

HUMAN IMPACTS by the numbers

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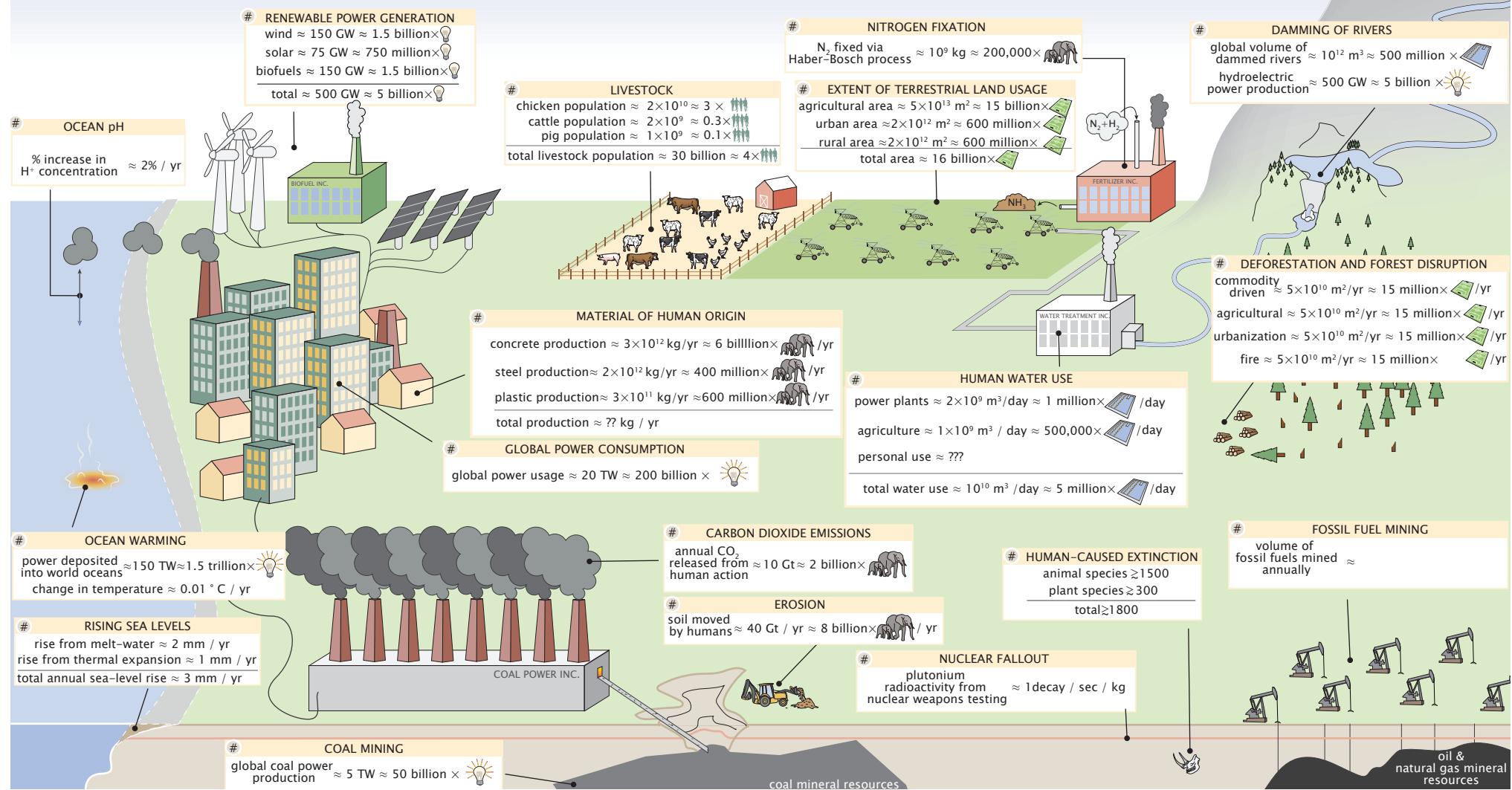
Department of Plant and Environmental Sciences

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	=	3 people	$\approx 7 \times 10^9$	mass of an elephant	=	elephant icon	≈ 5000 kg
area of soccer pitch	=	soccer pitch icon	≈ 3000 m ²	power of a lightbulb	=	lightbulb icon	≈ 100 W
volume of olympic pool	=	olympic pool icon	≈ 2000 m ³				



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SUPPORTING INFORMATION

MELTWATER

glacial melt rate	MELTWATER HuID: 32459
ice-sheet melt rate	HuID: 000000
total melt rate	HuID: 000000

Data Source(s): Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed diam nonummy nibh euismod tincidunt ut laoreet dolore magna aliquam erat volutpat. Ut wisi enim ad minim veniam, quis nostrud exercitiation ullamcorper suscipit lobortis nisl ut

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RENEWABLE POWER GENERATION

wind	RENEWABLE POWER GENERATION 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 hydroelectric power generation.

NITROGEN FIXATION

N_2 flux through Haber-Bosch [HuID: 000000](#)

Data Source(s): Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed diam nonummy nibh euismod tincidunt ut laoreet dolore magna aliquam erat volutpat. Ut wisi enim ad minim veniam, quis nostrud exercitiation ullamcorper suscipit lobortis nisl ut

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DAMMING OF RIVERS

dammed river volume [HuID: 000000](#)

Data Source(s): Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed diam nonummy nibh euismod tincidunt ut laoreet dolore magna aliquam erat volutpat. Ut wisi enim ad minim veniam, quis nostrud exercitiation ullamcorper suscipit lobortis nisl ut

hydroelectric power [HuID: 000000](#)

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

Notes: Value corresponds to the reported value of global hydroelectricity production for 2019

LIVESTOCK POPULATION

chicken	LIVESTOCK POPULATION 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.

