EMS717U/EMS717P

Renewable Energy Sources

Introduction

Prof. Huasheng Wang

Introduction

Content

- **Evidences of climate change and global warming**
- **Global energy scene from past to present**
- **Renewable and non-renewable energies**
- **Emissions of GHSs**
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- **Modelling and prediction of climate change**
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Introduction

Air pollution 1950s

Introduction

2014, Beijing

Introduction

Air pollution in London

Latest air pollution levels for South East

Last updated at 11:00 on 24th January 2017

Agglomerations in the South East area:

- Portsmouth Urban Area **Low (3)**
- Brighton/Worthing/Littlehampton **Low (2)**

In towns and cities near busier roads

Pollution is currently: High (Index 8)

1 2 3 4 5 6 7 **8** 9 10

Elsewhere in towns and cities

Pollution is currently: High (Index 7)

1 2 3 4 5 6 **7** 8 9 10

In rural areas

Pollution is currently: High (Index 7)

1 2 3 4 5 6 **7** 8 9 10

Introduction

Air pollution in London

'Filthy air' prompts 'very high' pollution alert for London

23 January 2017 | London

A "very high" air pollution warning has been issued for London for the first time under a new alert system.

Warnings are being issued at bus stops, roadside signs and Tube stations under the new system set up by London Mayor Sadiq Khan.

The rise has been attributed to cold, calm and settled weather, meaning winds are not dispersing local pollutants.

The mayor said "the shameful state of London's toxic air" meant he had to trigger the alert.

"This is the highest level of alert and everyone - from the most vulnerable to the physically fit - may need to take precautions to protect themselves from the filthy air," he said.

A spike in pollution on Sunday was the highest level recorded since April 2011.

London air pollution

9,400

Premature deaths a year in London linked to air pollution

500,000 aged under 19 who live in areas that breach EU limits

http://www.bbc.co.uk/news/uk-england-london-38716498 1/8

SOMETHING IN THE AIR What is toxic air pollution, where in London has the worst smog, what does it do to your lungs and should you stay indoors?

> Londoners were warned the air pollution could raise to "high" in parts of the capital for a number of days

By TOM GILLESPIE, ELLIE CAMBRIDGE AND AMANDA DEVLIN
8th February 2017, 10:00 am | Updated: 8th February 2017, 6:37 pm

COMMENT NOW

LONDON is on high alert after a number of severe smog warnings throughout the capital.

The Mayor of London Sadiq Khan last week issued a warning and urged millions of Londoners to protect their health by taking it easy.

And it has now emerged pupils at a London school may be given face masks to protect them from the toxic air.

What is toxic air pollution and how is it caused?

Hazardous pollutants from industrial facilities can have serious negative health impacts as they are released into the air.

In January 2017 cloud pollution from an industrial area of Germany settled over the city.

The main pollution problem in both developed and and rapidly industrialising countries has been high levels of smoke and sulphur dioxide – emitted through the combustion of sulphur-containing fossil fuels such as coal.

Petrol and diesel-engine vehicles emit several types of pollutants such as carbon monoxide, oxides of nitrogen, volatile organic compounds, and particulate matter.

In general pollution from industry is steady or improving with time, however the consequences of traffic pollution are worsening with time.

By January 19, 2017, London had already breached its legal limits for toxic air for the entire year.

The quality of air pollution in London is thought to be contributing to about 9,000 deaths every year.

Introduction

Air pollution in London

theguardian

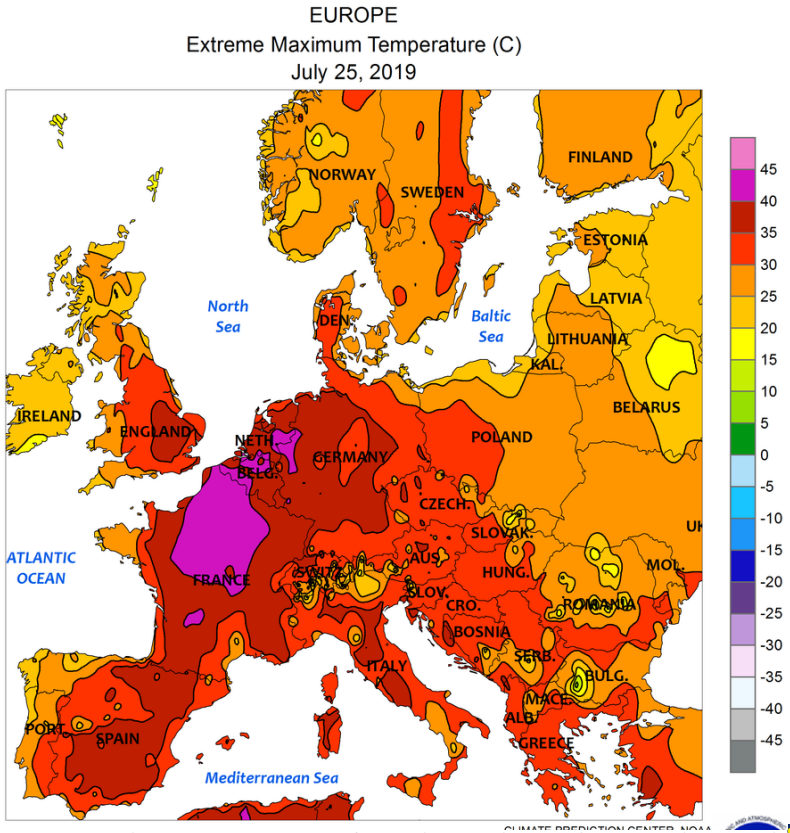
'Filthy glamour': could polluted Marylebone Road help fix London's air?

Marylebone Road has the odd distinction of being the world's most studied road in terms of air pollution – yet remains a chief culprit in London's 'shameful' air quality. Now it's home to a series of new experiments

'You can taste the pollution' ... London's Marylebone Road. Photograph: Martin Godwin for the Guardian

Introduction

Heat wave 2019



News › UK

UK heatwave 2019: 'Record broken' for Britain's hottest ever day as Met Office says mercury hit 38.7C

PATRICK GRAFTON-GREEN | Friday 26 July 2019 15:21 | 0 comments

A temperature of 38.7C was recorded in the UK on Thursday, appearing to break the record for the hottest ever day.

The recording at Cambridge Botanic Gardens, which the Met Office says is provisional and requires verification, would outstrip the previous record high of 38.5C, recorded in 2003.

Forecasters previously confirmed Thursday was the hottest July day on record, with a temperature of 38.1C, also recorded in Cambridge, surpassing the previous high of 36.7C set at Heathrow Airport in 2015.

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UK heatwave: Second hottest day on record leads to travel chaos

25 July 2019

ian Search jobs Dating Sign in Search UK edition

The Guardian

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y Law Scotland Wales Northern Ireland

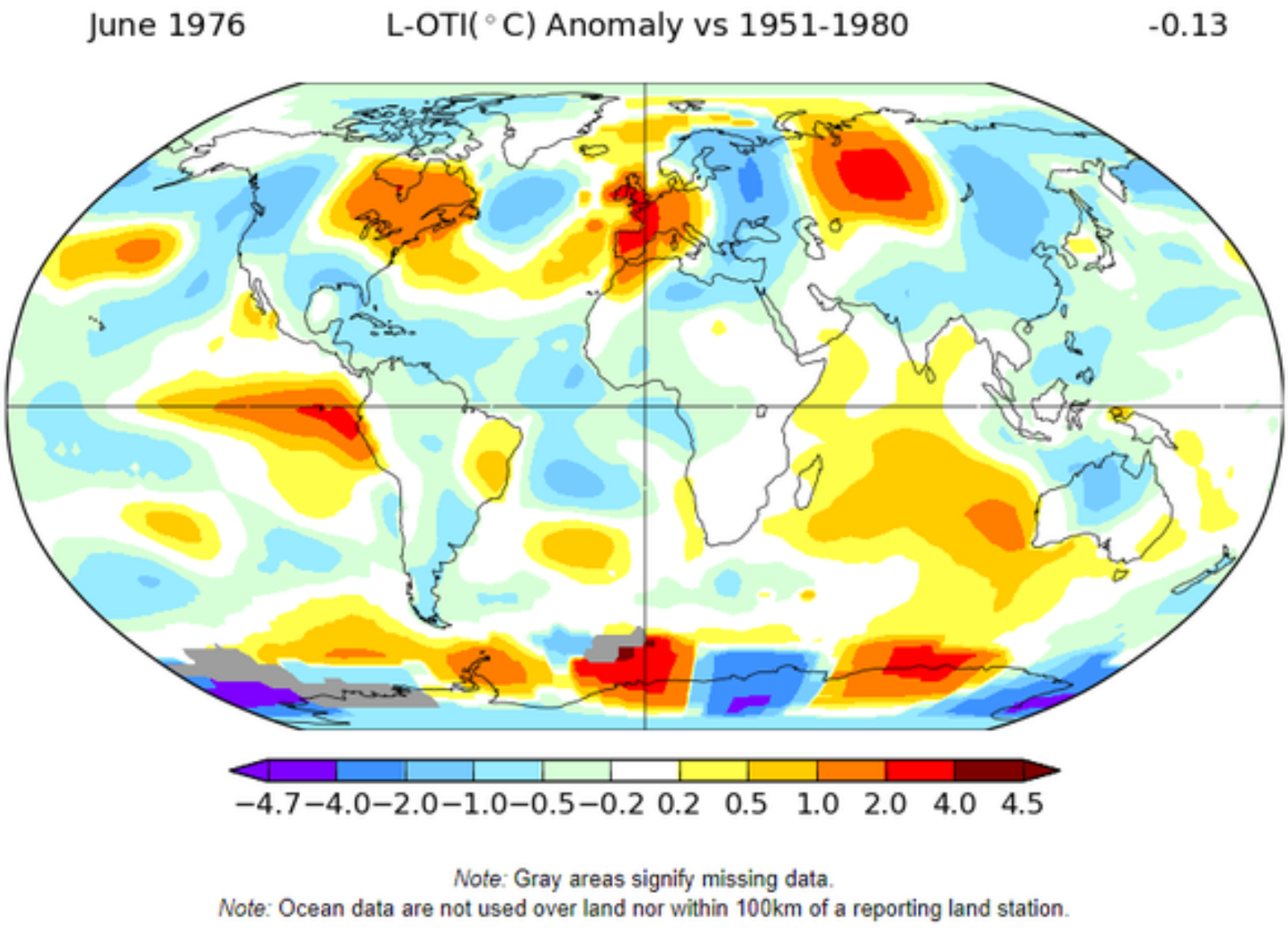
Heatwave: Paris suffers 42.6C hottest day ever as UK temperatures set July record - as it happened

Belgium, Netherlands and Germany join Paris in experiencing their hottest day ever, amid climate crisis concerns and health warnings as Europe swelters

Introduction

Extreme weather in 2022

Introduction



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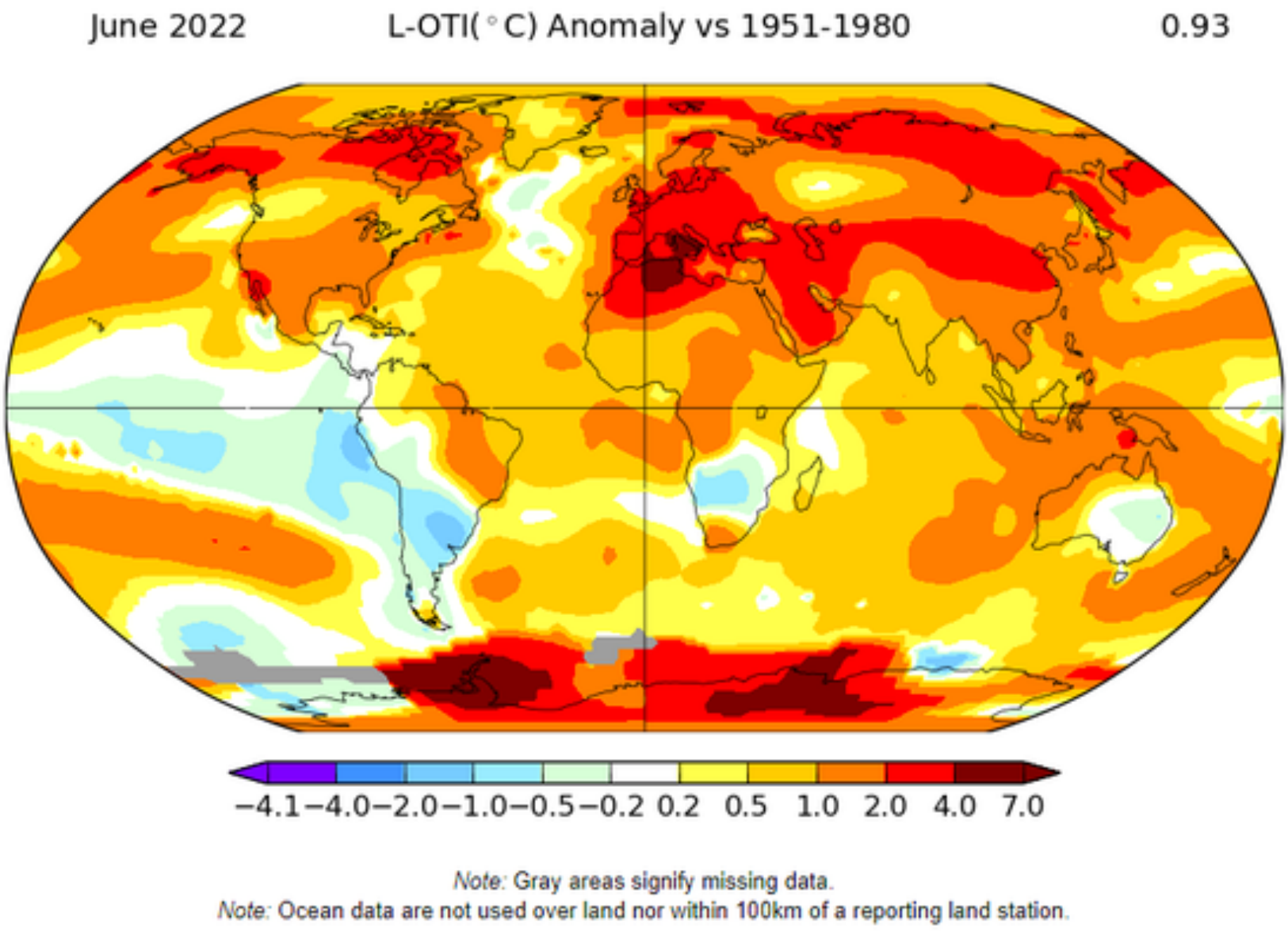


Introduction

Extreme weather in 2022

24/08/2022, 18:26 Europe drought worst in at least 500 years: EU report

WEATHER AND NATURAL DISASTERS

Europe is experiencing its worst drought in at least 500 years

PUBLISHED TUE, AUG 23 2022•11:58 AM EDT UPDATED TUE, AUG 23 2022•6:54 PM EDT

Emma Newburger
@EMMA_NEWBURGER

WATCH LIVE

KEY POINTS

Europe is experiencing its worst drought in at least 500 years, with hot and dry conditions fueling wildfires, reducing crop yields and impacting electricity generation, according to a preliminary analysis from the European Union's Joint Research Center.

