

26.1. – 26.2.2023

**A SILENT
OPERA
FOR
ANTHROPOGENIC
MASS**

A PROJECT BY JOANA MOLL

A recent study performed at the Weizmann Institute of Science has determined that in the year 2020 the collective weight of the objects built by humans exceeded that of the total biomass¹ of our planet². This estimate indicates that everything that humans have created, maintained or discarded (anthropogenic mass) weighs more than all the living things on earth combined (biomass). In a few words, this imbalance, in a process of constant acceleration, is radically eroding the biosphere's ability to regenerate itself.

A Silent Opera for Anthropogenic Mass focuses on exploring the insidious, yet *silent* production of anthropogenic mass. It is precisely the silent quality of this process (from a human perspective) that makes it particularly critical, as it blinds us to consciously experience and identify the different realities left by this subtle, yet brutal, transformation of our natural ecosystems, making it increasingly difficult to re-imagine relationships and future paradigms consistent with our contemporary climatic, technological, and human conditions. Moreover, a form of collective amnesia named the Shifting Baseline Syndrome (SBS), is progressively challenging any shared initiative of restoring our relationship with nature. SBS is based on 'a gradual change in the accepted norms for the conditions of a natural environment due to a lack of experience, memory, and/or knowledge of its past condition'. In other words, what a generation experiences as *normal*, can be radically different when another generation appears, and subsequently apprehend this emerging reality as *normal*. Thus, developing rituals aimed at experiencing the increasing cannibalization of ecologies, exemplified by the persistent increasing of anthropogenic mass, is an urgent exercise.

1.

Biomass refers to the mass of living organisms, including plants, animals, and microorganisms, or, from a biochemical perspective, cellulose, lignin, sugars, fats, and proteins.

2.

Elhacham, E., Ben-Uri, L., Grozovski, J. et al. Global human-made mass exceeds all living biomass. *Nature* 588, 442-444 (2020).

<https://doi.org/10.1038/s41586-020-3010-5>.

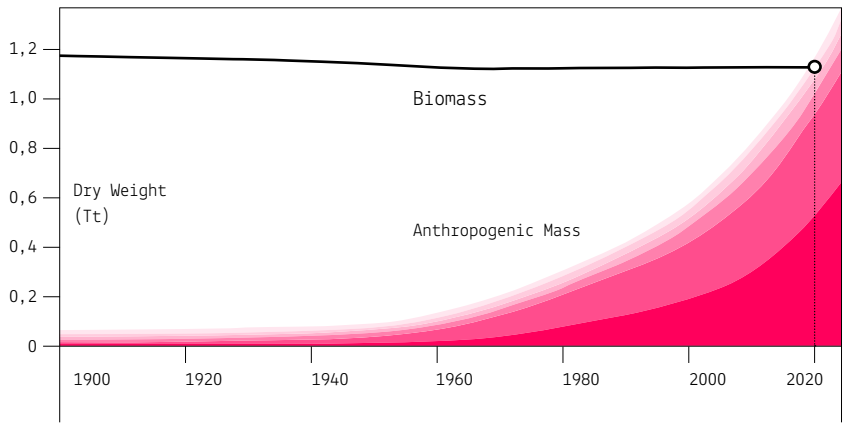


FIG 1.

Global production of anthropogenic mass from 1900 to 2020.
 Source: Elhacham, E., Ben-Uri, L., Grozovski, J. et al.
 Global human-made mass exceeds all living biomass.
Nature 588, 442-444 (2020).
<https://doi.org/10.1038/s41586-020-3010-5>.

- Concrete
- Aggregates
- Bricks
- Asphalt
- Metals
- Other

In the shape of a sound art and media installation, *A Silent Opera for Anthropogenic Mass* intends to perform the quiet metamorphosis of our life-giving habitats into anthropogenic mass. Ultimately, this project aims to highlight the subtle but continuous replacement of the natural order by technological progress, and reflect not only on the destruction of ecosystems but also on the difficulty of making climate change visible. The opera can be heard on the Tempelhofer Feld through a web app. You will need a mobile device with a data connection and some headphones.

An online version of this libretto is available here:

<https://janavirgin.com/OPERA/libretto.pdf>



WHAT ARE YOU GOING TO HEAR?

A Silent Opera for Anthropogenic Mass stages the global production of anthropogenic mass from 1900 to 2020 through a web app, using text, sound, and space.

Anthropogenic mass is defined as 'the mass embedded in solid inanimate human-made objects that have not yet been demolished or decommissioned', and is composed of six different groups of materials: concrete, bricks, asphalt, metals, aggregates (gravel and sand), and other materials (plastic, wood, and glass).

Since 1900, the global amount of anthropogenic mass has increased steadily (Fig. 1); however, the annual global production of this mass has been directly affected by global events (as shown in Fig. 2) and thus experienced substantial production rate changes in the last 122 years. This opera *sonifies*³ the yearly fluctuations in the production rate of the six groups that compose anthropogenic mass (Fig. 3 to 8), along with the global accumulation of anthropogenic mass (Fig. 1) from 1900 to 2020.

Anthropogenic mass
Relative annual change [%]

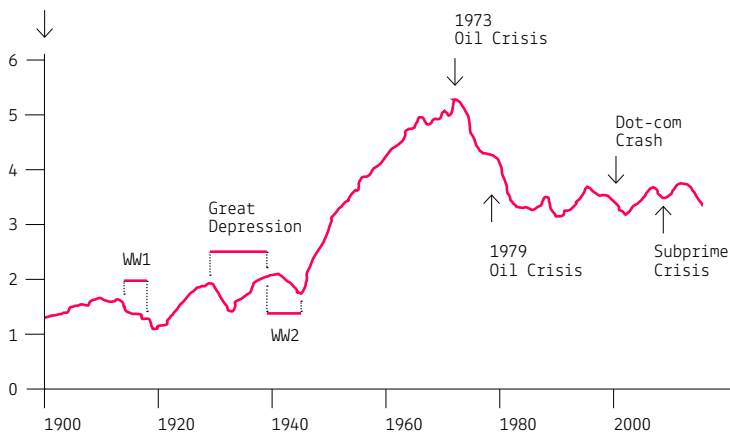


Fig 2.

Relative annual change of the global production of anthropogenic mass from 1900 to 2020. Source: Elhacham, E., Ben-Uri, L., Grozovski, J. et al. Global human-made mass exceeds all living biomass. *Nature* 588, 442-444 (2020). <https://doi.org/10.1038/s41586-020-3010-5>.

3.

To sonify: to translate data into sound.

GLOBAL RELATIVE ANNUAL CHANGES PRODUCTION FROM 1900 TO 2020

Fig 3.
Concrete

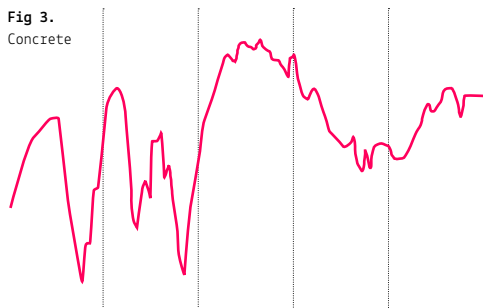


Fig 5.
Asphalt

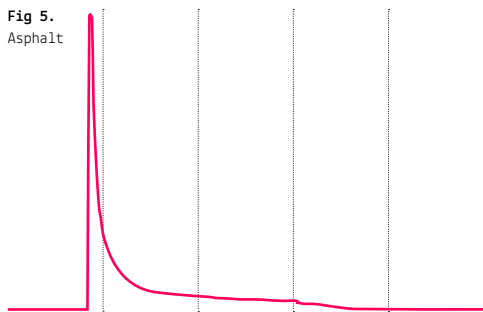


Fig 7.
Aggregates
(gravel and sand)

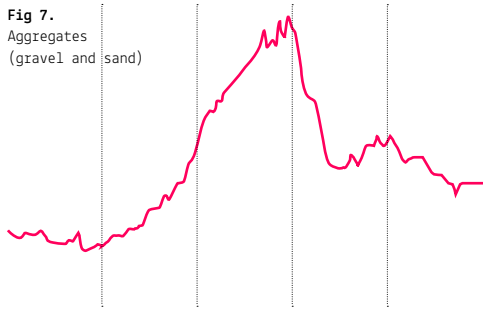


Fig 3.
Global relative annual change
in concrete production.

Fig 5.
Global relative annual change
in asphalt production.

Fig 7.
Global relative annual change
in aggregates (gravel and
sand) production.

Fig 4.
Global relative annual
change in brick production.

Fig 6.
Global relative annual
change in metal production.

Fig 8.
Global relative annual
change in other materials
(plastic, wood and glass)
production.

