Dynamics of atmospheric oxygen under anthropogenic stresses

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Scripps O_2 Program

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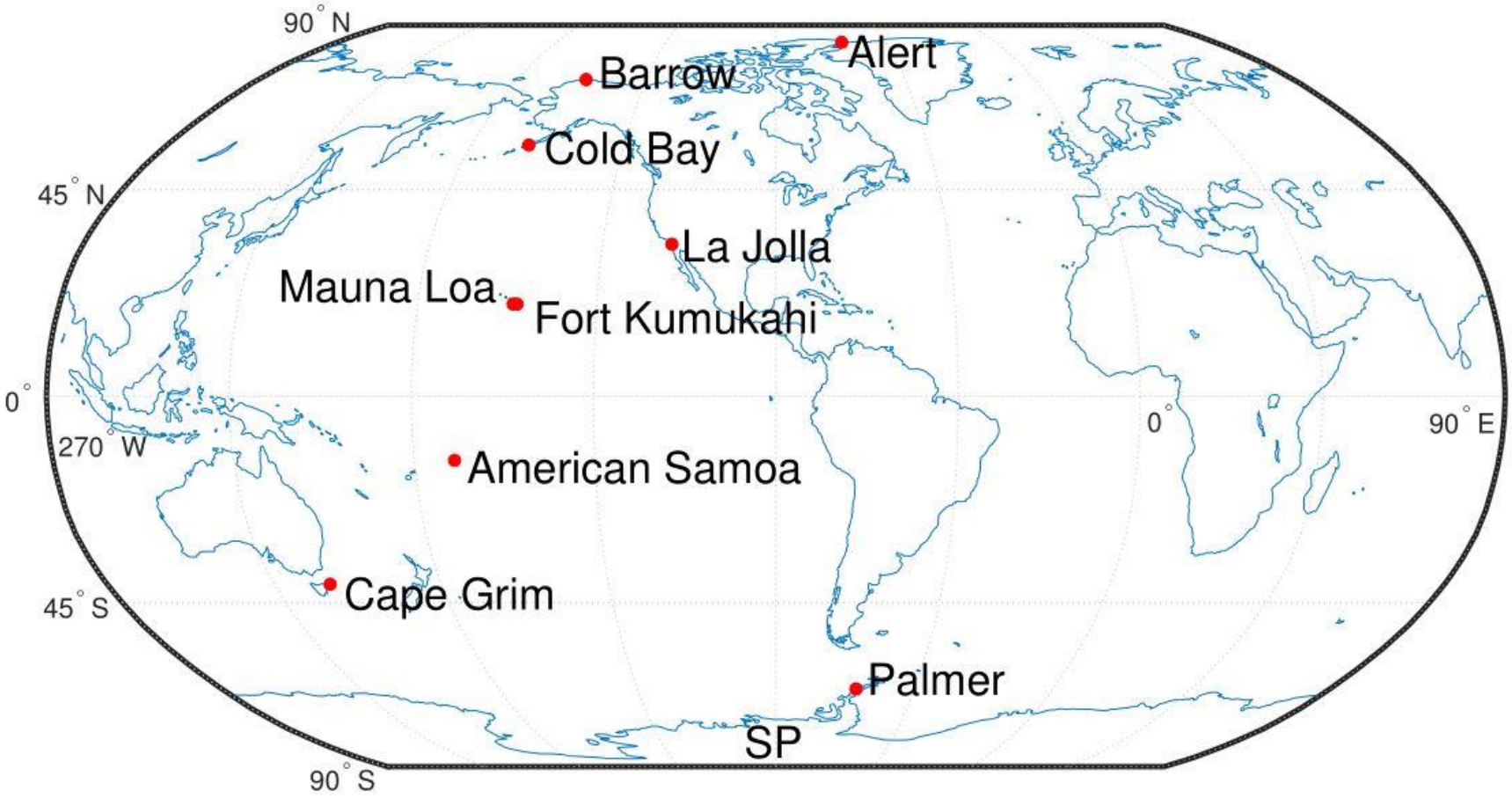
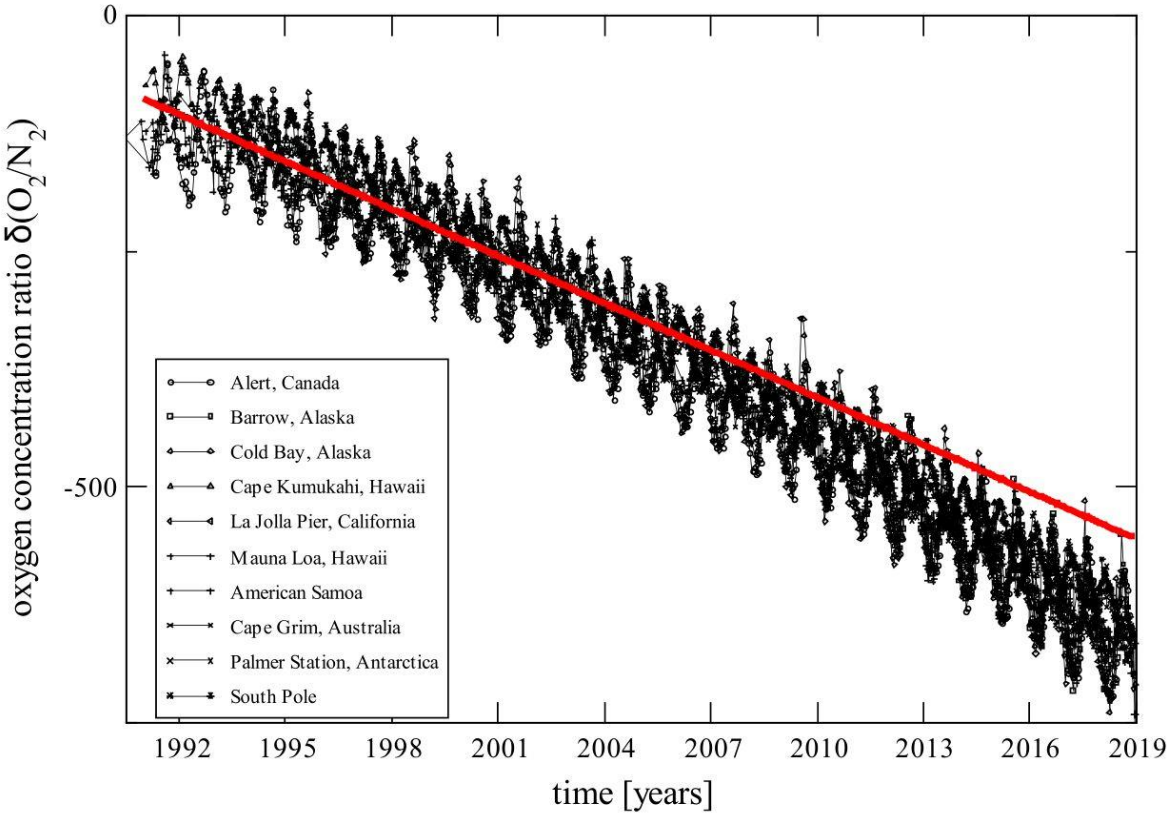