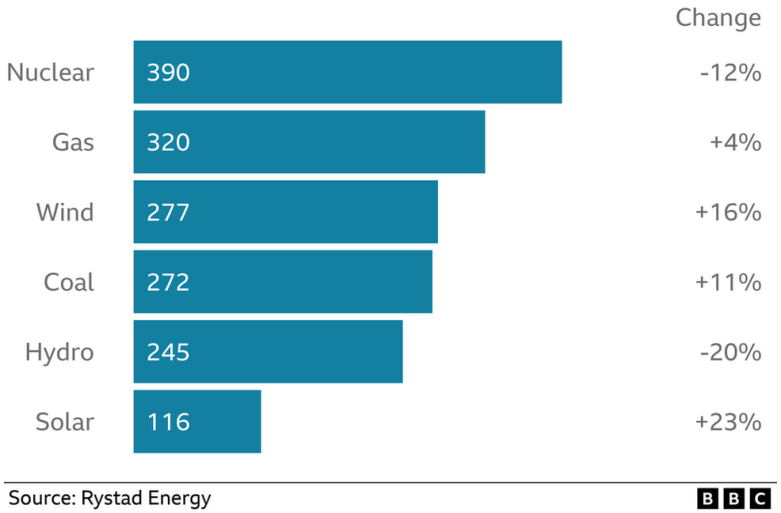
The report said that 47% of Europe is under warning conditions, with a clear deficit of soil moisture, and 17% of the continent is under a state of alert, in which vegetation is impacted.

Record-breaking temperatures in Europe this summer have disrupted transportation, displaced thousands of people and resulted in hundreds of heat-related deaths.

MARKETS CNBC TV WATCHLIST MENU

https://www.cnbc.com/2022/08/23/europe-drought-worst-in-at-least-500-years-eu-report.html 1/6

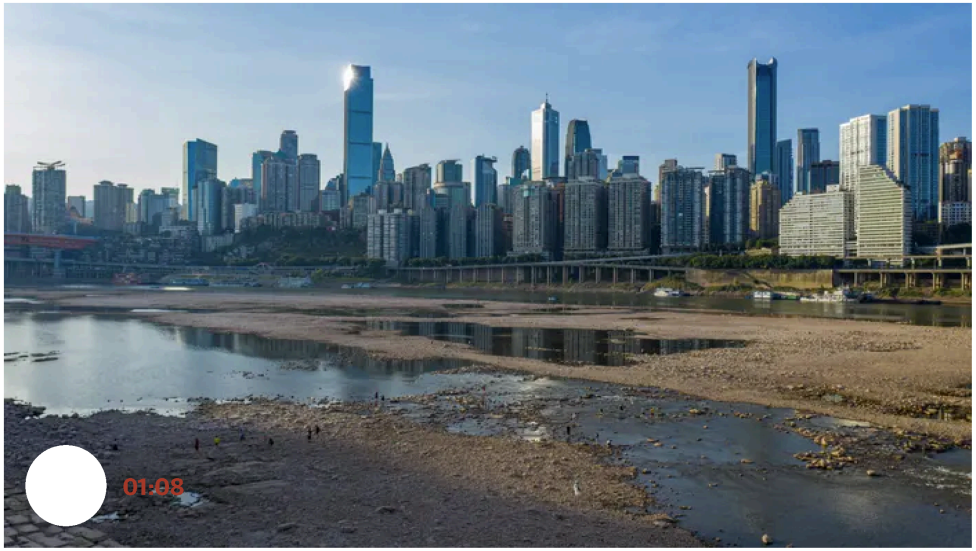
https://www.bbc.co.uk/news/science-environment-62524551



It's a similar story in Spain, where the amount of electricity generated is down 44%, according to data from energy researchers **Rystad Energy**.
"Hydropower can be quite volatile, but 40% is absolutely extreme," says Fabian Rønningen, a power analyst with Rystad.
The figures are not just down in one part of Europe, he explains, but all the big hydropower-producing countries are making less now.

Introduction

Extreme weather in 2022



China: world's third largest river dries up in drought – video

China

China drought causes Yangtze to dry up, sparking shortage of hydropower

Nationwide alert issued with south-west especially badly hit, as major companies forced to suspend work

Helen Davidson *in Taipei*

@heldavidson

Mon 22 Aug 2022 11.03 BST

A record-breaking drought has caused some rivers in China – including parts of the Yangtze – to dry up, affecting hydropower, halting shipping, and forcing major companies to suspend operations.

A nationwide drought alert was issued on Friday as a long-running and severe heatwave in China's heavily populated south-west was forecast to continue well into September.

The loss of water flow to China's extensive hydropower system has sparked a "grave situation" in Sichuan, which gets more than 80% of its energy from hydropower.

On Sunday the provincial government declared it was at the highest warning level of "particularly severe", with water flow to Sichuan's hydropower reservoirs dropping by half. The demand for electricity has increased by 25% this summer, local media reported. The reduction in hydropower has also

Introduction

2023, New York

OPINION

Editorial: Orange skies in New York? Welcome to our smoke-filled, climate-fueled future

Pedestrians pass One World Trade Center, center, on Wednesday as the air is filled with smoke from wildfires in Canada. (Julie Jacobson / Associated Press)

BY THE TIMES EDITORIAL BOARD

JUNE 9, 2023 3 AM PT

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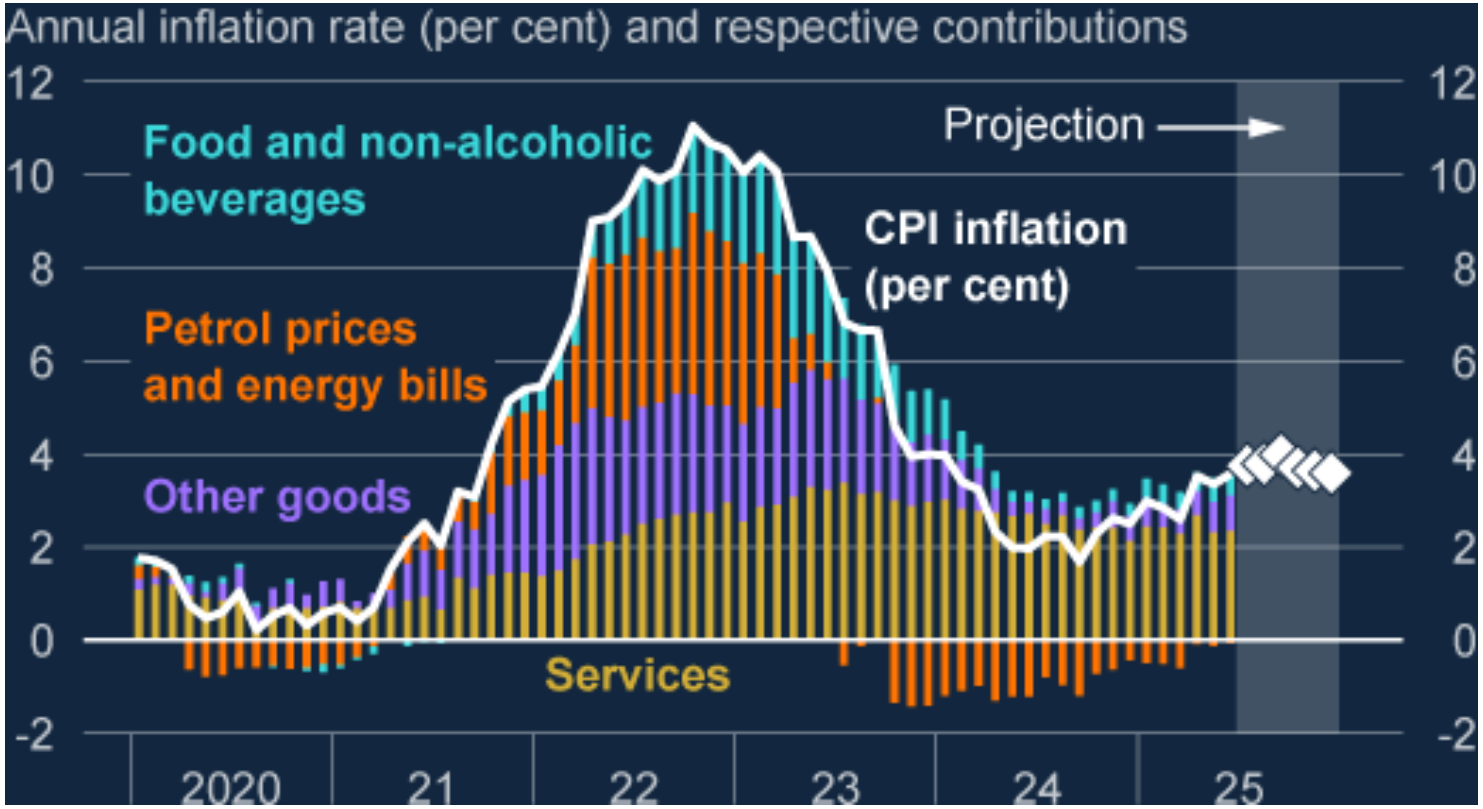
2024, Athens

Introduction

Inflation



Introduction

Electricity price

Introduction

Natural gas price

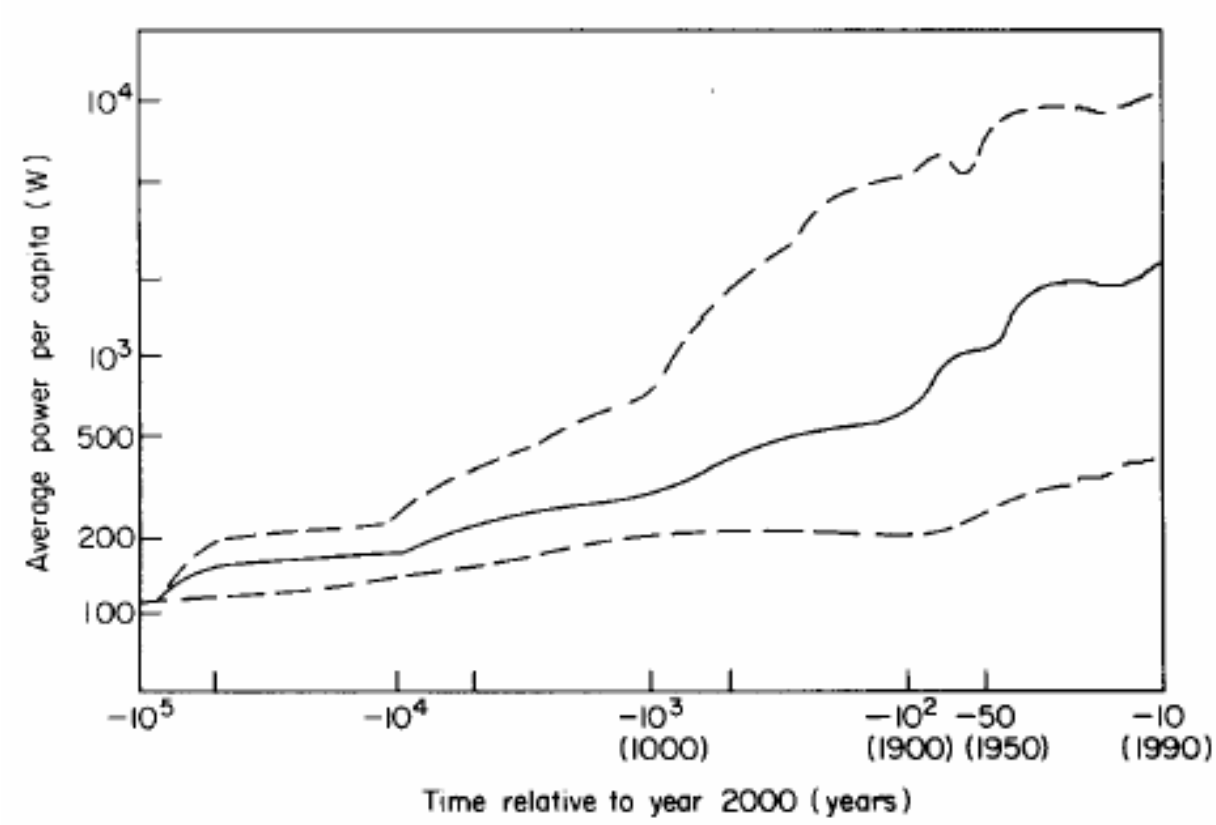
Introduction

Global Energy Scene – past and present

Milestones in human's energy history

- >10^5 YBP – Basic minimum energy for survival from chemical energy in food ~60-100 W. Hunting and gathering requires ~120 W per person, which is ~10 MJ per person per day
- c.10^5 YBP - Discovery of fire. Consumption increased to ~160 W per capita or 14 MJ per person per day
- c.10^4 YBP - First Settlements, leading to domestication of livestock and agriculture ~200-300 W per capita
- c.10^3 YBP - Increased quality of living, some homes with baths and central heating ~300-400 W per capita
- 200-300 YBP – Industrial revolution. However, no large increase occurred until fossil fuels became plentiful in 20th century ~1 kW
- Today - Average per capita consumption of ~ 2 kW ~180 MJ per person per day

Global Energy Scene – past and present



Trends in average rate of energy consumption (solid line). Dashed lines indicate the upper and lower ranges of consumption for differing societies. Source: Sorensen, B. 'Renewable Energy' 3rd Ed., P. 21.

Introduction

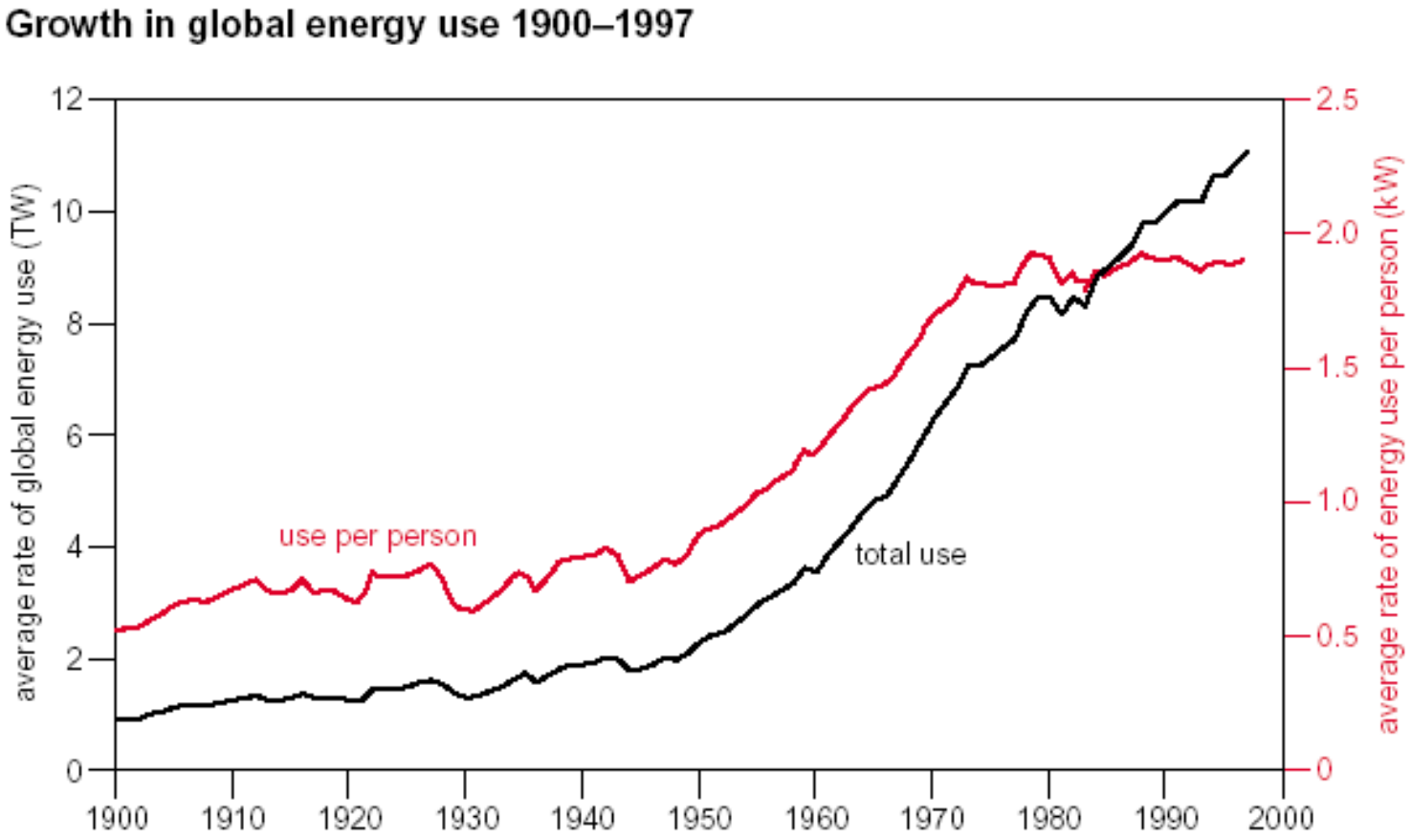
Global Energy Scene – past and present

World population growth

- c.10^4 YBP – estimated as ~5 million
- c.10^3 YBP – increased to around 200 million in Roman times
- Today has reached 7.8 billion (Sept 2020)

