

HUMAN IMPACTS by the numbers

Griffin Chure¹, Avi Flamholz², Nicholas S. Sarai³, Tine Valencic¹, Yinon Bar-On⁴, Ron Milo⁴, Rob Phillips^{2,5,*}

California Institute of Technology, Pasadena, CA, USA, 91125:

¹Department of Applied Physics; ²Division of Biology and Biological Engineering; ³Division of Chemistry and Chemical Engineering; ⁵ Department of Physics

⁴Weizmann Institute of Science, Rehovot 7610001, Israel:

Department of Plant and Environmental Sciences

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. One way to organize our thinking about what these impacts might be, with tongue in cheek, is to focus on Empedocles's classic elements, earth, air, water and fire, with the idea being to explore how humans have altered the land and its inhabitants, the atmosphere, the oceans and how our quest for cheaper and cheaper energy (fire) from the world around us has altered that world. This snapshot represents a small collection of numbers that summarize the broad reach of human action across the planet, presenting a view of the impact of human presence on Earth.

UNITS OF REFERENCE

per capita (global) = 1 person

area of soccer pitch = ≈ 3000 m²

volume of olympic pool = ≈ 2000 m³

power of a lightbulb = ≈ 100 W

mass of a pick-up truck = ≈ 1 t

D ANNUAL SEA-LEVEL RISE

total annual sea-level rise ≈ 3 mm

E OCEAN pH

% increase in H⁺ concentration ≈ 0.2% / yr

concrete ≈ 3 × 10¹⁰ t ≈ 4 cars per person
steel ≈ 2 × 10⁹ t ≈ 1 car per 4 people
plastic ≈ 4 × 10⁸ t ≈ 1 car per 1,500 people

J CORAL REEF LOSS

Great Barrier Reef coral coverage ≈ 30% decrease in 2016

P ANNUAL OCEAN WARMING

ocean heat uptake ≈ 160 TW ≈ 200 per person
change in surface temperature ≈ 0.03 °C

S NUCLEAR FALLOUT

plutonium radioactivity from nuclear weapons testing ≈ 1 decay / sec / kg

G POPULATION OF LIVESTOCK

chicken population ≈ 2 × 10¹⁰ ≈ 3 per person
cattle population ≈ 2 × 10⁹ ≈ 1 per 3 people
total livestock population ≈ 3 × 10¹⁰ ≈ 4 per person

I ANNUAL GREENHOUSE GAS EMISSION

anthropogenic CO₂ release ≈ 42 × 10⁹ t ≈ 6 cars per person
anthropogenic CH₄ release ≈ 4 × 10⁸ t ≈ 1 car per 20 people

L ANNUAL POWER CONSUMPTION

global power usage ≈ 20 TW ≈ 30 lightbulbs per person

O ANNUAL POWER FROM FOSSIL FUELS

natural gas ≈ 4 TW ≈ 6 lightbulbs per person
coal ≈ 5 TW ≈ 7 lightbulbs per person
oil ≈ 6 TW ≈ 9 lightbulbs per person

Q ANNUAL POWER FROM RENEWABLES

wind ≈ 0.4 TW ≈ 1 lightbulb per 2 people
solar ≈ 0.2 TW ≈ 1 lightbulb per 3 people
total renewables ≈ 1 TW ≈ 3 lightbulbs per 2 people

T HUMAN-CAUSED EXTINCTION

animal species > 800
plant species > 150

A ANNUAL ICEMELT

glacial melt volume ≈ 3 × 10¹¹ m³/yr ≈ 40 books per person
ice-sheet melt volume ≈ 4 × 10¹¹ m³/yr ≈ 60 books per person
total melt volume ≈ 10¹² m³/yr ≈ 150 books per person

B ANNUAL NITROGEN FIXATION

reactive nitrogen produced via Haber-Bosch ≈ 2 × 10⁸ t ≈ 1 truck per 30 people

H LAND USE

agriculture ≈ 5 × 10¹³ m² ≈ 2 books per person
urban ≈ 4 × 10¹² m² ≈ 1 book per 5 people

M ANNUAL SOIL EROSION

mass of soil moved intentionally ≈ 4 × 10¹⁰ t ≈ 5 trucks per person

K ANNUAL HUMAN WATER USE

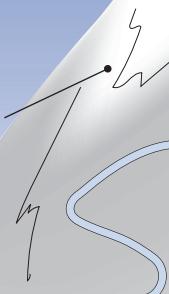
agriculture ≈ 1.5 × 10¹² m³/yr ≈ 1 book per 10 people
power generation ≈ 3 × 10¹¹ m³/yr ≈ 1 book per 50 people
domestic ≈ 6 × 10¹⁰ m³/yr ≈ 1 book per 200 people
total water use ≈ 2 × 10¹² m³/yr ≈ 1 book per 7 people

