

HUMAN IMPACTS

by the numbers

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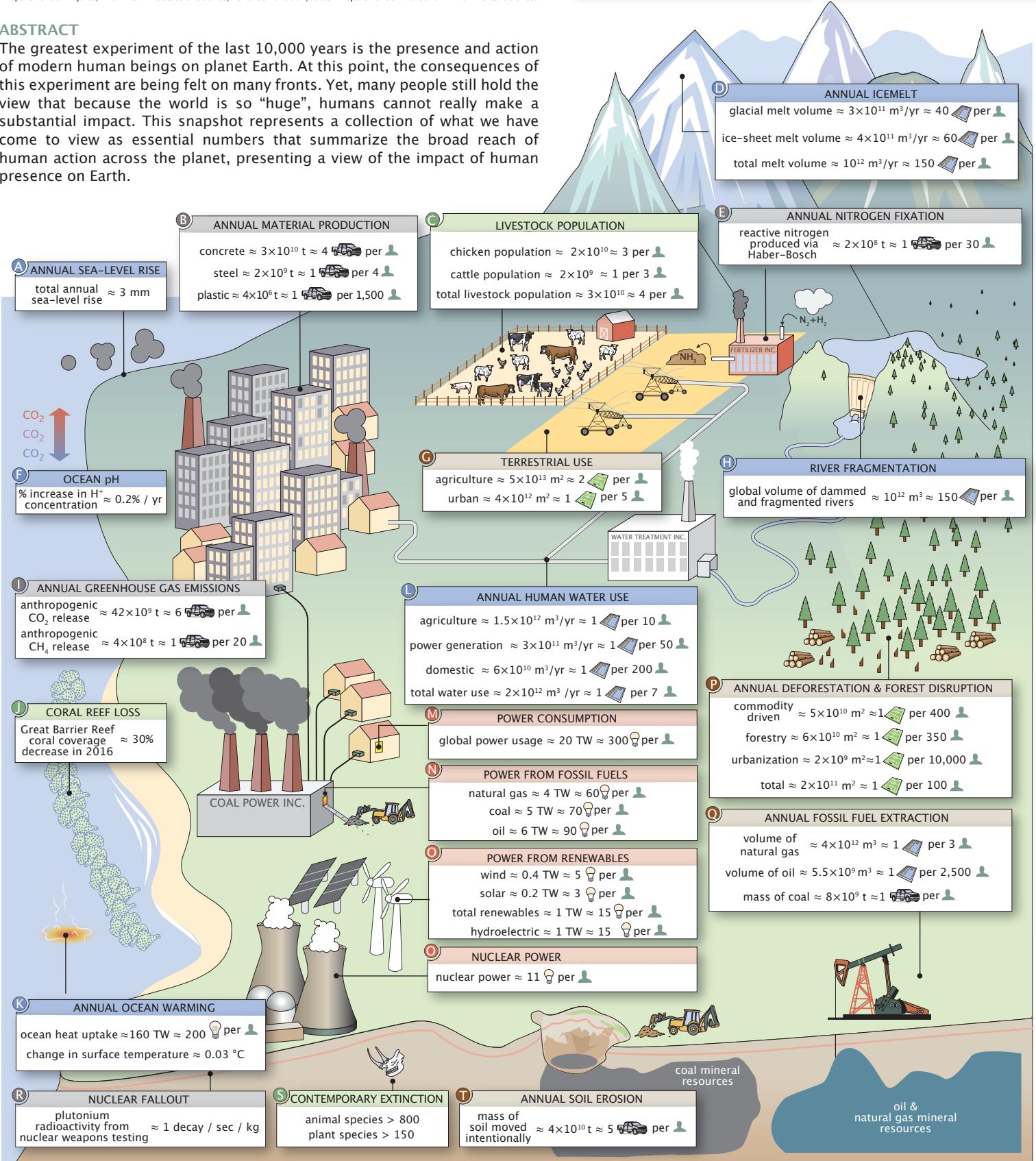
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ABSTRACT

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 what we have come to view as essential numbers that summarize the broad reach of human action across the planet, presenting a view of the impact of human presence on Earth.