This has led to a far steeper increase in total global energy consumption

Global Energy Scene – past and present



Changes in total global and *per capita* energy use over the twentieth century (Source: Royal Commission Report 'Energy - The Changing Climate')

Introduction

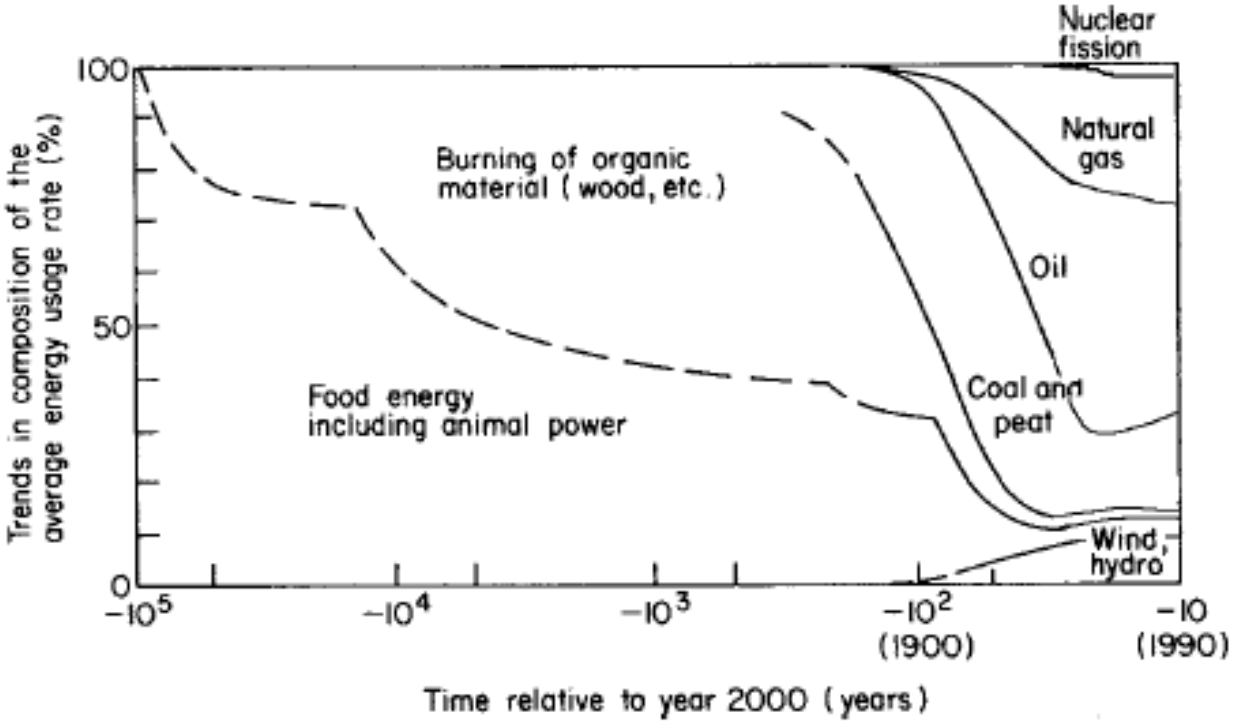
Global Energy Scene – past and present

Energy consumption of modern society

- per capita energy consumption ?
- Is the value typical? – depends mainly on degree of industrialization

Global Energy Scene – past and present

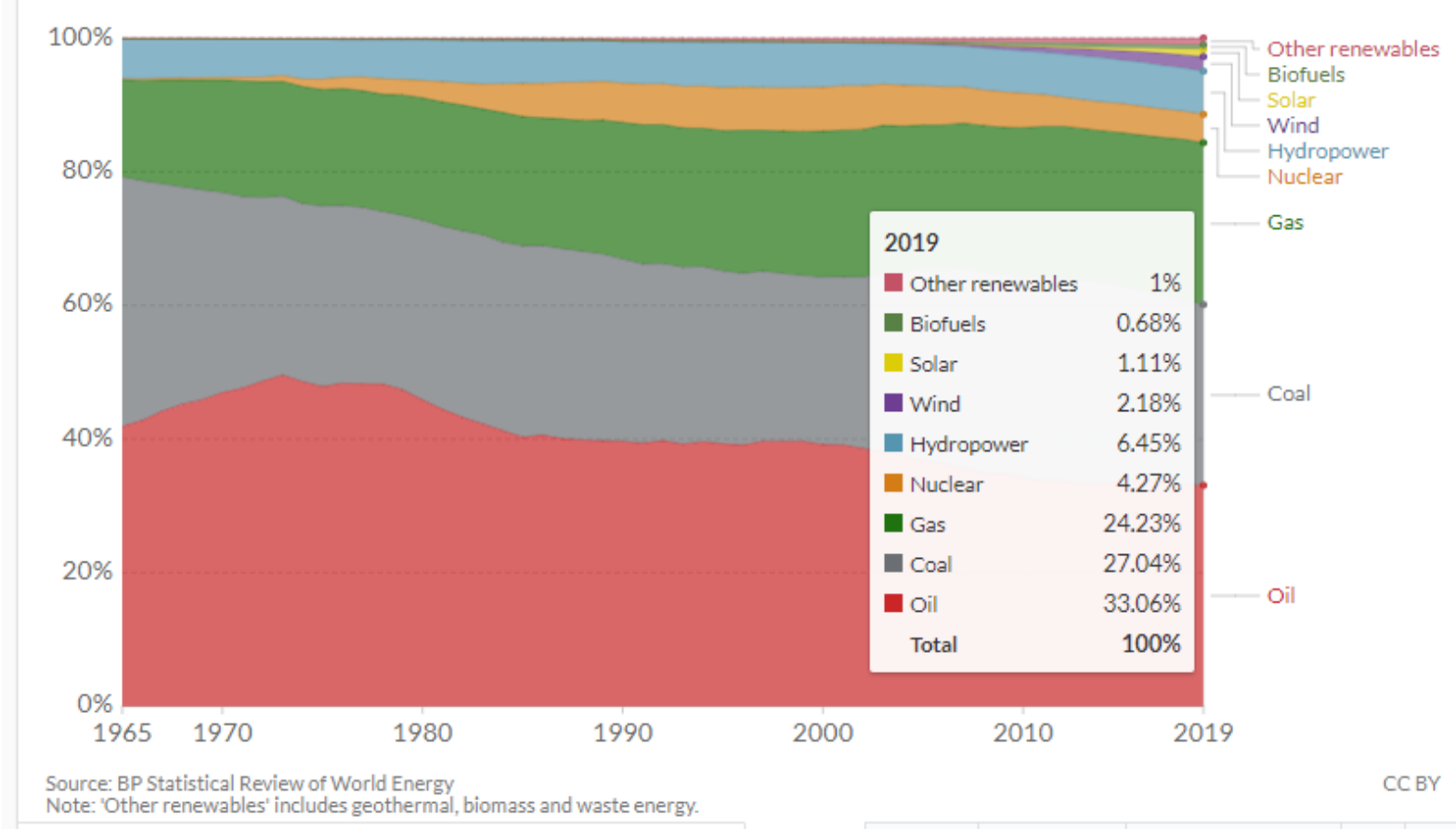
Energy sources to meet global demand



Trends in contribution of different types of energy resources to the average global rate of energy use. (Source: Sorensen, B. 'Renewable Energy' 3rd ed., Darmstadter et al. (1971) and European Commission (1997))

Global Energy Scene – past and present

Energy sources to meet global demand



Percentage contributions of different energy sources to global primary energy consumption in 2019

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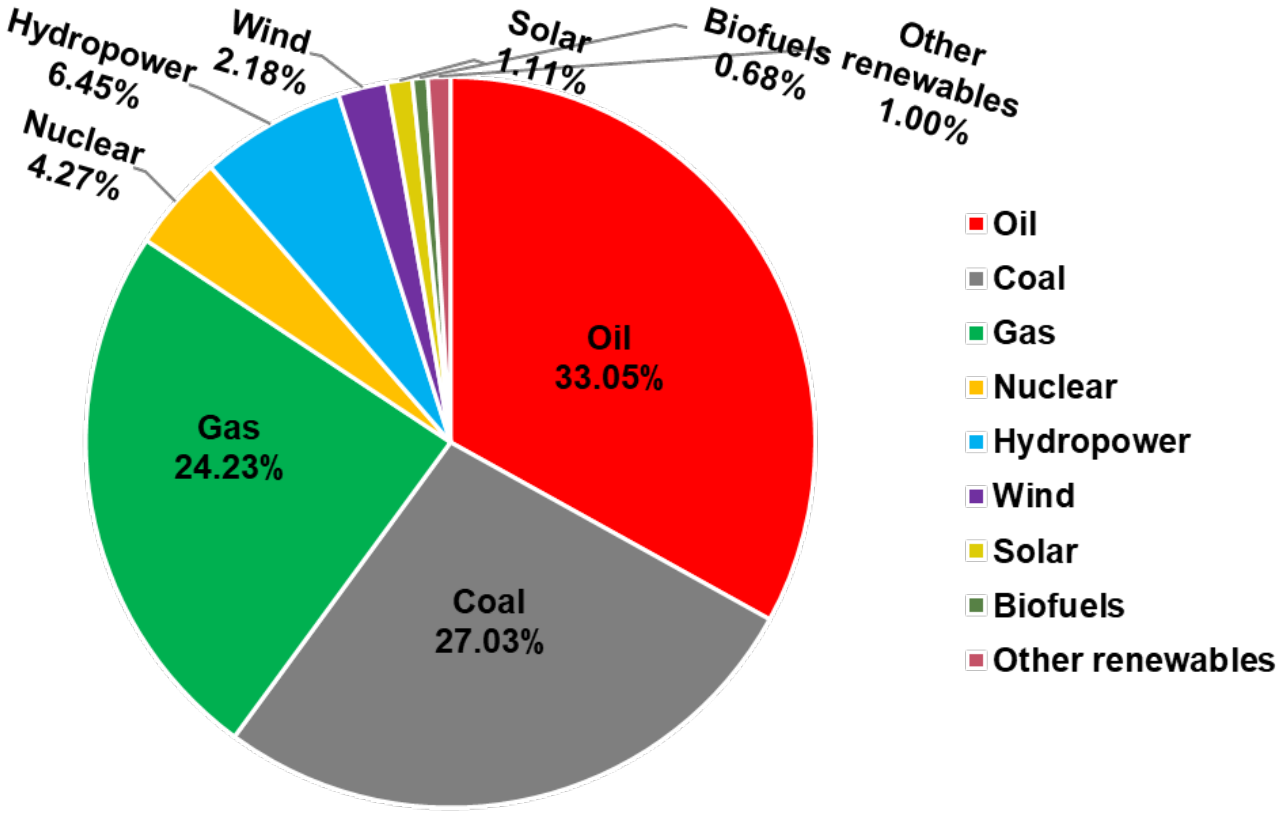
Global Energy Scene – past and present

Energy sources to meet global demand



Percentage contributions of different energy sources to global primary energy consumption in 2019

Global Energy Scene – past and present

Conclusions

- World's current energy consumption dominated by fossil fuel combustion
- Present day contribution of Renewable sources to global energy demand is ~10.74%

Introduction

What constitutes a renewable energy source?

- Renewable energy can be defined as ‘energy flows which are replenished at the same rate as they are “used”’ (Sorensen, 2000)
- Examples include; Solar power, wind power, geothermal, hydro, tidal and wave power
- Non renewable energy sources include; fossil fuels and nuclear energy

Introduction

Fossil fuels – advantages/disadvantages

- Why so extensively used?
- Fossil fuels have very high energy density
- Easily transported – especially oil and gas (pipelines)

How long will they last?

- Coal – R/P ratio of 160 giving 160 years at current consumption rate and 75% of reserves concentrated in Australia, China, South Africa and US (Source: BP Energy Review 2005)
- Gas - R/P ratio of 60. Majority of reserves in Middle East, North Africa and former Soviet Union
- Oil - R/P ratio of 40. Majority of reserves in Middle East and North African, North American regions

Introduction

What are the problems associated with fossil fuels?