Fig 4.
Brick

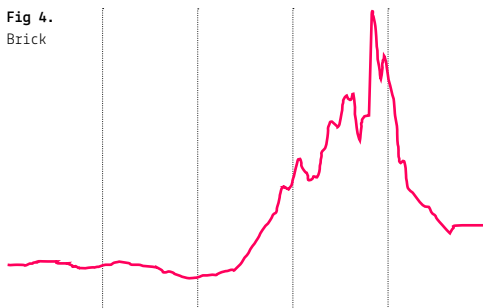


Fig 6.
Metal

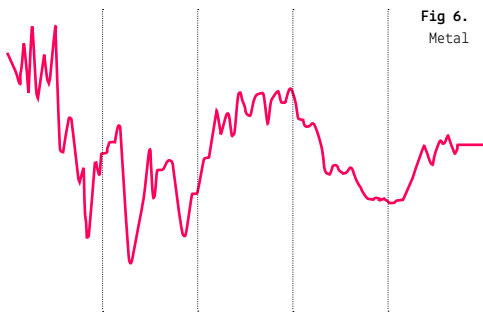
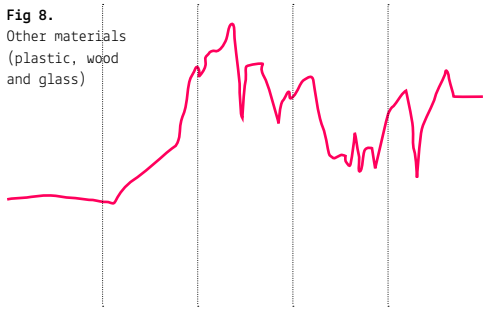


Fig 8.
Other materials
(plastic, wood
and glass)



WHAT ARE YOU GOING TO SEE?

The audio composition played by the web app is supported with text for contextualization purposes. The web app interface shows the year that corresponds to the sound currently playing and a headline of a historical event that happened in that very same year. The web app also displays the global amount of concrete, bricks, asphalt, metals, aggregates, and other materials produced during that year, together with the annual accumulation of anthropogenic mass.

The web app interface allows the activation and deactivation of the seven audio channels that create the composition of the opera for a personalized listening experience.

HOW DOES IT WORK?

The opera is activated by walking through a specific space and it is located in one of the main airstrips of Tempelhofer Feld (see the map below to locate the starting and ending points). The starting point stages the overall anthropogenic mass produced in 1900, while the ending point represents the global accumulation of such mass in 2020. This setup allows the audience to experience the opera not only forwards but also backwards: from 1900 to 2020, and from 2020 to 1900.

INSTRUCTIONS:

1. Activate GPS.
2. Scan this QR code to access the web app.
3. Go to the starting point (see map).
4. Start walking towards the ending point.



janavirgin.com/OPERA

ANTHROPOGENIC MASS ANNUAL CHANGE

1900

Over 1,000 tonnes of waste are removed from demolished buildings in Sydney, Australia, in areas affected by an outbreak of the bubonic plague.

All values expressed in gigatonnes.

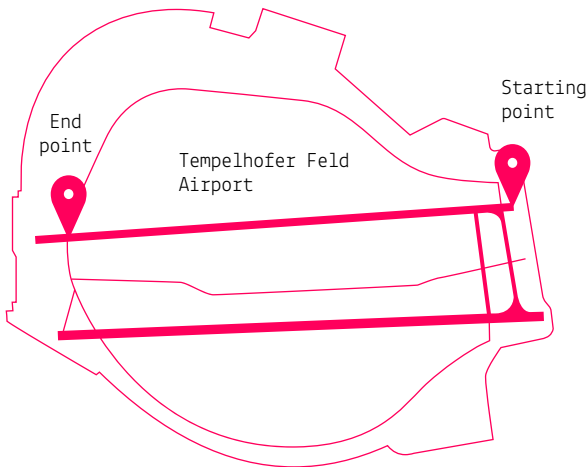
● Concrete	2.31
▲ Aggregates	16.89
■ Bricks	11.24
◆ Asphalt	0.00
▼ Metals	0.88
● Plastic, Wood & Glass	4.28

200%

100%

10%

Map



0%

35.61

Gigatonnes
Total Anthropogenic Mass

1901

J.P. Morgan creates the United States Steel Co., which will become the first \$1 billion corporation in the world.

All values expressed in gigatonnes.

● Concrete	2.37
▲ Aggregates	17.15
■ Bricks	11.34
◆ Asphalt	0.00
▼ Metals	0.93
● Plastic, Wood & Glass	4.29

200%

100%

10%

0%

36.08

Gigatonnes
Total Anthropogenic Mass

1902

The teddy bear is first produced. It is named after President Theodore Roosevelt.

● Concrete	2.44
▲ Aggregates	17.39
■ Bricks	11.44
◆ Asphalt	0.00
▼ Metals	0.97
● Plastic, Wood & Glass	4.31

200%

100%

10%

0%

36.56

Gigatonnes
Total Anthropogenic Mass

1903

The first box of Crayola crayons is made and sold for 5 cents. It contains 8 colors; brown, red, orange, yellow, green, blue, violet and black.

● Concrete	2.53
▲ Aggregates	17.64
■ Bricks	11.55
◆ Asphalt	0.00
▼ Metals	1.02
● Plastic, Wood & Glass	4.32

200%

100%

10%

0%

37.06

Gigatonnes
Total Anthropogenic Mass

1904

Roger Casement publishes his account of Belgian atrocities in the Congo.

1905

Wolves become extinct in Japan.

1906

Xerox, the global digital office machine brand, is founded in Rochester, New York as the Haloid Photographic Company.

● Concrete	2.62
▲ Aggregates	17.88
■ Bricks	11.65
◆ Asphalt	0.00
▼ Metals	1.07
● Plastic, Wood & Glass	4.34

Concrete	2.73
Aggregates	18.14
Bricks	11.76
Asphalt	0.00
Metals	1.12
Plastic, Wood & Glass	4.36

Concrete	2.85
Aggregates	18.40
Bricks	11.87
Asphalt	0.00
Metals	1.17
Plastic, Wood & Glass	4.37

200%

100%

10%



0%

37.56

Gigatonnes
Total Anthropogenic Mass

38.11

Gigatonnes
Total Anthropogenic Mass

38.67

Gigatonnes
Total Anthropogenic Mass

1907

Radiometric dating finds the earth is 2.2 billion years old.

All values expressed in gigatonnes.

● Concrete	2.98
▲ Aggregates	18.67
■ Bricks	11.98
◆ Asphalt	0.00
▼ Metals	1.24
● Plastic, Wood & Glass	4.39

1908

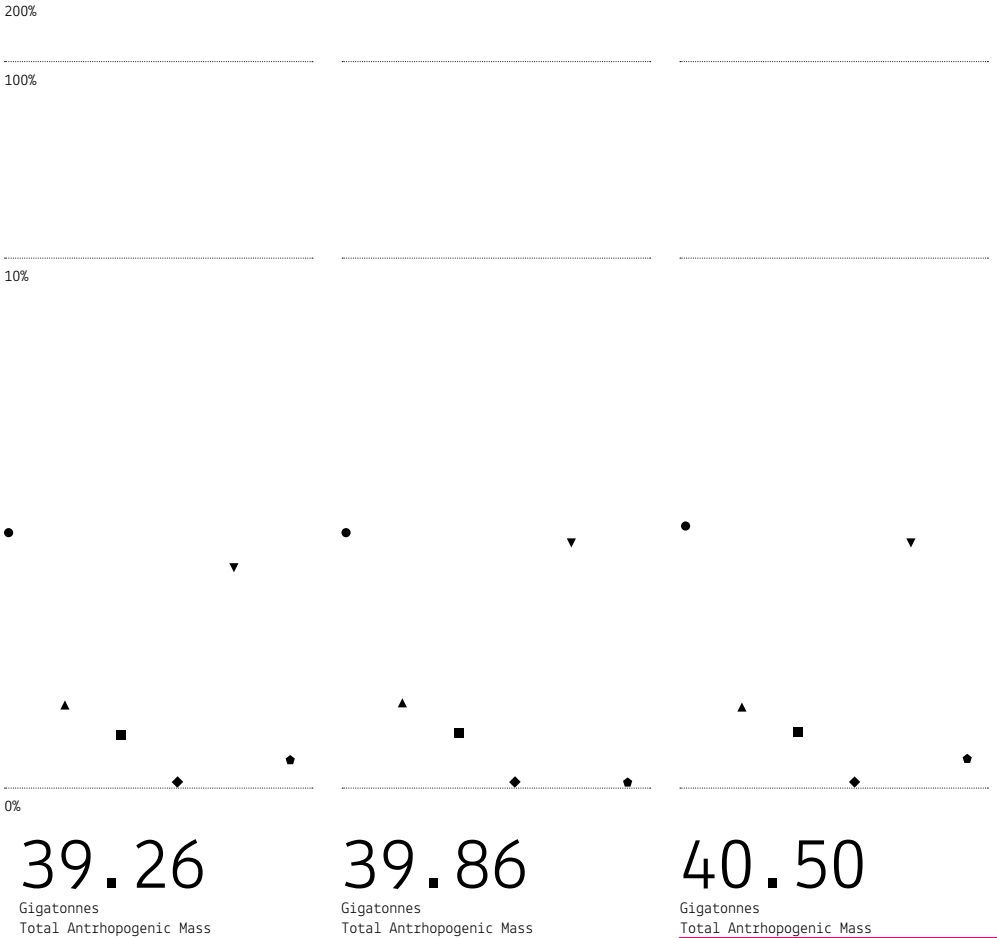
Mysterious Siberian explosion levels hundreds of square miles of forest. Explanations include a comet, meteorite, natural atomic explosion, or crashed UFO.

● Concrete	3.13
▲ Aggregates	18.95
■ Bricks	12.09
◆ Asphalt	0.00
▼ Metals	1.29
● Plastic, Wood & Glass	4.41

1909

One year after petroleum production starts in the Middle-East the Anglo-Per-sian Oil Company forms in London.

● Concrete	3.28
▲ Aggregates	19.23
■ Bricks	12.21
◆ Asphalt	0.00
▼ Metals	1.35
● Plastic, Wood & Glass	4.44



1910

The Vatican introduces a compulsory oath against modernism (Sacrorum antis-titum), to be taken by all priests upon ordination.