http://scrippso2.ucsd.edu/

Observed oxygen time series



$$\delta = ((O_2/N_2)_{sample} - (O_2/N_2)_{reference})/(O_2/N_2)_{reference},$$

where $(O_2/N_2)_{sample}$ is the mole ratio of an air sample, and $(O_2/N_2)_{reference}$ is the mole ratio of the stored reference (mid-1980s samples stored at Scripps)

Red line denotes linear fit of the first 10 years of observations

Atmospheric oxygen is declining nonlinearly

Industrial use of oxygen

Indirect use of oxygen (energy-demanding production)	**Direct use of oxygen** (oxygen-demanding production)
Metallurgy (power supply)	Metallurgy (combustion and coal gasification)
Transport (electricity-based)	Transport (petrol-based)
Fossil-fuel electricity supply	Oxyfuels in glass manufacturing
Fossil-fuel heat supply	Pharmaceutical ammoxidation
Fertilisers production	Food and farm industry (oxygenation)
Petrochemical production	Aeration in wastewater treatment
Cement production	Construction industry (welding)
Seawater desalination	Medical supply of oxygen
Hydrogen production	Bleaching of fibres (delignification)

Fossil fuels used for energy production, with consumption of oxygen and carbon emissions

Oxygen consumed directly, often in purified form, not necessarily with carbon emissions

Most resource-demanding industries: cement, ceramics, chemicals, food & drink, glass, iron & steel, oil refining, pulp & paper (Industrial Decarbonisation and Energy Efficiency Action Plans, BEIS UK 2017)

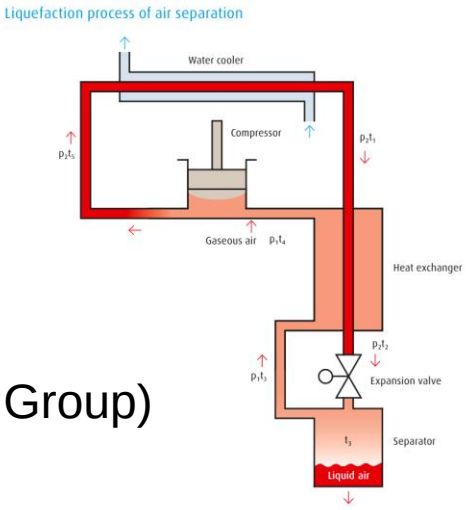
How is industrial oxygen obtained?

Industrial Air Separation Units (ASU)

Global ASU capacity

Major industrial players:

- Linde
- Praxair
- Air Liquide (including Airgas)
- Air Products (including Yingde Gases Group)



Global sales of industrial oxygen in 2018: **380 million tonnes**

The current approximate number of ASUs is 20000 units, each of average capacity 100 tonnes per day of oxygen (although some reach 6000 tpd)

Air separation technology currently drains atmospheric oxygen content by about $[2 \ldots 3] \times 10^{13}$ moles per year

