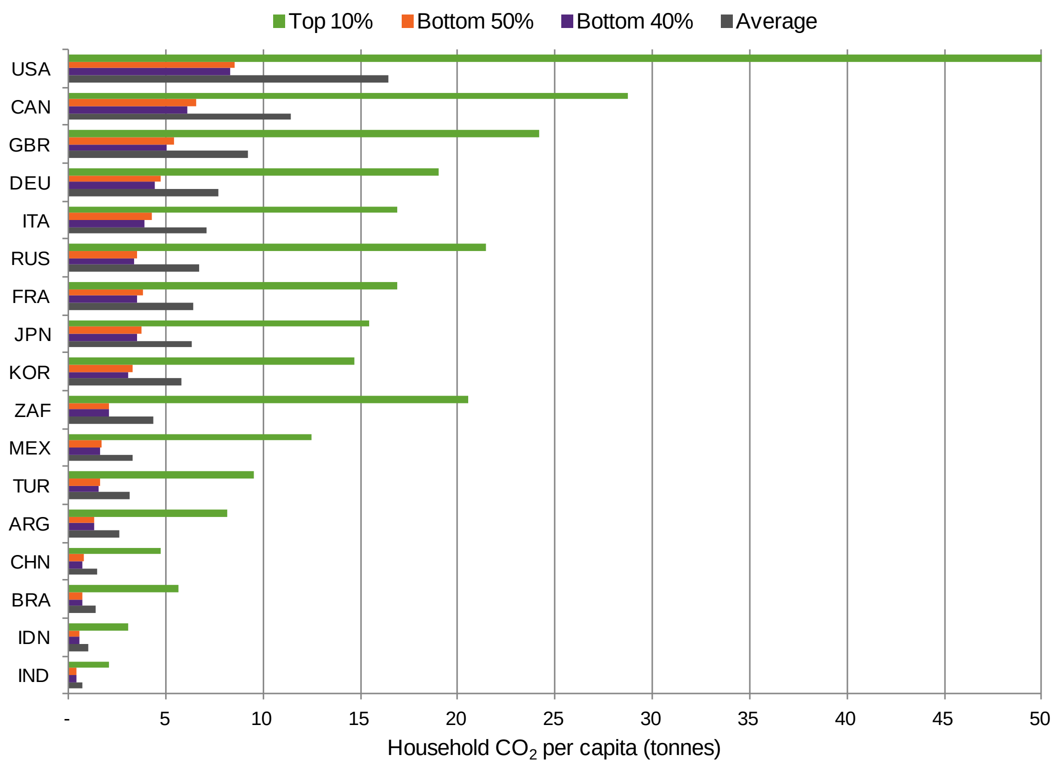


Figure 6: Total household emissions in G20 countries [g5]

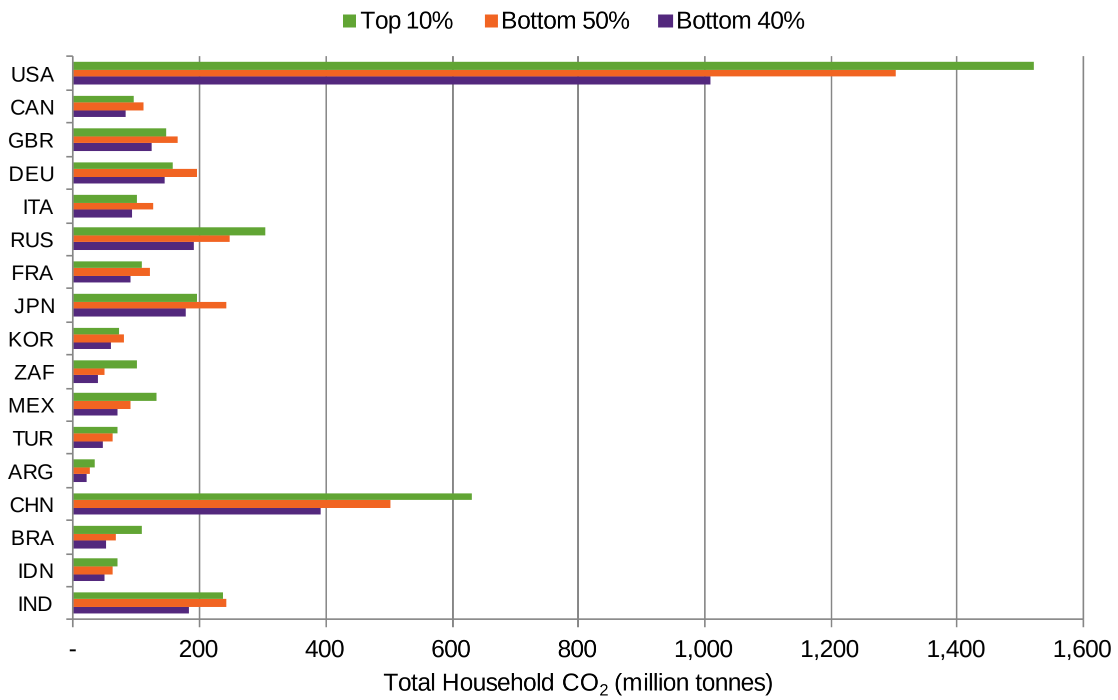


Table 2: Table 2: Emissions summary for G20 countries [2]