1911

The Nakhla meteorite falls in the Abu Hummus region of Egypt, providing evidence of water on Mars.

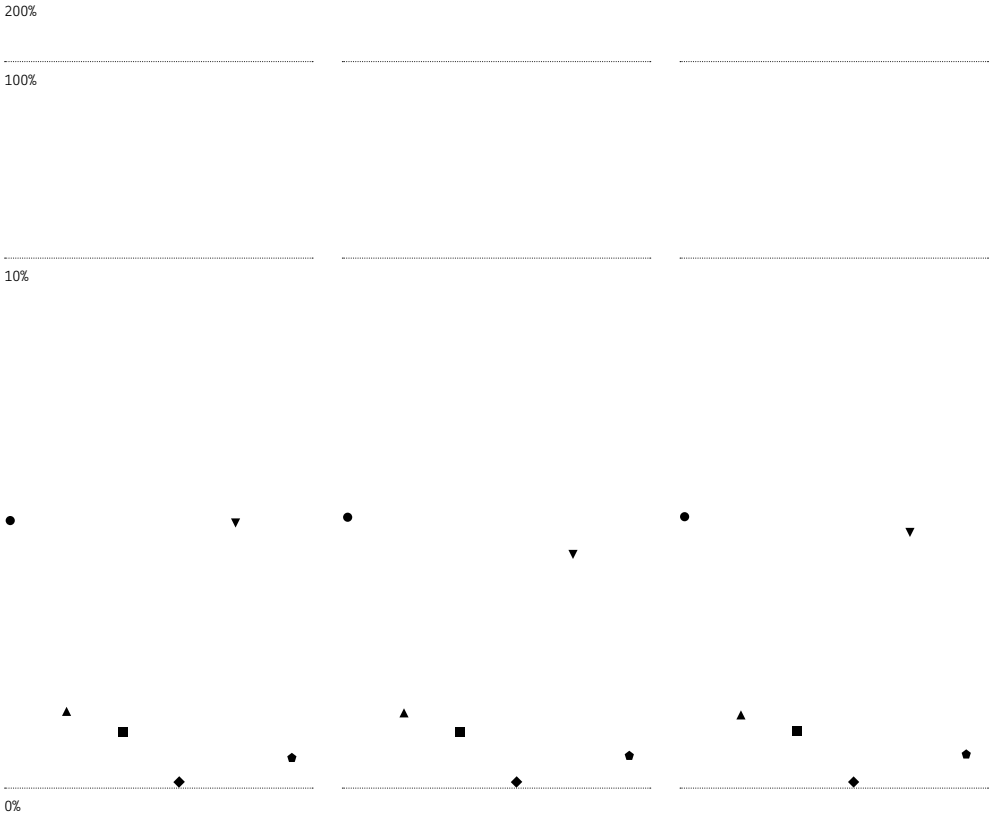
1912

Kazimierz Funk is among the first scientists to identify vitamins.

● Concrete	3.44
▲ Aggregates	19.51
■ Bricks	12.33
◆ Asphalt	0.00
▼ Metals	1.42
● Plastic, Wood & Glass	4.46

Concrete	3.61
Aggregates	19.77
Bricks	12.45
Asphalt	0.00
Metals	1.48
Plastic, Wood & Glass	4.48

Concrete	3.79
Aggregates	20.04
Bricks	12.57
Asphalt	0.00
Metals	1.55
Plastic, Wood & Glass	4.51



41.15

Gigatonnes
Total Anthropogenic Mass

41.80

Gigatonnes
Total Anthropogenic Mass

42.46

Gigatonnes
Total Anthropogenic Mass

1913

The Ford Motor Company introduces the first moving assembly line, reducing chassis assembly time from 12h and 30min to 2h and 40min, sparking an era of mass production.

All values expressed in gigatonnes.

● Concrete	3.99
▲ Aggregates	20.30
■ Bricks	12.69
◆ Asphalt	0.00
▼ Metals	1.64
● Plastic, Wood & Glass	4.53

1914

Suffragette Mary Richardson damages Velázquez's painting Rokeby Venus in London's National Gallery, with a meat chopper.

Concrete	4.15
Aggregates	20.56
Bricks	12.82
Asphalt	0.00
Metals	1.70
Plastic, Wood & Glass	4.56

1915

The first stop sign appears in Detroit.

Concrete	4.29
Aggregates	20.81
Bricks	12.94
Asphalt	0.00
Metals	1.75
Plastic, Wood & Glass	4.59

200%

100%

10%

0%

43.15

Gigatonnes
Total Anthropogenic Mass

43.78

Gigatonnes
Total Anthropogenic Mass

44.38

Gigatonnes
Total Anthropogenic Mass

1916

Oxycodone, a narcotic pain-killer closely related to codeine, is first synthesized in Germany.

1917

The first edition of the World Book Encyclopedia, simply known as The World Book, is published.

1918

Daylight Saving Time goes into effect in March.

● Concrete	4.40
▲ Aggregates	21.09
■ Bricks	13.07
◆ Asphalt	0.00
▼ Metals	1.82
● Plastic, Wood & Glass	4.62

Concrete	4.49
Aggregates	21.36
Bricks	13.18
Asphalt	0.00
Metals	1.88
Plastic, Wood & Glass	4.65

Concrete	4.55
Aggregates	21.67
Bricks	13.31
Asphalt	0.00
Metals	1.94
Plastic, Wood & Glass	4.68

200%

100%

10%



0%

45.00

Gigatonnes
Total Anthropogenic Mass

45.57

Gigatonnes
Total Anthropogenic Mass

46.15

Gigatonnes
Total Anthropogenic Mass

1919

The eight-hour day and free Sunday become law for workers in the Netherlands.

All values expressed in gigatonnes.

● Concrete	4.58
▲ Aggregates	21.92
■ Bricks	13.42
◆ Asphalt	0.00
▼ Metals	1.99
● Plastic, Wood & Glass	4.72

1920

France prohibits the sale or prescription of contraceptives. Estimated world population: 1,860 million.

● Concrete	4.66
▲ Aggregates	22.18
■ Bricks	13.54
◆ Asphalt	0.00
▼ Metals	2.05
● Plastic, Wood & Glass	4.75

1921

Luxury goods brand Gucci is founded in Florence, Italy.

● Concrete	4.74
▲ Aggregates	22.44
■ Bricks	13.66
◆ Asphalt	0.00
▼ Metals	2.08
● Plastic, Wood & Glass	4.79

200%

100%

10%

0%

46.63

Gigatonnes
Total Anthropogenic Mass

47.19

Gigatonnes
Total Anthropogenic Mass

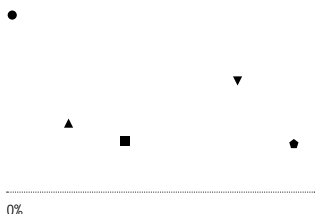
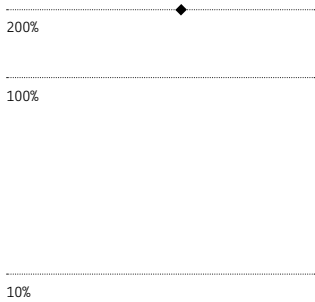
47.71

Gigatonnes
Total Anthropogenic Mass

1922

An ice mass breaks the Oder Dam, a dam in the Harz mountains of Germany.

● Concrete	4.90
▲ Aggregates	22.71
■ Bricks	13.77
◆ Asphalt	0.00
▼ Metals	2.12
● Plastic, Wood & Glass	4.83



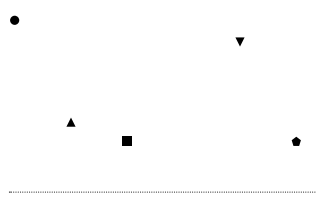
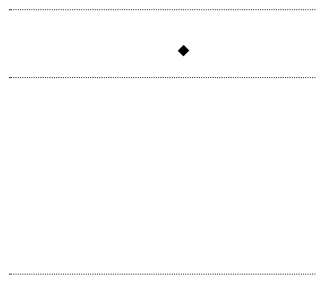
48.34

Gigatonnes
Total Anthropogenic Mass

1923

Scopolamine, previously used as a childbirth anesthetic, is found to act as a "truth" serum after tests on convicts at San Quentin Prison in San Francisco (US).

Concrete	5.05
Aggregates	22.99
Bricks	13.89
Asphalt	0.01
Metals	2.19
Plastic, Wood & Glass	4.87



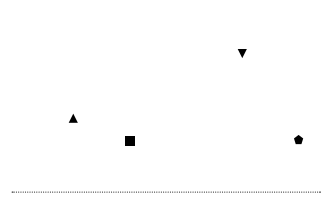
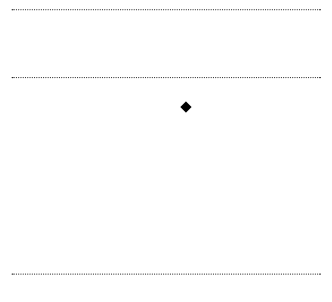
49.01

Gigatonnes
Total Anthropogenic Mass

1924

Walt Disney creates his first cartoon, "Alice's Wonderland."

Concrete	5.27
Aggregates	23.29
Bricks	14.02
Asphalt	0.02
Metals	2.25
Plastic, Wood & Glass	4.92



49.75

Gigatonnes
Total Anthropogenic Mass

1925

John Baird transmits the first television image in London.

1926

Auto antifreeze allows people to use cars year-round.

1927

Dancer Isadora Duncan dies when her scarf gets caught in the wheel of a moving car.