R ANNUAL FOSSIL FUEL EXTRACTION

volume of natural gas ≈ 4 × 10¹² m³ ≈ 1 book per 3 people
volume of oil ≈ 5.5 × 10⁹ m³ ≈ 1 book per 2,500 people
mass of coal ≈ 8 × 10⁹ t ≈ 1 truck per person

C RIVER FRAGMENTATION

global volume of dammed and fragmented rivers ≈ 10¹² m³ ≈ 150 books per person
hydroelectric power consumption ≈ 1 TW/yr ≈ 3 lightbulbs per 2 people per year



commodity driven ≈ 5 × 10¹⁰ m² ≈ 1 book per 400 people
forestry ≈ 6 × 10¹⁰ m² ≈ 1 book per 350 people
urbanization ≈ 2 × 10⁹ m² ≈ 1 book per 10,000 people
total ≈ 2 × 10¹¹ m² ≈ 1 book per 100 people

oil & natural gas mineral resources

Human Impacts by the Numbers

SIZING UP THE ANTHROPOCENE

A brief, introductory paragraph which sets the stage for why we expand onto the first page of this snapshot to consider dimensionless ratios. the rest of this paragraph is nonsense

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THE TERRA NUMBER

$$Te = \frac{\text{urban and rural land area}}{\text{Earth's terrestrial land area}} = \frac{\text{buildings} + \text{agriculture}}{\text{Earth}} \approx 0.3$$

The **Terra Number** reflects the fact that, while we have been constrained to the 30% of Earth's surface that is terrestrial, we have transformed the habitable area of the terrestrial land to support our dwellings and, more importantly, our agriculture. Approximately 50 million km² (HuD: 29582) of land on Earth is used either to grow crops or rear livestock. Despite being icons of humanity, urban centers occupy only a few million km² (HuD: 87575). Together, agricultural and urban land makes up $\approx 30\%$ of Earth's terrestrial area.

THE BARNYARD NUMBER

$$By = \frac{\text{livestock population}}{\text{human population}} = \frac{\text{cows}}{\text{people}} \approx 4$$

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THE ANTHROPOMASS NUMBER

$$An = \frac{\text{total anthropomass}}{\text{total biomass}} = \frac{\text{humans} + \text{concretes}}{\text{trees} + \text{plants}} \approx 1$$

The **Anthropomass Number** reflects that humans have synthesized a mass of materials that is comparable to entire mass of Earth's biosphere. The sum total mass of all concretes, plastics, metals, and other aggregated materials (collectively termed the 'anthropomass') has now surpassed the planet's biomass. As of 2019, the planetary anthropomass was $\approx 1.1 \times 10^{12}$ tonnes (HuD: XXXXX), equivalent to a recent estimation of the total mass of all living organisms¹. Including discarded (waste) anthropomass increases the total anthropomass to $> 1.6 \times 10^{12}$ tonnes.

THE EXTINCTION NUMBER

$$Ex = \frac{\text{contemporary extinction rate}}{\text{background extinction rate}} = \frac{\text{extinct bird}}{\text{background extinction}} > 10^3$$

A visit to any natural history museum will reveal that much about Earth's history can be learned by examining the geological and fossil record. The **Extinction Number** reflects the fact that over the past 500 years, the extinction rate of the surveyed plant and animal species is larger than the pre-historic background extinction rate by at least a factor of 10^3 (HuD: XXXXX). While the data is incomplete, recent work² has estimated that the modern extinction rate of plants and animals is ≈ 1000 extinctions per million-species-years (E/MSY) whereas the fossil record exhibits a background rate of ≈ 1 E/MSY.

THE DEFORESTATION NUMBER

$$Df = \frac{\text{human-caused forest area loss}}{\text{forest area loss due to wildfire}} \approx \frac{\text{logs}}{\text{burned trees}} \approx 3$$

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, HuD: 96098) and forestry (HuD: 38352), where as expansion of urban areas accounts for $< 1\%$ of the total annual forest loss (HuD: 19429). Wildfires account for $\approx 20\%$ or $\approx 5 \times 10^{10}$ m² annually (HuD: XXXXX).

