HUMAN IMPACTS by the numbers

Griffin Chure[1], Avi Flamholz[2], Nicholas S. Sarai[3], Tine Valencic[1], Yinon Bar-On[4], Ron Milo[4], Rob Phillips[2,5,*]

California Institute of Technology, Pasadena, CA, USA, 91125:
[1]Department of Applied Physics; [2]Division of Biology and Biological Engineering; [3]Division of Chemsitry and Chemical Enigineering; [5] Department of Physics
[4]Weizmann 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

human population = $\approx 7\times10^9$ mass of a pick-up truck = ≈ 1 t
area of soccer pitch = ≈ 3000 m^2 power of a lightbulb = ≈ 100 W
volume of olympic pool = ≈ 2000 m^3

A MELT WATER

glacial melt volume $\approx 3\times10^{11}$ m^3/yr $\approx$ 150 million × /yr
ice-sheet melt volume $\approx 5\times10^{11}$ m^3/yr $\approx$ 250 million × /yr
total melt volume $\approx 10^{12}$ m^3/yr $\approx$ 500 million × /yr

B POWER DERIVED FROM RENEWABLES

wind $\approx$ 360 GW $\approx$ 4 billion ×
solar $\approx$ 200 GW $\approx$ 2 billion ×
biofuels $\approx$ 150 GW $\approx$ 1.5 billion ×
total $\approx$ 875 GW $\approx$ 9 billion ×

C NITROGEN FIXATION

N_2 fixed via Haber-Bosch process $\approx 10^6$ t $\approx$ 1 million ×

D RIVER FRAGMENTATION

global volume of dammed rivers $\approx 10^{12}$ m^3 $\approx$ 500 million ×
hydroelectric power consumption $\approx$ 1 TW $\approx$ 10 billion ×

E POPULATION OF LIVESTOCK

chicken population $\approx 2\times10^{10} \approx 3$ ×
cattle population $\approx 2\times10^9 \approx 0.3$ ×
pig population $\approx 1\times10^9 \approx 0.1$ ×
total livestock population $\approx$ 30 billion ≈ 4 ×

F EXTENT OF TERRESTRIAL LAND USAGE

agriculture $\approx 5\times10^{13}$ m^2 $\approx$ 15 billion ×
urban $\approx 4\times10^{12}$ m^2 $\approx$ 1 billion ×
total area $\approx$ 16 billion ×

G OCEAN pH

% increase in H^+ concentration $\approx$ 0.2% / yr

H DEFORESTATION AND FOREST DISRUPTION

commodity driven $\approx 5\times10^{10}$ m^2 $\approx$ 16 million × /yr
shifting agriculture $\approx 4\times10^{10}$ m^2 $\approx$ 10 million × /yr
forestry $\approx 6\times10^{10}$ m^2 $\approx$ 20 million × /yr
urbanization $\approx 2\times10^9$ m^2 $\approx$ 600,000 × /yr
total $\approx 2\times10^{11}$ m^2 $\approx$ 60 million × /yr

I MATERIAL OF HUMAN ORIGIN

concrete production $\approx 3\times10^{10}$ t/yr $\approx$ 30 billion × /yr
steel production $\approx 2\times10^9$ t/yr $\approx$ 2 billion × /yr
plastic production $\approx 4\times10^6$ t/yr $\approx$ 4 million × /yr
total anthropomass $\approx$?? t / yr

J HUMAN WATER USE

agriculture $\approx 1.5\times10^{12}$ m^3/yr $\approx$ 750 million × /yr
power generation $\approx 3\times10^{11}$ m^3/yr $\approx$ 150 million × /yr
domestic $\approx 6\times10^{10}$ m^3/yr $\approx$ 30 million × /yr
total water use $\approx 2\times10^{12}$ m^3 /yr $\approx$ 1 billion × /yr

K GLOBAL POWER CONSUMPTION

global power usage $\approx$ 20 TW $\approx$ 200 billion ×

L OCEAN WARMING

power deposited into oceans $\approx$160 TW$\approx$1.5 trillion ×
change in surface temperature $\approx$ 0.03 °C / yr

M GREENHOUSE GAS PRODUCTION

CO_2 release $\approx$
CH_4 release $\approx$

N OIL & NATURAL GAS EXTRACTION

volume of natural gas extracted $\approx 4\times10^{12}$ m^3 /yr $\approx$ 2 billion ×
volume of oil extracted $\approx 5.5\times10^9$ mv $\approx$ 3 million ×
power derived from natural gas $\approx$ 4 TW $\approx$ 40 billion ×
power derived from oil $\approx$ 6 TW $\approx$ 60 billion ×

