University of Trieste

"There is no planet B! How to avoid the perfect storm"

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Outline of the talk

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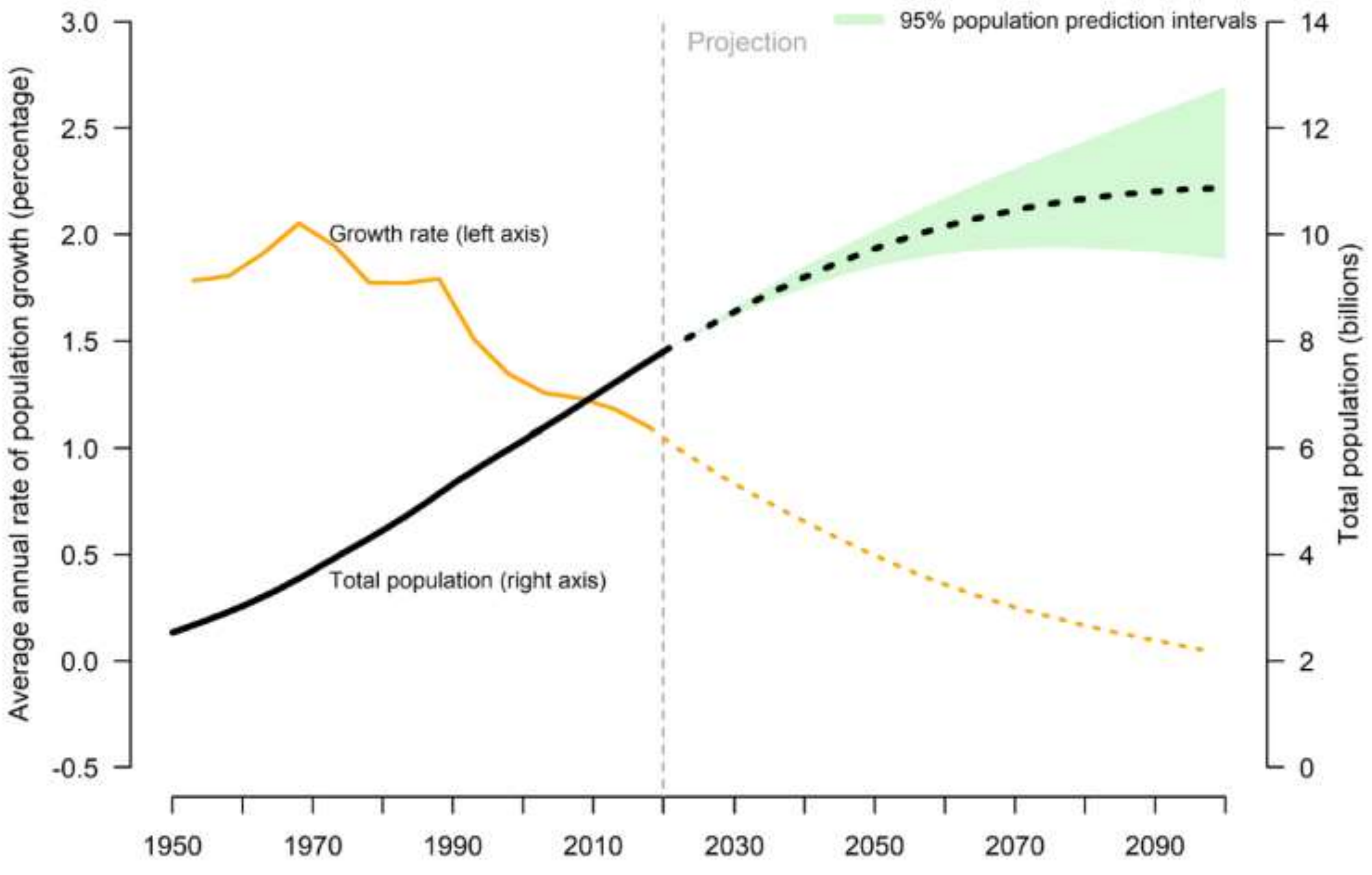
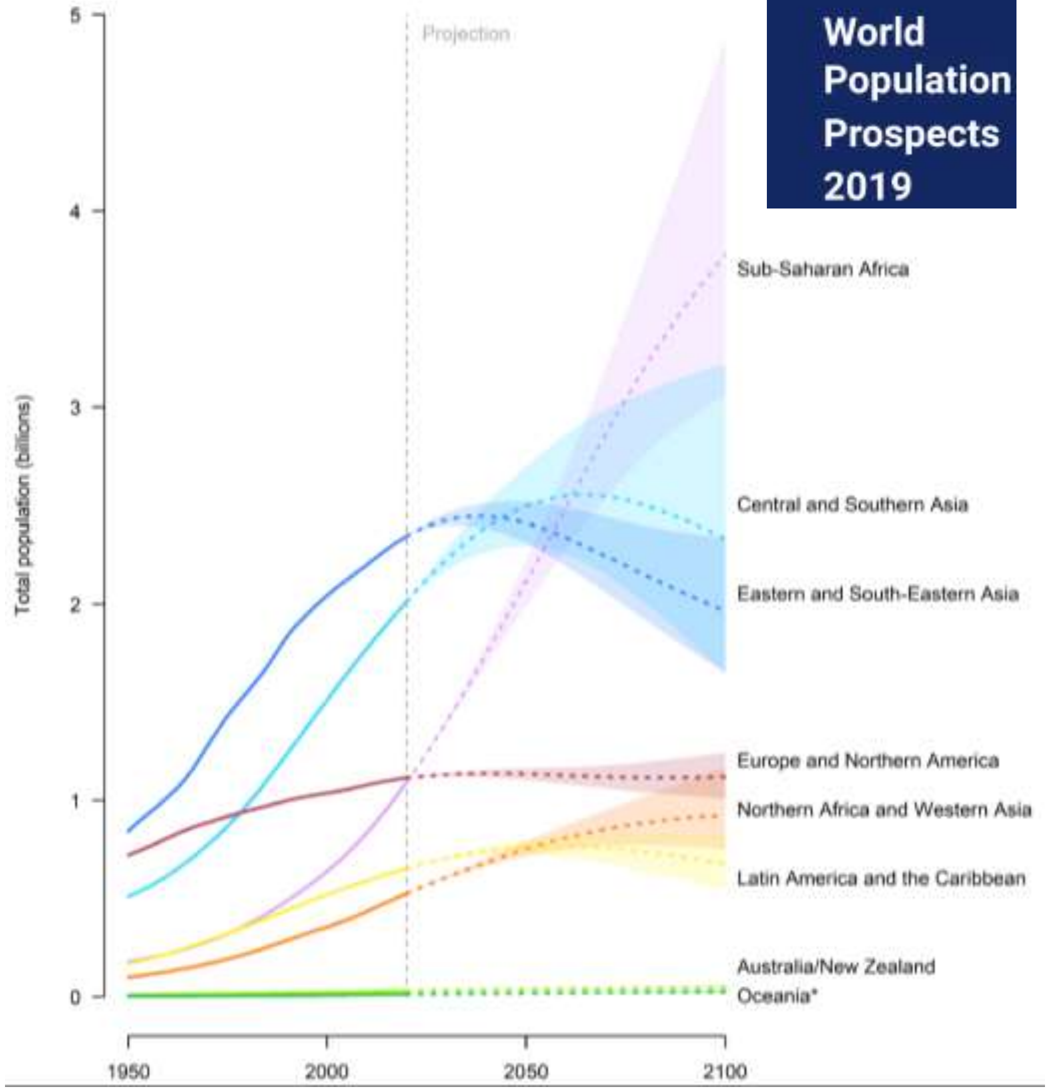
- Global warming: an environmental emergency
  - The perfect storm: John Beddington and other “weathermen”
  - CO_2 concentration in the atmosphere
  - Effects of global warming
  - Why we should act quickly
- The energy system: the main cause of global warming
  - Energy sources: past, present and future
  - Indicators for helping decisions on energy production
  - Non conventional fossil fuels
- Energy for transportation
  - Hydrogen as energy carrier
  - Hydrogen production processes: the colours of hydrogen
- Conclusions