Updated oxygen budget
reservoirs and fluxes

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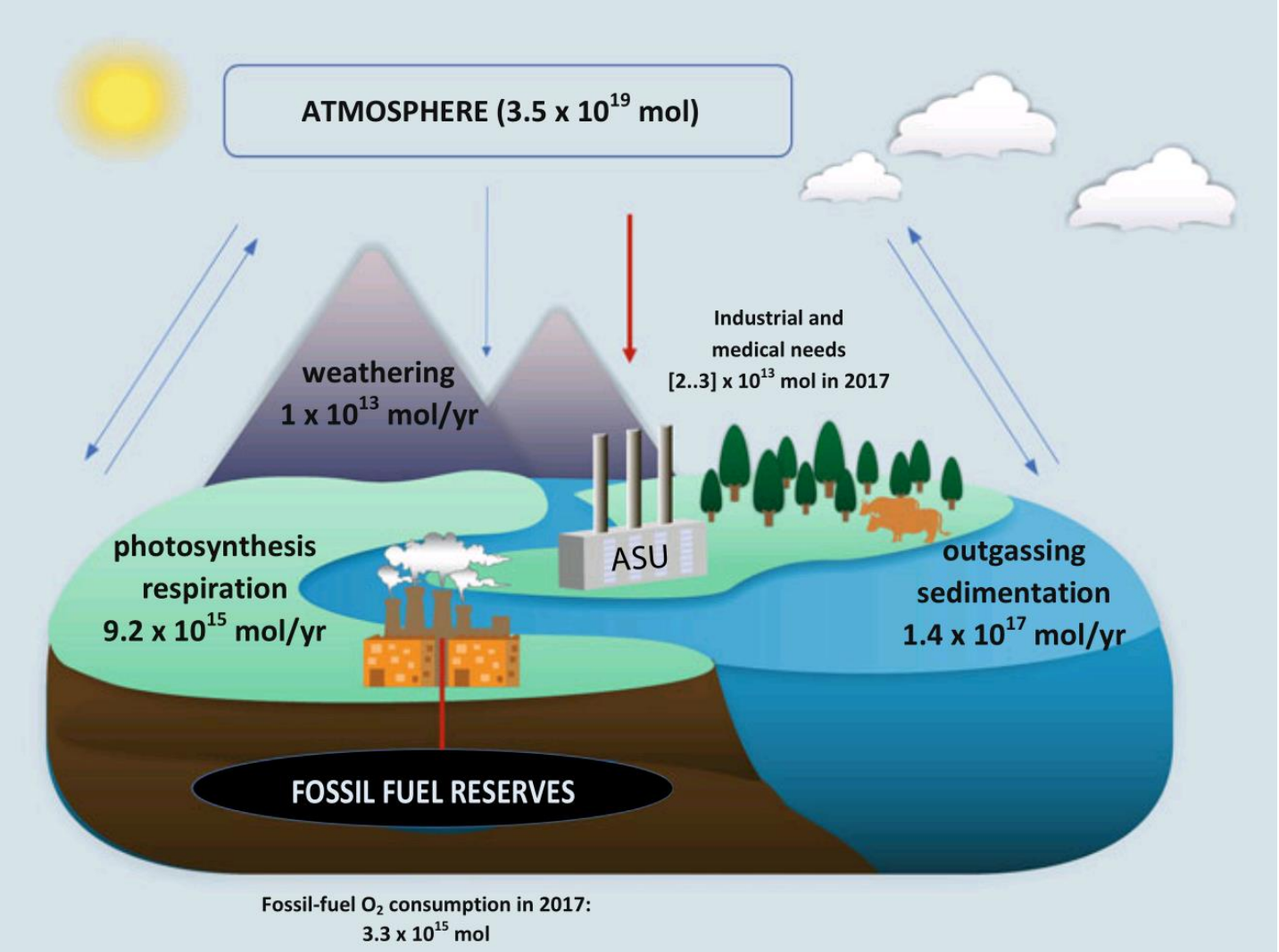
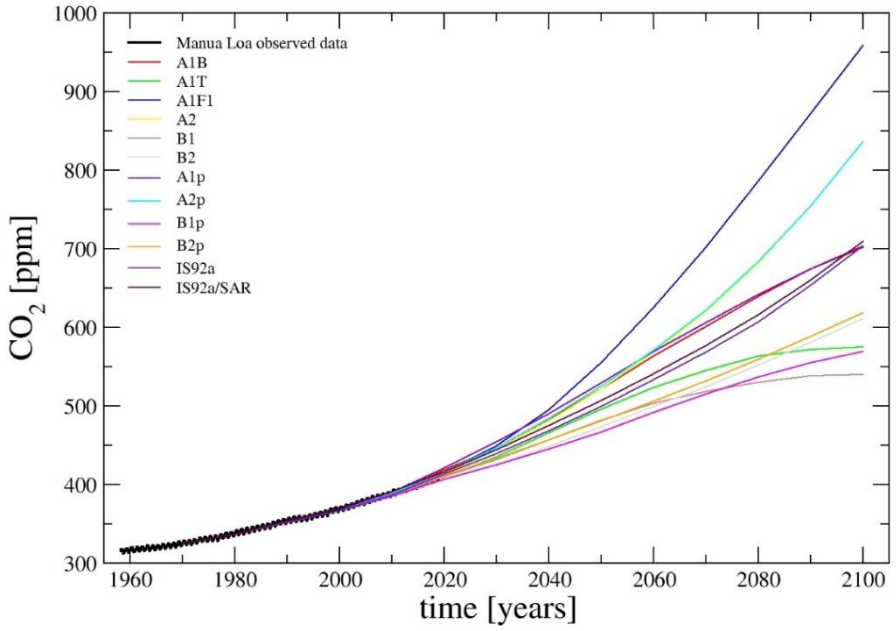
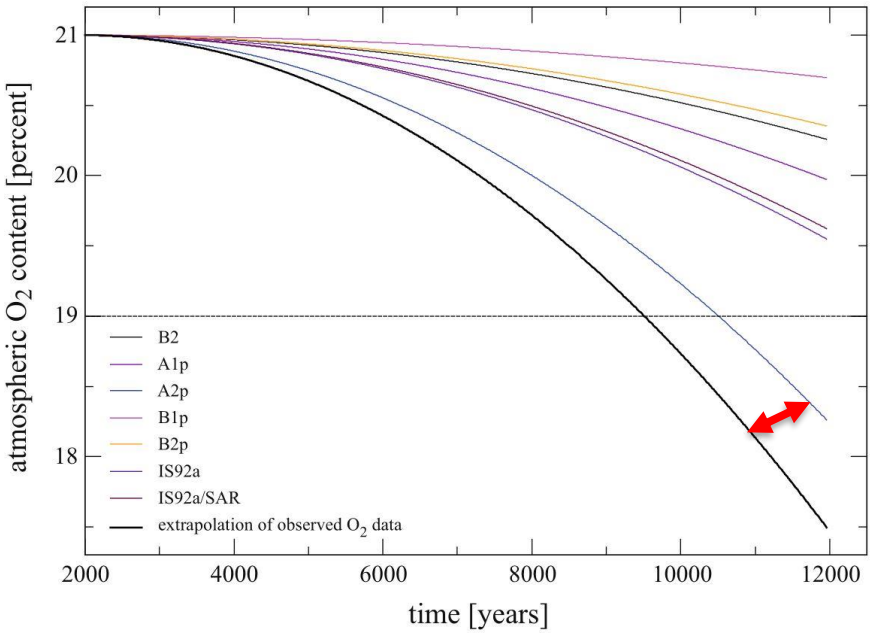


