

HUMAN IMPACTS

by the numbers

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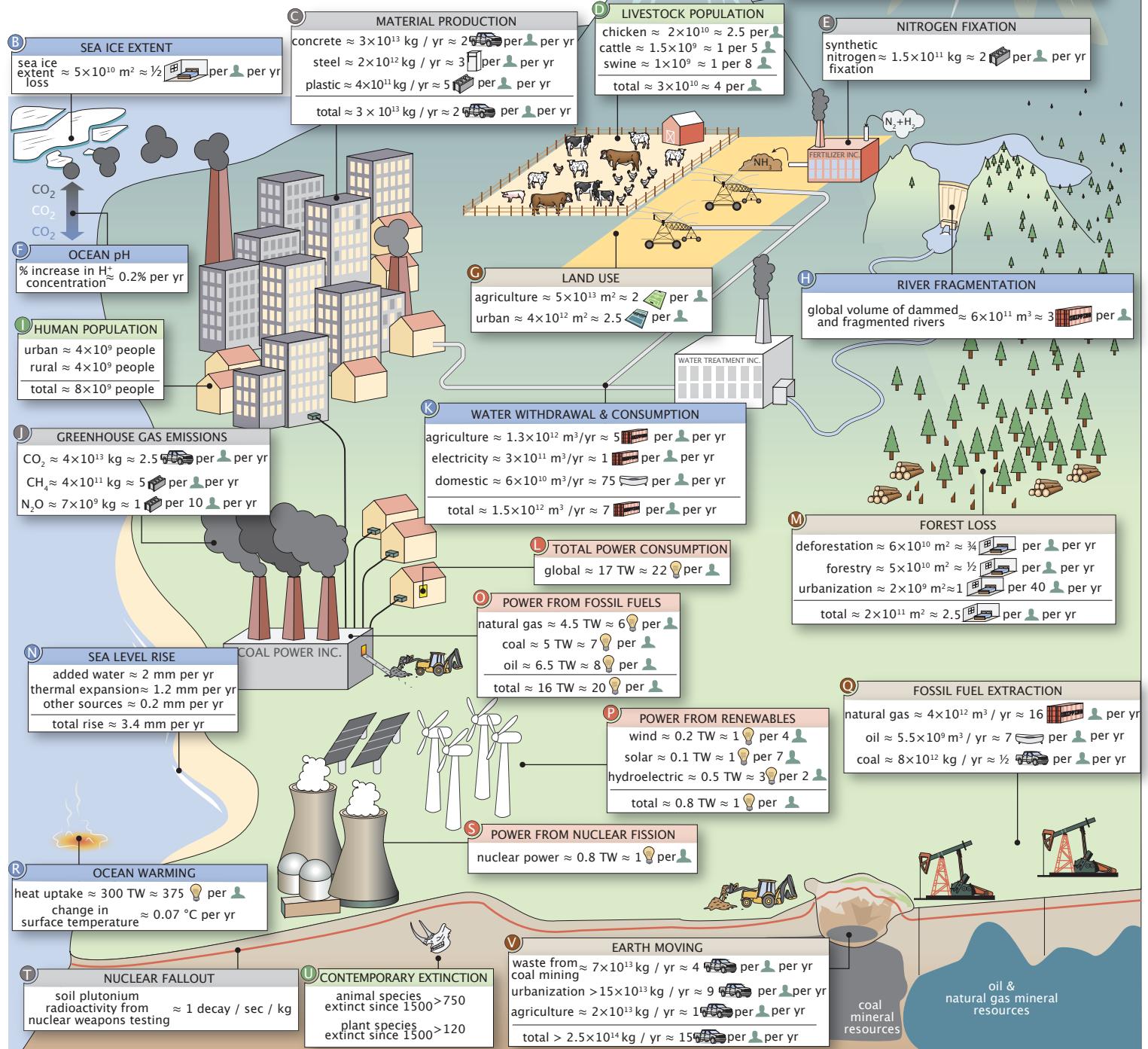
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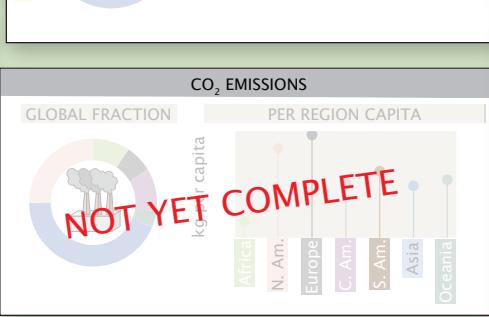
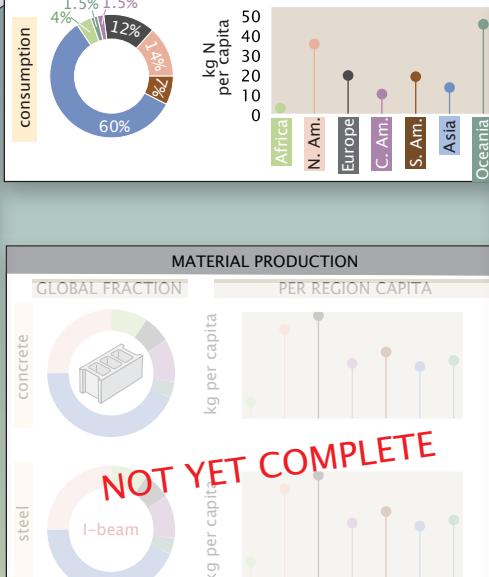
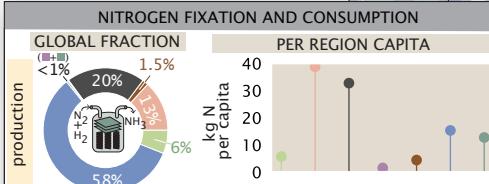
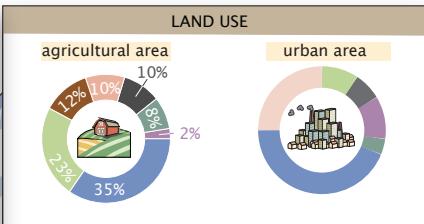
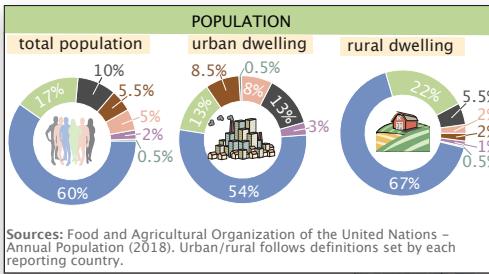
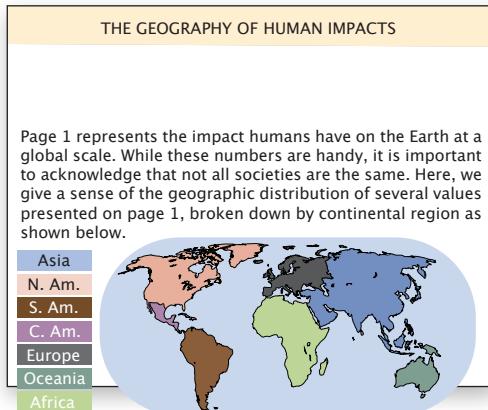
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ABSTRACT