THE NIAGARA NUMBER

$$Ni = \frac{\text{daily human water use}}{\text{Niagara Falls drainage rate}} = \frac{\text{household} + \text{industry}}{\text{Niagara Falls}} \approx 10$$

The **Niagara Number** captures the magnitude of human water usage relative to Niagara Falls, the largest waterfall in North America by flow rate. Agriculture once again defines this aspect of the human interaction with the Earth system, comprising $\approx 5 \times 10^9$ m³/day, accounting for the majority of human water usage. Combining agricultural use with the water volume used for power generation ($\approx 10^9$ m³/day, HuD: 78784), domestic/municipal use ($\approx 10^8$ m³/day, HuD: 69424), and all other uses yields a total daily volume of water 10 times that which flows over Niagara Falls daily. This is a volume comparable to the daily drainage of the Amazon river.

THE RIVER NUMBER

$$Rv = \frac{\text{fragmented water volume}}{\text{free-flowing water volume}} = \frac{\text{dam}}{\text{amazon}} \approx 1$$

The potential energy in rivers' elevation gradients has long been an appealing source of power for growing energy needs of civilization. The **River Number** demonstrates the human pursuit of this renewable energy source by relating the volume of fragmented river systems (such as dammed rivers) to that of wild, free-flowing rivers. Globally, approximately an equal volume of water is free flowing ($\approx 6 \times 10^{11}$ m³, HuD: 61661) as is under direct human control, such as through dams and reservoirs or through man-made channels (\approx XXXXX, HuD: XXXXX). Of the global free-flowing river volume, approximately 50% of the volume is contained within the Amazon river system alone, illustrating its ecological, economic, and hydrological importance.

THE EROSION NUMBER

$$Er = \frac{\text{soil moved by humans}}{\text{soil moved by rivers}} \approx \frac{\text{bulldozer}}{\text{muddy river}} \approx 8$$

Humans are becoming formidable rivals to natural geomorphological processes. This is illustrated by the **Erosion Number** which reveals humans move approximately 8 times more soil than is natively moved by global river systems. Through construction, mining, and other processes outside of agriculture, humans move ≈ 40 billion tonnes of soil a year (HuD: 59841). Rivers, by comparison, transport ≈ 5 billion tonnes a year (HuD: 60397) when corrected for the increased river sediment load via human action. This remarkable anthropogenic action rapidly increases erosion rates, leading to increased topsoil loss and turnover, ultimately perturbing natural biogeochemical cycles (Have citation, need to dig for it).

THE NITROGEN NUMBER

$$Ni = \frac{\text{N}_2 \text{ fixation through Haber-Bosch process}}{\text{N}_2 \text{ fixation through biological processes}} \approx \frac{\text{reactor}}{\text{bacteria}} \approx 1$$

Deemed the "detonator of the population explosion"⁴, the development of Haber-Bosch process for synthesis of ammonia from molecular nitrogen was critical for supporting a global population above ≈ 2 billion. The **Nitrogen Number** reveals that humans synthesize an amount of reactive nitrogen that is comparable to biosynthesis through nitrogen fixing microbes in the soil, albeit at a much lower efficiency. XXX

THE CO₂ NUMBER

$$CO_2 = \frac{\text{atmospheric CO}_2 \text{ now}}{\text{pre-industrial CO}_2} \approx \frac{\text{smokestack}}{\text{??}} \approx 1.5$$

No molecular signature is more indicative of the human experience than the tremendous increase in atmospheric CO₂ following the industrial revolution of the early 19th century and the rapid acceleration of CO₂ release from the 1970's through today. The **CO₂ Number** compares the mass of anthropogenic CO₂ present in the atmosphere today compared to the level before the industrial revolution. This ratio is ≈ 1.5 , revealing that humans have drastically increased the atmospheric CO₂. Beyond atmospheric deposition, the ocean absorbs $\approx 30\%$ of the atmospheric CO₂ leading to an increase in the overall ocean acidity, posing widespread ecological dangers to the marine system which rely on the carbonate buffering system of the ocean. XXX

THE METHANE NUMBER

$$Me = \frac{\text{volume of anthropogenic CH}_4}{\text{volume of biological CH}_4} \approx \frac{\text{candle} + \text{cow}}{\text{wetlands}} \approx \frac{400 \text{ Mt / yr}}{300 \text{ Mt / yr}} \approx 1.3$$

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THE SOLAR NUMBER

$$Su = \frac{\text{annual human energy usage}}{\text{annual incident solar energy}} \approx \frac{\text{lightbulb}}{\text{sun}} \approx \frac{20 \text{ TW}}{2 \times 10^5 \text{ TW}} \approx 0.0001$$

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Human Impacts by the Numbers — Supporting Information

Griffin Chure¹, Avi Flamholz², Nicholas Sarai³, Tine Valencic¹, Yinon Bar-On⁴, Ron Milo⁴ and Rob Phillips^{2,5,*}

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 subset of the numbers presented here are investigated in more depth and presented as a collection of vignettes accessible via https://rpgroup.caltech.edu/hi_vignettes (URL subject to change).