Keeling et al, 1993; Petsch, 2014; Livina & Vaz Martins 2020

Oxygen projections





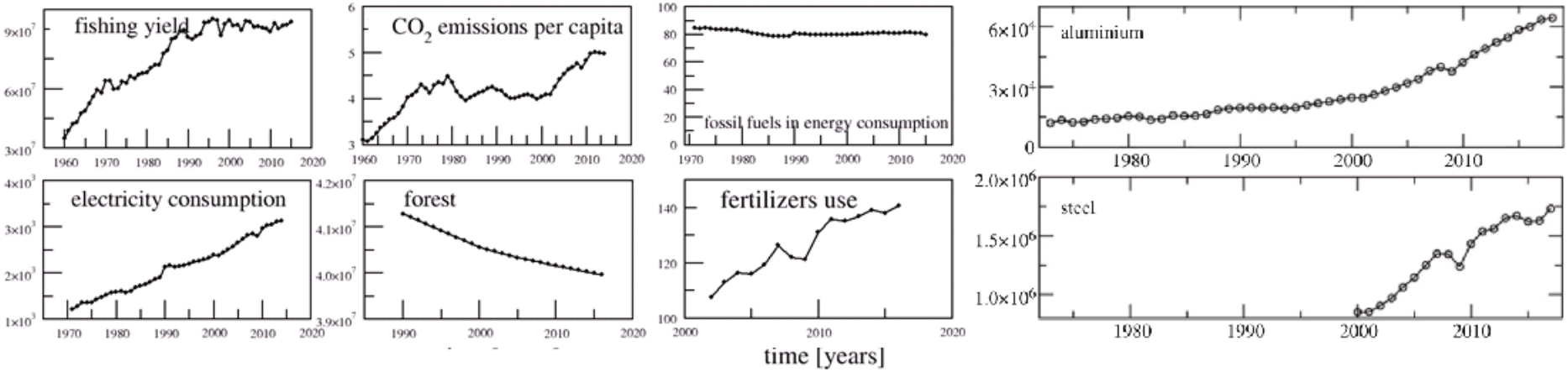
SRES IPCC-TAR CO_2 scenarios

Oxygen projections

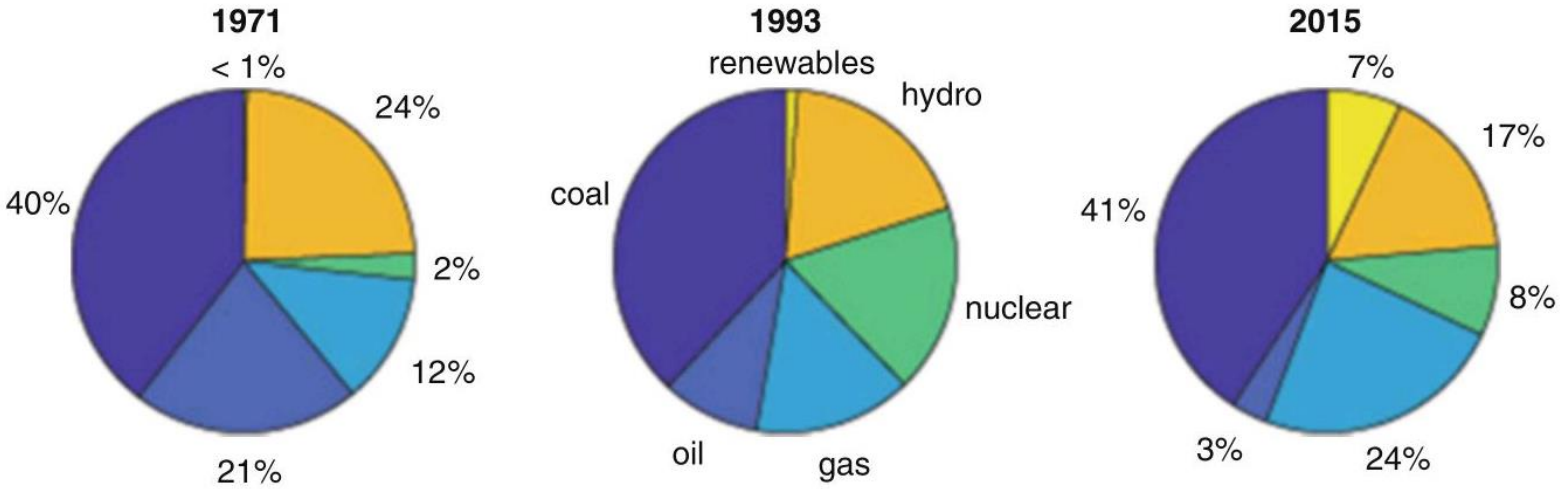
Projection based on extrapolation of observed data shows faster oxygen decline than the extrapolation of the worst SRES IPCC-TAR scenario