The greatest experiment of the last 10,000 years is the presence and action of modern human beings on planet Earth. At this point, the consequences of this experiment are being felt on many fronts. Yet, many people still hold the view that because the world is so "huge", humans cannot really make a substantial impact. This snapshot represents a collection of essential numbers that summarize the broad reach of human action across the planet, presenting a view of the impact of human presence on Earth.

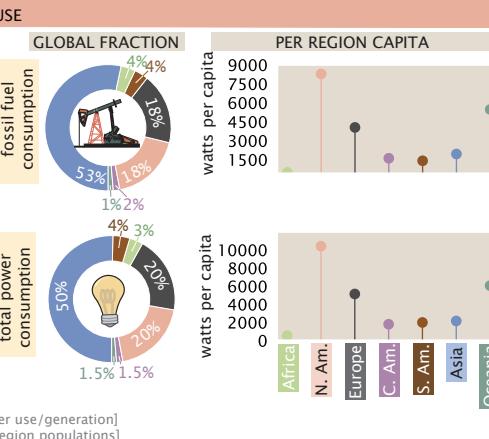


Human Impacts by the Numbers — Impacts by Region

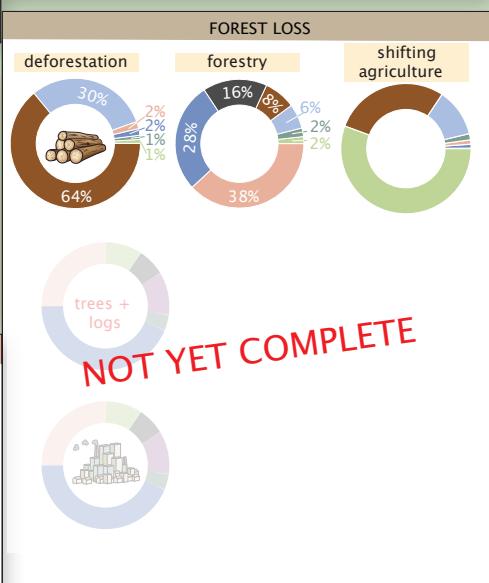


CO₂ EMISSIONS

NOT YET COMPLETE



Sources: Energy Information Administration of the United States (2017) [power use/generation]
Notes: "Renewables" includes hydroelectric, biofuels, biomass (wood), geothermal, wind, and solar. "Fossil fuels" includes coal, oil, and natural gas.