O HUMAN-CAUSED EXTINCTION

vertebrate species > 400
invertebrate species > 400
plant species > 150

P EROSION

intentional soil movement $\approx 4\times10^{10}$ t/yr $\approx$ 40 billion × /yr

Q SEA LEVEL RISE

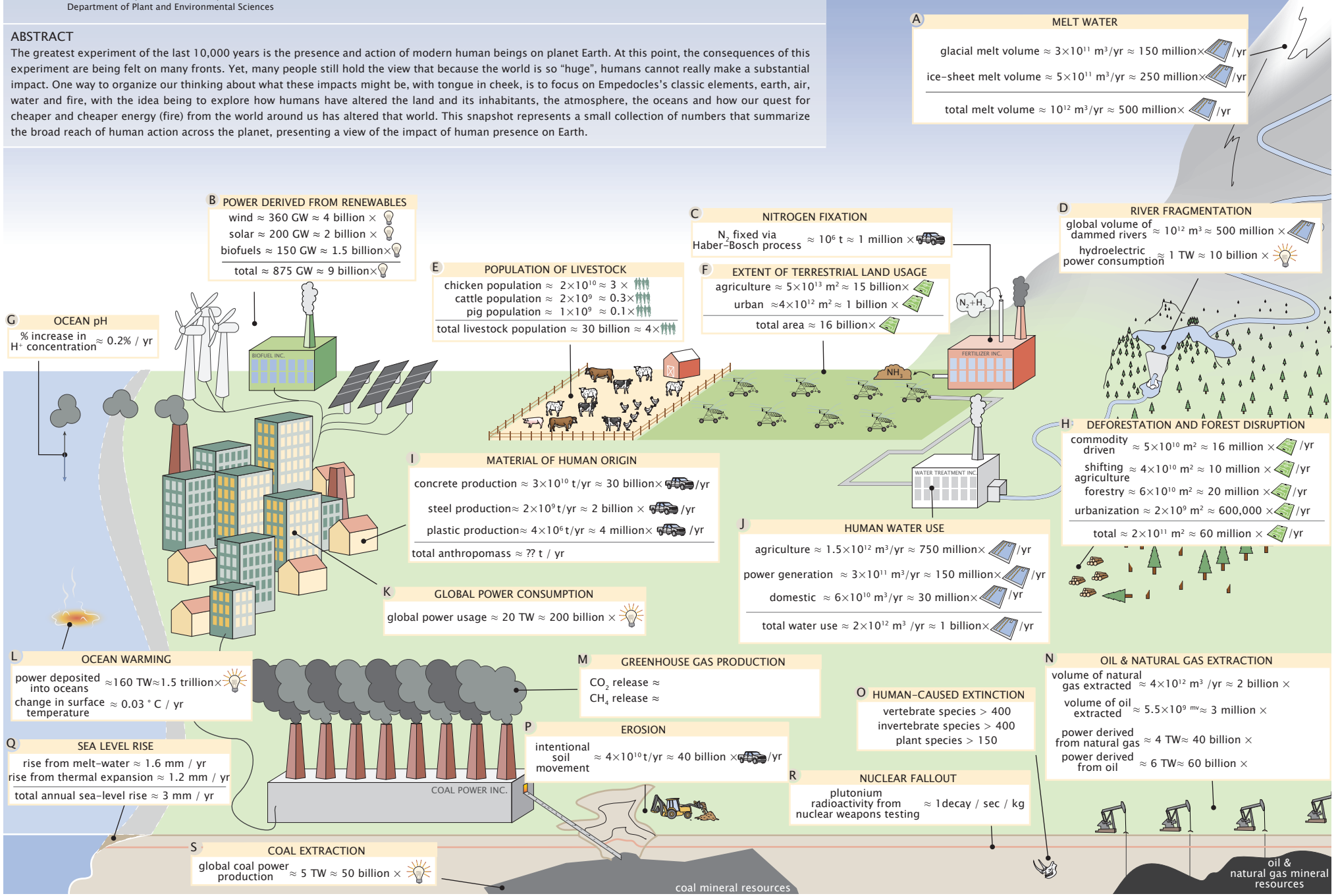
rise from melt-water $\approx$ 1.6 mm / yr
rise from thermal expansion $\approx$ 1.2 mm / yr
total annual sea-level rise $\approx$ 3 mm / yr