Difference may indicate the new sink of oxygen

Global use of resources

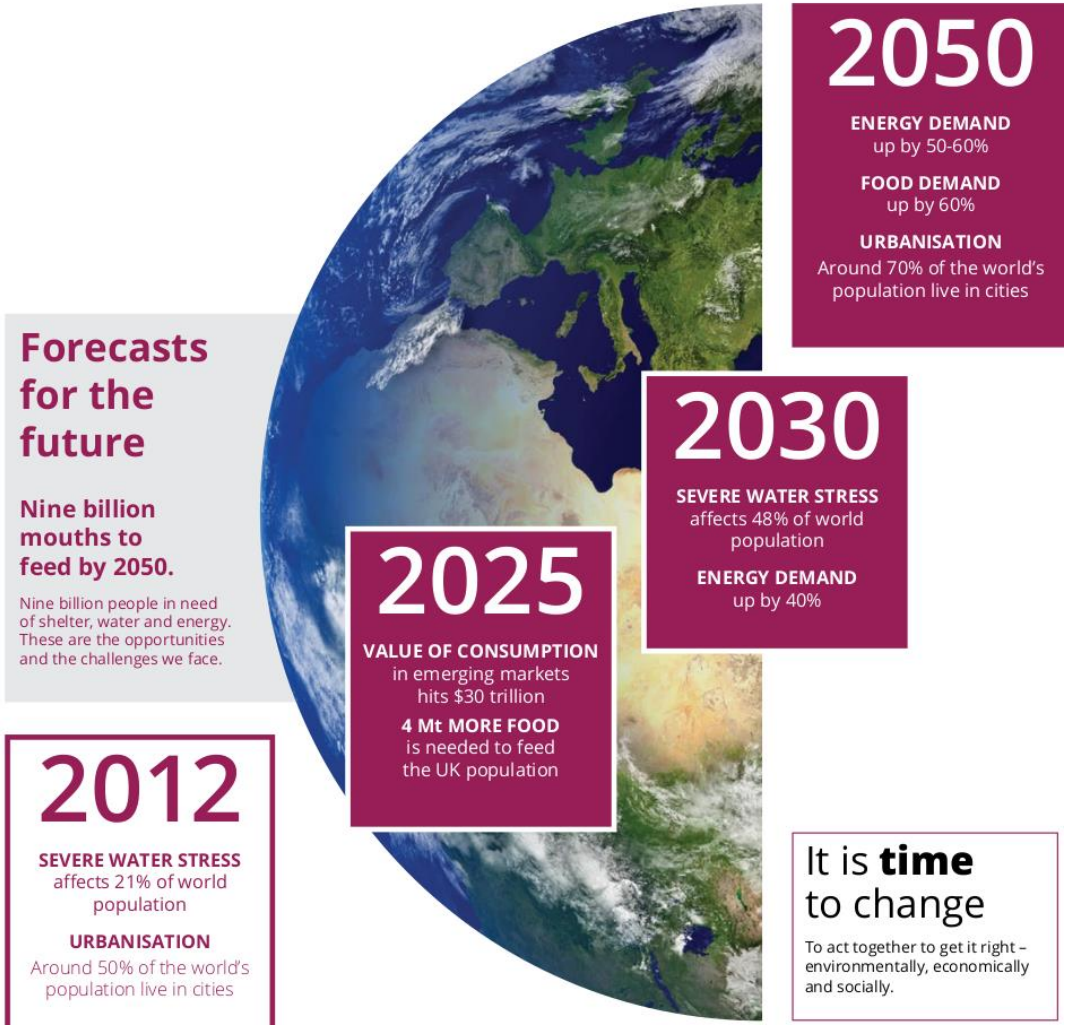


Source: World Bank Data Portal



Electricity generation based on different fuel sources (% of total). The three blue sectors corresponding to fossil fuels remain almost unchanged for the past 40 years.

Anthropogenic stresses



Timescales of stresses

Diminishing fresh water
Depleting soils
Rising temperature
Increasing emissions
Decreasing ocean oxygen
Decreasing atmospheric oxygen

Source: The Waste and Resources Action Plan

Circular economy, responsible consumption

The Waste and Resources Action Plan
WRAP https://www.wrap.org.uk/

engages the society in recycling technologies to prepare for circular economy

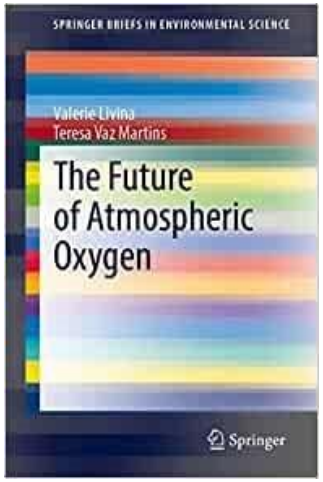
“Love Food Hate Waste” (https://www.lovefoodhatewaste.com/),
“LoveYourClothes” (https://www.loveyourclothes.org.uk/),
“RecycleNow” (https://www.recyclenow.com/)

Summary

- Atmospheric oxygen is declining nonlinearly
- Anthropogenic use of oxygen is both direct and indirect
- ASU impact is comparable with natural weathering
- Challenges of life-cycle assessment of technologies
- Need of modelling resources use for circular economy

The results of the analysis are in press:

Livina V. and T. Vaz Martins,
The future of atmospheric oxygen,
SpringerBriefs in Environmental Sciences, 2020



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Thank you