All values expressed in gigatonnes.

● Concrete	5.54
▲ Aggregates	23.58
■ Bricks	14.14
◆ Asphalt	0.03
▼ Metals	2.32
● Plastic, Wood & Glass	4.96

Concrete	5.85
Aggregates	23.89
Bricks	14.27
Asphalt	0.04
Metals	2.39
Plastic, Wood & Glass	5.01

Concrete	6.18
Aggregates	24.23
Bricks	14.41
Asphalt	0.06
Metals	2.47
Plastic, Wood & Glass	5.06



50.57

Gigatonnes
Total Anthropogenic Mass

51.45

Gigatonnes
Total Anthropogenic Mass

52.41

Gigatonnes
Total Anthropogenic Mass

1928

The Aschheim-Zondek urine pregnancy test is developed.

1929

The Kellogg-Briand Pact, a treaty renouncing war as an instrument of national policy, goes into effect.

1930

Astronomers discover Pluto, the ninth planet.

● Concrete	6.55
▲ Aggregates	24.58
■ Bricks	14.54
◆ Asphalt	0.08
▼ Metals	2.55
● Plastic, Wood & Glass	5.11

● Concrete	6.92
▲ Aggregates	24.93
■ Bricks	14.68
◆ Asphalt	0.10
▼ Metals	2.64
● Plastic, Wood & Glass	5.16

● Concrete	7.27
▲ Aggregates	25.28
■ Bricks	14.82
◆ Asphalt	0.13
▼ Metals	2.72
● Plastic, Wood & Glass	5.21



53.40

Gigatonnes
Total Anthropogenic Mass

54.43

Gigatonnes
Total Anthropogenic Mass

55.43

Gigatonnes
Total Anthropogenic Mass

1931

General Motors's Frigidaire makes refrigerators safe for household use.

1932

Haile Selassie announces an anti-slavery law in Abyssinia.

1933

The Nazi Party in Germany introduces a law to legalize eugenic sterilization.

All values expressed in gigatonnes.

● Concrete	7.54
▲ Aggregates	25.67
■ Bricks	14.96
◆ Asphalt	0.15
▼ Metals	2.77
● Plastic, Wood & Glass	5.27

● Concrete	7.72
▲ Aggregates	26.07
■ Bricks	15.10
◆ Asphalt	0.18
▼ Metals	2.80
● Plastic, Wood & Glass	5.32

● Concrete	7.88
▲ Aggregates	26.47
■ Bricks	15.24
◆ Asphalt	0.22
▼ Metals	2.83
● Plastic, Wood & Glass	5.38

200%

100%

10%

0%

56.36

Gigatonnes
Total Anthropogenic Mass

57.19

Gigatonnes
Total Anthropogenic Mass

58.02

Gigatonnes
Total Anthropogenic Mass

1934

Du Pont chemist Wallace Hume Carothers creates nylon, the first completely synthetic fabric.

1935

Electric guitars debut.

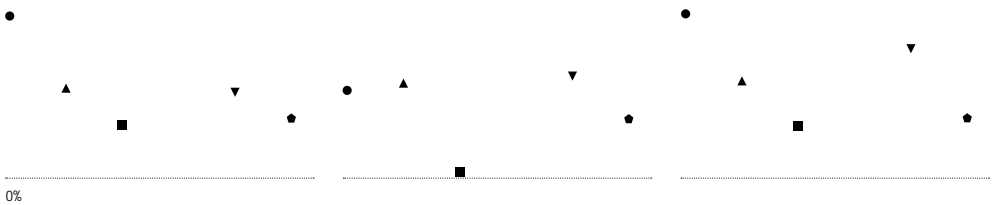
1936

First publication recognizing stress as a biological condition.

● Concrete	8.12
▲ Aggregates	26.89
■ Bricks	15.38
◆ Asphalt	0.26
▼ Metals	2.88
● Plastic, Wood & Glass	5.43

● Concrete	8.40
▲ Aggregates	27.31
■ Bricks	15.51
◆ Asphalt	0.30
▼ Metals	2.94
● Plastic, Wood & Glass	5.49

● Concrete	8.65
▲ Aggregates	27.79
■ Bricks	15.65
◆ Asphalt	0.35
▼ Metals	3.01
● Plastic, Wood & Glass	5.55



58.96

Gigatonnes
Total Anthropogenic Mass

59.95

Gigatonnes
Total Anthropogenic Mass

61.00

Gigatonnes
Total Anthropogenic Mass

1937

The Kogushi Sulfur Mine collapse in western Gunma, Japan, kills at least 245 people.

All values expressed in gigatonnes.

● Concrete	9.03
▲ Aggregates	28.31
■ Bricks	15.79
◆ Asphalt	0.40
▼ Metals	3.11
● Plastic, Wood & Glass	5.60

1938

George and Ladislav Biro invent the ballpoint pen.

● Concrete	9.43
▲ Aggregates	28.84
■ Bricks	15.92
◆ Asphalt	0.46
▼ Metals	3.18
● Plastic, Wood & Glass	5.66

1939

Paul Muller develops DDT, originally developed as an insecticide, infamous for its environmental impacts.

● Concrete	9.87
▲ Aggregates	29.38
■ Bricks	16.06
◆ Asphalt	0.53
▼ Metals	3.26
● Plastic, Wood & Glass	5.72



62.24

Gigatonnes
Total Anthropogenic Mass

63.49

Gigatonnes
Total Anthropogenic Mass

64.82

Gigatonnes
Total Anthropogenic Mass

1940

The first McDonald's hamburger stand opens in Pasadena, California (US).

● Concrete	10.21
▲ Aggregates	29.99
■ Bricks	16.19
◆ Asphalt	0.60
▼ Metals	3.35
● Plastic, Wood & Glass	5.78

200%

100%

10%



66.13

Gigatonnes
Total Anthropogenic Mass

1941

Thailand's Prime Minister Plaek Phibunsongkhram decrees January 1 as the official start of the Thai solar calendar new year (thus the previous year that began April 1 had only 9 months).

● Concrete	10.60
▲ Aggregates	30.63
■ Bricks	16.32
◆ Asphalt	0.69
▼ Metals	3.45
● Plastic, Wood & Glass	5.84



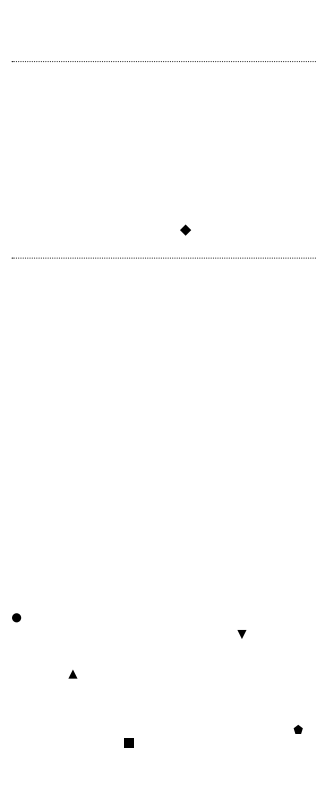
67.51

Gigatonnes
Total Anthropogenic Mass

1942

The experimental early-type nuclear reactor L-IV has an accident, becoming the first nuclear accident in history and consisting of a steam explosion and reactor fire in Leipzig.

● Concrete	10.93
▲ Aggregates	31.26
■ Bricks	16.44
◆ Asphalt	0.78
▼ Metals	3.55
● Plastic, Wood & Glass	5.90



68.86

Gigatonnes
Total Anthropogenic Mass

1943

Lyle Goodhue and William Sullivan patent the refillable aerosol spray in the United States, for use with mosquito repellent.

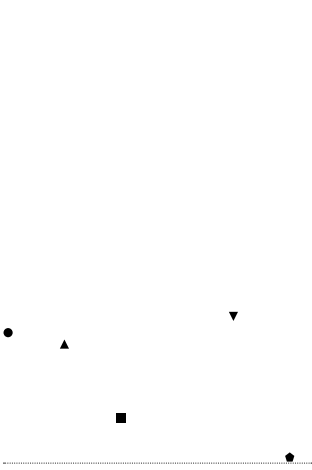
All values expressed in gigatonnes.

● Concrete	11.19
▲ Aggregates	31.93
■ Bricks	16.57
◆ Asphalt	0.88
▼ Metals	3.65
● Plastic, Wood & Glass	5.96

200%

100%

10%



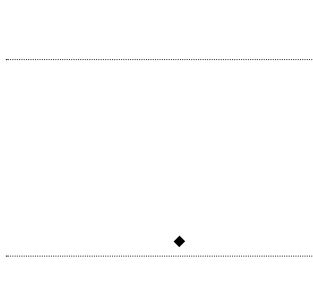
70.18

Gigatonnes
Total Anthropogenic Mass

1944

Jean-Paul Sartre's existentialist drama No Exit (Huis Clos) première in Nazi-occupied Paris.

● Concrete	11.33
▲ Aggregates	32.68
■ Bricks	16.69
◆ Asphalt	0.99
▼ Metals	3.74
● Plastic, Wood & Glass	6.02



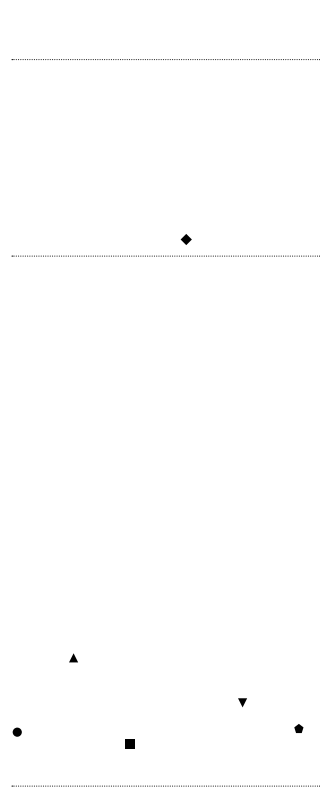
71.44

Gigatonnes
Total Anthropogenic Mass

1945

Adolf Hitler orders that all industries, military installations, machine shops, transportation facilities and communications facilities in Germany be destroyed.