ACKNOWLEDGMENTS

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SIZING UP THE ANTHROPOCENE

Much of our understanding of the scales of things is comparative. When we measure lengths, we do so relative to some standard length that helps us develop intuition for whatever situation we might be thinking about. With the many examples of human impacts presented on Page 1, our aim here is to present some measure of each of those numbers in a ratiometric form that compares the magnitude of a given human impact to some natural scale for that same quantity. For example, in considering the use of land by humans, a natural dimensionless way to characterize that number is by comparing it to the total land area available on our planet, a comparison that yields what we will christen the Terra number. Similarly, when we consider the entirety of human-made materials, a dimensionless version of that mass that provides a sense of perspective is to compare it to the total biomass on our planet. Here we present twelve key human impacts in this kind of dimensionless form that range across the earth, the atmosphere, the oceans and our energy use, with the hope that our readers will be emboldened to consider their own favorite examples in a similar dimensionless format.

THE TERRA NUMBER

$$Te = \frac{\text{land area used by humans}}{\text{total land area of Earth}} = \frac{\text{area of a small town}}{\text{area of the Earth}} \approx 0.3$$

The Terra Number reflects the fact that, while we have been constrained to the 30% of Earth's surface that is land, we have transformed the terrestrial surface to support our dwellings and, much more importantly, our agriculture. Despite being icons of human action, urban centers occupy between 750 thousand and a few million km² (Huld: 39341, 87575). In contrast, approximately 50 million km² (Huld: 29582) of land on Earth is used either to grow crops or rear livestock. Together, urban and agricultural lands make up $\approx 30\%$ of Earth's terrestrial surface. [Read more about this number.](#)

THE ANTHROPOMASS NUMBER

$$An = \frac{\text{total anthropomass}}{\text{total biomass}} = \frac{\text{humans + buildings + infrastructure}}{\text{trees + animals + soil}} \approx 1$$

The Anthropomass Number takes stock of our material production by comparing the total quantity of human-made materials to the entirety of the biomass on planet Earth. Surprisingly, already in 2007, human-made materials added up to more mass than that of the entire biosphere itself (Huld: XXXXX to be added). Concretes and aggregates dominate the anthropomass, with bricks and asphalt coming in a distant second. Though around us everywhere, plastics and metal constitute a tiny fraction of the total anthropomass. The total anthropomass budget amounts to a dizzying 10⁵ kg of human made mass per person on planet earth, with a volume per person that corresponds to roughly the entirety of one lane of an Olympic-sized swimming pool.

THE EXTINCTION NUMBER

$$Ex = \frac{\text{number of known animal extinctions}}{\text{number of expected natural animal extinctions}} = \frac{\text{dodo bird}}{\text{extinct bones}} > 10$$

The Extinction Number reflects the fact that over the past 500 years, far more animal species have gone extinct than would be expected due to natural processes. Since 1500, more than 760 species of animals have been determined to be extinct (Huld: 44641). Recent estimates of ancient rates of animal extinction predict that tenfold fewer (≈ 50) species would have gone extinct over the same period in the absence of human alteration of the environment. It's important to emphasize that these data are incomplete and reflect only a fraction of nature that has been assessed for conservation status. The Extinction Number therefore represents a lower bound on the degree of modern species loss, with the true value likely being much higher.

THE BARNYARD NUMBER

$$By = \frac{\text{mass of terrestrial livestock}}{\text{mass of terrestrial wild animals}} = \frac{\text{cows, chickens, pigs}}{\text{elephants, foxes, pelicans}} \approx 30$$

The Barnyard Number focuses another lens onto this massive transformation of the planet by comparing the total biomass of terrestrial livestock (e.g. cows, chickens, and pigs) to that of wild terrestrial wild animals (e.g. elephants, foxes, and pelicans)². As a result of agricultural intensification throughout the 20th century, livestock now outweigh all wild terrestrial animals by a factor of ≈ 30 . While poultry make up the vast majority of terrestrial livestock (≈ 25 billion individuals, Huld: 94934), they represent a small proportion of the total livestock biomass. This biomass is dominated by cattle which collectively weigh in at $\approx 1.5 \times 10^{12}$ kg, despite having a population of only ≈ 1.5 billion (Huld: 92006). [Read more about this number.](#)

THE DEFORESTATION NUMBER

$$Df = \frac{\text{annual forest loss from human action}}{\text{annual forest loss from wildfire}} = \frac{\text{logs}}{\text{smoke}} \approx 3$$