R NUCLEAR FALLOUT

plutonium radioactivity from nuclear weapons testing $\approx$ 1decay / sec / kg

S COAL EXTRACTION

global coal power production $\approx$ 5 TW $\approx$ 50 billion ×



HUMAN IMPACTS by the numbers

Griffin Chure[1], Avi Flamholz[2], Nicholas Sarai[3], Tine Valencic[1], Yinon Bar-On[4], Ron Milo[4], and Rob Phillips[2,5,*]

California Institute of Technology, Pasadena, CA, USA, 91125: [1]Department of Applied Physics; [2]Division of Biology and Biological Engineering; [3]Division of Chemsitry and Chemical Engineering; [5] Department of Physics [4]Weizmann Institute of Science, Rehovot 7610001, Israel: Department of Plant and Environmental Sciences

THE ANTHROPOCENE

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. As humans have made extensive changes to the Earth's chemistry and biology, in addition to the physical changes to the Earth's crust, the record of our existence will similarly be preserved in the geological record. The Anthropomass Number reveals that, as of 2020, the total mass of human-derived material (concrete, plastic, steel, etc.) is now approximately equal to the mass of the entire biosphere. The Terra Number illustrates that humans occupy or directly control ≈30% of the terrestrial surface area, meaning artifacts of human society is widespread across the planet. The Radionuclide Number describes a radioactive signature of nuclear weapons testing in a 20,000 fold enrichment in plutonium isotope radioactivity that will be detectable in stratified soil several hundred thousand years into the future. Finally, the Extinction Number shows that the current extinction rate is at least several hundred times above the background extinction rate for plant and animal species, dictating the future fossil record. While incomplete, these dimensionless numbers represent the magnitude to which human activity will be evident in Earth's geological record beyond the existence of our species as we currently know it.

ANTHROPOMASS NUMBER

$$Am = \frac{\text{total anthropomass}}{\text{total biomass}} \approx \frac{\quad}{\quad} \approx \frac{\quad}{550\ \text{Gt C}} \approx 1$$

TERRA NUMBER

$$Te = \frac{\text{land area used by humans}}{\text{land area of Earth}} \approx \frac{\quad}{\quad} \approx \frac{5\times10^{13}\ \text{m}^2}{1.5\times10^{14}\ \text{m}^2} \approx 0.3$$

RADIONUCLIDE NUMBER

$$Rn = \frac{\text{anthropogenic } {}^{239/240}\text{Pu in soil}}{\text{naturally occuring } {}^{239/240}\text{Pu in soil}} \approx \frac{\quad}{\quad} \approx \frac{1000\ \text{mBq / kg}}{0.05\ \text{mBq / kg}} \approx 2\times10^{4}$$

EXTINCTION NUMBER

$$Ex = \frac{\text{human-induced extinction rate}}{\text{background extinction rate}} \approx \frac{\text{dodo}}{\text{trilobite? non-mass ex}}$$

THE MAGNITUDE OF HUMAN WATER USAGE

Humans use more water than any other substance on the planet. Our requirement for water, both for personal use and for industrial purposes, coupled with changes in our atmospheric chemistry have substantially altered the hydrosphere from many angles. The Niagara Number captures the magnitude of human water usage, revealing that on a daily basis, humans use approximately and order of magnitude more water than falls over Niagara falls in a single day. This use is dominated by power-plant usage (for cooling) and agriculture. The flow of water from high to low elevations can be used to generate hydroelectricity via river damming. The Hoover Number reveals that there is an approximately equal volume global river water used by hydroelectric dams as there are free-flowing rivers on Earth, which has strong implications on stability of watersheds and river ecosystems. Anthropogenic emission of CO_2 has lead to widespread warming of the climate, resulting in melting of glaciers and ice-caps. The Ice-Melt Number summarizes the extent as this melting as releasing ≈ 1 Grand Canyon's worth of water into the hydrosphere per year. Approximately 40% of CO_2 emissions are absorbed by Earth's oceans and seas, ultimately shifting the equilibrium of carbonic acid. The Acidic Ocean Number captures the extent of this effect, revealing a ≈30% increase in hydrogen ion concentration in the oceans over the 60 year period of 1960 - present.