● Concrete	11.43
▲ Aggregates	33.44
■ Bricks	16.80
◆ Asphalt	1.12
▼ Metals	3.80
● Plastic, Wood & Glass	6.08



72.68

Gigatonnes
Total Anthropogenic Mass

1946

Frederic Calland Williams receives a patent for a random-access memory (RAM) device.

1947

Global casual fashion brand H&M (Hennes & Mauritz) is founded in Sweden.

1948

The world's largest landfill, Fresh Kills Landfill, opens on Staten Island, New York (US).

● Concrete	11.69
▲ Aggregates	34.25
■ Bricks	16.91
◆ Asphalt	1.26
▼ Metals	3.86
● Plastic, Wood & Glass	6.14

Concrete	12.03
Aggregates	35.18
Bricks	17.02
Asphalt	1.41
Metals	3.93
Plastic, Wood & Glass	6.20

Concrete	12.48
Aggregates	36.16
Bricks	17.14
Asphalt	1.58
Metals	4.02
Plastic, Wood & Glass	6.26



Gigatonnes
Total Anthropogenic Mass

Gigatonnes
Total Anthropogenic Mass

Gigatonnes
Total Anthropogenic Mass

1949

Albert II, a rhesus monkey, becomes the first primate to enter space on U.S. Hermes project V-2 rocket Blossom IVB, but is killed on impact at return.

1950

The plastic bin bag for garbage collection is invented in Canada.

1951

A blue sun is seen over Europe: the effect is due to ash coming from the Canadian forest fires 4 months previously.

All values expressed in gigatonnes.

● Concrete	13.00
▲ Aggregates	37.23
■ Bricks	17.25
◆ Asphalt	1.77
▼ Metals	4.12
● Plastic, Wood & Glass	6.32

Concrete	13.63
Aggregates	38.44
Bricks	17.36
Asphalt	1.99
Metals	4.22
Plastic, Wood & Glass	6.38

Concrete	14.36
Aggregates	39.76
Bricks	17.48
Asphalt	2.23
Metals	4.35
Plastic, Wood & Glass	6.45



79.69

Gigatonnes
Total Anthropogenic Mass

82.03

Gigatonnes
Total Anthropogenic Mass

84.62

Gigatonnes
Total Anthropogenic Mass

1952

During the Mau Mau Uprising, the poisonous latex of the African milk bush is used to kill cattle, in an incident of Biological warfare.

● Concrete	15.15
▲ Aggregates	41.19
■ Bricks	17.60
◆ Asphalt	2.48
▼ Metals	4.48
● Plastic, Wood & Glass	6.52

200%

100%

10%

0%

87.42

Gigatonnes
Total Anthropogenic Mass

1953

Global meat packing industry JBS is founded in Anapolis, Goias, Brazil.

● Concrete	16.05
▲ Aggregates	42.65
■ Bricks	17.72
◆ Asphalt	2.75
▼ Metals	4.63
● Plastic, Wood & Glass	6.59

200%

100%

10%

0%

90.39

Gigatonnes
Total Anthropogenic Mass

1954

April 11th 1954 is denoted as the most boring day in the 20th century by True Knowledge, an answer engine. According to this software, no significant newsworthy events, births, or deaths are known to have happened on this day.

● Concrete	17.04
▲ Aggregates	44.24
■ Bricks	17.84
◆ Asphalt	3.04
▼ Metals	4.81
● Plastic, Wood & Glass	6.67

200%

100%

10%

0%

93.64

Gigatonnes
Total Anthropogenic Mass

1955

Ruth Ellis is hanged for murder in London, becoming the last woman ever to be executed in the United Kingdom.

1956

The first practical and commercially successful videotape format known as 2" Quadruplex is demonstrated.

1957

The Africanized bee is accidentally released in Brazil.

All values expressed in gigatonnes.

● Concrete	18.15
▲ Aggregates	45.87
■ Bricks	17.97
◆ Asphalt	3.34
▼ Metals	4.98
● Plastic, Wood & Glass	6.76

Concrete	19.37
Aggregates	47.66
Bricks	18.11
Asphalt	3.68
Metals	5.16
Plastic, Wood & Glass	6.84

Concrete	20.64
Aggregates	49.55
Bricks	18.25
Asphalt	4.05
Metals	5.36
Plastic, Wood & Glass	6.93



97.08

Gigatonnes
Total Anthropogenic Mass

101

Gigatonnes
Total Anthropogenic Mass

105

Gigatonnes
Total Anthropogenic Mass

1958

For the first time, the total of passengers carried by air this year exceeds the total carried by sea in transatlantic service.

● Concrete	21.99
▲ Aggregates	51.56
■ Bricks	18.40
◆ Asphalt	4.43
▼ Metals	5.55
● Plastic, Wood & Glass	7.03

200%

100%

10%

0%

109

Gigatonnes
Total Anthropogenic Mass

1959

Luna 2 becomes the first man-made object to crash on the Moon.

● Concrete	23.51
▲ Aggregates	53.67
■ Bricks	18.54
◆ Asphalt	4.84
▼ Metals	5.75
● Plastic, Wood & Glass	7.13

200%

100%

10%

0%

113

Gigatonnes
Total Anthropogenic Mass

1960

The German company HARIBO created the first gummy candy in the form of little gummy bears called Gummibärchen.

● Concrete	25.17
▲ Aggregates	55.92
■ Bricks	18.70
◆ Asphalt	5.27
▼ Metals	6.00
● Plastic, Wood & Glass	7.23

200%

100%

10%

0%

118

Gigatonnes
Total Anthropogenic Mass

1961

"Barbie" gets a boyfriend when the "Ken" doll is introduced in the United States.

All values expressed in gigatonnes.

● Concrete	26.90
▲ Aggregates	58.34
■ Bricks	18.87
◆ Asphalt	5.73
▼ Metals	6.24
● Plastic, Wood & Glass	7.34

200%

100%

10%

●

▲

◆

▼

■

0%

123

Gigatonnes
Total Anthropogenic Mass

1962

Rachel Carson's book Silent Spring is released in the U.S., giving rise to the modern environmentalist movement. Meanwhile, Ranger 4 spacecraft crashes into the Moon.

Concrete	28.77
Aggregates	60.90
Bricks	19.07
Asphalt	6.22
Metals	6.48
Plastic, Wood & Glass	7.45

200%

100%

10%

●

▲

◆

▼

■

0%

129

Gigatonnes
Total Anthropogenic Mass

1963

The Institute of Mental Health, the first social-psychiatric institution in Southeast Europe, is established in Belgrade.

Concrete	30.73
Aggregates	63.63
Bricks	19.29
Asphalt	6.75
Metals	6.73
Plastic, Wood & Glass	7.58

200%

100%

10%

●

▲

◆

▼

■

0%

135

Gigatonnes
Total Anthropogenic Mass

1964

Thieves steal the head of the Little Mermaid statue in Copenhagen, Denmark.

1965

Ranger 8 crashes into the Moon.

1966

Spain declares general amnesty for crimes committed during the Spanish Civil War, effective only for the neo-fascist Falangist's side, the sole legal political party of the Francoist regime.

● Concrete	32.91
▲ Aggregates	66.57
■ Bricks	19.53
◆ Asphalt	7.33
▼ Metals	7.02
● Plastic, Wood & Glass	7.73

Concrete	35.16
Aggregates	69.68
Bricks	19.79
Asphalt	7.95
Metals	7.32
Plastic, Wood & Glass	7.91

Concrete	37.58
Aggregates	73.13
Bricks	20.08
Asphalt	8.63
Metals	7.63
Plastic, Wood & Glass	8.09



0%

141

Gigatonnes
Total Anthropogenic Mass

148

Gigatonnes
Total Anthropogenic Mass

155

Gigatonnes
Total Anthropogenic Mass

1967

A significant worldwide geo-magnetic flare unfolded. Radio emissions coming from the Sun jammed military surveillance radars.

All values expressed in gigatonnes.

● Concrete	40.05
▲ Aggregates	76.52
■ Bricks	20.41
◆ Asphalt	9.32
▼ Metals	7.91
● Plastic, Wood & Glass	8.28

1968

This year represents the Female Fire-Goat year in the Tibetan calendar.

Concrete	42.71
Aggregates	80.21
Bricks	20.75
Asphalt	10.08
Metals	8.24
Plastic, Wood & Glass	8.48

1969

The world population increases by 2.09%, the highest increase in history.

Concrete	45.50
Aggregates	83.97
Bricks	21.13
Asphalt	10.86
Metals	8.59
Plastic, Wood & Glass	8.69

200%

100%

10%

0%

162

Gigatonnes
Total Anthropogenic Mass

170

Gigatonnes
Total Anthropogenic Mass

179

Gigatonnes
Total Anthropogenic Mass

1970

The international bestseller Future Shock is published. The book defines a certain psychological state of individuals and entire societies based in a personal perception of "too much change in too short a period of time".