World population grows … even if less than in the past years





United Nations
World Population Prospects 2019

John Beddington’s perfect storm

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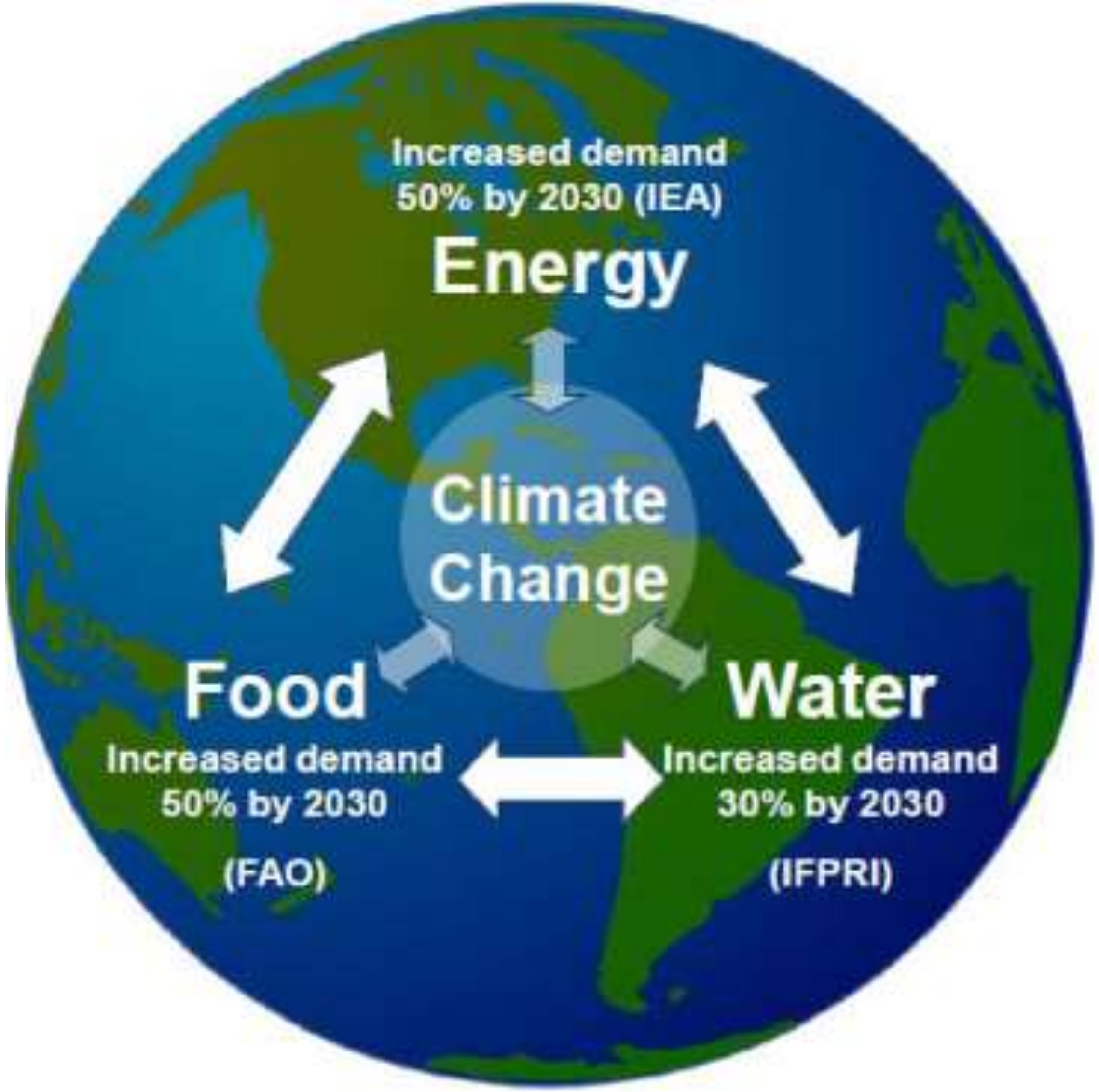