- Finite resource not sustainable – depletion inevitable
- Concentrated resource – conflicts, instability in supply
- Pollution – increasing climate change and global warming concerns due to carbon dioxide emissions

Human's interference with the environment

Composition of Clean Dry Air (fraction by volume in Troposphere, 1994)

Constituent	Formula	Percent by volume	Parts per million
Nitrogen	N_2	78.08	780,800
Oxygen	O_2	20.95	209,500
Argon	Ar	0.93	9300
Carbon dioxide	CO_2	0.035	358
Neon	Ne	0.0018	18
Helium	He	0.0005	5.2
Methane	CH_4	0.00017	1.7
Krypton	Kr	0.00011	1.1
Nitrous oxide	N_2O	0.00003	0.3
Hydrogen	H_2	0.00005	0.5
Ozone	O_3	0.000004	0.04

Introduction

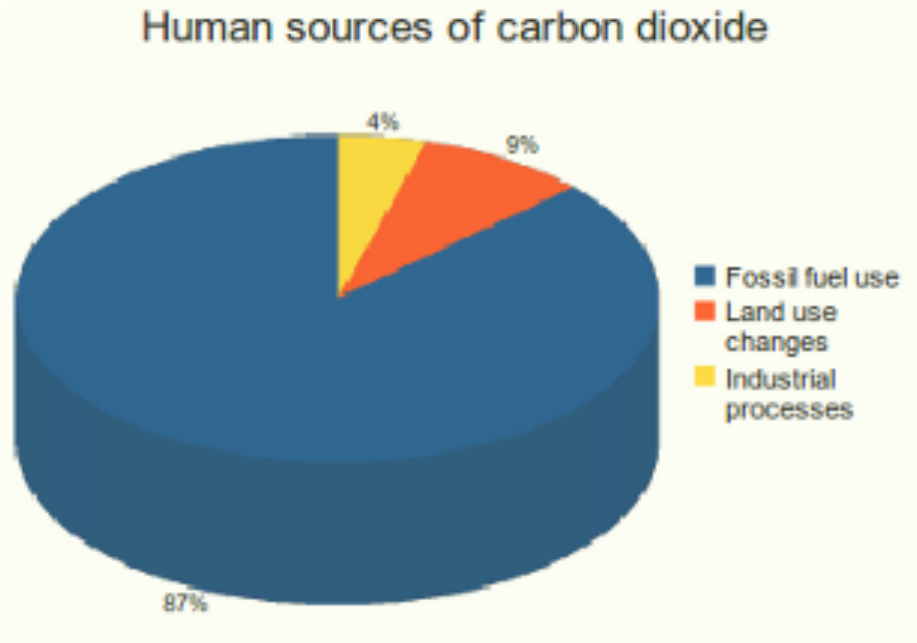
Human's interference with the environment

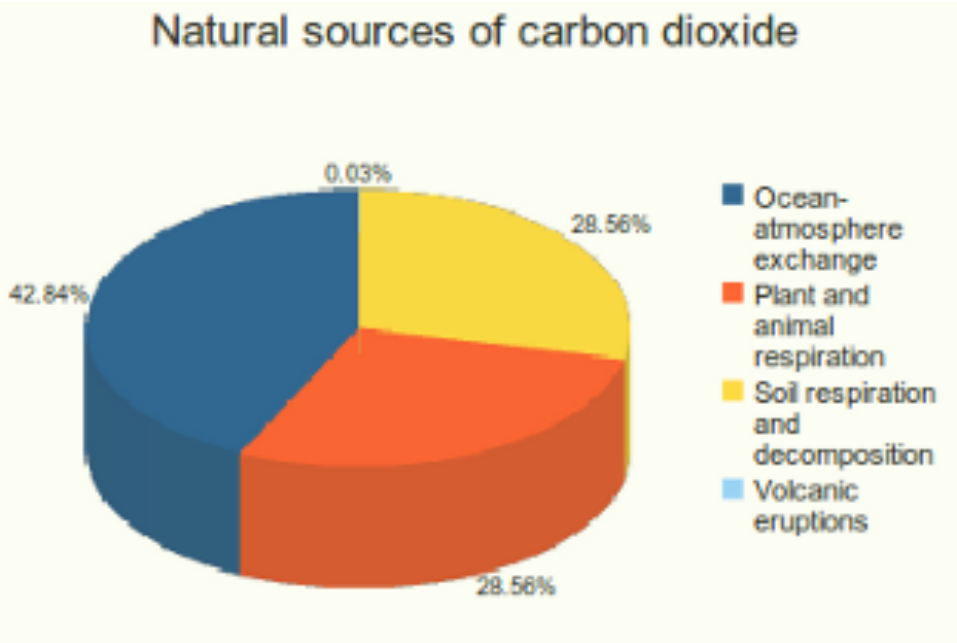
- During past 50 years it has become apparent that an important consequence of our energy consumption is human induced climate change
- Principally this is due to increasing levels of carbon dioxide in our atmosphere due to extensive use of fossil fuels
- Example: combustion of methane (natural gas)

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Introduction

Human's interference with the environment





Carbon dioxide emissions from differing sources

Source: https://whatsyourimpact.org/greenhouse-gases/carbon-dioxide-emissions

Introduction

Human's interference with the environment

Charred areas of the Amazon in Brazil, August 27, 2019

Total area burned
Through July 2019 over 7,200 square miles of the Brazilian rainforest has burned—an aggregated area nearly the size of New Jersey.

Introduction

Heating values of fossil fuels

The energy released from burning 1 mole of methane can be calculated by summing the enthalpy change of the reaction and is called the *heat of reaction*

Heat of reaction for methane combustion

$$\mathbf{CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)}$$

$$\mathbf{(-74.9) \quad 2 \times (0) \quad (-393.5) \quad 2 \times (-285.8)}$$

Therefore

H^0_{298} = [(-393.5) + 2 x (-285.8)] – [(-74.9) + 2 x (0)] = -890.2 kJ/mol of CH_4 burnt

This value is the higher heat value (HHV) for methane as it assumes condensation of water vapour. LHV for CH_4 is 802 kJ/mol

Carbon intensity of fossil fuels

LHV and HHV Carbon Intensities and 1990 World Carbon Emissions

Fuel	LHV Carbon intensity (gC/MJ)	LHV Energy consumption[b] (10^{12} MJ/yr)	Carbon emissions (GtC/yr)	HHV Carbon intensity (gC/MJ)
Natural gas	15.3	71	1.1	13.8
Oil	20.0	128	2.6	19.7
Coal (bituminous)	25.8	91	2.3	24.2
Nuclear, hydro	0.0	40	0	0
Totals		*330*	*6.0*	

[a]1 GtC = 10^9 tonne C = 10^{15} gC; 1 MJ = 10^6 Joules.
[b]IPCC/OECD use LHV values; United States tends to report energy as HHV.
Source: Nakicenovic, 1996.

The relative amount of carbon emitted per unit of energy released is measured by the *carbon intensity*

What happens to the carbon dioxide we emit?

Annual average budget of CO_2 perturbations from 1980-89

Carbon dioxide sources	
Emissions from fossil fuel combustion and cement production	5.5 ± 0.5
Net emissions from changes in tropical land use	1.6 ± 1.0
Total anthropogenic emissions	7.1 ± 1.1 GtC/yr
Partitioning among reservoirs	
Ocean uptake	2.0 ± 0.8
Uptake by northern hemisphere forest regrowth	0.5 ± 0.5
Other terrestrial sinks (CO_2 and nitrogen fertilization, climatic effects)	1.3 ± 1.5
Net storage in the atmosphere	3.3 ± 0.2 GtC/yr

Source: IPCC, 1996.

$$\text{Airborne fraction remaining} = \frac{3.3\,\text{GtC/yr}}{7.1\,\text{GtC/yr}} = 0.46 \quad \text{(almost 50\%)}$$

Introduction

How does this affect the atmospheric CO_2 level?

Calculate the relationship between mass loading of carbon and increase in atmospheric ppm concentration of CO_2

Assuming the following:

Density of Earth's atmosphere at STP (0 ^oC, 1 atm) is 1291.4 g/m^3

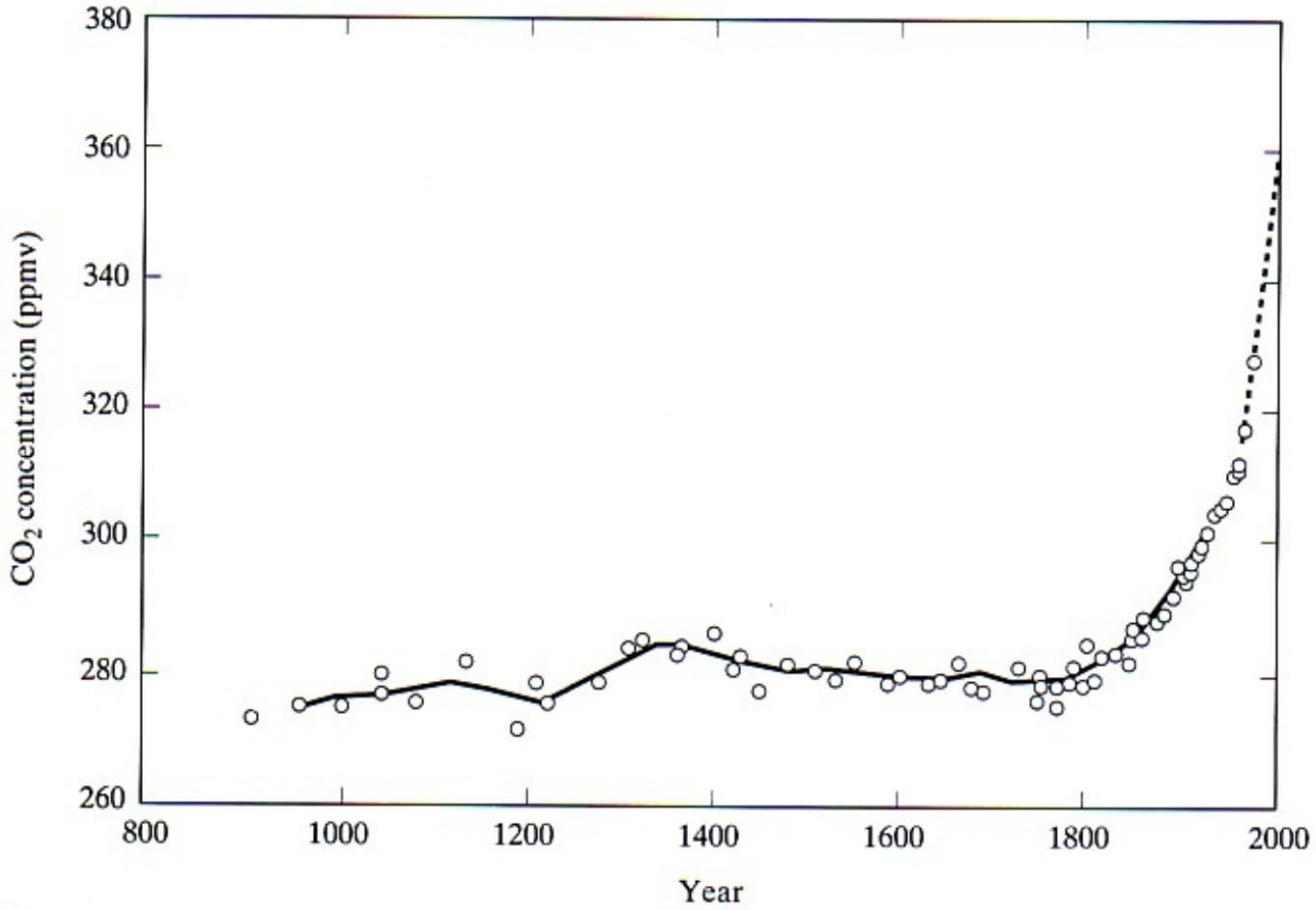
Mass of Earth's atmosphere is 5.12×10^{21} g

1mole of gas at STP occupies 22.4×10^{-3} m^3

There are 12 gC/mole

Introduction

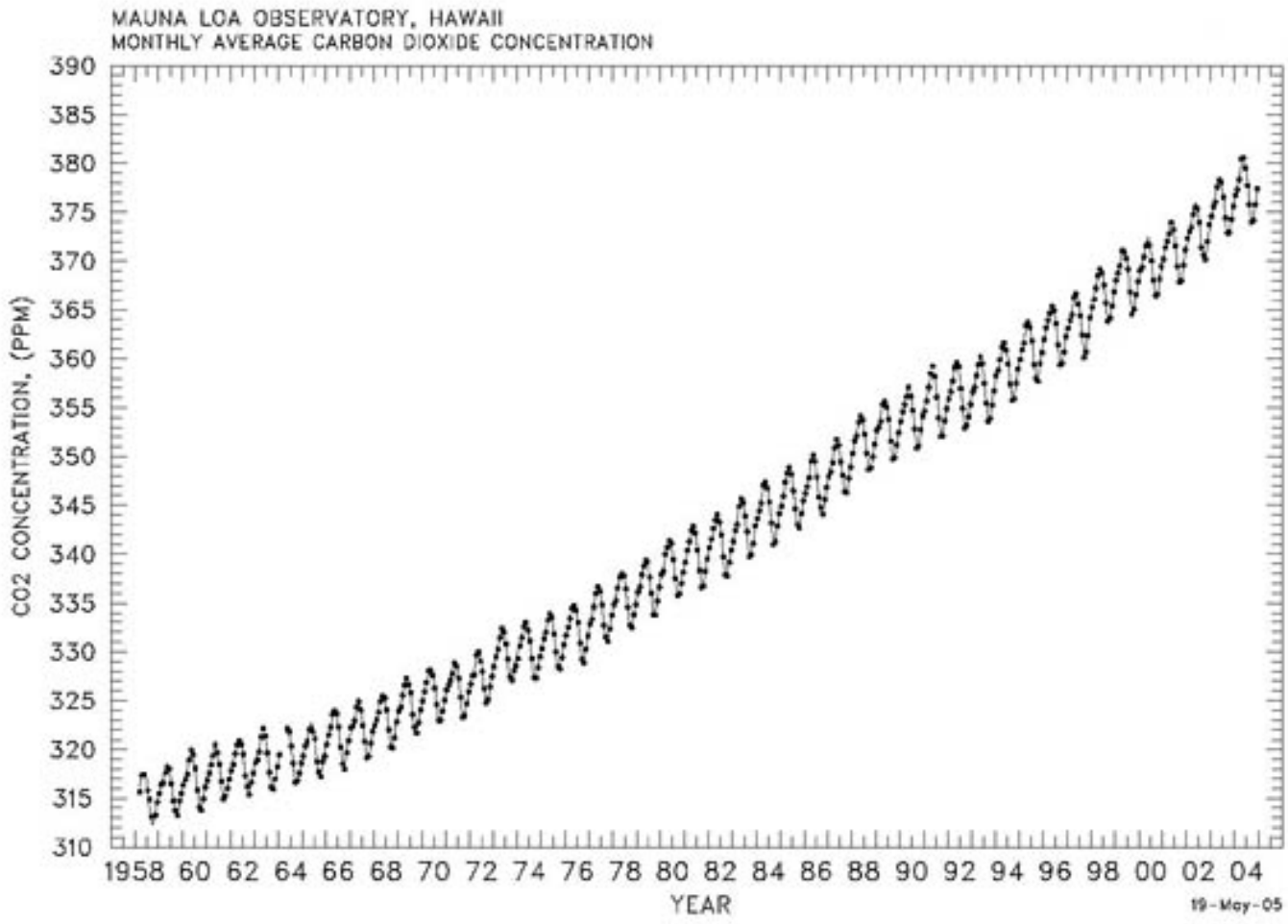
Carbon dioxide (CO_2) – the story so far



Combined ice core data and direct measurements of carbon dioxide concentration over past 1000 years

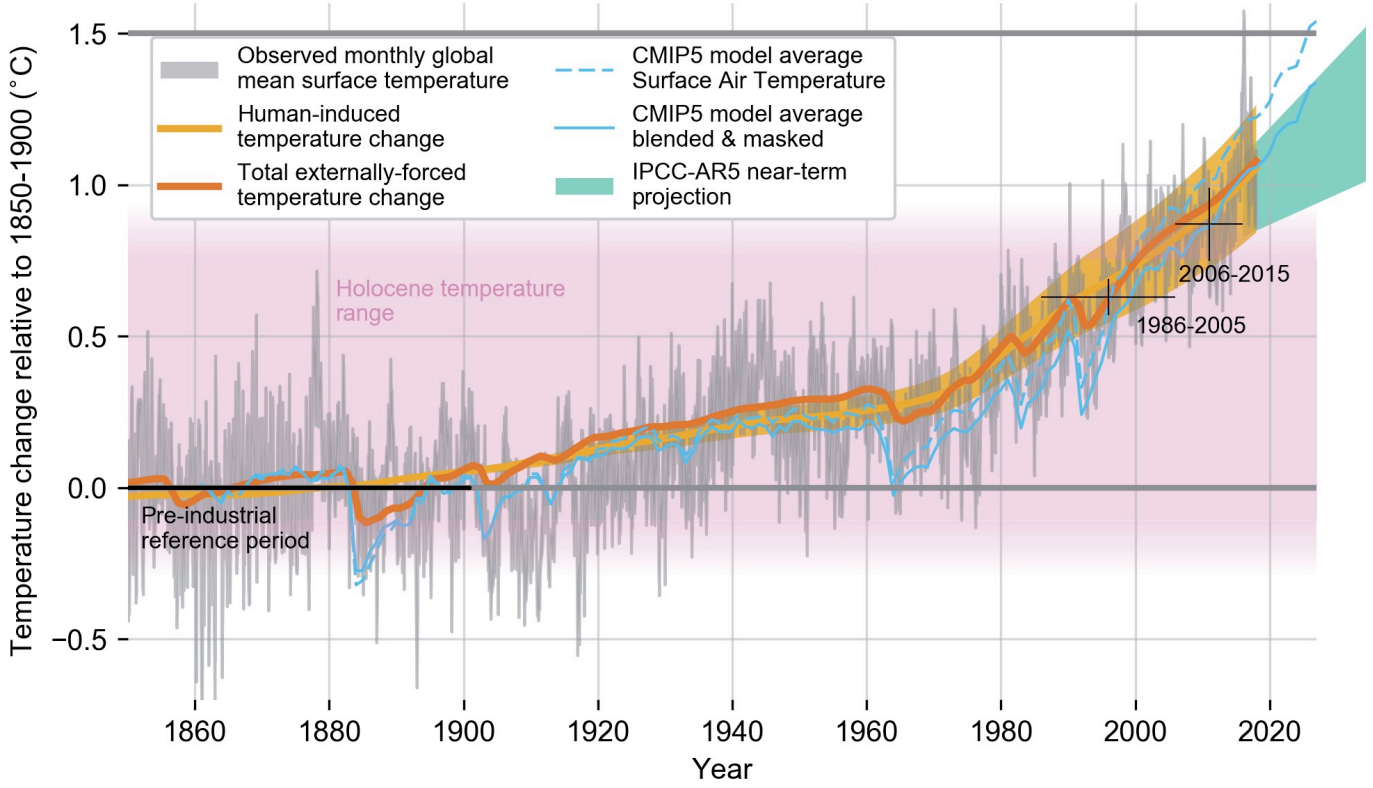
Introduction

Carbon dioxide (CO_2) – the story so far



Direct measurements of carbon dioxide concentration from Mauna Loa observatory, Hawaii

Evidence for human induced climate change



Evolution of global mean surface temperature (GMST) over the period of instrumental observations. (Source: IPCC 2018)

Fossil fuels are finite resources – do we need to worry?