NIAGARA NUMBER

$$Ni = \frac{\text{daily human water use}}{\text{Niagara Falls drainage rate}} \approx \frac{\quad}{\quad} \approx \frac{10^{10}\ \text{m}^3\text{/day}}{10^{9}\ \text{m}^3\text{/day}} \approx 10$$

HOOVER NUMBER

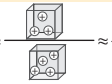
$$Hv = \frac{\text{fragmented river volume}}{\text{free-flowing river volume}} \approx \frac{\text{dam}}{\text{river}} \approx \frac{10^{12}\ \text{m}^3}{10^{12}\ \text{m}^3} \approx 1$$

ICE-MELT NUMBER

$$Ic = \frac{\text{annual melt volume from glaciers \& ice-caps}}{\text{volume of Grand Canyon}} \approx \frac{\quad}{\quad} \approx \frac{10^{12}\ \text{m}^3\text{/yr}}{10^{12}\ \text{m}^3} \approx 1\ \text{/yr}$$

ACIDIC OCEAN NUMBER

$$Ac = \frac{\text{ocean } [H^+] \text{ in 1960}}{\text{ocean } [H^+] \text{ today}} \approx \frac{\quad}{\quad} \approx \frac{1\text{M}\times10^{-8.2}}{1\text{M}\times10^{-8.1}} \approx 0.7$$



HUMANS AS THE EARTH'S GREATEST EVOLUTIONARY FORCE

Biology's greatest idea is evolution, the fact that over time, the living world has always and will continue to always change. Species come and species go. Natural forces, such as the closing of the Isthmus of Panama, result in profound changes to the living world. As humans have increased in population and technological prowess, so too has their impact on the evolutionary process. The Barnyard Number captures the magnitude of animal husbandry by humans by measuring the relative population sizes of the entirety of our domesticated animals relative to the size of the human population itself. Natural habitats across the globe have been altered significantly by human action. The Deforestation Number compares the loss of forest resulting from human activity to that which occurs naturally.

BARNYARD NUMBER

$$By = \frac{\text{livestock population}}{\text{human population}} \approx \frac{\quad}{\quad} \approx \frac{30\times10^{9}}{7\times10^{9}} \approx 4$$

DEFORESTATION NUMBER

$$Df = \frac{\text{human-caused forest area loss}}{\text{natural forest area loss}} \approx \frac{\quad}{\quad} \approx \frac{10^{7}\ \text{ha/year}}{3\times10^{6}\ \text{ha/year}} \approx 3$$

NUMBER RELEVANT TO ECOLOGY

NUBER RELEVANT TO MARINE LIFE

HUMAN IMPACTS ON ATMOSPHERIC AND BIOGEOCHEMICAL CYCLES

The Keeling curve has the same iconic status as the DNA double helix. Beginning in the 1950s, we have had a largely uninterrupted quantitative glimpse into the atmospheric concentration of CO_2. To get an impression of the human-induced increase in atmospheric CO_2, the Keeling Number compares the total anthropogenic CO_2 released in comparison with the CO_2 released from the eruption of Mt. St. Helens, revealing humans have released 200,000 times the amount of CO_2 as this infamous eruption. Perhaps even more dramatic than our impact on the CO_2 budget of the atmosphere is our role in nitrogen fixation. The Haber-Bosch Number measures the ratio of atmospheric nitrogen fixed through the Haber-Bosch process to that occurring naturally in the rhizosphere due to microbes. The Volta Number characterizes a less well-known example, namely, the volume of anthropogenic methane in comparison with the methane of XXXX. The Erosion number compares the volume of soil moved by humans to that moved by rivers.

KEELING NUMBER

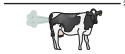
$$Ke = \frac{\text{anthropogenic } CO_2 \text{ since 1880}}{CO_2 \text{ released from Mt. St. Helens}} \approx \frac{\quad}{\quad} \approx \frac{2\times10^{15}\ \text{kg } CO_2}{10^{10}\ \text{kg } CO_2} \approx 2\times10^{5}$$

HABER-BOSCH NUMBER

$$Ha = \frac{N_2 \text{ fixation through Haber-Bosch process}}{N_2 \text{ fixation through biological processes}} \approx \frac{\quad}{\quad} \approx \frac{200\ \text{Tg N}}{200\ \text{Tg N}} \approx 1$$

VOLTA NUMBER

$$V = \frac{\text{volume of anthropogenic } CH_4}{\text{volume of biological } CH_4} \approx \frac{???}{\quad} \approx \frac{\quad}{\quad} \approx$$