theguardian

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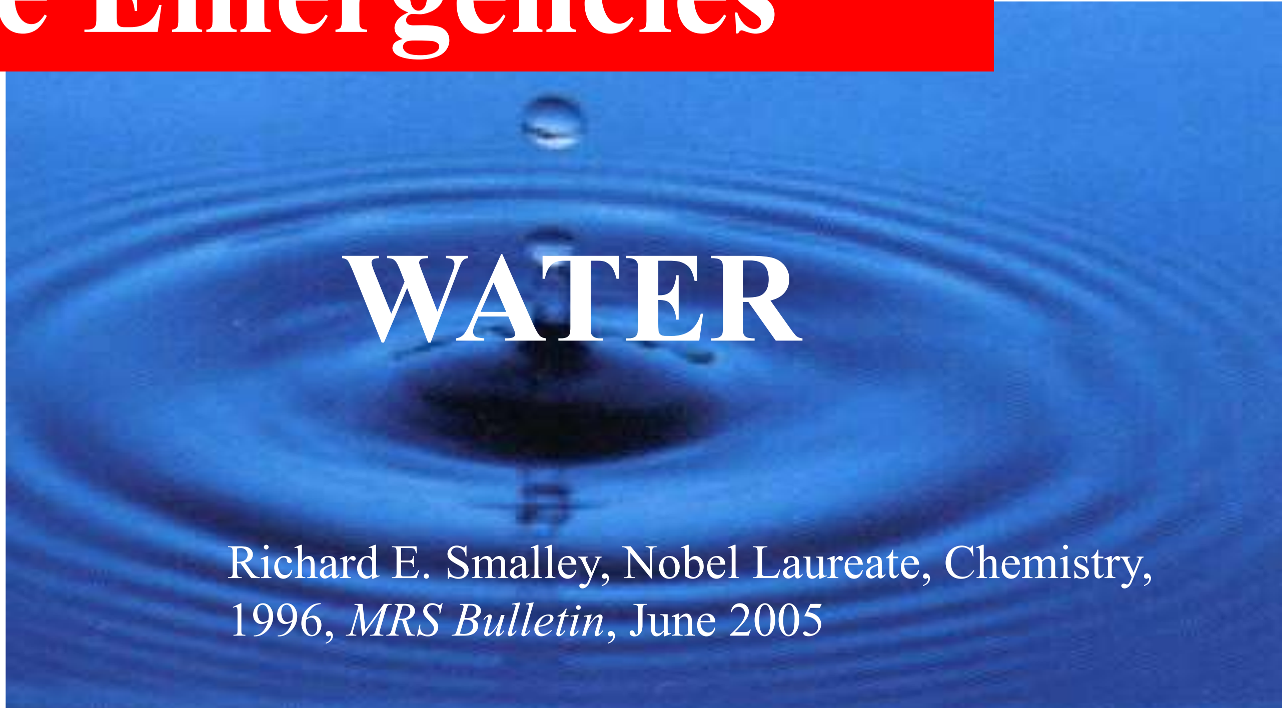
News › Science

World faces 'perfect storm' of problems by 2030, chief scientist to warn

Food, water and energy shortages will unleash public unrest and international conflict, Professor John Beddington will tell a conference tomorrow

4 World Wide Emergencies



Richard E. Smalley, Nobel Laureate, Chemistry, 1996, *MRS Bulletin*, June 2005

Timeline: the weathermen

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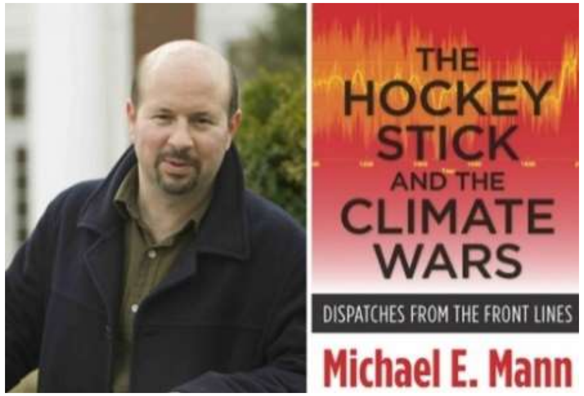
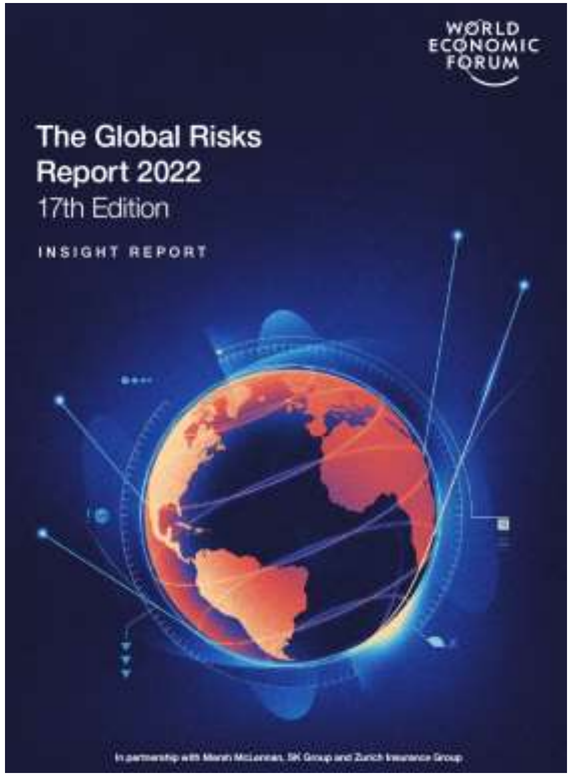
- ***1824 - Jean Baptiste Joseph Fourier*** *predicts* ***greenhouse effect.***
- ***1896 - Svante Arrhenius*** *calculates that greenhouse effect will lead to the* ***global warming****.*
- ***1938 - Guy Stewart Callendar first scientific proof of global warming.***
- ***1957 - Roger Revelle*** *much less* ***CO_2 is adsorbed by oceans.***
- ***1958 - Charles David Keeling Mauna Loa*** *measurements.*
- ***1998 - Michael Mann, et al., hockey stick' graph****.*
- ***2007 – IPCC*** human responsibility of **CO_2 *growth is 90%.***
- ***2013 – IPCC*** human responsibility of **CO_2 *growth is 95%.***
- ***2021 – IPCC*** **temperature will continue to raise** until at least 2050, for any scenario



World Economic Forum: Global Risk Report 2022



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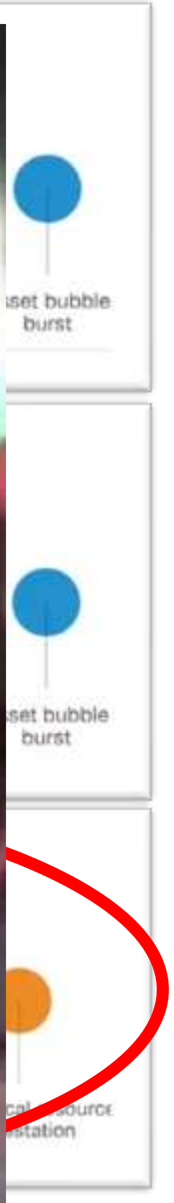