| REFERENCE UNITS | HUMAN IMPACT CATEGORIES |
|---|-------------------------------------|
| per capita (global) = 1 person | LAND |
| human population = ≈ 7 × 10 ⁹ | ENERGY |
| area of soccer pitch = ≈ 3000 m ² | FLORA & FAUNA |
| volume of olympic pool = ≈ 2000 m ³ | WATER |
| power of an LED lightbulb = ≈ 10 W | ATMOSPHERIC & BIOGEOCHEMICAL CYCLES |
| mass of a pick-up truck = ≈ 1 t | |



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

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

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 ≈ 30% of Earth's terrestrial area.

THE ANTHROPOMASS NUMBER

$$An = \frac{\text{total anthropomass}}{\text{total biomass}} = \frac{\text{concrete buildings}}{\text{trees and animals}} \approx 1$$

The **Anthropomass Number** reflects the fact 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 ≈ 1.1 × 10¹² 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 × 10¹² tonnes.

THE EXTINCTION NUMBER

$$Ex = \frac{\text{number of known animal extinctions}}{\text{predicted number of animal extinctions}} = \frac{\text{dodo bird}}{\text{extinct species}} > 10$$

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 10³ (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 BARNYARD NUMBER

$$By = \frac{\text{mass of terrestrial livestock}}{\text{mass of terrestrial wild animals}} \approx \frac{\text{cows and chickens}}{\text{elephant and deer}} \approx 30$$

Human land use as reflected in the Terra number illustrates the lengths to which we have turned to keep food on our tables. Much of that land is used to feed the animals that feed us. The Barnyard number takes a by the numbers, rather than by the mass, approach to understanding the total quantity of animals in our farms and on our pastures. The **Barnyard Number** reveals that our domesticated animals outnumber us by a factor of 4. By numbers, it is our poultry with several tens of billions of chickens (HuD:) handily outnumbering humans. For our cows, the number is more like one cow on planet Earth for every three humans, though their land use footprint is monstrously larger than that of all other domesticated farm animals.

THE DEFORESTATION NUMBER

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

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, HUID: 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 ≈ 20% or ≈ 5 × 10¹⁰ m² annually (HuD: 92221).

THE NIAGARA NUMBER

$$Ni = \frac{\text{daily human water use}}{\text{Niagara Falls drainage rate}} \approx \frac{\text{water flow}}{\text{water fall}} \approx 10$$

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 ≈ 5 × 10⁹ m³/day, accounting for the majority of human water usage. Combining agricultural use with the water volume used for power generation (≈ 10⁹ m³/day, HUID: 78784), domestic/municipal use (≈ 10⁸ m³/day, HUID: 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

$$Rv = \frac{\text{fragmented river volume}}{\text{free-flowing river volume}} \approx \frac{\text{dammed river}}{\text{natural river}} \approx 1$$

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 (≈ 6 × 10¹¹ m³, HUID: 61661) as is under direct human control, such as through dams and reservoirs or through man-made channels (≈ XXXXX , HUID: 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

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

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.

THE NITROGEN NUMBER

$$N_2 = \frac{\text{N}_2\text{ fixation through Haber-Bosch process}}{\text{N}_2\text{ fixation through biological processes}} \approx \frac{\text{industrial tank}}{\text{soil plant}} \approx 1$$

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

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

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 ≈ 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.

THE METHANE NUMBER

$$Me = \frac{\text{mass of anthropogenic CH}_4}{\text{mass of biological CH}_4} \approx \frac{\text{factory}}{\text{cow}} \approx \frac{400 \text{ Mt / yr}}{300 \text{ Mt / yr}} \approx 1.3$$

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THE SOLAR NUMBER

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

It could be argued that human impacts derive from two main sources: our need to eat and our need for power. Human power usage is enormous and demand for it has been increasing at a steady pace as the entire human population seeks to raise their standard of living. The **Solar Number** puts the 20 TW power consumption of human activities (HuD: 94934) in relief by comparing it to the incident power that arrives on our planet from the sun. As can be seen, despite our enormous power consumption, it still pales in comparison with the incident power coming from the nuclear reactions taking place within the sun.