● Concrete	48.43
▲ Aggregates	88.24
■ Bricks	21.53
◆ Asphalt	11.74
▼ Metals	8.96
● Plastic, Wood & Glass	8.91

1971

Intel releases the world's first microprocessor, the Intel 4004. For the first time, artificial intelligence was translated into an inanimate object.

● Concrete	51.43
▲ Aggregates	92.49
■ Bricks	21.99
◆ Asphalt	12.62
▼ Metals	9.33
● Plastic, Wood & Glass	9.13

1972

Unix time, a widely use representation of time in computing which measures time by the number of seconds that have elapsed since January 1st 1970, runs from 63072000 to 94694399.

● Concrete	54.83
▲ Aggregates	97.31
■ Bricks	22.52
◆ Asphalt	13.65
▼ Metals	9.72
● Plastic, Wood & Glass	9.37

200%

100%

10%

0%

188

Gigatonnes
Total Anthropogenic Mass

197

Gigatonnes
Total Anthropogenic Mass

207

Gigatonnes
Total Anthropogenic Mass

1973

Soviet copyright law begins to recognize foreign copyrights.

All values expressed in gigatonnes.

● Concrete	58.45
▲ Aggregates	102.16
■ Bricks	23.05
◆ Asphalt	14.70
▼ Metals	10.15
● Plastic, Wood & Glass	9.64

200%

100%

10%

0%

218

Gigatonnes
Total Anthropogenic Mass

1974

Rubik's Cube puzzle, the bestselling puzzle game and bestselling toy, is invented by Hungarian architecture professor Ernő Rubik.

● Concrete	62.01
▲ Aggregates	107.21
■ Bricks	23.61
◆ Asphalt	15.81
▼ Metals	10.58
● Plastic, Wood & Glass	9.87

200%

100%

10%

0%

229

Gigatonnes
Total Anthropogenic Mass

1975

Estimated world population 4,068 million.

● Concrete	65.48
▲ Aggregates	111.94
■ Bricks	24.22
◆ Asphalt	16.85
▼ Metals	10.98
● Plastic, Wood & Glass	10.05

200%

100%

10%

0%

240

Gigatonnes
Total Anthropogenic Mass

1976

The Tangshan earthquake flattens Tangshan, China, killing 242,769 people, and injuring 164,851.

● Concrete	69.11
▲ Aggregates	116.42
■ Bricks	24.94
◆ Asphalt	17.80
▼ Metals	11.40
● Plastic, Wood & Glass	10.29

200%

100%

10%

0%

250

Gigatonnes
Total Anthropogenic Mass

1977

The rings of Uranus are discovered.

● Concrete	73.07
▲ Aggregates	120.85
■ Bricks	25.63
◆ Asphalt	18.71
▼ Metals	11.81
● Plastic, Wood & Glass	10.53

261

Gigatonnes
Total Anthropogenic Mass

1978

Romanian painter Doina Bumbea is abducted by the North Korean government.

● Concrete	77.33
▲ Aggregates	125.37
■ Bricks	26.33
◆ Asphalt	19.69
▼ Metals	12.25
● Plastic, Wood & Glass	10.78

272

Gigatonnes
Total Anthropogenic Mass

1979

A blowout at the Ixtoc I oil well in the southern Gulf of Mexico causes at least 600,000 tons of oil to be spilled into the waters, the worst oil spill to date.

All values expressed in gigatonnes.

● Concrete	81.66
▲ Aggregates	130.06
■ Bricks	26.99
◆ Asphalt	20.74
▼ Metals	13.14
● Plastic, Wood & Glass	11.04

1980

Pac-Man, the highest-earning arcade game of all time, is released in Japan.

● Concrete	85.96
▲ Aggregates	134.65
■ Bricks	27.72
◆ Asphalt	21.77
▼ Metals	13.14
● Plastic, Wood & Glass	11.28

1981

The first Coca-Cola bottling plant in China is opened.

● Concrete	90.22
▲ Aggregates	138.79
■ Bricks	28.43
◆ Asphalt	22.68
▼ Metals	13.56
● Plastic, Wood & Glass	11.51

200%

100%

10%

0%

283

Gigatonnes
Total Anthropogenic Mass

295

Gigatonnes
Total Anthropogenic Mass

305

Gigatonnes
Total Anthropogenic Mass

1982

Time magazine's Man of the Year is given, for the first time to a non-human, the computer.

1983

The lowest temperature on Earth is recorded in Vostok Station, Antarctica with -89.2 °C.

1984

The first Hackers Conference is held.

● Concrete	94.41
▲ Aggregates	142.63
■ Bricks	29.31
◆ Asphalt	23.49
▼ Metals	13.94
● Plastic, Wood & Glass	11.71

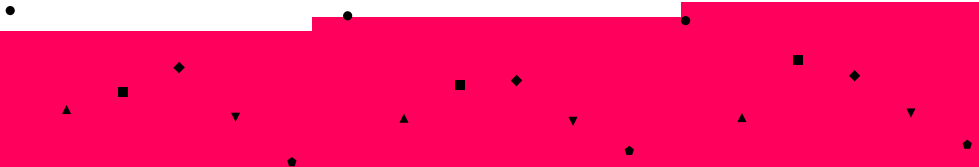
Concrete	98.70
Aggregates	146.35
Bricks	30.25
Asphalt	24.28
Metals	14.31
Plastic, Wood & Glass	11.94

Concrete	103.09
Aggregates	150.18
Bricks	31.38
Asphalt	25.12
Metals	14.73
Plastic, Wood & Glass	12.20

200%

100%

10%



0%

315

Gigatonnes
Total Anthropogenic Mass

326

Gigatonnes
Total Anthropogenic Mass

337

Gigatonnes
Total Anthropogenic Mass

1985

The ideology of Hezbollah is declared in a program issued in Beirut.

1986

Hailstones weighing 1 kilogram fall on Gopalganj District, Bangladesh, killing 92.

1987

Fluoxetine, marketed as Prozac, is approved for use as an antidepressant in the United States.

All values expressed in gigatonnes.

● Concrete	107.51
▲ Aggregates	154.03
■ Bricks	32.53
◆ Asphalt	25.95
▼ Metals	15.14
● Plastic, Wood & Glass	12.45

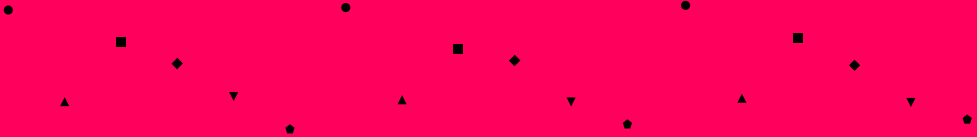
Concrete	112.18
Aggregates	158.03
Bricks	33.69
Asphalt	26.82
Metals	15.56
Plastic, Wood & Glass	12.71

Concrete	117.09
Aggregates	162.18
Bricks	34.96
Asphalt	27.70
Metals	15.98
Plastic, Wood & Glass	13.00

200%

100%

10%



0%

348

Gigatonnes
Total Anthropogenic Mass

359

Gigatonnes
Total Anthropogenic Mass

371

Gigatonnes
Total Anthropogenic Mass

1988

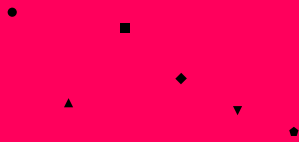
The cargo ship Khian Sea deposits 4,000 tons of toxic waste in Haiti after wandering around the Atlantic for sixteen months.

● Concrete	122.35
▲ Aggregates	166.70
■ Bricks	36.43
◆ Asphalt	28.61
▼ Metals	16.43
● Plastic, Wood & Glass	13.29

200%

100%

10%



0%

384

Gigatonnes
Total Anthropogenic Mass

1989

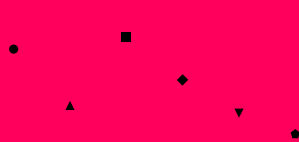
Richard C. Duncan introduces the Olduvai theory, which states that the current industrial civilization would have a maximum duration of one hundred years, counted from 1930.

● Concrete	127.00
▲ Aggregates	171.26
■ Bricks	37.90
◆ Asphalt	29.54
▼ Metals	16.88
● Plastic, Wood & Glass	13.58

200%

100%

10%



0%

396

Gigatonnes
Total Anthropogenic Mass

1990

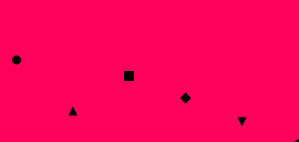
The first known web page is written.

● Concrete	131.57
▲ Aggregates	175.76
■ Bricks	39.50
◆ Asphalt	30.40
▼ Metals	17.32
● Plastic, Wood & Glass	13.85

200%

100%

10%



0%

408

Gigatonnes
Total Anthropogenic Mass

1991

Ukraine becomes the first post-Soviet republic to decriminalize homosexuality.

All values expressed in gigatonnes.

● Concrete	137.01
▲ Aggregates	180.73
■ Bricks	40.80
◆ Asphalt	31.43
▼ Metals	17.73
● Plastic, Wood & Glass	14.09

200%

100%

10%

0%

422

Gigatonnes
Total Anthropogenic Mass

1992

STS-45: Space Shuttle Atlantis takes off from Cape Canaveral carrying instruments designed to study global warming.

● Concrete	141.92
▲ Aggregates	186.04
■ Bricks	42.26
◆ Asphalt	32.48
▼ Metals	18.14
● Plastic, Wood & Glass	14.29

200%

100%

10%

0%

435

Gigatonnes
Total Anthropogenic Mass

1993

A bug in a program sends an article to 200 newsgroups simultaneously. The term spamming is coined by Joel Furr to describe the incident.