EROSION NUMBER

$$Er = \frac{\text{soil moved by humans}}{\text{soil moved by rivers}} \approx \frac{\quad}{\text{muddy river}} \approx \frac{40\ \text{Gt / yr}}{5\ \text{Gt / yr}} \approx 8$$

THE MAGNITUDE OF HUMAN ENERGY USAGE

Finding new ways to extract useful work from the world is one of the signature achievements of the human condition. And yet, this act of learning how to extract energy from the environment is a large part of the story of human impacts, whether in the burning of various fuels that change the atmosphere, or the damming of the world's rivers to produce electricity. The Solar Number is one of the most important human impacts numbers of all and compares the 20 TW per year energy use of humans to the 10,000 fold higher incident power from the sun. The Fossil Fuel Number

SOLAR NUMBER

$$Su = \frac{\text{annual human energy usage}}{\text{annual incident solar energy}} \approx \frac{\quad}{\quad} \approx \frac{20\ \text{TW}}{2\times10^{5}\ \text{TW}} \approx 0.0001$$

FOSSIL FUEL NUMBER

$$Fo = \frac{\text{volume of fossil fules mined annually}}{\text{volume of fossil fuels in proven resources}} \approx \frac{\quad}{\quad} \approx \frac{20\ \text{TW}}{2\times10^{5}\ \text{TW}} \approx 0.0001$$

NUMBER RELEVANT TO OTHER MINING

NUMBER RELEVANT TO RENEWABLE USE

HUMAN IMPACTS by the numbers

Griffin Chure[1], Avi Flamholz[2], Nicholas Sarai[3], Tine Valencic[1], Yinon Bar-On[4], Ron Milo[4], and Rob Phillips[2,5,*]

California Institute of Technology, Pasadena, CA, USA, 91125: [1]Department of Applied Physics; [2]Division of Biology and Biological Engineering; [3]Division of Chemsitry and Chemical Enigineering; [5] Department of Physics [4]Weizmann Institute of Science, Rehovot 7610001, Israel: Department of Plant and Environmental Sciences

SUPPORTING INFORMATION

A MELTWATER

glacial melt rate	HuID: 32459
ice-sheet melt rate	HuID: 44746; 88530
total melt rate	HuID: 000000

Data Source(s):
Notes:

B POWER DERIVED FROM RENEWABLES

wind	HuID: 30581
solar	HuID: 99885
biofuels	HuID: 89570
total	HuID: 20246

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 does not include hydroelectic power generation.

C NITROGEN FIXATION

N_2 flux through Haber-Bosch	HuID: 000000

Data Source(s):
Notes:

D RIVER FRAGMENTATION

dammed river volume	HuID: 000000

Data Source(s):
Notes:

hydroelectric power	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.

E LIVESTOCK POPULATION

chicken	HuID: 94934
cattle	HuID: 92006
swine	HuID: 21368
total	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.

F EXTENT OF TERRESTRIAL LAND USAGE

agriculture	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, permant crops, temporary crops, land under fallow, and land under agricultural structures. Reported value corresponds to 2017 measurements by FAO.

urban	HuID: 00000

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. Rural land is defined as Urban and value correspons to the most recent estimate from 2010.

total	HuID: 15765

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, permant crops, temporary crops, land under fallow, and land under agricultural structures.

G OCEAN pH

yearly change in $[H^+]$	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 ≈ 0.001 pH units, corresponding to a change in $[H^+]$ of ≈ 0.2 % / yr.

N OIL & NATURAL GAS EXTRACTION

power derived from nat. gas	HuID: 49947
power derived from oil	HuID: 42121
volume of nat. gas extraction	HuID: 11468
volume of oil extraction	HuID: 66789

Data Source(s): bp Statistical Review of World Energy, 2020.
Notes: Values pertain to 2019 estimates only. 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.

H DEFORESTATION AND DISRUPTION

commodity-driven	HuID: 96098
shifting agriculture	HuID: 24388
forestry	HuID: 38352
urbanization	HuID: 19429
total	HuID: 78576

Data Source(s): Table 1 and Figure 3 of Curtis et al. 2018 DOI:10.1126/science.aau3445. Hansen et al. 2013 DOI:10.1126/-science.1244693. Global Forest Watch, 2020.
Notes: Commodity-driven deforestation is defined as "long-term, permanent, conversion of forest and shurbland toa 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 rforst 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." Total value of deforested and disrupted forest land includes wildfires of both human and natural causes. Values correspond to calendar year 2015 and are calculated from the statistic that $\approx$ 25% of total deforested and disrupted forest land sums to $\approx$ 5 MHa/yr. See Table 1 and Figure 3 of Curtis et al. 2018 for further discussion.