Global fossil fuel resources and occurrences, in EJ[a]

Fuel	Conventional resources	Unconventional resources	Total resource base	Additional occurrences
Gas	9,200	26,900	36,100	> 832,000
Oil	8,500	16,100	24,600	> 25,000
Coal	25,200	100,300	125,500	> 130,000
Totals	42,900	143,300	186,200	> 987,000

[a] 1 EJ = 10^{18} J.
Source: Nakicenovic, 1996.

Question: If we burn all proven reserves of fossil fuels what increase in atmospheric CO_2 concentration would result?

Assume airborne fraction of 0.5 (50%)

Future CO_2 emissions and concentration predictions

Climate modelling

Many uncertainties involved in future CO_2 level and global temperature predictions, including;

- Future energy demand and socio-economic factors
- Technological developments
- Variations in natural forcing levels
- Changes in climate feedback mechanisms
- Carbon sink efficiencies

Future CO_2 emissions and concentration predictions

Key recent reports/findings

BP, *Statistical Review of World Energy 2020* | *69th edition*

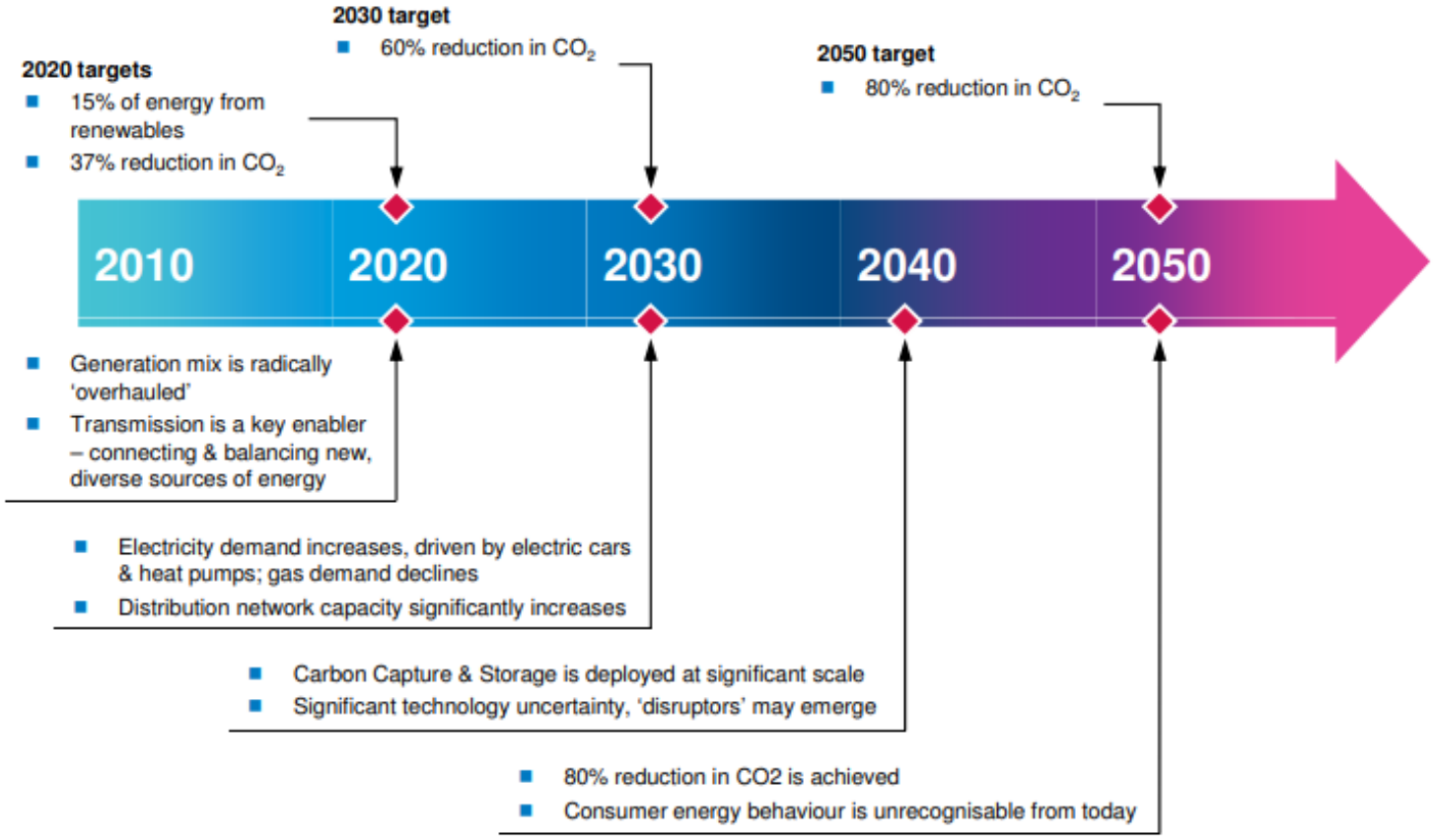
Available online: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

- Carbon emissions from energy use grew by 0.5%, less than half 10-year average growth of 1.1% per year, partially reversing some of the unusually strong increase in 2018 (2.1%)
- By region, consumption fell in North America, Europe and CIS and growth was below average in South & Central America. Demand growth in Africa, Middle East and Asia was roughly in line with historical averages.

Introduction

Future CO_2 emissions and concentration predictions

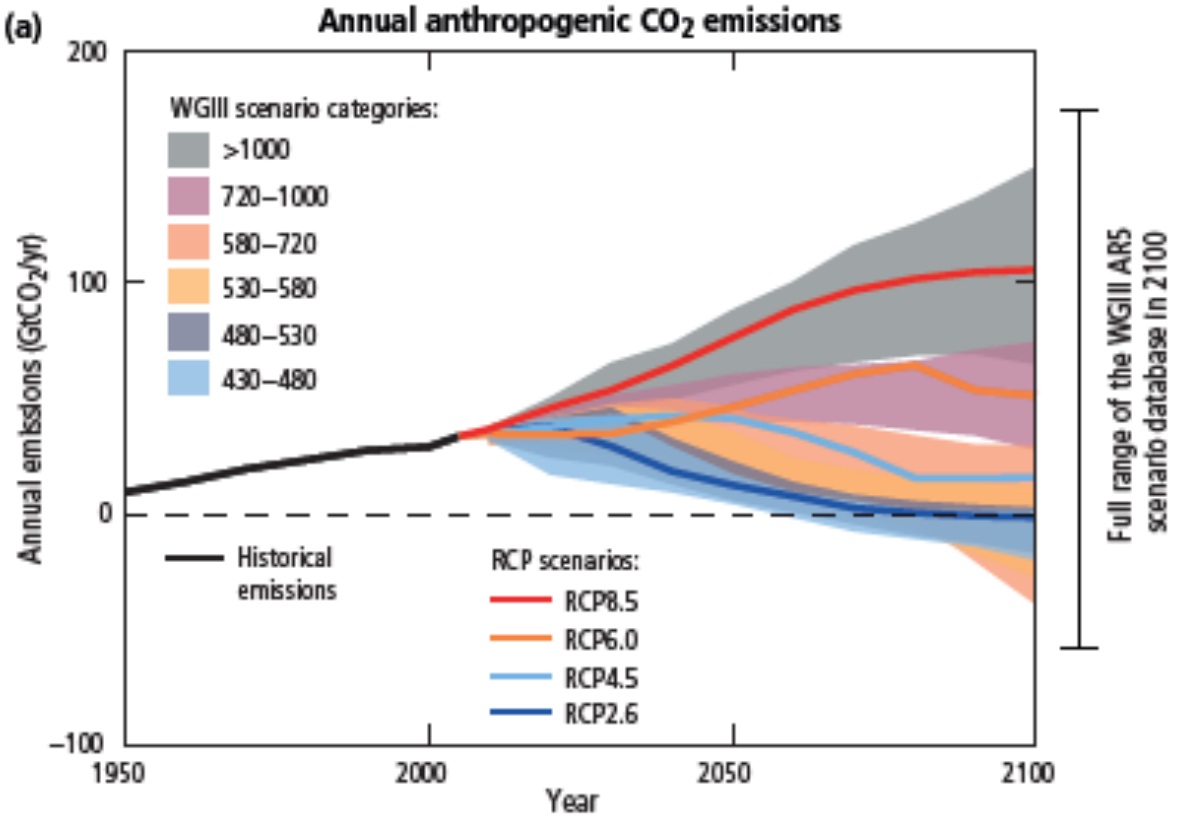
Key recent reports/findings



Gone Green: some key themes

Source: UK Future Energy Scenarios - National Grid

Future CO_2 emissions and concentration predictions



Emissions of carbon dioxide (CO_2) alone in the Representative Concentration Pathways (RCPs) (lines) and the associated scenario categories used in WGIII (coloured areas show 5 to 95% range). (Source: IPCC 2014)

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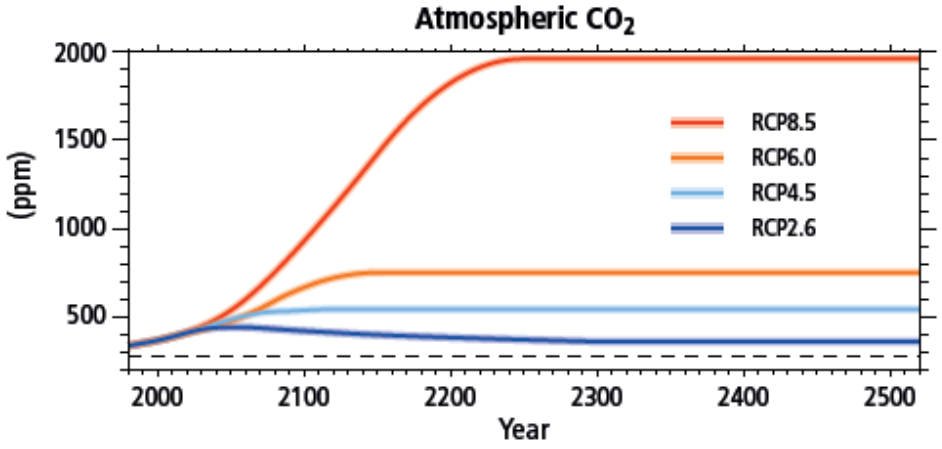
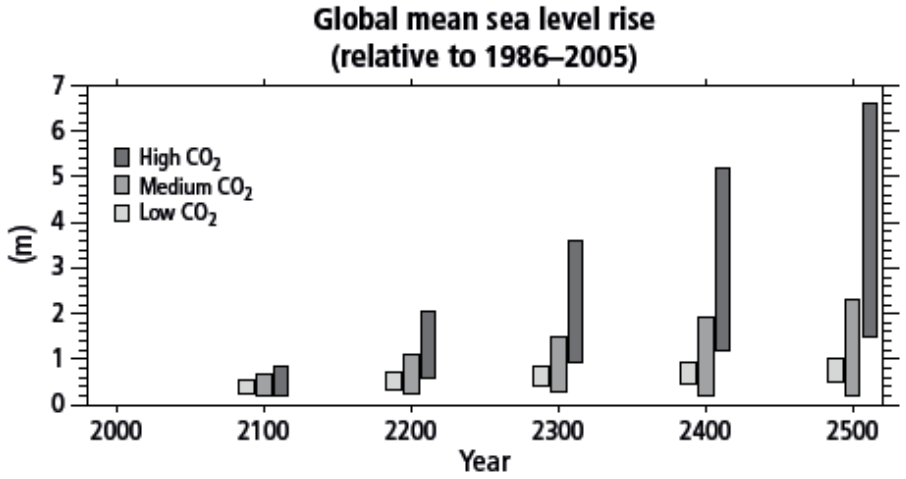
Future CO_2 emissions and concentration predictions



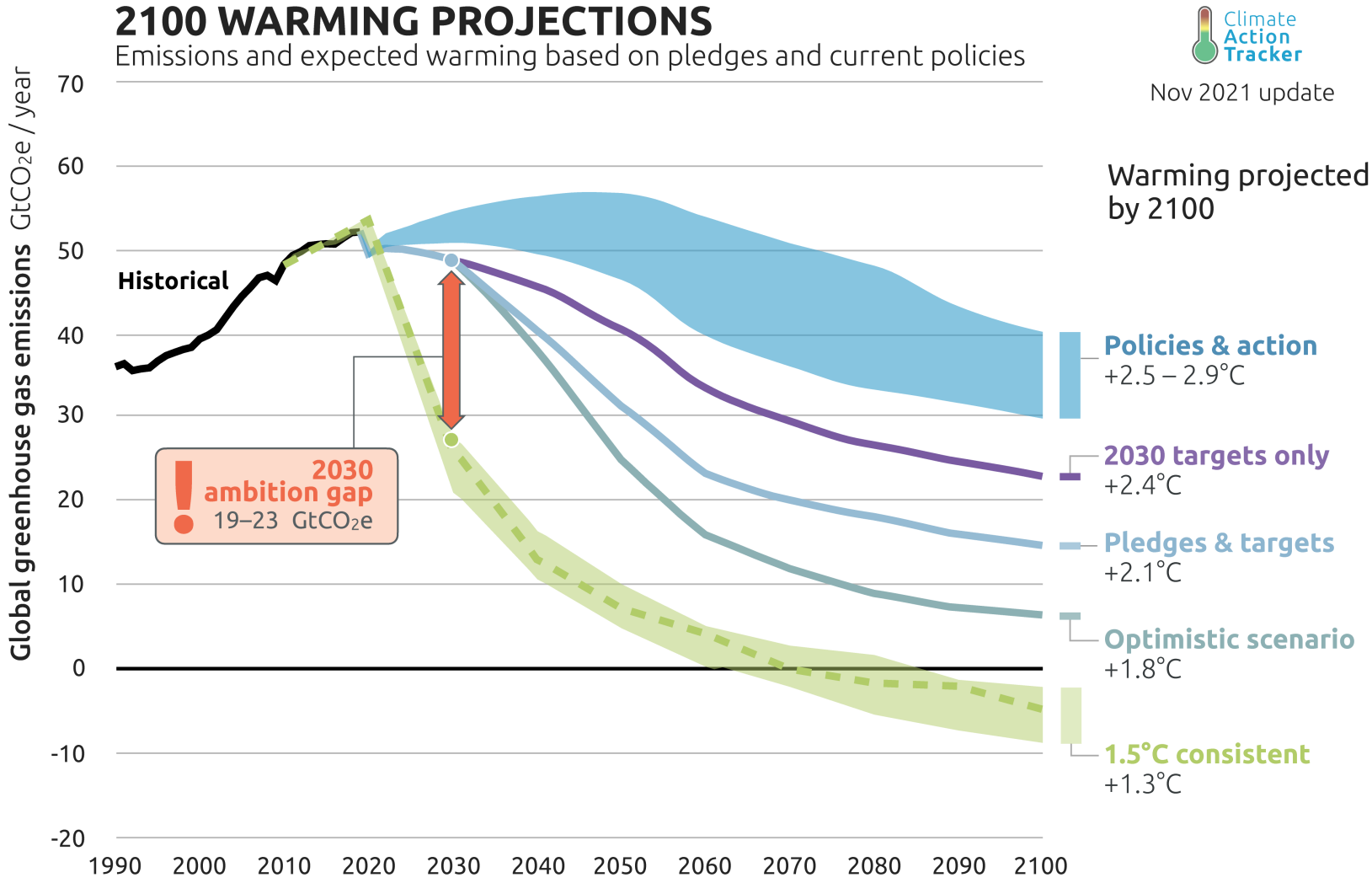
Atmospheric carbon dioxide (CO2)