A	ANNUAL ICE MELT	
glaciers $\approx 3 \times 10^{11} \text{ m}^3$	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 $\approx 4 \times 10^{11} \text{ m}^3$	HuID: 44746; 88530	
Data Source(s): NASA JPL Physical Oceanography Distributed Active Archive Center. Notes: Value corresponds to the trend of annual mass loss from the Greenland and Antarctic Ice Sheets (2002–2020). Volume loss was calculated from mass loss.		
arctic sea ice $\approx 3 \times 10^{11} \text{ m}^3$	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 $\approx 1 \times 10^{12} \text{ m}^3$	HuID: 89075	
Data Source(s): Sum of glacial, ice sheet, and sea ice melt rate. Notes: Antarctic sea ice loss is not included due to data sparsity. The periods of analysis are not the same, therefore this rate represents an approximation rather than an exact calculation.		
B	ANNUAL NITROGEN FIXATION	
fixed mass of nitrogen $\approx 2 \times 10^{10} \text{ t}$	HuID: 60580; 30310; 78152	
Data Source(s): USGS Mineral Commodies Summaries (Fixed Nitrogen), January 2020; Table 2 of "World fertilizer trends and outlook to 2022" Food and Agricultural Organization of the United Nations, 2019, ISBN: 978-92-5131894-2. Smit et al. 2010, DOI:10.1039/c9ee02873k. Notes: The approximate mass of contained nitrogen in salient ammonia produced globally in 2018 as reported by the USGS is $\approx 144 \text{ Mt}$. This value is in moderate agreement with the forecast of $\approx 160 \text{ Mt}$ of nitrogen-contained ammonia as forecast for 2018 by the FAO. Approximately all of this mass is produced by the Haber-Bosch process (>96%, Smith et al. 2020).		
C	RIVER FRAGMENTATION	
fragmented river volume $\approx 10^{12} \text{ m}^3$	HuID: 61661, 15550	
Data Source(s): CSV dataset: DOI: 10.5281/zenodo.3875115, original data source: Grill et al. 2019 DOI: 10.1038/s41586-019-1111-9. Notes: Values correspond to the sum of river volume contained in rivers (or only rivers connected to the ocean) that fall below the connectivity threshold required to classify them as free-flowing. Disruption factors indexed in this dataset are fragmentation, flow regulation, sediment trapping, water consumption, and infrastructure development. This analysis is based on a dataset of global rivers whose upstream catchment areas are greater than 10 km^2 or whose discharge is greater than $0.1 \text{ m}^3 \text{ per second}$. This dataset thus contains a global river network of 35.9 million kilometers. 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 .		
hydroelectric power $\approx 1 \text{ TW} / \text{yr}$	HuID: 27945	
Data Source(s): bp Statistical Review of World Energy, 2020. Notes: Value corresponds to the reported value of global hydroelectricity consumption for 2019.		
D	ANNUAL SEA LEVEL RISE	
meltwater rise $\approx 1.6 \text{ mm}$	HuID: 97108	
thermal expansion $\approx 1.2 \text{ mm}$	HuID: 97688	
total annual sea-level rise $\approx 3 \text{ mm}$	HuID: 81373	
Data Source(s): Table 1 of Frederikse et al. 2020. DOI:10/d689. Notes: Values correspond to the average global sea level rise of the years 1993 – 2018. Meltwater is defined as the global annual sea level rise due to melt of glaciers, the Greenland ice sheet, and the Antarctic ice sheet.		
E	ANNUAL OCEAN pH DECREASE	
yearly change in $[\text{H}^+]$ $\approx 2\%$	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 $\approx 0.001 \text{ pH units}$, corresponding to a change in $[\text{H}^+]$ of $\approx 0.2\% / \text{yr}$.		
F	ANNUAL MATERIAL PRODUCTION	
concrete production $\approx 3 \times 10^8 \text{ t}$	HuID: 25488	
steel production $\approx 2 \times 10^9 \text{ t}$	HuID: 51453	
Data Source(s): USGS 2020, Mineral commodities. DOI:10.3133/mcs2020; Monteiro et al. 2017, DOI:10.1383/mnats4930. 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.		
plastic production $\approx 4 \times 10^6 \text{ t}$	HuID: 97241	