I MATERIAL OF HUMAN ORIGIN

concrete production	HuID: 25488
steel production	HuID: 51453

Data Source(s): USGS 2020, Mineral commodities. DOI:10.3133/mcs2020; Monteiro et al. 2017, DOI:10.138/nmat4930;
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 ofactor of $\approx$ 7 as described in Monteiro et al. 2017. Steel production correpsonds to the USGS 2019 value.

plastic production	HuID: 97241

Data Source(s): Geyer et al. 2017. DOI:10.1126/sciadv.1700782, Table S2.
Notes: Value represents the sum total global production of plastic fibers and plastic resin during calendar year 2015. Original data set reports data from 1950 - 2015.

total anthropomass production	HuID: 00000

Data Source(s):
Notes:

J HUMAN WATER USE

agriculture	HuID: 43593
power generation	HuID: 78784
domestic	HuID: 69424
total	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 maintencance of municipal water supply. "Total" water use includes the above categories as well as other uses of water in reservoir managment including flood control andd other unannotated uses. All values pertain to estimates for 2016.

K GLOBAL POWER CONSUMPTION

global power consumption	HuID: 31373

Data Source(s): bp Statistical Review of World Energy, 2020.
Notes: Reported values correspond to estimates for the 2019 calendar year. Represents the sum total consumed energy from oil, natural gas, coal, nuclear energy, hydroelectric, and renewables.

L OCEAN WARMING

power deposition	HuID: 59201
ocean surface warming	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. 458 and footnote 4 on pp. 457.
Notes: Value is caluclated from the reported annual heat uptake of $\approx$ 5 ZJ/yr over the time period of 2005-2017. This assumes a constant value for deposition into the ocean surface (0-700m depth) and deep ocean (700 - 2000 m depth) where heat deposition is lower. Ocean surface temperature change is calculated from $\approx$ 5 ZJ/yr heat uptake by noting that deposition of $\approx$ 144 ZJ/yr raises the temperature of the top 100 m of ocean by $\approx 1^\circ$ C. See the complete report or section 5.2.2.2 of the source material for more information.

M GREENHOUSE GAS EMISSIONS

yearly CO_2 released	HuID: 00000

Data Source(s):
Notes:

O HUMAN CAUSED EXTINCTION

animal species recently extinct	HuID: 44641
plant species recently extinct	HuID: 86866

Data Source(s): The IUCN Red List of Threatened Species. Version 2020-2. https://www.iucnredlist.org.
Notes: Values correspond to absolute lower-bound measurements of extinctions caused over the past $\approx$ 500 years. Of the predicted $\approx$ 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 $\approx$285 being assigned a conservation status, respectively. The number of extinct animal species is undoubetly higher than these reported values, as signified by an inequality symbol (>).

P EROSION

intentional soil movement	HuID: 59841

Data Source(s): Table 1 and Figure 4 of Hooke 2000. DOI:10/bdnqv9. K-Tec Earthmovers Inc. March 2018 Newsletter URL:https://tinyurl.com/y5tkm98j (accessed 08/2020). Grand View Research Construction Industry Analysis, April 2020. URL:https://tinyurl.com/y2jxxpv3
Notes: Hooke 2000 estimates $\approx$ 35 Gt of soil moved annually in latter years of 20th century. This is in agreement with reported soil volume moved by 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, which is more difficult to confidently quantify.

Q SEA LEVEL RISE

rise due to meltwater	HuID: 97108
rise due to thermal expansion	HuID: 97688
total annual sea-level rise	HuID: 81373

Data Source(s): Table 1 of Frederikse et al. 2020. DOI:10/d689.
Notes: Values corresopnond 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 antarctic ice sheet.

R NUCLEAR FALLOUT

plutonium activity in soil	HuID: 0000

Data Source(s): Figure 4 and Figure 5 in Hancock et al. 2014. DOI:10.1144/SP395.15
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 CE during the peak of atmospheric nuclear weapons testing.

S POWER DERIVED FROM COAL

annual consumed power	HuID: 10400

Data Source(s): bp Statistical Review of World Energy, 2020.
Notes: 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.