Sea level change projections grouped into three categories according to the concentration of greenhouse gas (in CO2-eq) in 2100

(Source: IPCC 2014)

Future CO_2 emissions and concentration predictions

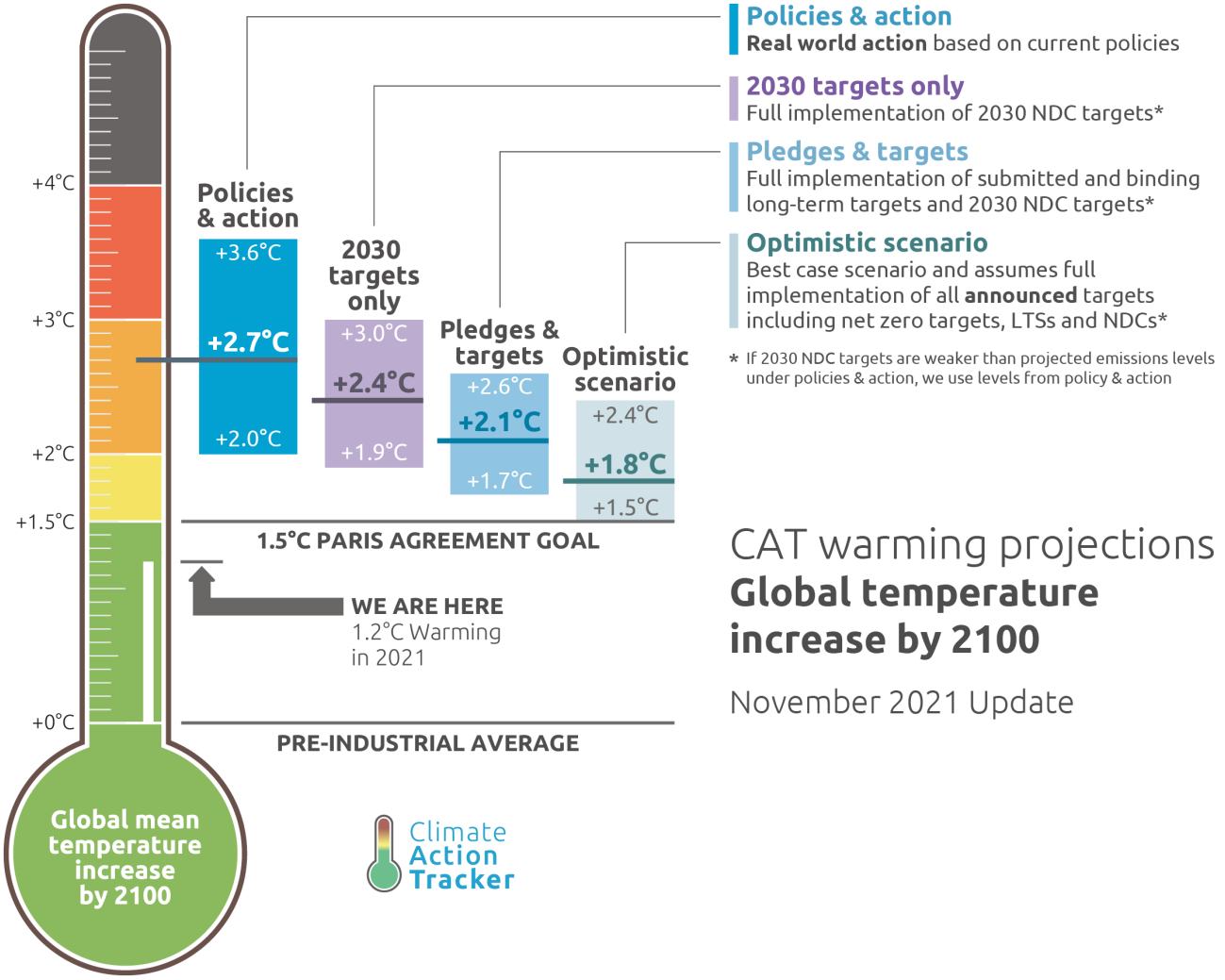


Introduction

Future energy production – a tough challenge

- Biggest challenge is to halt the steady rise in atmospheric concentrations of CO_2 and other greenhouse gases without losing quality of life
- If all fossil fuel reserves are burnt during this and the next century the CO_2 concentration of the atmosphere will be well above 550 ppm level
- Even if global use of fossil fuels held at current levels the concentration of CO_2 in the atmosphere will continue to rise
- To limit the damage we inflict on our environment large reductions in global emissions are necessary
- Due to increasing emissions from rapidly developing countries strong and effective action needs to taken immediately with developed countries taking the lead
- Global agreement necessary

Future energy production – a tough challenge



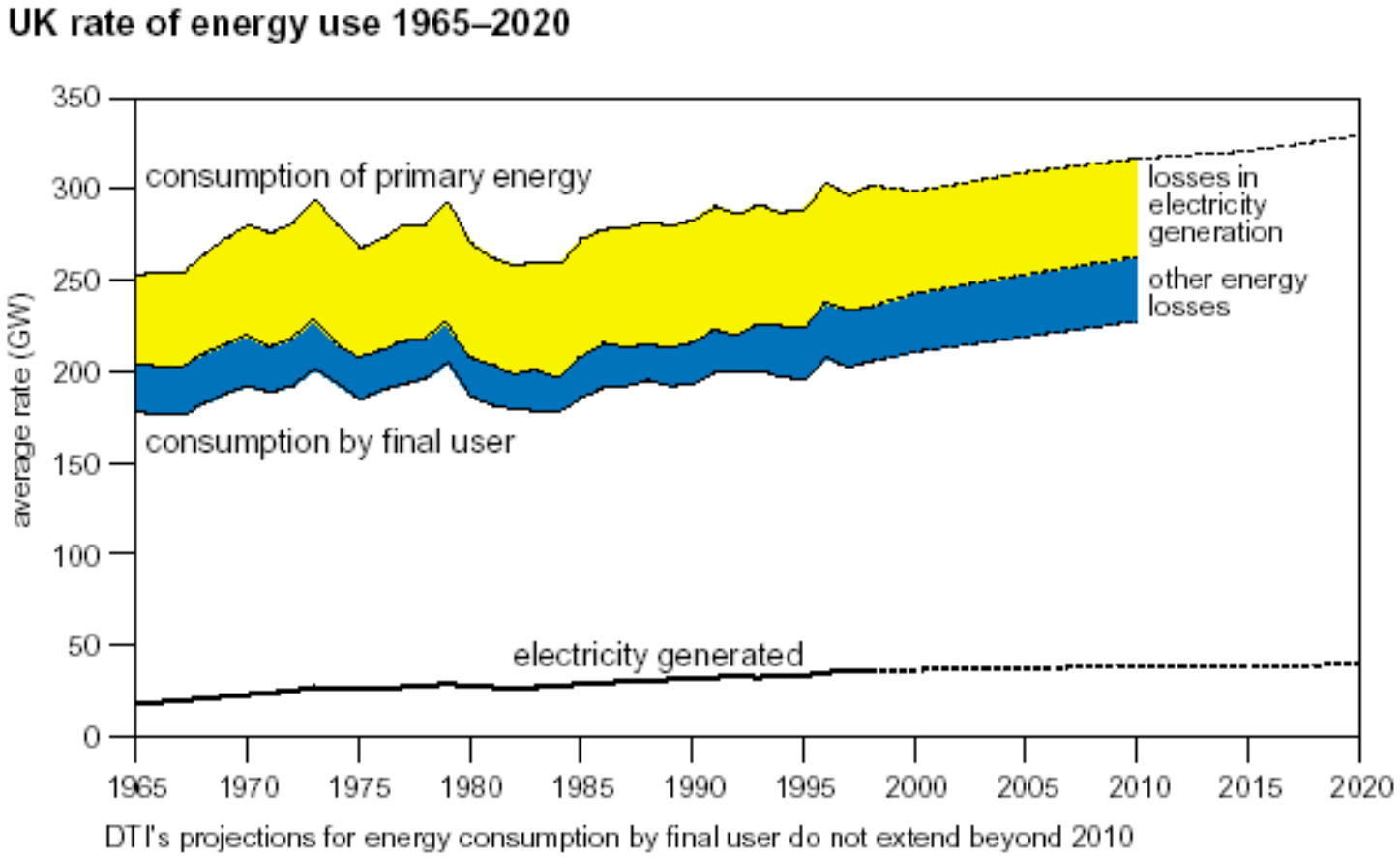
Introduction

The UK's Role and Future Emission and Energy Options

The UK is the first major economy in the world to pass laws to end its contribution to global warming by 2050. The target will require the UK to bring all greenhouse gas emissions to net zero by 2050, compared with the previous target of at least 80% reduction from 1990 levels.

Difficult task but there would be benefits, including reduced air pollution, acid rain and photochemical smog and improved human health

The UK's Role and Future Emission and Energy Options



Introduction

What are the UK's options to reduce future emissions?

Carbon dioxide removal schemes

- Forest re-growth. This could only compensate for a small amount of the overall emissions. For the UK there is not enough land area for these schemes to make a significant contribution
- Ocean reservoirs. Suggestions for stimulating the growth of microscopic marine plants, or for injection of liquid carbon dioxide directly into the ocean. Either may have unforeseen consequences, particularly for marine life
- Carbon sequestration. Involving injection of liquid carbon dioxide into deep geological strata. This could make a significant contribution to reducing emissions. However, can only be applied to large scale installations such as power station and is not appropriate for controlling the larger share of emissions from transport vehicles and houses

Introduction

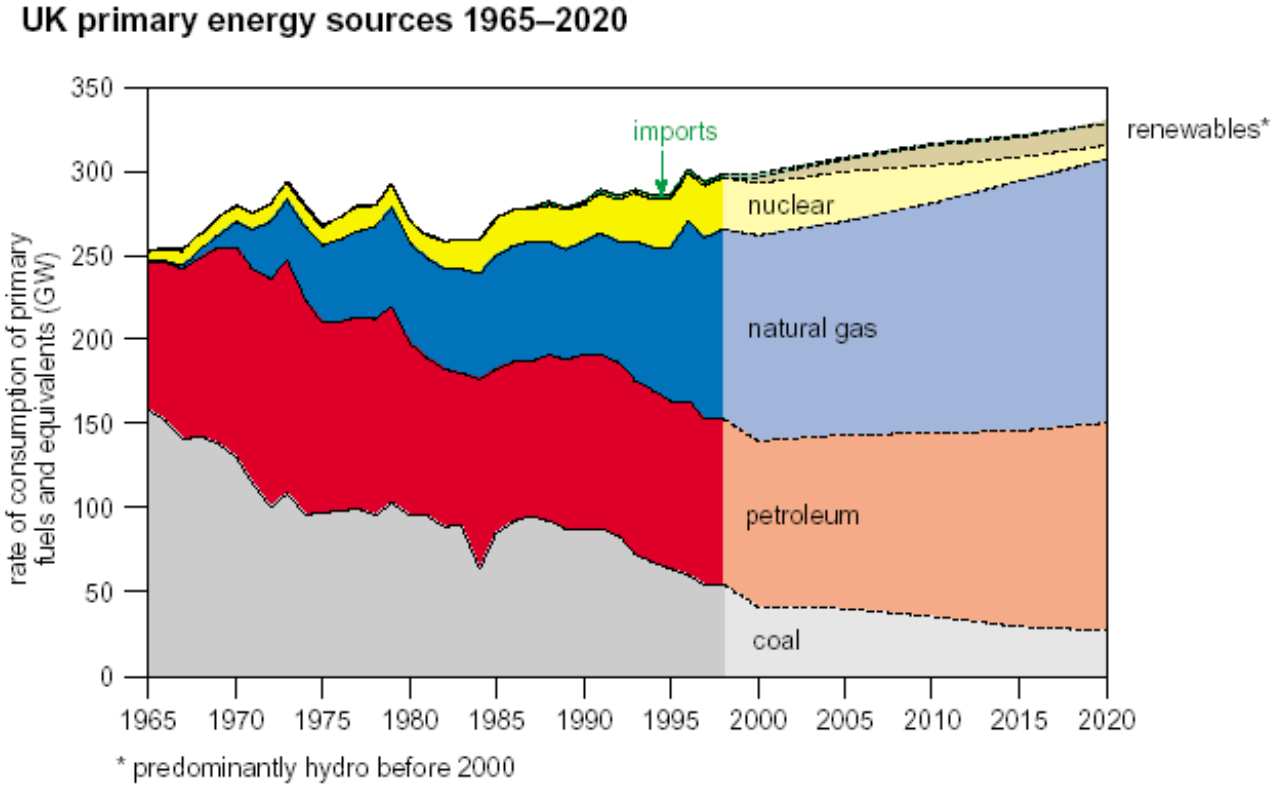
What are the UK's options to reduce future emissions?

Reduced Energy Usage

- Demand for energy in the UK has been rising steadily. This increase is linked to growing economy and output of goods and services – increasing GDP (gross domestic product)
- Energy consumption risen more slowly than GDP due to improvements in efficiency of energy use
- Opportunities for further increases in efficiency in manufacturing industry, commercial and public services, transport and household buildings
- Government needs to give higher priority to energy efficiency by building on current campaigns and introducing new incentives such as a carbon tax

Alternative Energy Sources

Nuclear Power: Currently a significant source of carbon free energy for UK but unless new plants are built, nuclear power will almost have ceased by 2020



Introduction

Alternative Energy Sources

Nuclear Power: The UK has 15 reactors generating about 21% of its electricity but almost half of this capacity is to be retired by 2025.