Greenhouse gases concentration in the atmosphere

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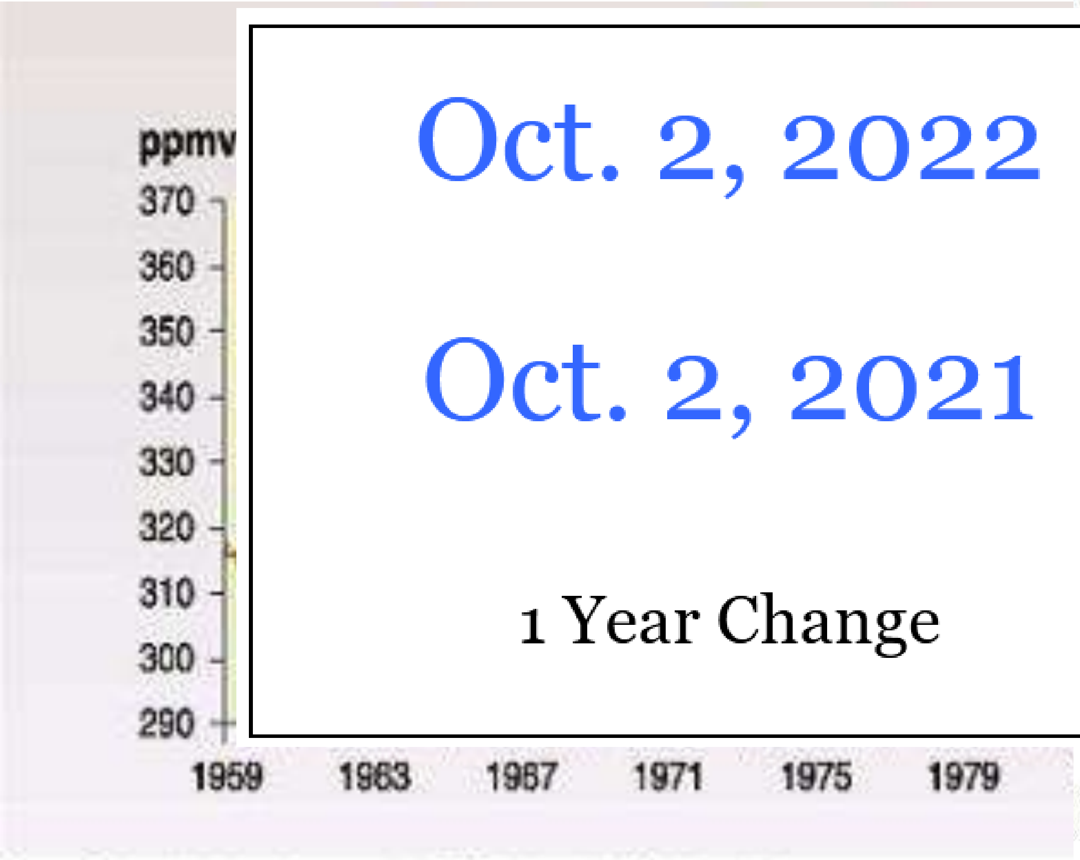
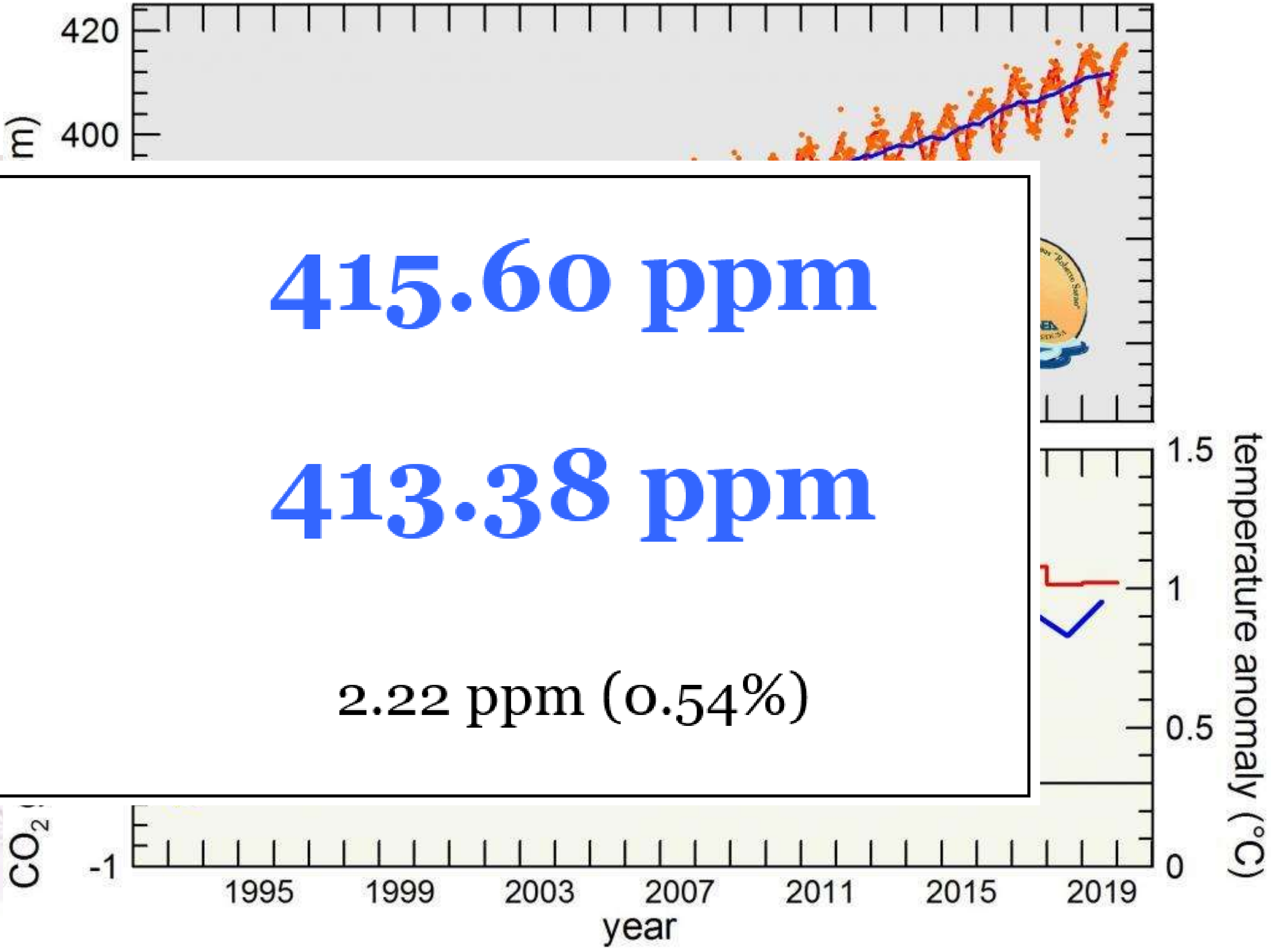
2010: 380ppm
1900: 280ppm