The Deforestation Number reflects that through direct action, humans deforest and disrupt forested land at three times the rate of natural forest loss. The bulk of this forest loss is due to commodity-driven deforestation (such as logging, Huld: 96098) and forestry (Huld: 38352), whereas expansion of urban areas accounts for $< 1\%$ of the total annual forest loss (Huld: 19429). Wildfires account for $\approx 20\%$ or $\approx 5 \times 10^{10}$ m² annually (Huld: XXXXX). [This paragraph will be rewritten after the vignette is finalized.](#)

THE NIAGARA NUMBER

$$Ni = \frac{\text{daily water volume used by humans}}{\text{Niagara Falls daily discharge volume}} = \frac{\text{water truck}}{\text{Niagara Falls}} \approx 30$$

The Niagara Number captures the magnitude of human water usage relative to the scale of Niagara Falls, the largest waterfall in North America by discharge (volumetric flow rate). Agriculture once again defines this aspect of the human interaction with the Earth system as it uses $\approx 4 \times 10^9$ m³ (Huld: 43593) of water per day, accounting for the majority of human water usage. Combining agricultural use with the water volume used for hydroelectric power generation ($\approx 7 \times 10^8$ m³/day, Huld: 77411), domestic/municipal use ($\approx 10^8$ m³/day, Huld: 69424), and all other uses yields a total daily volume of water ≈ 30 times that which flows over Niagara Falls daily. This is a volume comparable to $\frac{1}{3}$ the daily discharge of the Amazon river.

THE RIVER NUMBER

$$Rv = \frac{\text{river volume controlled by humans}}{\text{free-flowing river volume}} = \frac{\text{dammed river}}{\text{free-flowing river}} \approx 1$$

Hydroelectric power generation captures the potential energy stored in water found at elevation, for example snowmelt cascading from alpine glaciers towards the ocean. Capturing this energy, however, requires damming the river – thus interrupting its flow and altering the riverine ecosystem. The River Number quantifies the scale of human interference in river flow by relating the volume of river systems under human control (primarily due to damming) to that of free-flowing rivers. Globally, approximately an equal volume of river water is free flowing ($\approx 6 \times 10^{11}$ m³, Huld: 55718) as is under direct human control, such as through dams and reservoirs or through man-made channels ($\approx 6 \times 10^{11}$ m³, Huld: 61661). Of the global free-flowing river volume, approximately 50% of the volume is contained within the Amazon river alone.

THE EARTH MOVER NUMBER

$$Em = \frac{\text{annual mass of earth moved by humans}}{\text{annual mass of earth moved by rivers}} = \frac{\text{bulldozer}}{\text{rivers}} > 15$$

Humans are becoming formidable rivals to the natural processes by which sediment is generated and moved. This is illustrated by The Earth Mover Number, which reveals that humans move approximately 15 times more earth than is moved by global river systems. Through construction, mining, and agriculture, humans move more than 250 billion tonnes of sediment a year (Huld: XXXXX). Rivers, by comparison, transport ≈ 12 billion tonnes a year when corrected for the increased river sediment load via human action³. This remarkable anthropogenic action rapidly increases erosion rates, leading to increased topsoil loss and turnover, ultimately perturbing natural biogeochemical cycles.

THE NITROGEN NUMBER

$$N_2 = \frac{\text{mass of } N_2 \text{ fixed via the Haber-Bosch Process}}{\text{mass of } N_2 \text{ fixed biologically}} = \frac{Haber-Bosch }{\text{biological}} \approx 1$$

Though molecular nitrogen (N₂) makes up nearly 80% of our atmosphere, it must be converted into a more reactive form like ammonia (NH₃) in order for most plants to synthesize biomass. Deemed the “detonator of the population explosion,” the development of the Haber-Bosch process for industrial synthesis of ammonia from molecular nitrogen was critical for supporting a global population above ≈ 3 billion⁴. The Nitrogen Number reveals that humans synthesize as much reactive nitrogen industrially ($\approx 1.5 \times 10^{11}$ kg per year, Huld: 91803) as is synthesized by nitrogen-fixing microbes in terrestrial ecosystems ($\approx 1 \times 10^{11}$ kg per year, Huld: 15205). Beyond influencing the balance of reactive nitrogen in the environment, the Haber-Bosch process uses a sizable amount of energy and significantly contributes to global CO₂ emissions.

THE CO₂ NUMBER

$$CO_2 = \frac{\text{annual mass of anthropogenic CO}_2}{\text{annual mass of volcanic CO}_2} = \frac{\text{fossil fuel + cement}}{\text{volcanoes}} \approx 100$$

The CO₂ Number compares annual amount of human-caused CO₂ emissions to the dominant natural source of CO₂ emissions, volcanism. There are many climate-related consequences of increasing CO₂ emissions. Beyond accelerating climate change, $\approx 30\%$ of CO₂ released into the atmosphere is absorbed by the oceans, making them appreciably more acidic over time. In recent years, human activities including burning fossil fuels and making concrete have led to the release of $\approx 4 \times 10^{13}$ kg of CO₂ into the atmosphere each year. Whether through seeps or eruptions, volcanism releases a total of $\approx 10^{11}$ kg of CO₂ per year. Thus, the CO₂ number is ≈ 100 , representing the magnitude by which humans outpace nature as a source of CO₂ emissions.