RCEP findings: not a recommendation of the RCEP 2000 to build any new nuclear power stations until the problems of managing nuclear waste has been solved to the satisfaction of the scientific community

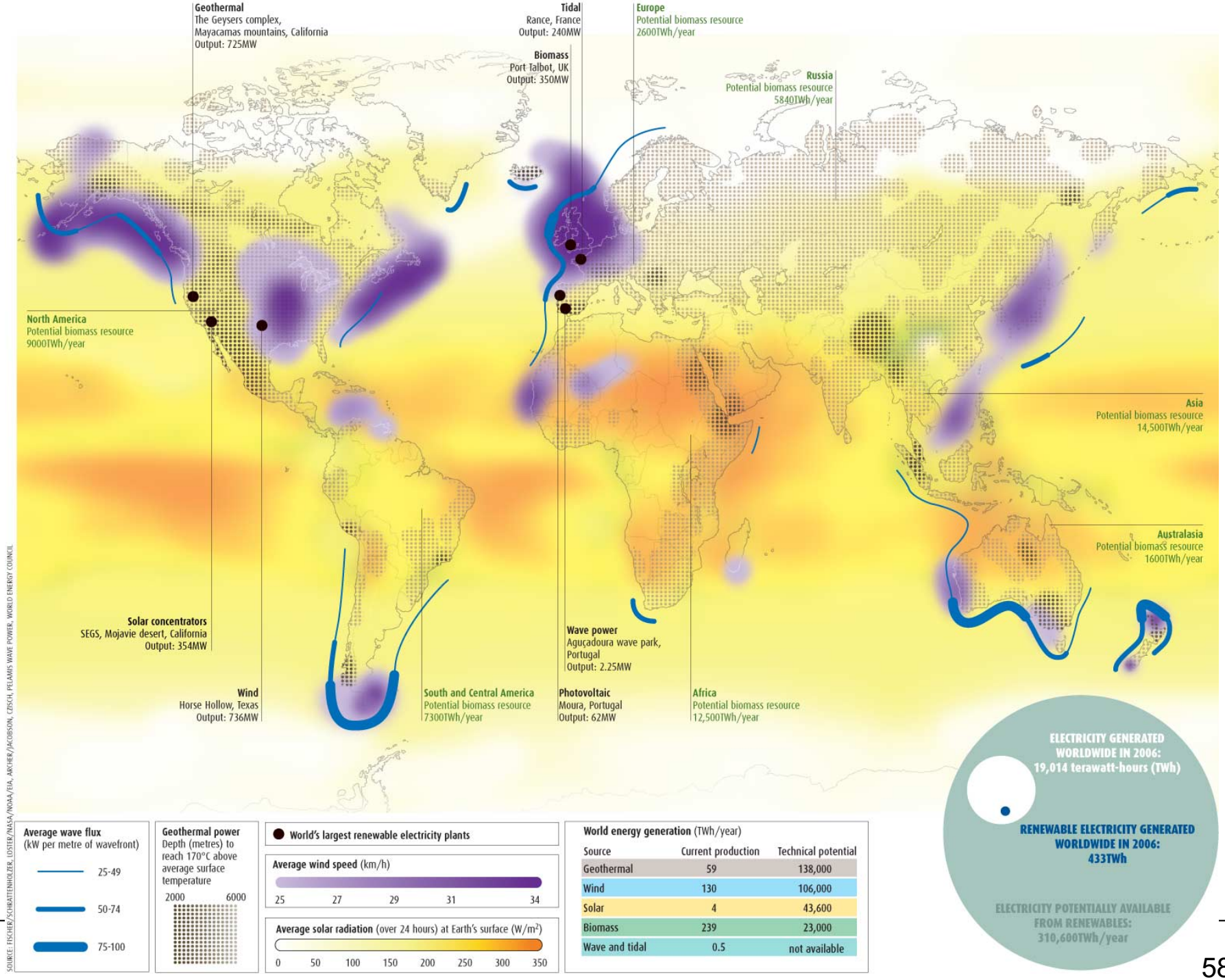
Also, public opinion unlikely to allow many nuclear plants unless part of broader strategy promoting development of other alternatives to fossil fuels

Alternative Energy Sources

Renewable Energy Sources:

33.3%% to UK primary energy supply and a third (33%) of the UK's electricity generation came from renewable sources (2018).

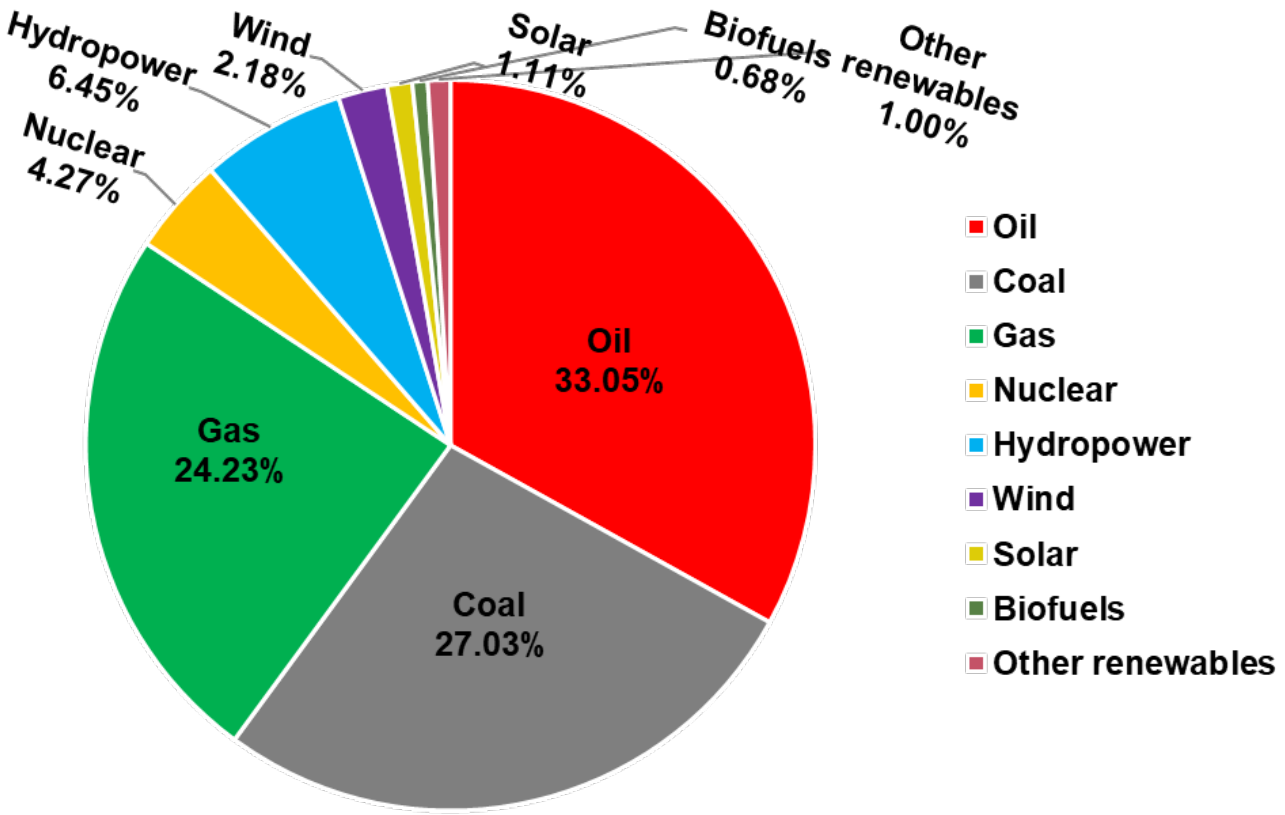
UK renewables generate more electricity than fossil fuels for the first time in the third quarter of 2019.



Source: New Scientist

Introduction

Energy sources to meet global demand

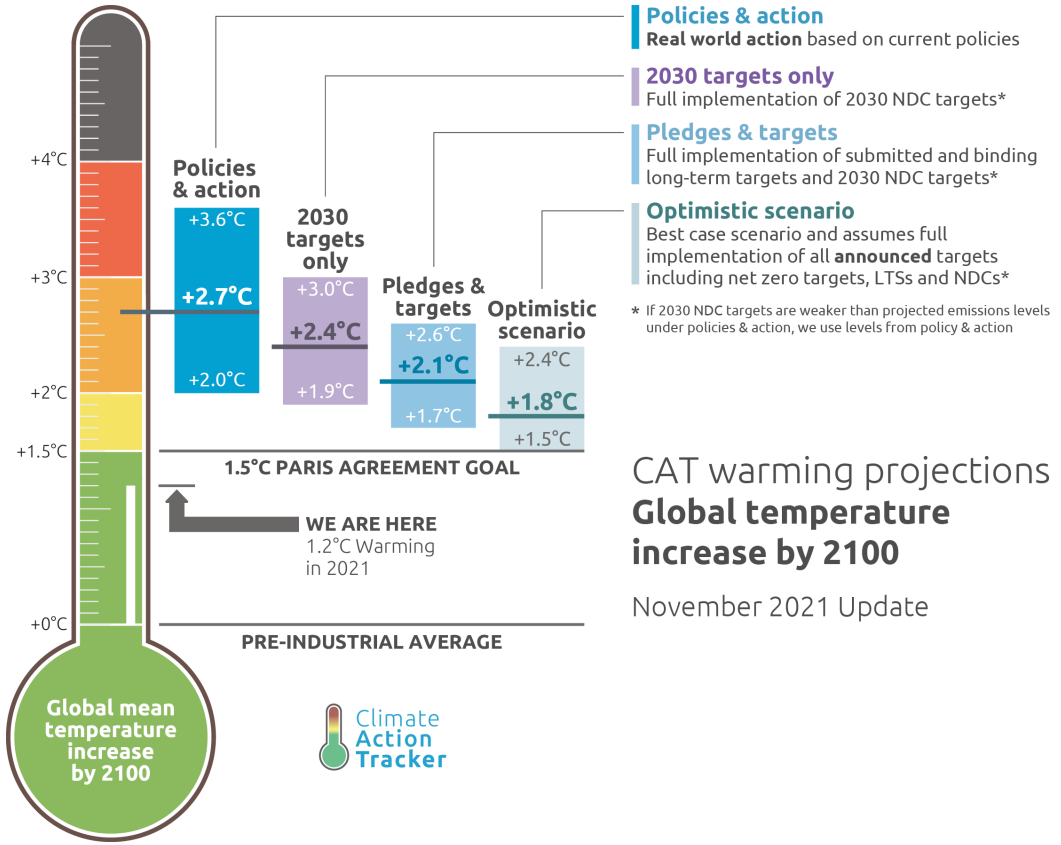


Percentage contributions of different energy sources to global primary energy consumption in 2019

Global agreement on reducing carbon dioxide emissions

The Paris Agreement on Climate Change, 2015

- The agreement aims at lowering the global GHG emissions to minimize the global temperature increase rate in the 21st century to 2 K above preindustrial levels while pursuing means to limit the increase to 1.5 K.



Introduction

What are the UK's options to reduce future emissions?

Decarbonisation

- The UK Government's *Low Carbon Transition Plan*, committed the UK to achieving a 34% cut in CO_2 emissions over 1990 levels by 2020 and 80% by 2050.

- The Future Homes Standard: mandate to end fossil fuels in new buildings from 2025.

- New law: net zero emissions of greenhouse gases by 2050.

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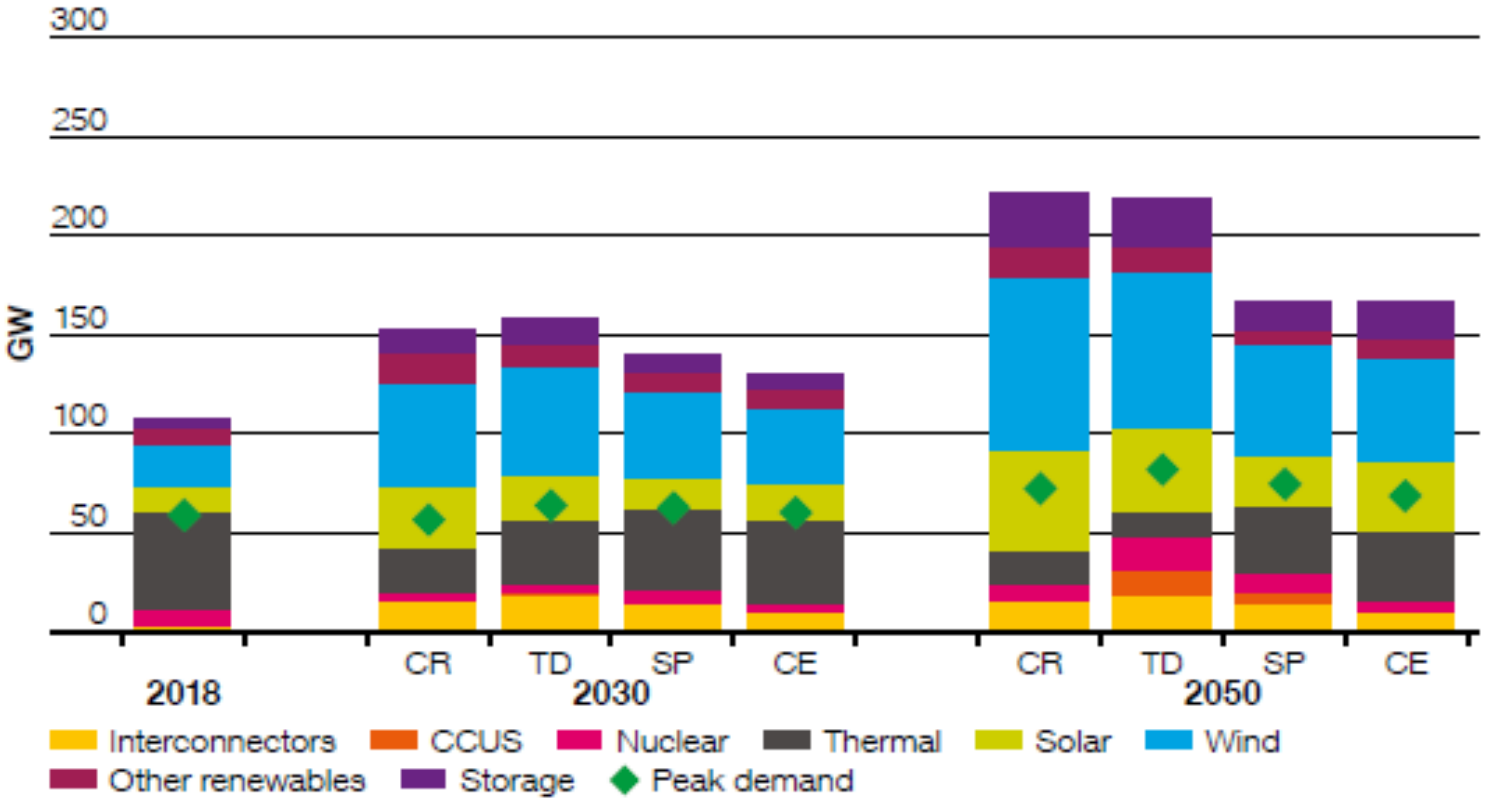
Predictions of electricity generation, UK



Installed electricity generation capacity, plus storage and interconnection (no vehicle-to-grid)

Source: Future Energy Scenarios, National Grid ESO, July 2019

Introduction

Is there any hope for the future?

Allocation of emission rights: Very promising solution to allocate emission rights to nations on per capita basis. This will enshrine the idea that every human is entitled to release the same quantity of CO_2 into the atmosphere each year.

This would need a period of contraction (to reduce overall emissions) and convergence (due to initially large difference in per capita emissions between nations).