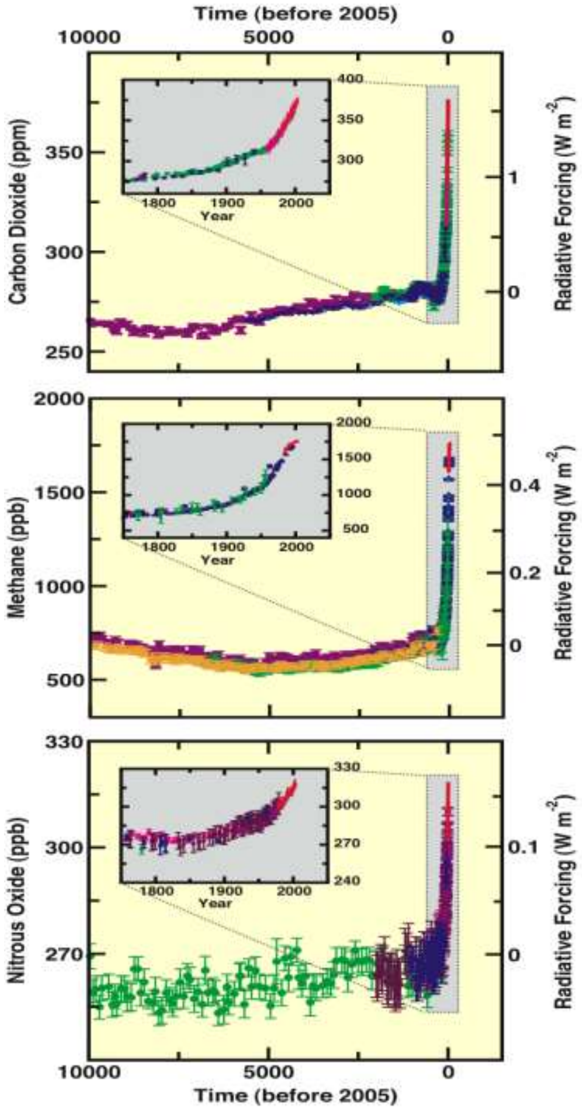


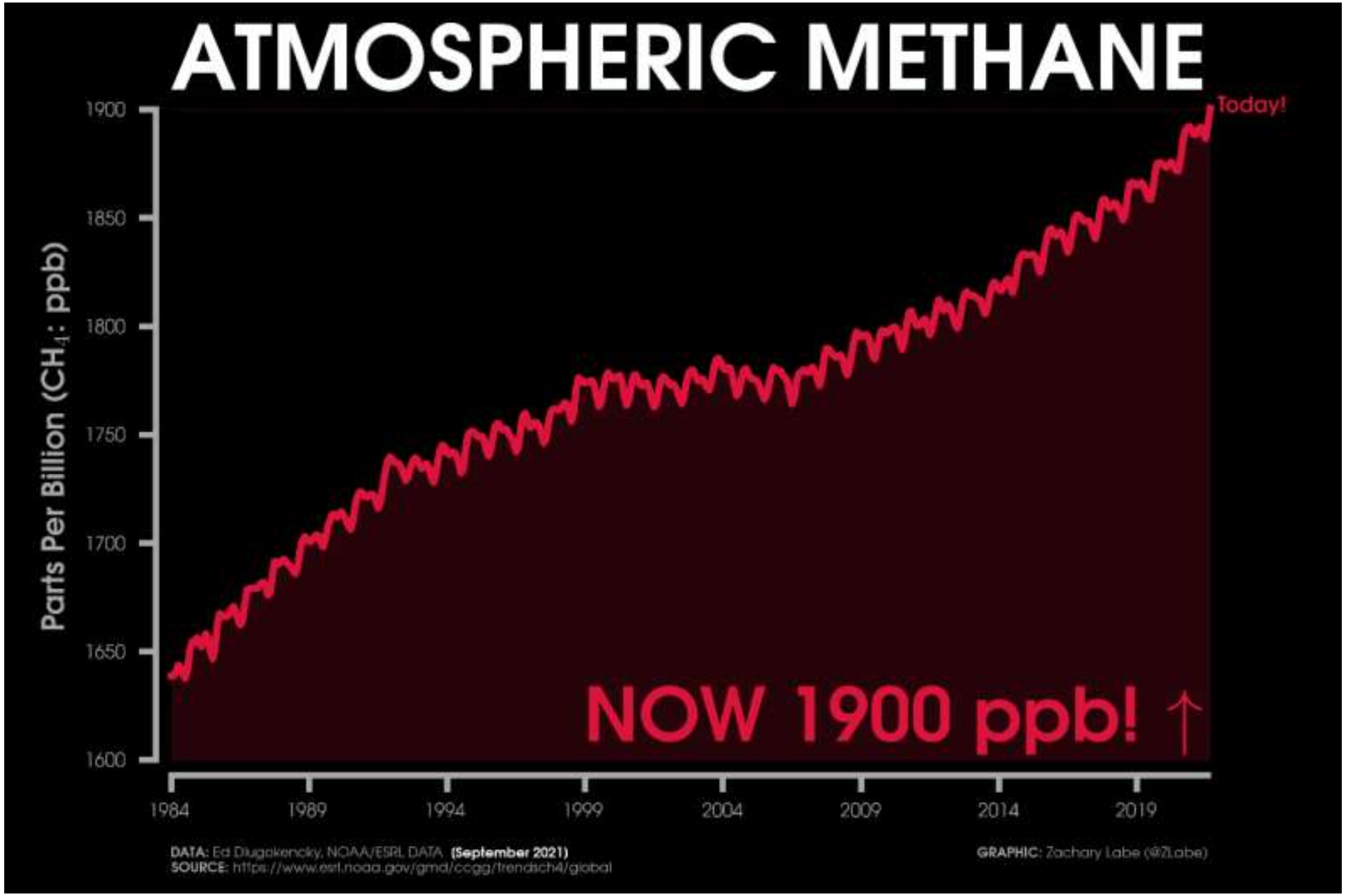
Source : Scripps institution of oceanography (SIO), University of California, 1998.



Oct. 2, 2022	**415.60 ppm**
Oct. 2, 2021	**413.38 ppm**
1 Year Change	2.22 ppm (0.54%)