● Concrete	147.87
▲ Aggregates	191.54
■ Bricks	43.88
◆ Asphalt	33.53
▼ Metals	18.54
● Plastic, Wood & Glass	14.50

200%

100%

10%

0%

450

Gigatonnes
Total Anthropogenic Mass

1994

Serial Killer Jeffery Dahmer is baptised in prison.

1995

Sudden oak death, the tree disease caused by the plant pathogen *Phytophthora ramorum*, is first observed in California (US).

1996

Sildenafil (Viagra), a treatment for erectile dysfunction, is patented by Pfizer.

● Concrete	154.27
▲ Aggregates	197.21
■ Bricks	45.59
◆ Asphalt	34.56
▼ Metals	18.95
● Plastic, Wood & Glass	14.71

Concrete	161.03
Aggregates	203.38
Bricks	48.25
Asphalt	35.57
Metals	19.38
Plastic, Wood & Glass	14.93

Concrete	168.00
Aggregates	209.37
Bricks	50.75
Asphalt	36.56
Metals	19.80
Plastic, Wood & Glass	15.14

200%

100%

10%

0%

465

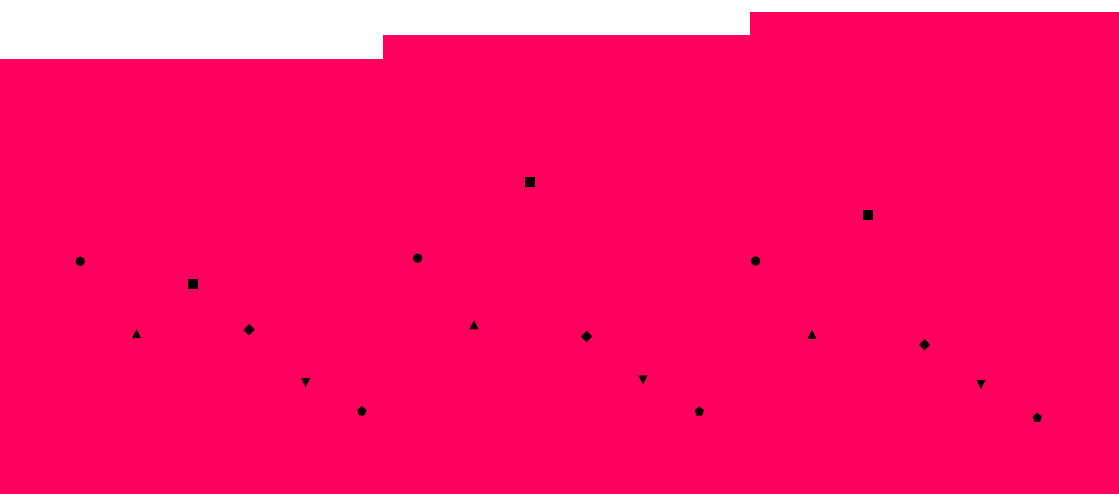
Gigatonnes
Total Anthropogenic Mass

483

Gigatonnes
Total Anthropogenic Mass

500

Gigatonnes
Total Anthropogenic Mass



1997

The domain name for the web search engine Google is registered.

All values expressed in gigatonnes.

● Concrete	175.22
▲ Aggregates	215.57
■ Bricks	53.03
◆ Asphalt	37.62
▼ Metals	20.24
● Plastic, Wood & Glass	15.39

200%

100%

10%

0%

517

Gigatonnes
Total Anthropogenic Mass

1998

Ibrahim Hanna, the last native speaker of Mlahsô, dies in Qamishli, Syria, making the language effectively extinct.

● Concrete	182.22
▲ Aggregates	222.33
■ Bricks	55.67
◆ Asphalt	38.77
▼ Metals	20.68
● Plastic, Wood & Glass	15.59

200%

100%

10%

0%

535

Gigatonnes
Total Anthropogenic Mass

1999

The Melissa worm, a mass-mailing macro virus released on or around March 26, attacks the Internet.

● Concrete	189.48
▲ Aggregates	229.17
■ Bricks	58.25
◆ Asphalt	39.92
▼ Metals	21.11
● Plastic, Wood & Glass	15.83

200%

100%

10%

0%

554

Gigatonnes
Total Anthropogenic Mass

2000

The last naturally-conceived Pyrenean ibex is found dead, apparently killed by a falling tree.

2001

Bratz, an American fashion doll and mass media franchise debuted on May 21.

2002

Clozapine is the first drug approved by the United States Food and Drug Administration for reducing the risk of suicidal behaviour.

● Concrete	197.02
▲ Aggregates	236.02
■ Bricks	60.76
◆ Asphalt	41.12
▼ Metals	21.58
● Plastic, Wood & Glass	16.07

Concrete	205.03
Aggregates	242.59
Bricks	62.97
Asphalt	42.26
Metals	22.05
Plastic, Wood & Glass	16.29

Concrete	213.55
Aggregates	249.06
Bricks	64.81
Asphalt	43.39
Metals	22.54
Plastic, Wood & Glass	16.54

200%

100%

10%

0%

573

Gigatonnes
Total Anthropogenic Mass

591

Gigatonnes
Total Anthropogenic Mass

610

Gigatonnes
Total Anthropogenic Mass

2003

Dennis Schmitt discovers the island of 83-42 in the Artic Ocean, a candidate for being the northernmost point of land.

All values expressed in gigatonnes.

● Concrete	223.07
▲ Aggregates	255.81
■ Bricks	66.75
◆ Asphalt	44.54
▼ Metals	23.09
● Plastic, Wood & Glass	16.82

2004

According to a study published in Nature, trees have a theoretical maximum height of 130 m before gravity restricts their growth.

● Concrete	233.57
▲ Aggregates	262.90
■ Bricks	68.38
◆ Asphalt	45.87
▼ Metals	23.69
● Plastic, Wood & Glass	17.14

2005

The first ever YouTube video is uploaded, titled Me at the zoo. Meanwhile another second is added to the end of the year 2005, the first time since 1998.

● Concrete	244.88
▲ Aggregates	270.14
■ Bricks	70.00
◆ Asphalt	47.24
▼ Metals	24.35
● Plastic, Wood & Glass	17.47

200%

100%

10%

0%

630

Gigatonnes
Total Anthropogenic Mass

652

Gigatonnes
Total Anthropogenic Mass

674

Gigatonnes
Total Anthropogenic Mass

2006

British Petroleum introduces the first 'carbon footprint calculator', which allows consumers to assess their impact on the environment, translating the public narrative about climate protection from the fossil fuel industry to the citizens.

● Concrete	257.81
▲ Aggregates	277.67
■ Bricks	71.60
◆ Asphalt	48.67
▼ Metals	25.09
● Plastic, Wood & Glass	17.84

2007

Gliese 581c, a potentially Earth-like extrasolar planet habitable for life, is discovered in the constellation Libra. Estimated world population: 6,629 million.

● Concrete	271.78
▲ Aggregates	285.25
■ Bricks	73.15
◆ Asphalt	50.08
▼ Metals	25.91
● Plastic, Wood & Glass	18.21

2008

2008 was designated as the International Year of the Potato.

● Concrete	285.77
▲ Aggregates	292.57
■ Bricks	74.64
◆ Asphalt	51.41
▼ Metals	26.72
● Plastic, Wood & Glass	18.54



699

Gigatonnes
Total Anthropogenic Mass

724

Gigatonnes
Total Anthropogenic Mass

750

Gigatonnes
Total Anthropogenic Mass

2009

Bolivia becomes the first South American country to declare the right of indigenous people to govern themselves.

All values expressed in gigatonnes.

● Concrete	300.91
▲ Aggregates	299.73
■ Bricks	76.16
◆ Asphalt	52.64
▼ Metals	27.49
● Plastic, Wood & Glass	18.78

200%

100%

10%

0%

776

Gigatonnes
Total Anthropogenic Mass

2010

Volcanic ash from one of several eruptions beneath Mount Eyjafjallajökull, an ice cap in Iceland, begins to disrupt air traffic across northern and western Europe.

● Concrete	317.29
▲ Aggregates	307.12
■ Bricks	77.65
◆ Asphalt	53.85
▼ Metals	28.37
● Plastic, Wood & Glass	19.11

200%

100%

10%

0%

803

Gigatonnes
Total Anthropogenic Mass

2011

This year, the nation of Samoa only had 364 days.

● Concrete	335.82
▲ Aggregates	314.73
■ Bricks	79.07
◆ Asphalt	55.00
▼ Metals	29.32
● Plastic, Wood & Glass	19.46

200%

100%

10%

0%

833

Gigatonnes
Total Anthropogenic Mass

2012

Kwangmyöngsöng-3, a North Korean Earth observation satellite, explodes shortly after launch.

2013

Philippines climate negotiator Naderev "Yeb" Saño of the Philippines announced to COP 19's plenary session that he will conduct a hunger strike for the remainder of the UN climate summit in Warsaw.