THE CH₄ NUMBER

$$Me = \frac{\text{annual mass of anthropogenic CH}_4}{\text{annual mass of natural CH}_4} = \frac{\text{factory + cow}}{\text{wetlands}} \approx 1$$

While CO₂ is the most often discussed greenhouse gas, human activities also entail substantial emissions of methane (CH₄), which even more potent greenhouse gas than CO₂. The CH₄ Number compares humanity's methane emissions to all natural sources of methane. Anthropogenic emissions from factories and ruminant livestock (mostly cows) total ≈ 4 billion kg per year, comparable to natural emissions of CH₄ from wetlands, though there is substantial uncertainty regarding the magnitude of natural methane emissions. Thus, human methane emissions roughly equal emissions from all natural sources, indicating that we are approaching nature in our impact on atmospheric methane chemistry.

THE SOLAR NUMBER

$$Su = \frac{\text{annual human power usage}}{\text{annual incident solar power}} = \frac{\text{building}}{\text{sun}} \approx 0.0001$$

While humans derive biological energy from food, we derive mechanical and electrical power from various fuel sources like coal, oil, natural gas, and fissile nuclear material. Current global human power usage amounts to an enormous 20 terawatts (20×10^{12} W), a number which has been increasing steadily over the last 200 years. The Solar Number puts the 20 TW power consumption of human activities (Huld: 94934) in relief by comparing it to the power incident on our planet from the sun, which represents a power source roughly 10,000 times greater than our current demands. Of course, it is unlikely that we could ever harness 100% of solar energy incident on our planet, but capturing even 1% of this energy would be sufficient to produce 100 times more power than we currently use.

Human Impacts by the Numbers — Supporting Information

About: Here, we present citations and notes corresponding to each quantity assessed here. Each value presented on page 1 is assigned a Human Impacts Database identifier (**HuID**), accessible via <https://human-impacts.herokuapp.com>. When possible, primary data sources have been collated and stored as files in comma-separated-value (csv) format on the GitHub repository associated with this snapshot, accessible via **DOI: XXXXXX** and https://github.com/rpgroup-pboc/human_impacts

A ANNUAL ICE MELT

glaciers = $(2.8 \pm 1.1) \times 10^{11} \text{ m}^3 / \text{yr}$

HuID: 32459

Data Source(s): Intergovernmental Panel on Climate Change (IPCC) 2019 Special Report "The Ocean and Cryosphere in a Changing Climate." Table 2.A.1 on pp. 199–202. **Notes:** Value corresponds to the trend of annual mass loss from major glaciated regions (2006–2015). Volume loss was calculated from mass loss.

ice sheets = $(4.3 \pm 0.4) \times 10^{11} \text{ m}^3 / \text{yr}$

HuID: 95798; 93137

Data Source(s): D. N. Wiese et al. 2019 <https://doi.org/10.5067/TEM-SC-3Mf62>. **Notes:** Value corresponds to the trends of combined annual mass loss from the Greenland and Antarctic Ice Sheets (2002–2020). Volume loss was calculated from mass loss.

arctic sea ice ≈ $(3 \pm 1) \times 10^{11} \text{ m}^3 / \text{yr}$

HuID: 89520

Data Source(s): PIOMAS Arctic Sea Ice Volume Reanalysis, original method source: Schweiger et al. 2011 DOI: 10.1029/2011JC007084. **Notes:** Value reported corresponds to the trend of decadal volume loss from Arctic sea ice (1979–2020) which was converted to annual volume loss.

total ≈ $(10.0 \pm 1.5) \times 10^{12} \text{ m}^3 / \text{yr}$

HuID: 89075

Data Source(s): Sum of glacial, ice sheet, and sea ice melt rate. **Notes:** Uncertainty is propagated assuming uncorrelated, normally-distributed errors of individual measurements and is calculated as $\pm 10^{11} \text{ m}^3 \cdot \text{yr}^{-1} \times (1^2 + 0.4^2 + 1.2^2)^{0.5}$.

B ANNUAL SEA ICE EXTENT LOSS

arctic sea ice extent loss ≈ $5 \times 10^{10} \text{ m}^2 / \text{yr}$

HuID: 66277

Data Source(s): Fetterer, F., K. Knowles, W. N. Meier, M. Savoie, and A. K. Windnagel. 2017, updated daily. Sea Ice Index, Version 3. [Sea_Ice_Index_Monthly_Data_With_Statistics_G02135_v3.0.xls]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: <https://doi.org/10.7265/N5K072FB>. [Accessed 2020–Oct–19]. **Notes:** Value corresponds to the average annual loss of Arctic sea ice extent from 1979–2019. Sea ice extent refers to the area of the sea with > 15% ice coverage. The Antarctic sea ice extent trend is not shown because a significant long-term trend over the satellite observation period is not observed and short-term trends are not yet attributable.