Greenhouse gases concentration in the atmosphere





The energy system is the main responsible of the emissions

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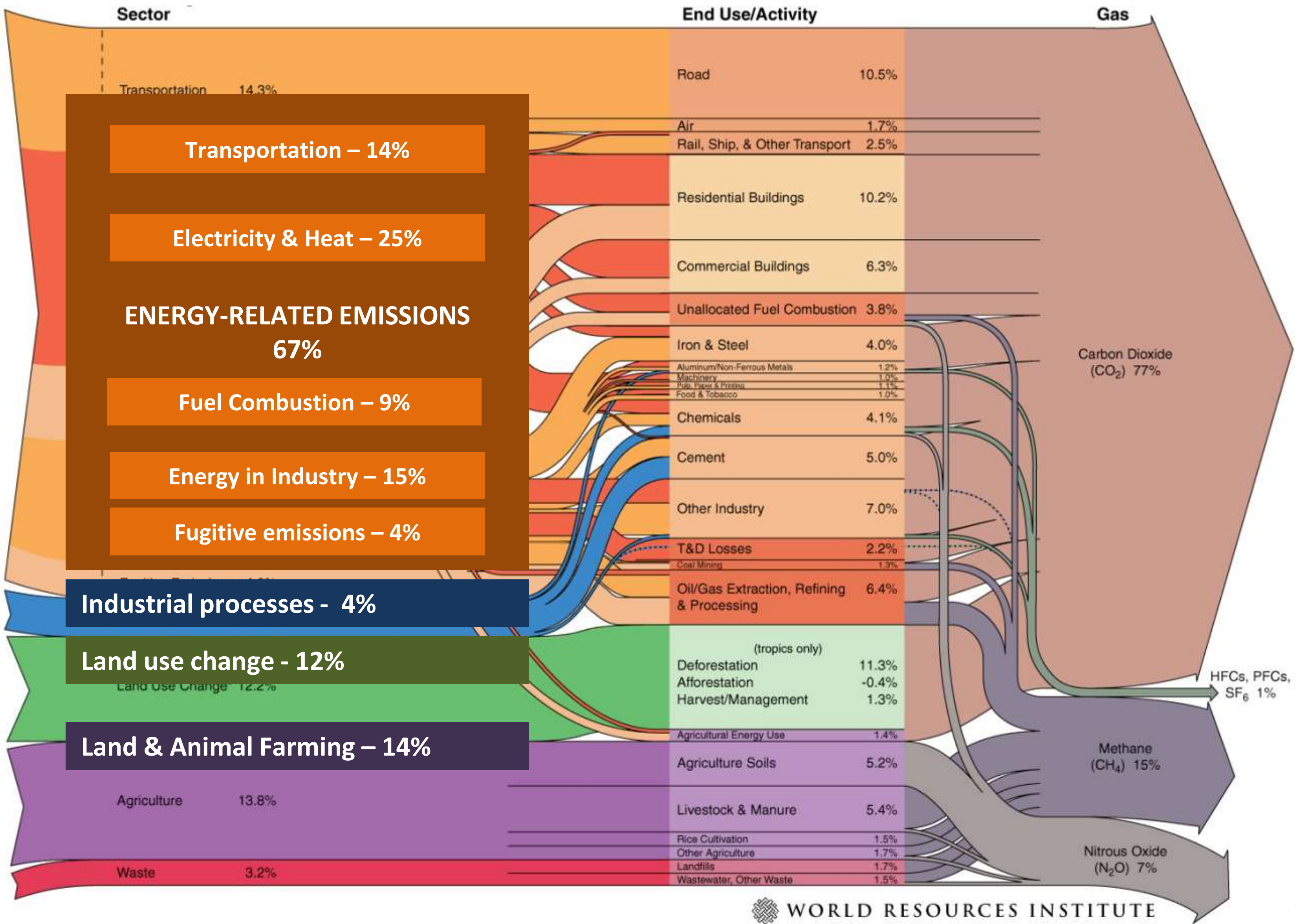
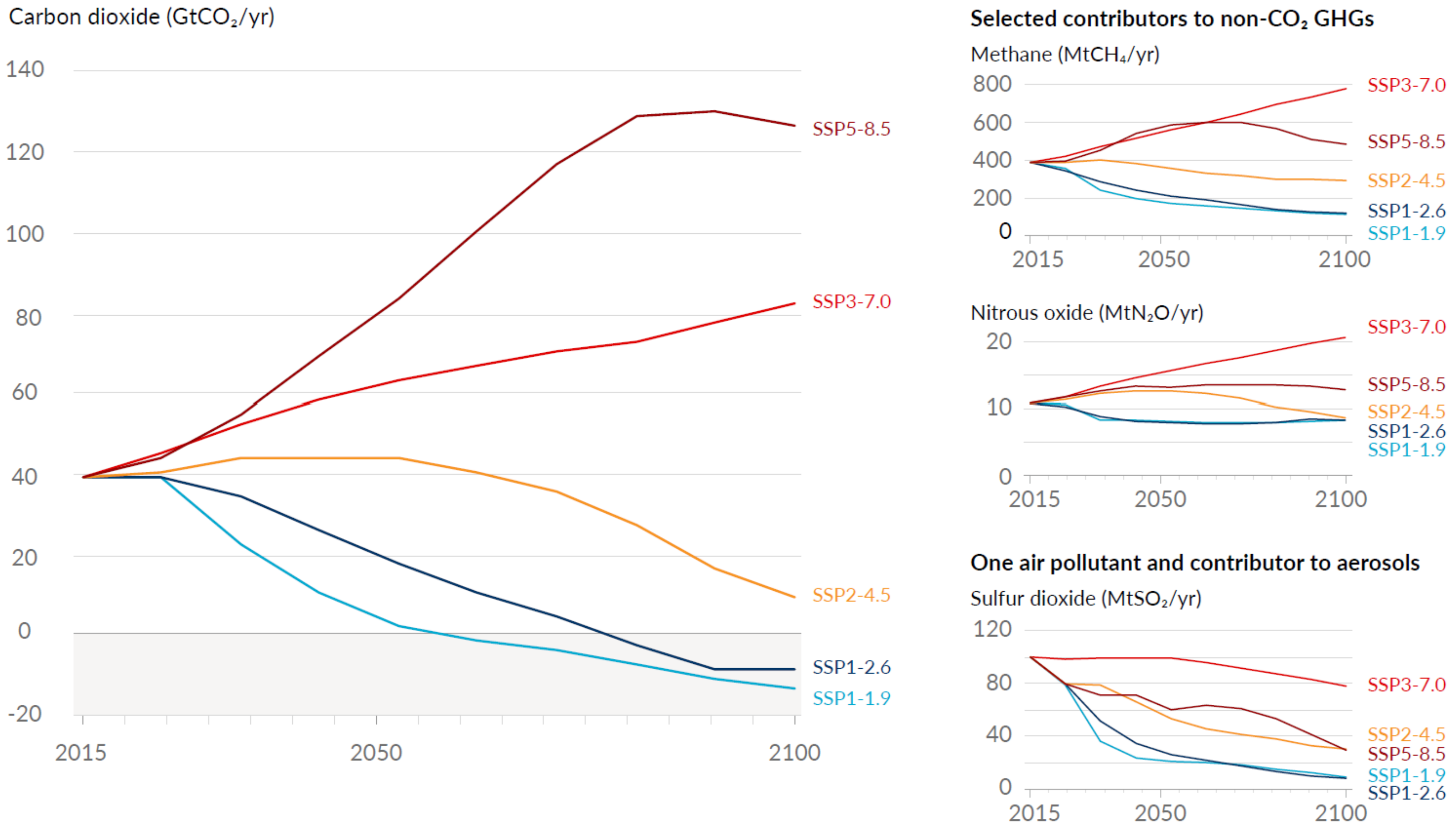


IPCC 2021: future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right).