Data Source(s): Table S2 of Geyer et al. 2017. DOI:10.1126/sciadv.1700782. Notes: Value represents the sum total global production of plastic fibers and plastic resin during calendar year 2015.		
G	LIVESTOCK POPULATION	
chicken $\approx 2 \times 10^{10}$	HuID: 94934	
cattle $\approx 2 \times 10^9$	HuID: 92006	
swine $\approx 1 \times 10^9$	HuID: 21368	
total $\approx 3 \times 10^{10}$	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.		
H	LAND USE	
agriculture $\approx 5 \times 10^{13} \text{ m}^2$	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 $\approx 4 \times 10^{12} \text{ m}^2$	HuID: 87575	
Data Source(s): World Bank and Center for International Earth Science Information Network (CIESIN)/Columbia University. 2013. 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. Value corresponds to the most recent estimate from 2010.		
I	ANNUAL GREENHOUSE GAS EMISSIONS	
anthropogenic CO ₂ $\approx 42 \times 10^9 \text{ t}$	HuID: 47200; 98043	
Data Source(s): 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://energy.appstate.edu/CDIAC 2) Average of two bookkeeping models: Houghton and Nassikas 2018 DOI: 10.1002/2016GB005546; Hansis et al. 2015 DOI: Dlugokencky and Tans, NOAA/GML https://www.esrl.noaa.gov/gmd/ccgg/trends/ . Notes: Value corresponds to CO ₂ emissions from fossil fuel combustion, industrial emissions (predominantly cement production), and land-use change during calendar year 2018. CO ₂ was added to the atmosphere at a rate of $\approx 18 \text{ Gt} / \text{yr}$ in 2018 (HuID: 98043); most of the remainder is taken up by the land sink and ocean sink.		
anthropogenic CH ₄ $\approx 4 \times 10^9 \text{ t}$	HuID: 96837; 56405; 30725	
Data Source(s): Table 2 of Saunois, et al. 2020. DOI: 10.5194/essd-12-1561-2020. Notes: Value corresponds to CH ₄ 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. Natural emissions amount to $\approx 0.3 \text{ Gt} / \text{yr}$ in 2017. CH ₄ was added to the atmosphere at a rate of $\approx 17 \text{ Mt} / \text{yr}$ in 2017; most of the remainder is taken up by chemical loss sink and soil sink.		
J	CORAL REEF LOSS	
2016 GBR cover loss $\approx 30\%$	HuID: 90720	
Data Source(s): Figures 1A, S1, and S2 of Hughes et al. 2018, DOI:10.1038/s41586-018-0041-2. Notes: Value corresponds to measured loss in coral coverage on members of the Great Barrier Reef using field measurements and satellite imaging. Time period considers the total area loss of coral between March and November of 2016. See methods section "Longer Term Mortality" of source publication.		
K	ANNUAL HUMAN WATER USE	
agriculture $\approx 1.5 \times 10^{12} \text{ m}^3$	HuID: 43593	
power generation $\approx 3 \times 10^{11} \text{ m}^3$	HuID: 78784	
domestic $\approx 6 \times 10^{10} \text{ m}^3$	HuID: 69424	
total $\approx 2 \times 10^{12} \text{ m}^3$	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	ANNUAL GLOBAL POWER CONSUMPTION	
global power consumption $\approx 20 \text{ TW}$	HuID: 31373	
Data Source(s): bp Statistical Review of World Energy, 2020. Notes: Reported values correspond to estimates for the 2019 calendar year. Renewable resources are defined as wind, geothermal, solar, biomass and waste, and do not include hydroelectric power generation.		
M	ANNUAL EROSION	
intentionally moved soil mass $\approx 40 \text{ Gt}$	HuID: 59841	
Data Source(s): Table 1 and Figure 4 of Hooke 2000, DOI:10/bdnqv9. K-Tec Earthmovers Inc. March 2018 Newsletter. Grand View Research Construction Industry Analysis, April 2020. Notes: Hooke 2000 estimates $\approx 35 \text{ Gt}$ of soil moved annually in the latter years of the 20 th century. This is in agreement with reported soil volume moved by an industry member (K-Tec) and total revenue of soil movement and construction industry as reported by Grand View Research in April 2020. This value accounts for intentional soil movement only (such as mining and construction) and does not include agricultural soil movement.		