C ANNUAL MATERIAL PRODUCTION

concrete production = $(2 - 3) \times 10^{13} \text{ kg} / \text{yr}$

HuID: 25488

steel production = $(1.87 - 1.90) \times 10^{12} \text{ kg} / \text{yr}$

HuID: 51453; 44894

Data Source(s): USGS 2020, Mineral commodities. DOI: 10.3133/mcs2020; Monteiro et al. 2017, DOI: 10.138/nmat4930; World Steel Association 2020. **Notes:** Concrete production value corresponds to approximate value from multiple sources. USGS 2020 Mineral Commodities Survey reports mass of cement produced in 2019. This is converted to concrete using a multiplicative conversion factor of ≈ 7 as described in Monteiro et al. 2017. Steel production corresponds to the USGS 2019 value. Crude steel includes stainless steels, carbon steels, and other alloys.

plastic production ≈ $4 \times 10^{11} \text{ kg} / \text{yr}$

HuID: 97241

Data Source(s): Table S1 of Geyer et al. 2017. DOI: 10.1126/sciadv.1700782. **Notes:** Value represents the approximate sum total global production of plastic fibers and plastic resin during calendar year

D LIVESTOCK POPULATION

chicken ≈ 2×10^{10}

HuID: 94934

cattle ≈ 2×10^9

HuID: 92006

swine ≈ 1×10^9

HuID: 21368

total ≈ 3×10^{10}

HuID: 15765

Data Source(s): Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT). **Notes:** Counts correspond to the approximate average of the standing populations reported between 2010 – 2018. Values are reported directly by countries, yet the FAO uses non-governmental statistical sources to address uncertainty and missing (non-reported) data.

E ANNUAL NITROGEN FIXATION

fixed mass of nitrogen = $1.4 \times 10^{11} \text{ kg} / \text{yr}$

HuID: 60580; 78152

Data Source(s): USGS Mineral Commodity Summaries 2020, DOI: 10.3133/mcs2020. International Fertilizer Association 2020. **Notes:** The approximate mass of nitrogen in salient ammonia (NH₃) produced globally in 2018 is reported by the USGS as ≈ 144 Mt and by the International Fertilizer association as ≈ 146 Mt. Approximately all of this mass is produced by the Haber–Bosch process (>96%, Smith et al. 2020). In the United States most of this mass is used for fertilizer, with the remainder being used to synthesize nitrogen-containing chemicals including explosives, plastics, and pharmaceuticals (≈ 88%, USGS Mineral Commodity Summaries 2020).

F OCEAN pH

change in [H⁺] ≈ 0.2% / yr

HuID: 19394

Data Source(s): Figure 2 of European Environment Agency report CLIM 043 (2020). Original data source of report is "Global Mean Sea Water pH" from Copernicus Marine Environment Monitoring Service. **Notes:** Reported value is calculated from the average annual change in pH over years 1985–2018. Annual change in pH is $\approx 0.001 \pm 0.001$ pH units, corresponding to a change in [H⁺] of $\approx 0.2\% / \text{yr}$.

G LAND USE

agriculture ≈ $5 \times 10^{13} \text{ m}^2 / \text{yr}$

HuID: 29582

Data Source(s): Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT). **Notes:** "Agriculture" land is defined as all land that is under agricultural management including pastures, meadows, permanent crops, temporary crops, land under fallow, and land under agricultural structures. Reported value corresponds to 2017 measurements by FAO.

urban ≈ $7 \times 10^{13} \text{ m}^2 / \text{yr}$

HuID: 41339; 39341

Data Source(s): Florczyk et al. 2019 (<http://data.europa.eu/89h/5373144-b8c8-44bc-b4a3-4583ed1f547e>) and Liu et al. 2018 DOI: 10.1016/j.rse.2018.02.055. **Notes:** Urban land area is determined from satellite imagery. An area is determined to be "urban" if the total population is greater than 5,000. Reported value is average of recent measurements of $\approx 6.5 \times 10^{13} \text{ m}^2$ and $\approx 7.5 \times 10^{13} \text{ m}^2$ from Florczyk et al. 2019 and Liu et al. 2018, respectively.

H RIVER FRAGMENTATION

fragmented river volume ≈ $6 \times 10^{11} \text{ m}^3$

HuID: 61661; 15550

Data Source(s): Grill et al. 2019 DOI: 10.1038/s41586-019-1111-9. **Notes:** Values correspond to the sum of river volume contained in rivers that fall below the connectivity threshold required to classify them as free-flowing. Disruption factors include fragmentation, flow regulation, sediment trapping, water consumption, ...