Average earth temperature from 1880 to 2021

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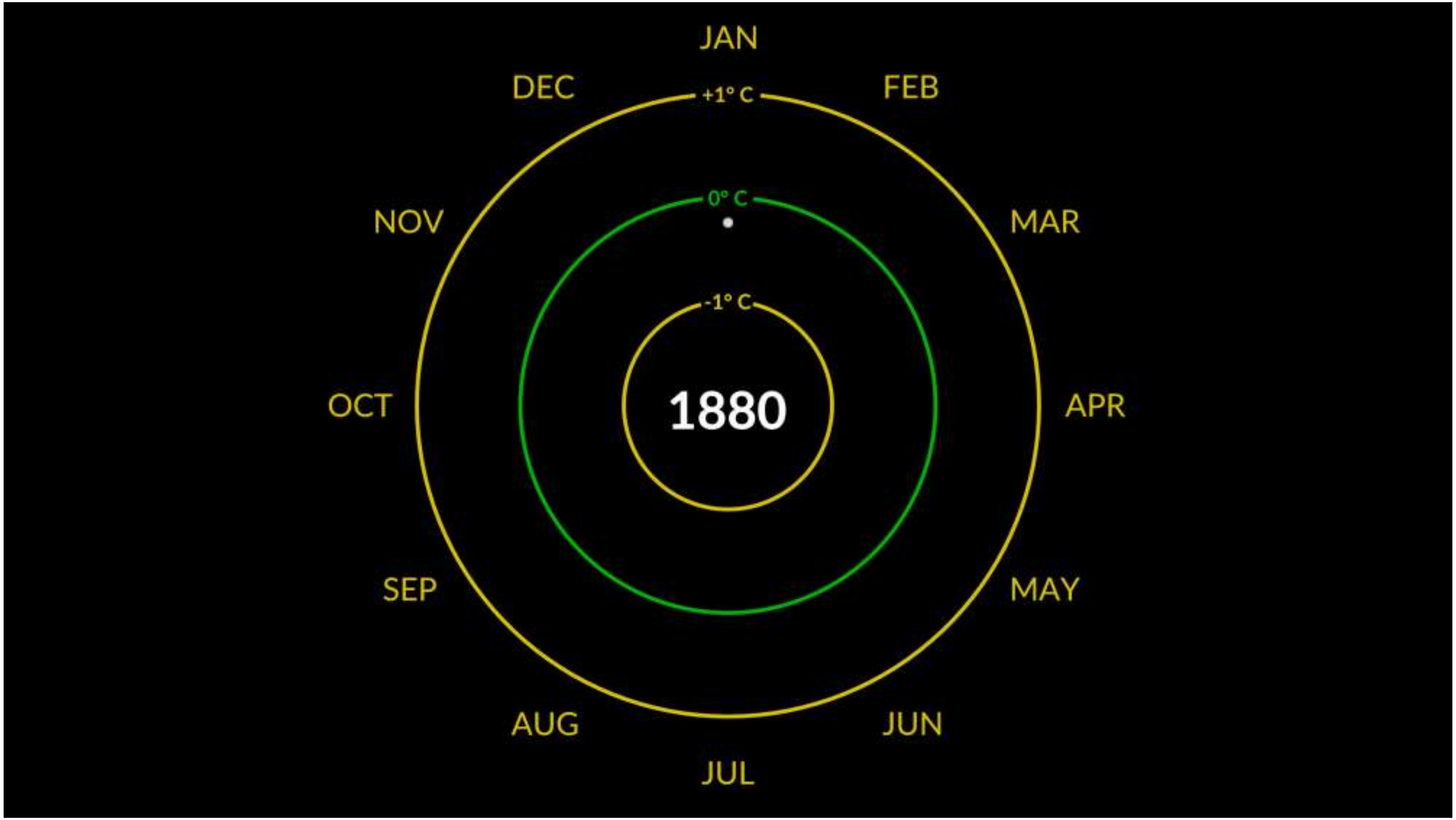

What is *really* warming the planet?

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IPCC 2021: the current state of the climate: temperature raised of about 1.2° in 100 years

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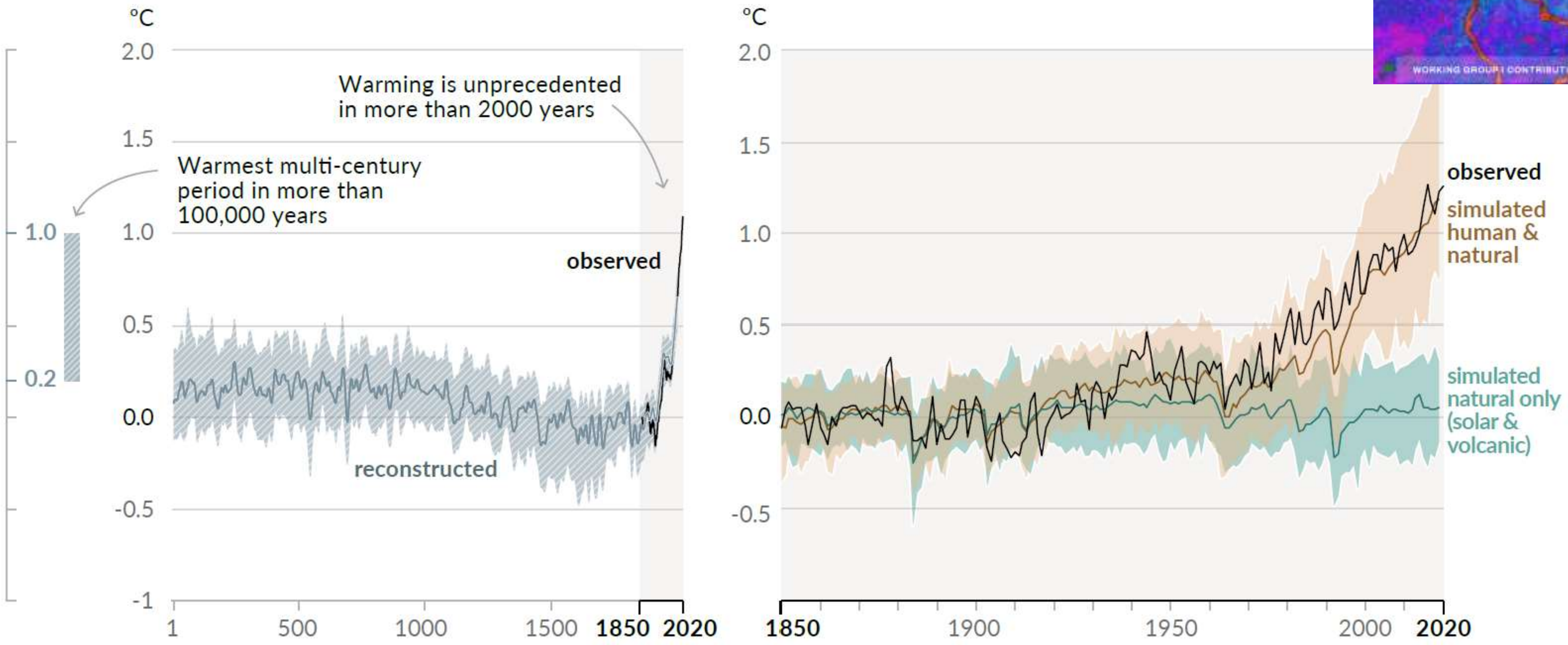
- Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years
  - Changes in global surface temperature relative to 1850-1900