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

urbanian [HuID: 92006](#)

rural [HuID: 21368](#)

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.

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OCEAN pH

yearly change in [H ⁺]	OCEAN pH HuID: 00000
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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.

DEFORESTATION

commodity-driven [HuID: 00000](#)

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.

agricultural [HuID: 00000](#)

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.

plastic production [HuID: 00000](#)

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.

total anthropomass production [HuID: 00000](#)

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.

MATERIAL OF HUMAN ORIGIN

concrete production	MATERIAL OF HUMAN ORIGIN HuID: 00000
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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.

steel production [HuID: 00000](#)

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.

total anthropomass production [HuID: 00000](#)

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.

urbanization [HuID: 00000](#)

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.

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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 $\approx 30\%$ 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.

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 an 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 **Damming 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 CO₂ 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 CO₂ 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 $\approx 30\%$ increase in hydrogen ion concentration in the oceans over the 60 year period of 1960 – present.

HUMANS AS THE EARTH'S GREATEST EVOLUTIONARY FORCE

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HUMAN IMPACTS ON ATMOSPHERIC AND BIOGEOCHEMICAL CYCLES

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THE MAGNITUDE OF HUMAN ENERGY USAGE

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ANTHROPOMASS NUMBER		TERRA NUMBER	
$Am = \frac{\text{total anthropomass}}{\text{total biomass}}$	$\approx \frac{\text{ }}{\text{ }} \approx 1$	$Te = \frac{\text{land area used by humans}}{\text{land area of Earth}}$	$\approx \frac{5 \times 10^{13} \text{ m}^2}{1.5 \times 10^{14} \text{ m}^2} \approx 0.3$
RADIONUCLIDE NUMBER		EXTINCTION NUMBER	
$Rn = \frac{\text{anthropogenic } ^{239/40}\text{Pu in soil}}{\text{naturally occurring } ^{239/40}\text{Pu in soil}}$	$\approx \frac{\text{ }}{\text{ }} \approx 2 \times 10^4$	$Ex = \frac{\text{human-induced extinction rate}}{\text{background extinction rate}}$	$\approx \frac{\text{dodo}}{\text{trilobite? non-mass ex}} > 200$

NIAGARA NUMBER		DAMMING NUMBER	
$Ni = \frac{\text{daily human water use}}{\text{Niagara Falls drainage rate}}$	$\approx \frac{10^{10} \text{ m}^3/\text{day}}{10^9 \text{ m}^3/\text{day}} \approx 10$	$Hv = \frac{\text{dammed river volume}}{\text{free-flowing river volume}}$	$\approx \frac{\text{dam}}{\text{river}} \approx \frac{10^{12} \text{ m}^3}{10^{12} \text{ m}^3} \approx 1$
ICE-MELT NUMBER		ACIDIC OCEAN NUMBER	
$Ic = \frac{\text{annual melt volume from glaciers \& ice-caps}}{\text{volume of Grand Canyon}}$	$\approx \frac{10^{12} \text{ m}^3/\text{yr}}{10^{12} \text{ m}^3} \approx 1/\text{yr}$	$Ac = \frac{\text{ocean [H}^+ \text{ in 1960}}{\text{ocean [H}^+ \text{ today}}$	$\approx \frac{1M \times 10^{-8.2}}{1M \times 10^{-8.1}} \approx 0.7$

BARNYARD NUMBER		DEFORESTATION NUMBER	
$By = \frac{\text{livestock population}}{\text{human population}}$	$\approx \frac{30 \times 10^9}{7 \times 10^9} \approx 4$	$Df = \frac{\text{human-caused forest area loss}}{\text{natural forest area loss}}$	$\approx \frac{\text{ }}{\text{ }} \approx 3$
???		???	

KEELING NUMBER		HABER-BOSCH NUMBER	
$Ke = \frac{\text{anthropogenic CO}_2 \text{ since 1880}}{\text{CO}_2 \text{ released from Mt. St. Helens}}$	$\approx \frac{2 \times 10^{15} \text{ kg CO}_2}{10^{10} \text{ kg CO}_2} \approx 2 \times 10^5$	$Ha = \frac{\text{N}_2 \text{ fixation through Haber-Bosch process}}{\text{N}_2 \text{ fixation through biological processes}}$	$\approx \frac{\text{ }}{\text{ }} \approx 1$
VOLTA NUMBER		EROSION NUMBER	
$V = \frac{\text{volume of anthropogenic CH}_4}{\text{volume of biological CH}_4}$	$\approx \frac{\text{ }}{\text{ }} \approx 1$	$Er = \frac{\text{soil moved by humans}}{\text{soil moved by rivers}}$	$\approx \frac{40 \text{ Gt / yr}}{5 \text{ Gt / yr}} \approx 8$

SOLAR NUMBER		FOSSIL FUEL NUMBER	
$Su = \frac{\text{annual human energy usage}}{\text{annual incident solar energy}}$	$\approx \frac{20 \text{ TW}}{2 \times 10^5 \text{ TW}} \approx 0.0001$	$Fo = \frac{\text{volume of fossil fuels mined annually}}{\text{volume of fossil fuels in proven resources}}$	$\approx \frac{20 \text{ TW}}{2 \times 10^5 \text{ TW}} \approx 0.0001$
???		???	