... and infrastructure development. Value considers only global rivers with upstream catchment areas greater than 10 km² or discharge volumes greater than 0.1 m³ per second. The ratio of global river volume in disrupted rivers / free-flowing rivers ≈ 0.9. The ratio of global ocean-connected river volume in disrupted rivers / free-flowing rivers ≈ 1.2.

I HUMAN POPULATION

fraction of population that is urban ≈ 55%

HuID: 93995

total population ≈ 7.6×10^9 people

HuID: 85255

Data Source(s): Food and Agricultural Organization (FAO) of the United Nations Report on Annual Population, 2019. **Notes:** Value for total population comes from a combination of direct population reports from country governments as well as inferred measurements from under-reporting or missing data. Fraction of urban population is determined from what each country reports as "urban" which does not follow a singular definition. As explained by the United Nations population division, "When the definition used in the latest census was not the same as in previous censuses, the data were adjusted whenever possible so as to maintain consistency." Rural population is computed from this fraction along with the total human population, implying that the total population is composed only of "urban" and "rural" communities.

J GREENHOUSE GAS EMISSIONS

anthropogenic CO₂ = $(42.5 \pm 3.3) \times 10^{12} \text{ kg} / \text{yr}$

HuID: 47200; 98043

Data Source(s): Table 6 of Friedlingstein et al. 2019, DOI: 10.5194/essd-11-1783-2019. Original data sources relevant to this study compiled in Friedlingstein et al.: 1) Gilfillan et al. <https://energyappstate.edu/CDACI2> 2) Average of two bookkeeping models: Houghton and Nassikas 2017 DOI: 10.1026/2016GB005546; Hansis et al. 2015 DOI: DiLugorecky and Tans, NOAA/GML <https://www.esrl.noaa.gov/gmd/cgg/trends/>. **Notes:** Value corresponds to CO₂ emissions from fossil fuel combustion, industrial emissions (predominantly cement production), and land-use change during calendar year 2018. CO₂ was added to the atmosphere at a rate of ≈ 18.8 Gt / yr in 2018 (HuID: 98043); most of the remainder is taken up by the land sink and ocean sink. Uncertainty corresponds to one standard deviation.

anthropogenic CH₄ ≈ $(3.4 - 4.1) \times 10^{11} \text{ kg} / \text{yr}$

HuID: 96837; 56405; 30725

Data Source(s): Table 3 of Saunois, et al. 2020. DOI: 10.5194/essd-12-1561-2020. **Notes:** Value corresponds to CH₄ emissions from anthropogenic sources in the calendar year 2017. Represents emissions from agriculture and waste, fossil fuels, and biomass and biofuel burning. Value is not simply the sum of these sources but is based on a full anthropogenic inventory of emissions. Reported range represents the minimum and maximum estimated emissions from a combination of "bottom-up" and "top-down" models.

anthropogenic N₂O = $1.1 \pm (0.6 - 0.5) \times 10^{10} \text{ kg} / \text{yr}$

HuID: 44575; 68619

Data Source(s): Table 1 of Tian, H., et al. (2020). DOI: 10.1038/s41586-020-2780-0. **Notes:** Value corresponds to annualized N₂O emissions from anthropogenic sources in the years 2007–2016. Reported value is mean with the uncertainty bounds (+–) representing the maximum and minimum values observed in the 2007–2016 time period.

K WATER WITHDRAWAL & CONSUMPTION (DESCRIPTION TO BE UPDATED)

agriculture ≈ $1.5 \times 10^{12} \text{ m}^3 / \text{yr}$

HuID: 43593

power generation ≈ $3 \times 10^{11} \text{ m}^3 / \text{yr}$

HuID: 78784

domestic ≈ $6 \times 10^{10} \text{ m}^3 / \text{yr}$

HuID: 69424

total ≈ $2 \times 10^{12} \text{ m}^3 / \text{yr}$

HuID: 27342

Data Source(s): Figure 1 of Qin et al. 2019, DOI: 10.1038/s41893-019-0294-2. **Notes:** "Agricultural use" is defined as water used for irrigation, maintenance of livestock, and water used in the management of irrigation via damming. "Power generation" is defined as water used for thermal power generation (coal, nuclear, gas, biomass, oil, and other/waste) and hydroelectric generation. "Domestic" is defined as water directly used by humans and water used in the maintenance of municipal water supply. "Total" water use includes the above categories as well as other uses of water in reservoir management including flood control and other unannotated uses. All values pertain to estimates for 2016.

L TOTAL POWER CONSUMPTION

global power consumption ≈ 17 – 18 TW

HuID: 31373; XXXXX

Data Source(s): bp Statistical Review of World Energy, 2020. U.S. Energy Information Administration, 2020. **Notes:** Value represents the sum total energy consumed from oil, natural gas, coal, and nuclear energy and electricity generated by hydroelectric and renewables. Value from bp Statistical Review of World Energy (17 TW) is used on pg. 1.