N	ANNUAL DEFORESTATION AND DISRUPTION	
commodity-driven $\approx 5 \times 10^{10} \text{ m}^3$	HuID: 96098	
shifting agriculture $\approx 4 \times 10^{10} \text{ m}^3$	HuID: 24388	
forestry $\approx 6 \times 10^{10} \text{ m}^3$	HuID: 38352	
urbanization $\approx 2 \times 10^{10} \text{ m}^3$	HuID: 19429	
total $\approx 2 \times 10^{11} \text{ m}^3$	HuID: 78576	
Data Source(s): Table 1 and Figure 3 of Curtis et al. 2018 DOI:10.1126/science.aau3445. Hansen et al. 2018 DOI:10.1126/science.1244693. Global Forest Watch, 2020. Notes: Commodity-driven deforestation is defined as "long-term, permanent, conversion of forest and shrubland to nonforest land use such as agriculture, mining, or energy infrastructure." Forest area loss due to shifting agriculture is defined as "smal-to-medium-scale forest and shrubland conversion for agriculture that is later abandoned and followed by subsequent forest regrowth." 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."		
O	ANNUAL POWER FROM FOSSIL FUELS	
natural gas volume $\approx 4 \times 10^{12} \text{ m}^3$	HuID: 11468	
oil volume $\approx 5.5 \times 10^9 \text{ m}^3$	HuID: 66789	
coal mass $\approx 8 \times 10^{10} \text{ t}$	HuID: 78435	
Data Source(s): bp Statistical Review of World Energy, 2020. Notes: Oil volume includes crude oil, shale oil, oil sands, condensates, and natural gas liquids separate from specific natural gas mining. Natural gas value excludes gas flared or recycled and includes natural gas produced for gas-to-liquids transformation. Coal value includes 2019 value exclusively for solid commercial fuels such as bituminous coal and anthracite, lignite and sub-bituminous coal, and other solid fuels. This includes coal used directly in power production as well as coal used in coal-to-liquids and coal-to-gas transformations.		
P	NUCLEAR FALLOUT	
²³⁹⁺²⁴⁰ Pu activity in soil $\approx 1 \text{ Bq/kg}$	HuID: 38748; 91171	
Data Source(s): Figure 4 and Figure 5 in Hancock et al. 2014, DOI:10.1144/SP395.15. Figure 3 (col. 2, rows 3 – 5) of Ciszewski and Łokas, 2019, DOI:10.1515/geochr-2015-0111. Notes: Value corresponds to current-day detectable combined radioactivity of ²³⁹ Pu and ²⁴⁰ Pu present in cores of stratified soil with estimated date of $\approx 1963 \text{ CE}$ during the peak of atmospheric nuclear weapons testing. Reported is approximate average activity from sediment samples in SE Australia (Hancock et al.) and Polish river basins (Ciszewski and Łokas).		
T	CONTEMPORARY EXTINCTION	
animal species > 800	HuID: 44641	
plant species > 400	HuID: 86866	
Data Source(s): The IUCN Red List of Threatened Species. Version 2020-2. Notes: Values correspond to absolute lower-bound measurements of extinctions caused over the past ≈ 500 years. Of the predicted ≈ 8 million animal species, the IUCN databases catalogues only $\approx 900,000$ with only $\approx 75,000$ being assigned a conservation status. Representation of plants and fungi is even more sparse with only $\approx 40,000$ and ≈ 285 being assigned a conservation status, respectively. The number of extinct animal species is undoubtedly higher than these reported values, as signified by an inequality symbol ($>$) of extinction. Representation of plants and fungi is even more sparse with only $\approx 40,000$ and ≈ 285 being assigned a conservation status, respectively. The number of extinct animal species is undoubtedly higher than these reported values, as signified by an inequality symbol ($>$) of extinction.		
R	ANNUAL OCEAN WARMING	
power deposition $\approx 160 \text{ TW}$	HuID: 59201	
ocean surface warming $\approx 0.03^\circ \text{C}$	HuID: 87228	
Data Source(s): Intergovernmental Panel on Climate Change (IPCC) 2019 Special Report "The Ocean and Cryosphere in a Changing Climate." Table 5.1 on pp. 45 and footnote 4 on pp. 457. Notes: Value is calculated from the reported annual heat...		

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