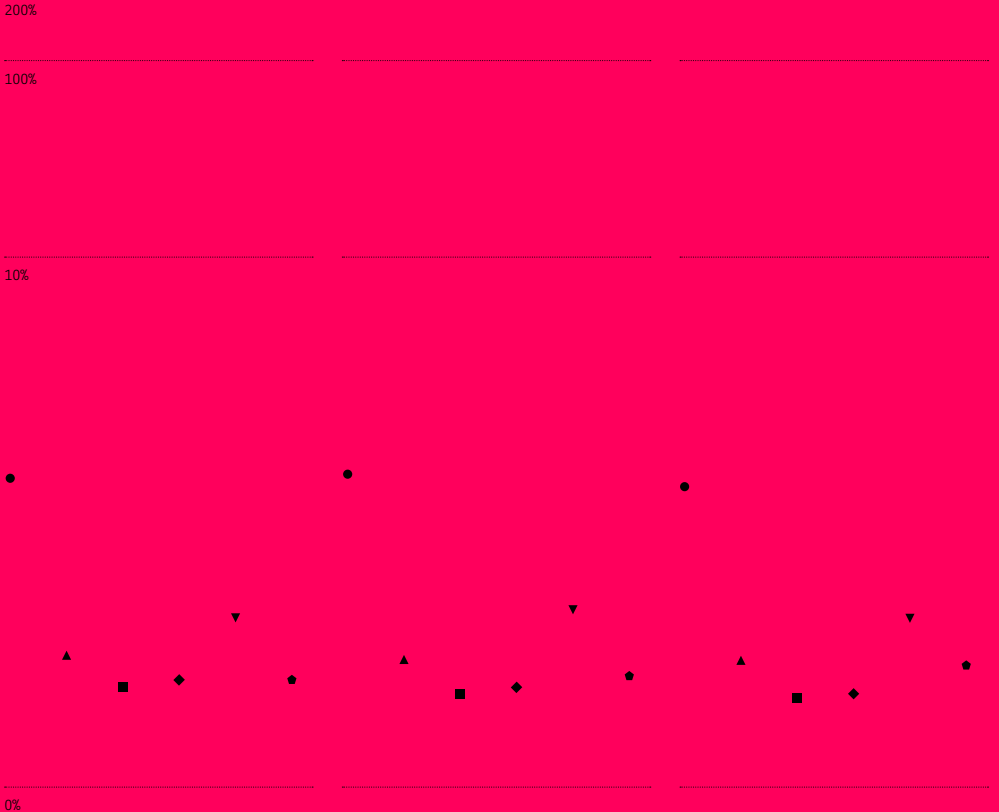
2014

A study published by the University of Queensland, states that an office enriched with plants makes staff happier and boosts productivity by 15%.

● Concrete	355.10
▲ Aggregates	322.28
■ Bricks	80.50
◆ Asphalt	56.08
▼ Metals	30.28
● Plastic, Wood & Glass	19.83

Concrete	375.76
Aggregates	329.75
Bricks	81.84
Asphalt	57.10
Metals	31.32
Plastic, Wood & Glass	20.23

Concrete	396.74
Aggregates	337.35
Bricks	83.15
Asphalt	58.08
Metals	32.35
Plastic, Wood & Glass	20.68



864

Gigatonnes
Total Anthropogenic Mass

896

Gigatonnes
Total Anthropogenic Mass

928

Gigatonnes
Total Anthropogenic Mass

2015

Researchers have extended the lifespan of fruit flies by 60% using a method that could one day lead to anti-aging treatments for humans.

2016

The last videocassette recorder is manufactured by the Japanese company Funai.

2017

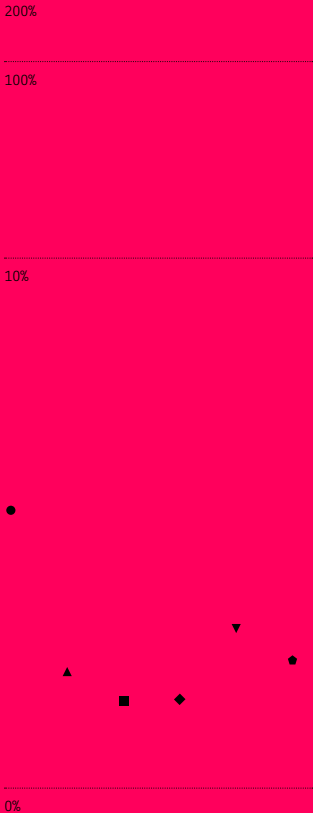
Donald Trump announces that the United States is to withdraw from the Paris Agreement,

All values expressed in gigatonnes.

● Concrete	417.20
▲ Aggregates	344.46
■ Bricks	84.43
◆ Asphalt	59.01
▼ Metals	33.35
● Plastic, Wood & Glass	21.16

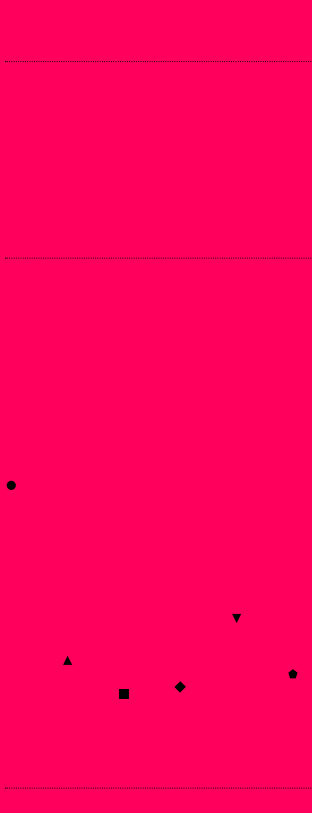
● Concrete	440.68
▲ Aggregates	352.46
■ Bricks	85.86
◆ Asphalt	60.10
▼ Metals	34.44
● Plastic, Wood & Glass	21.60

● Concrete	465.48
▲ Aggregates	360.64
■ Bricks	87.31
◆ Asphalt	61.22
▼ Metals	35.57
● Plastic, Wood & Glass	22.05



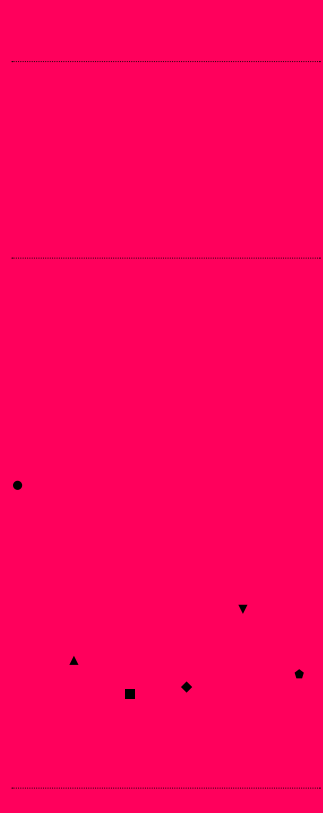
960

Gigatonnes
Total Anthropogenic Mass



995

Gigatonnes
Total Anthropogenic Mass



1032

Gigatonnes
Total Anthropogenic Mass

2018

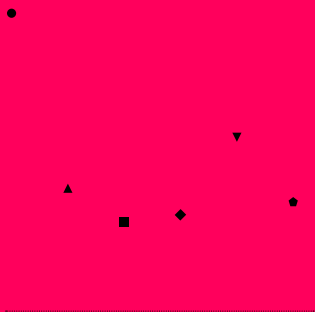
Cinemas open in Saudi Arabia for the first time since 1983 with the American film Black Panther chosen as the first to be screened.

● Concrete	491.67
▲ Aggregates	369.01
■ Bricks	88.78
◆ Asphalt	62.35
▼ Metals	36.74
● Plastic, Wood & Glass	22.50

200%

100%

10%



0%

1071

Gigatonnes
Total Anthropogenic Mass

2019

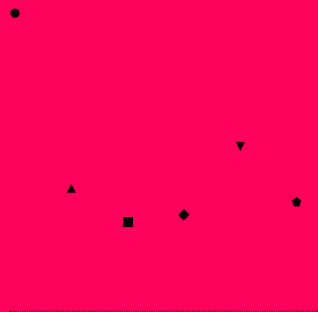
The consensus among research scientists on anthropogenic global warming grew to 100%.

● Concrete	519.34
▲ Aggregates	377.58
■ Bricks	90.28
◆ Asphalt	63.50
▼ Metals	37.95
● Plastic, Wood & Glass	22.97

200%

100%

10%



0%

1112

Gigatonnes
Total Anthropogenic Mass

2020

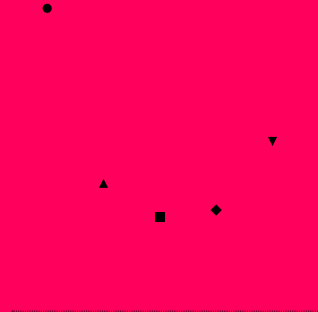
Time magazine used its sixth ever Red X cover to declare 2020 "the worst year ever".

● Concrete	548.57
▲ Aggregates	386.34
■ Bricks	91.80
◆ Asphalt	64.68
▼ Metals	39.19
● Plastic, Wood & Glass	23.44

200%

100%

10%



0%

1154

Gigatonnes
Total Anthropogenic Mass

A SILENT OPERA FOR ANTHROPOGENIC MASS

An online version of this
libretto is available here:

[https://janavirgin.com/
OPERA/libretto.pdf](https://janavirgin.com/OPERA/libretto.pdf)



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A project by Joana Moll

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All the data used in this project comes from the repository that contains all source data and code for the analysis found in "Global human-made mass exceeds all living biomass" by Emily Elhacham, Liad Ben Uri, Jonathan Grozovski, Yinon M. Bar-On, and Ron Milo." - Elhacham, E., Ben-Uri, L., Grozovski, J. *et al.* Global human-made mass exceeds all living biomass. *Nature* 588, 442-444 (2020). doi.org/10.1038/s41586-020-3010-5.