M FOREST LOSS

commodity-driven = $(5.7 \pm 1.1) \times 10^{10} \text{ m}^2 / \text{yr}$

HuID: 96098

forestry = $(5.4 \pm 0.8) \times 10^{10} \text{ m}^2 / \text{yr}$

HuID: 38352

urbanization = $(2 \pm 1) \times 10^9 \text{ m}^2 / \text{yr}$

HuID: 19429

total = $2.1 \times 10^{11} \text{ m}^2 / \text{yr}$

HuID: 78576

Data Source(s): Table 1 of Curtis et al. 2018 DOI: 10.1126/science.aau3445. Hansen et al. 2013 DOI: 10.1126/science.1244693. Global Forest Watch, 2020. Reported values in source correspond to total loss from 2001 – 2015. Values presented here represent the yearly average over this 15 year window. **Notes:** Commodity-driven deforestation is defined as "long-term, permanent, conversion of forest and shrubland to a 'nonforest' land use such as agriculture, mining, or energy infrastructure." Forest area disruption due to forestry is defined as large-scale forestry operations occurring within managed forests and tree plantations with evidence of forest regrowth in subsequent years. Forest land disruption due to urbanization is defined as "forest and shrubland conversion for the expansion and intensification of existing urban centers." Value for total forest area loss includes wildfire and shifting agriculture in addition to those presented here. Uncertainty corresponds to the 95% confidence interval.

N SEA LEVEL RISE

added water = $1.97 (+0.36, -0.34) \text{ mm} / \text{yr}$

HuID: 97108

thermal expansion = $1.19 (+0.25, -0.24) \text{ mm} / \text{yr}$

HuID: 97688

total annual sea-level rise = $3.35 (+0.47, -0.44) \text{ mm} / \text{yr}$

HuID: 81373

Data Source(s): Table 1 of Frederikse et al. 2020. DOI: 10/d689. **Notes:** Values corresponds to the average global sea level rise of the years 1993 – 2018. "Added water" (barystatic) change includes effects from meltwater from glaciers and ice sheets, and changes in the amount of terrestrial water storage. Thermal expansion accounts for the volume change of water with increasing temperature. Values or "added water" and "thermal expansion" come from modeling. Total sea level rise is the observed value using a combination of measurement methods. "Other sources" reported on pg 1 accounts for residual sea level rise not accounted for in the model. Values in brackets correspond to the upper and lower bounds of the 90% confidence interval.

POWER FROM FOSSIL FUELS	
natural gas = 4.3 – 4.5 TW	HuID: 49947; XXXXX
oil = 6 – 6.5 TW	HuID: 42121; XXXXX
coal = 5 TW	HuID: 10400; XXXXX
total = 15.3 – 16 TW	HuID: XXXXX; XXXXX

POWER FROM FOSSIL FUELS	
oil = 6 – 6.5 TW	HuID: 42121; XXXXX
coal = 5 TW	HuID: 10400; XXXXX
total = 15.3 – 16 TW	HuID: XXXXX; XXXXX

POWER FROM FOSSIL FUELS	
natural gas volume = $(3.9 - 4.0) \times 10^{12} \text{ m}^3 / \text{yr}$	HuID: 11468, XXXXX
oil volume = $5.5 \times 10^9 \text{ m}^3 / \text{yr}$	HuID: 66789; XXXXX
coal mass = $(7.8 - 8.1) \times 10^{12} \text{ kg} / \text{yr}$	HuID: 78435; XXXXX
total ≈ 0.8 TW	HuID: XXXXX

FOSSIL FUEL EXTRACTION	
natural gas volume = $(3.9 - 4.0) \times 10^{12} \text{ m}^3 / \text{yr}$	HuID: 11468, XXXXX
oil volume = $5.5 \times 10^9 \text{ m}^3 / \text{yr}$	HuID: 66789; XXXXX
coal mass = $(7.8 - 8.1) \times 10^{12} \text{ kg} / \text{yr}$	HuID: 78435; XXXXX
total ≈ 0.8 TW	HuID: XXXXX

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natural gas volume = $(3.9 - 4.0) \times 10^{12} \text{ m}^3 / \text{yr}$	HuID: 11468, XXXXX
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coal mass = $(7.8 - 8.1) \times 10^{12} \text{ kg} / \text{yr}$	HuID: 78435; XXXXX
total ≈ 0.8 TW	HuID: XXXXX

O OCEAN WARMING

average heat uptake = $295 \pm 34 \text{ TW}$

HuID: 59201

average surface (0 – 100 m) warming = $0.065 \pm 0.007^\circ \text{C}$