	Per Capita				**Total**			
	Average	*Bottom 40%*	*Bottom 50%*	*Top 10%*	*Total*	*Bottom 40%*	*Bottom 50%*	*Top 10%*
IND	0.73	0.40	0.42	2.07	831.68	182.68	241.67	236.16
IDN	1.01	0.53	0.56	3.10	229.74	47.89	63.09	70.38
BRA	1.40	0.69	0.69	5.68	268.78	52.72	66.53	109.06
CHN	1.50	0.74	0.76	4.76	1,984.24	391.85	502.99	630.61
ARG	2.60	1.31	1.34	8.19	103.80	20.85	26.64	32.67
TUR	3.11	1.58	1.64	9.52	230.24	46.63	60.68	70.36
MEX	3.31	1.63	1.68	12.45	352.44	69.44	89.07	132.44
ZAF	4.35	2.05	2.05	20.53	212.14	39.99	49.99	100.20
KOR	5.77	3.09	3.32	14.72	280.42	60.15	80.77	71.54
JPN	6.31	3.51	3.78	15.43	804.06	178.86	241.13	196.61
FRA	6.43	3.55	3.80	16.91	412.90	91.19	121.91	108.55
RUS	6.69	3.38	3.49	21.43	948.10	191.54	247.37	303.86
ITA	7.09	3.94	4.25	16.91	420.79	93.52	126.10	100.40
DEU	7.73	4.41	4.73	19.05	635.88	145.20	194.65	156.71
GBR	9.25	5.03	5.39	24.22	564.70	122.82	164.49	147.79
CAN	11.43	6.13	6.60	28.75	380.69	81.74	109.87	95.76
USA	16.43	8.30	8.57	50.00	4,996.45	1,009.74	1,302.67	1,520.31
WLD	3.42	1.57	1.57	17.60	20,245.30	3,722.96	4,653.70	10,407.93

Note: Excludes Australia and Saudi Arabia, for which no data are available

Annex: Countries included in analysis (93)

ALB	Albania	**EGY**	Egypt	**KHM**	Cambodia	**PRY**	Paraguay
ARG	Argentina	**ESP**	Spain	**KOR**	Korea, Republic of	**ROM**	Romania
ARM	Armenia	**EST**	Estonia	**LAO**	Lao PDR	**RUS**	Russian Federation
AUT	Austria	**FIN**	Finland	**LKA**	Sri Lanka	**SLV**	El Salvador
AZE	Azerbaijan	**FRA**	France	**LTU**	Lithuania	**SVK**	Slovakia
BEL	Belgium	**GBR**	United Kingdom	**LUX**	Luxembourg	**SVN**	Slovenia
BFA	Burkina Faso	**GEO**	Georgia	**LVA**	Latvia	**SWE**	Sweden
BGD	Bangladesh	**GHA**	Ghana	**MAR**	Morocco	**THA**	Thailand
BGR	Bulgaria	**GIN**	Guinea	**MDG**	Madagascar	**TUR**	Turkey
BLR	Belarus	**GRC**	Greece	**MEX**	Mexico	**TWN**	Taiwan, Republic of China
BOL	Bolivia	**GTM**	Guatemala	**MNG**	Mongolia	**TZA**	Tanzania, United Republic of
BRA	Brazil	**HND**	Honduras	**MOZ**	Mozambique	**UGA**	Uganda
CAN	Canada	**HRV**	Croatia	**MWI**	Malawi	**UKR**	Ukraine
CHL	Chile	**HUN**	Hungary	**MYS**	Malaysia	**URY**	Uruguay
CHN	China	**IDN**	Indonesia	**NGA**	Nigeria	**USA**	United States of America
CIV	Côte d'Ivoire	**IND**	India	**NIC**	Nicaragua	**VEN**	Venezuela, Bolivarian Republic of
CMR	Cameroon	**IRL**	Ireland	**NLD**	Netherlands	**VNM**	Vietnam
COL	Colombia	**IRN**	Iran, Islamic Republic of	**NOR**	Norway	**ZAF**	South Africa
CRI	Costa Rica	**ISR**	Israel	**NPL**	Nepal		
CYP	Cyprus	**ITA**	Italy	**PAK**	Pakistan		
CZE	Czech Republic	**JOR**	Jordan	**PAN**	Panama		
DEU	Germany	**JPN**	Japan	**PER**	Peru		
DNK	Denmark	**KAZ**	Kazakhstan	**PHL**	Philippines		
DOM	Dominican Republic	**KEN**	Kenya	**POL**	Poland		
ECU	Ecuador	**KGZ**	Kyrgyzstan	**PRT**	Portugal		

NOTES

All URLs accessed November 2015.

1 B. Milanovic (2015) "Replication data for: Global inequality of opportunity. How much of our income is determined by where we live?" http://dx.doi.org/10.7910/DVN/27326

2 World Bank. International Comparison Program http://siteresources.worldbank.org/ICPEXT/Resources/ICP_2011.html

3 Global Trade Analysis Project https://www.gtap.agecon.purdue.edu/

4 Earth System Science Data http://www.earth-syst-sci-data-discuss.net/7/521/2014/essdd-7-521-2014.html

5 'Sharing global CO_2 emission reductions among one billion high emitters', PNAS, http://www.pnas.org/content/106/29/11884

6 'Problems with burden-sharing proposal among one billion high emitters', PNAS, http://www.pnas.org/content/106/43/E122

7 E. Kemp-Benedict et al. (2013) 'Calculations for the Greenhouse Development Rights Calculator' http://www.gdrights.org/calculator/, see also http://gdrights.org/wp-content/uploads/2013/02/SEI_TechReport_GDRsCalculations.pdf

8 K. Ummel (2014) 'Who Pollutes? A Household-Level Database of America's Greenhouse Gas Footprint', Centre for Global Development, http://www.cgdev.org/publication/who-pollutes-household-level-database-americas-greenhouse-gas-footprint-working-paper

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For further information on the issues raised in this paper please e-mail advocacy@oxfaminternational.org

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