International trading in emission quotas could play an important role in maintaining agreement

Summary

- World's current energy consumption dominated by fossil fuel combustion
- Continued extensive use of fossil fuels for energy production very likely to cause catastrophic climate change within this century
- Global agreement on reducing carbon dioxide emissions necessary: **The Paris Agreement on Climate Change, 2015**.
- Renewable energy sources will play an increasing important role in meeting our future energy needs.
- **The Future Homes Standard**.
- **New Law: net zero emissions of GHGs by 2050**.

Introduction

A successful case of global effort - ODP

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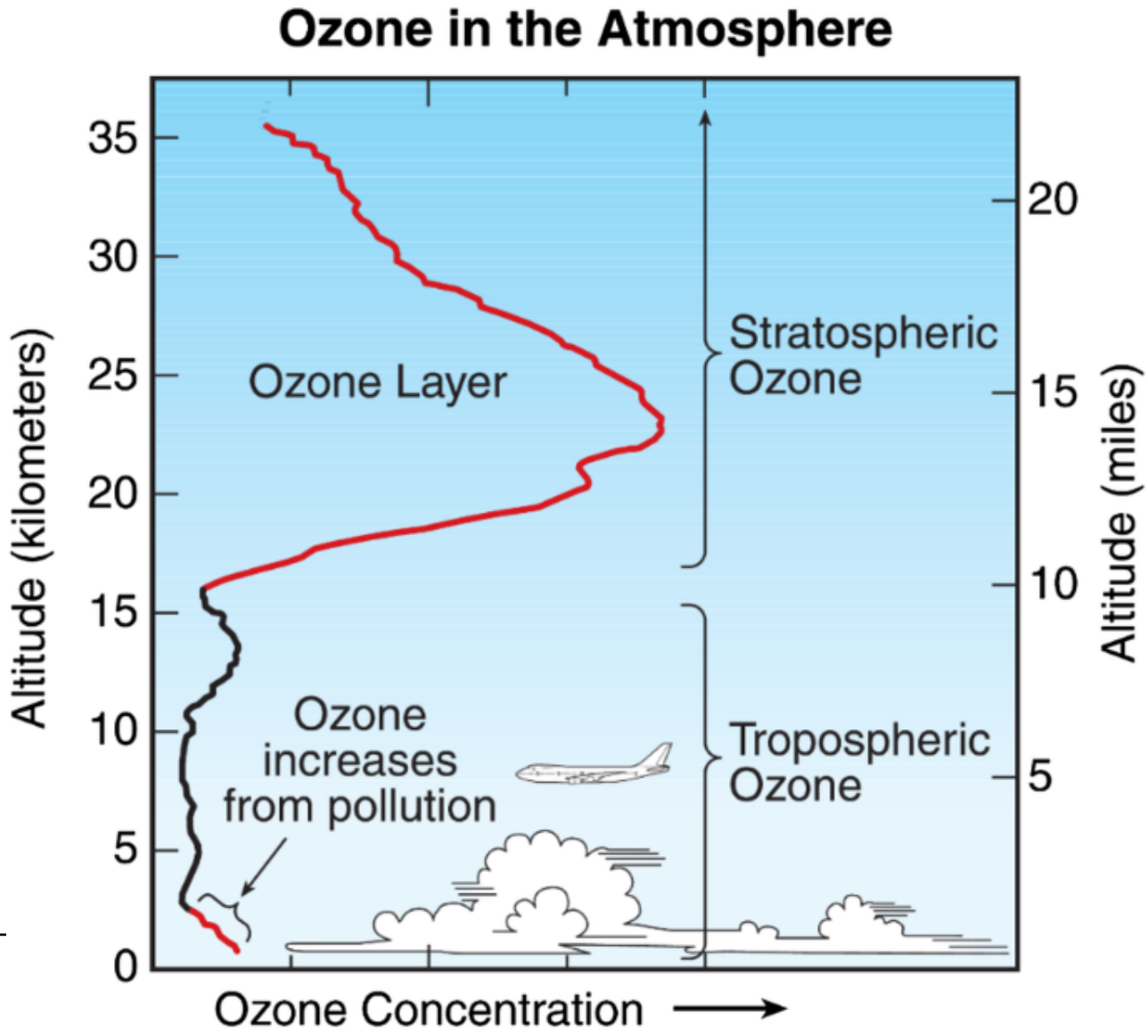

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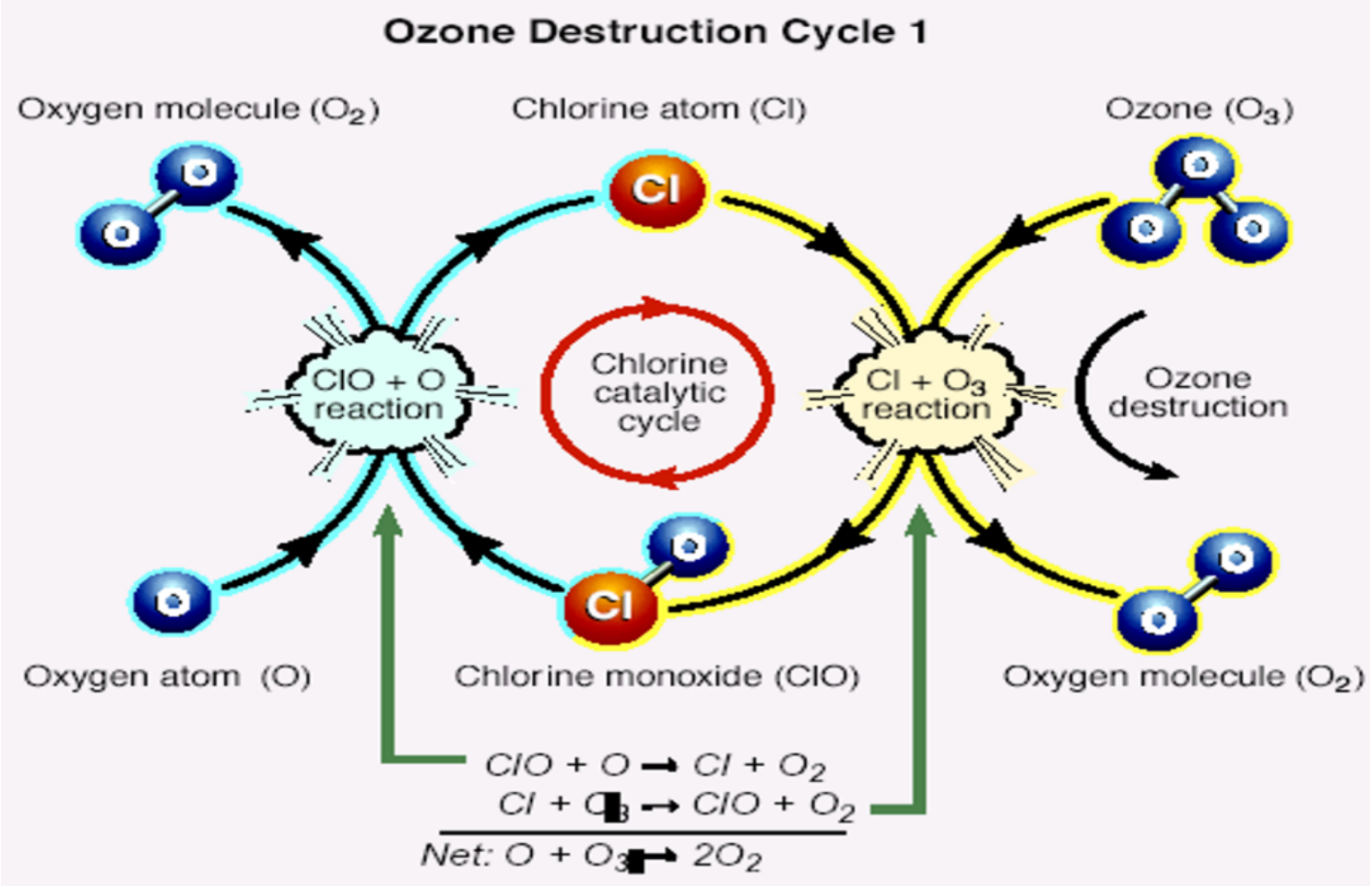
A successful case of global effort - ODP



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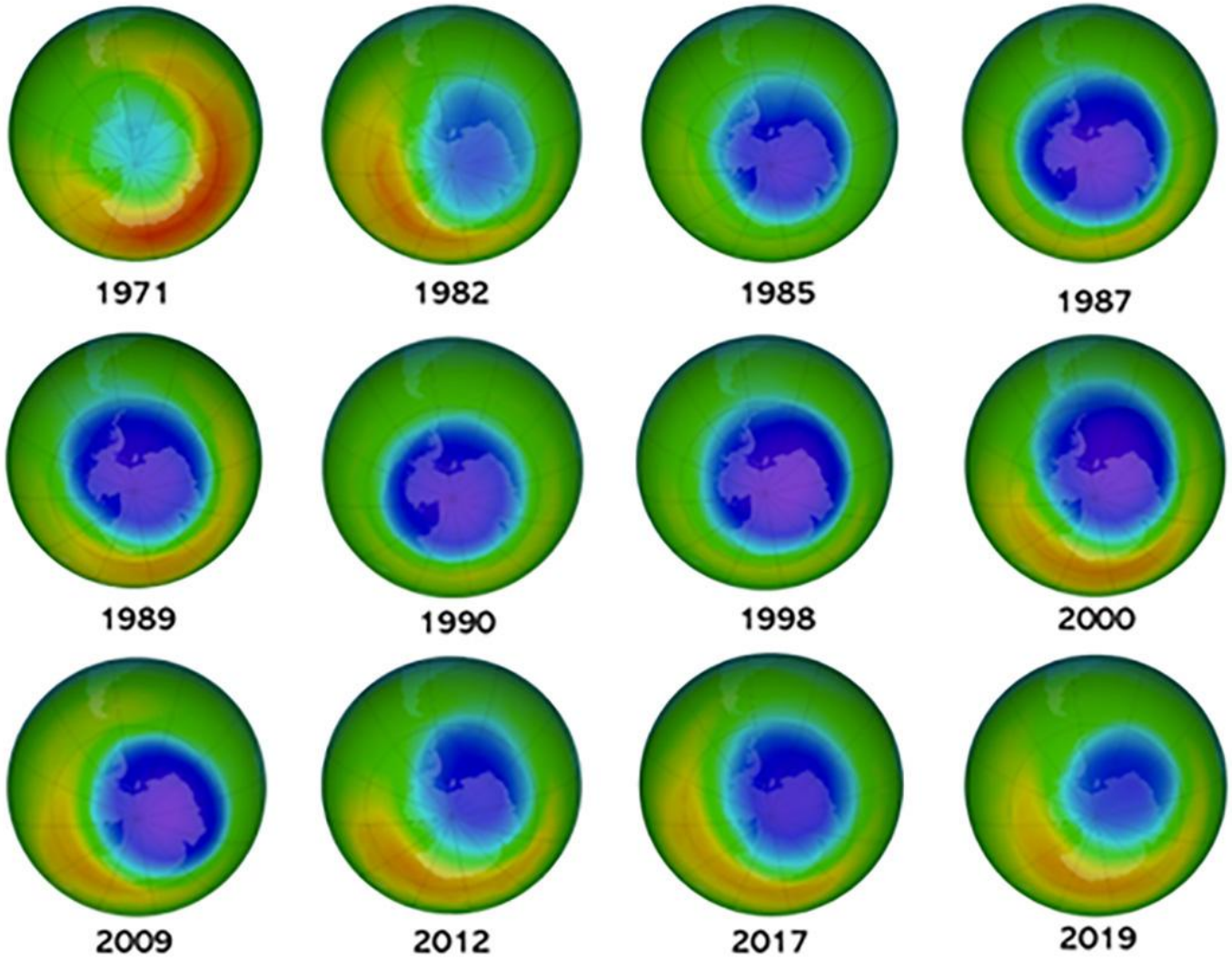

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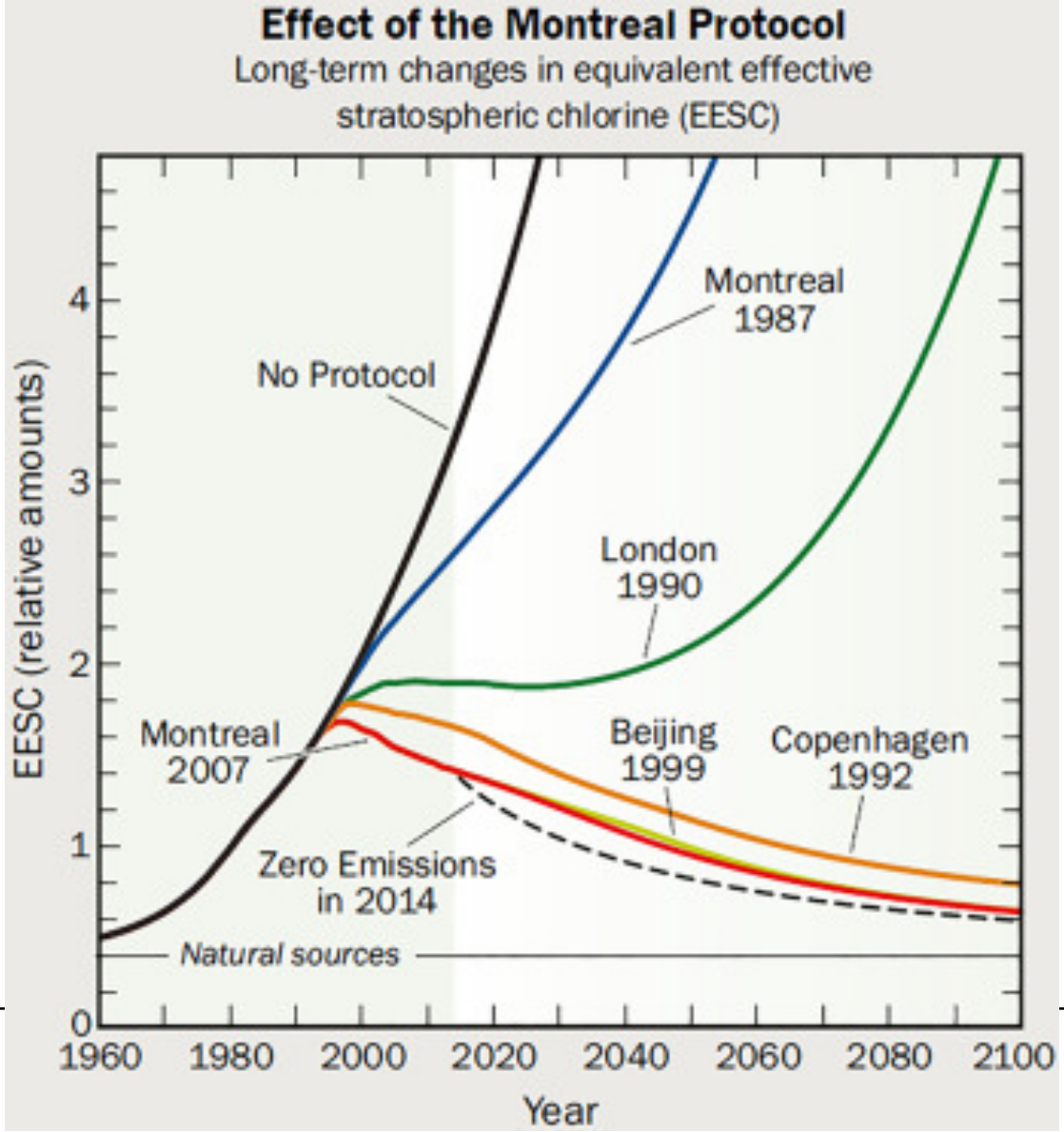

A successful case of global effort - ODP