The temperature of the planet has remained relatively stable for the last 11,000 years (Holocene)

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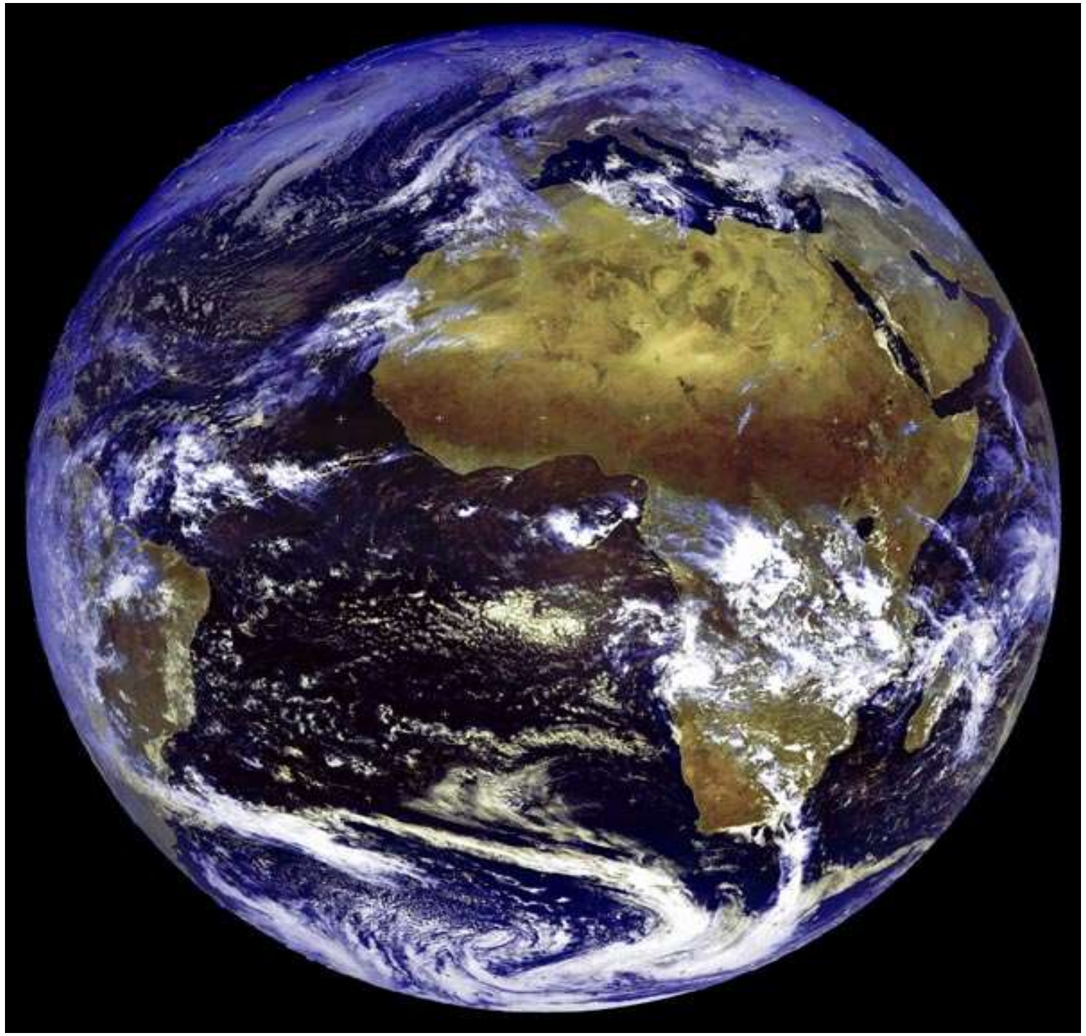
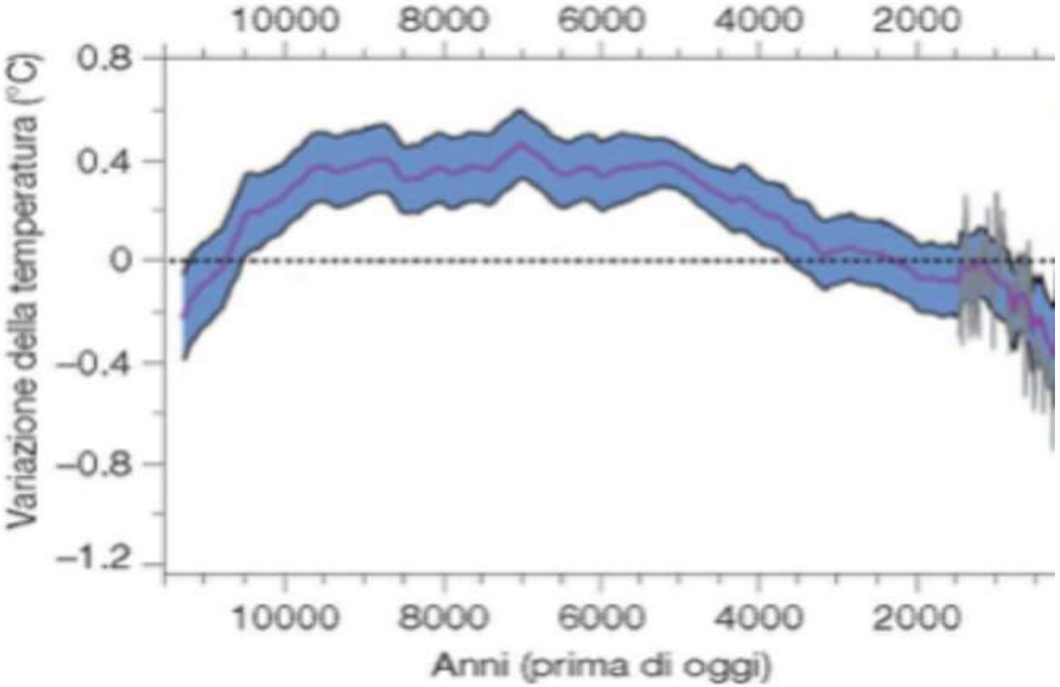
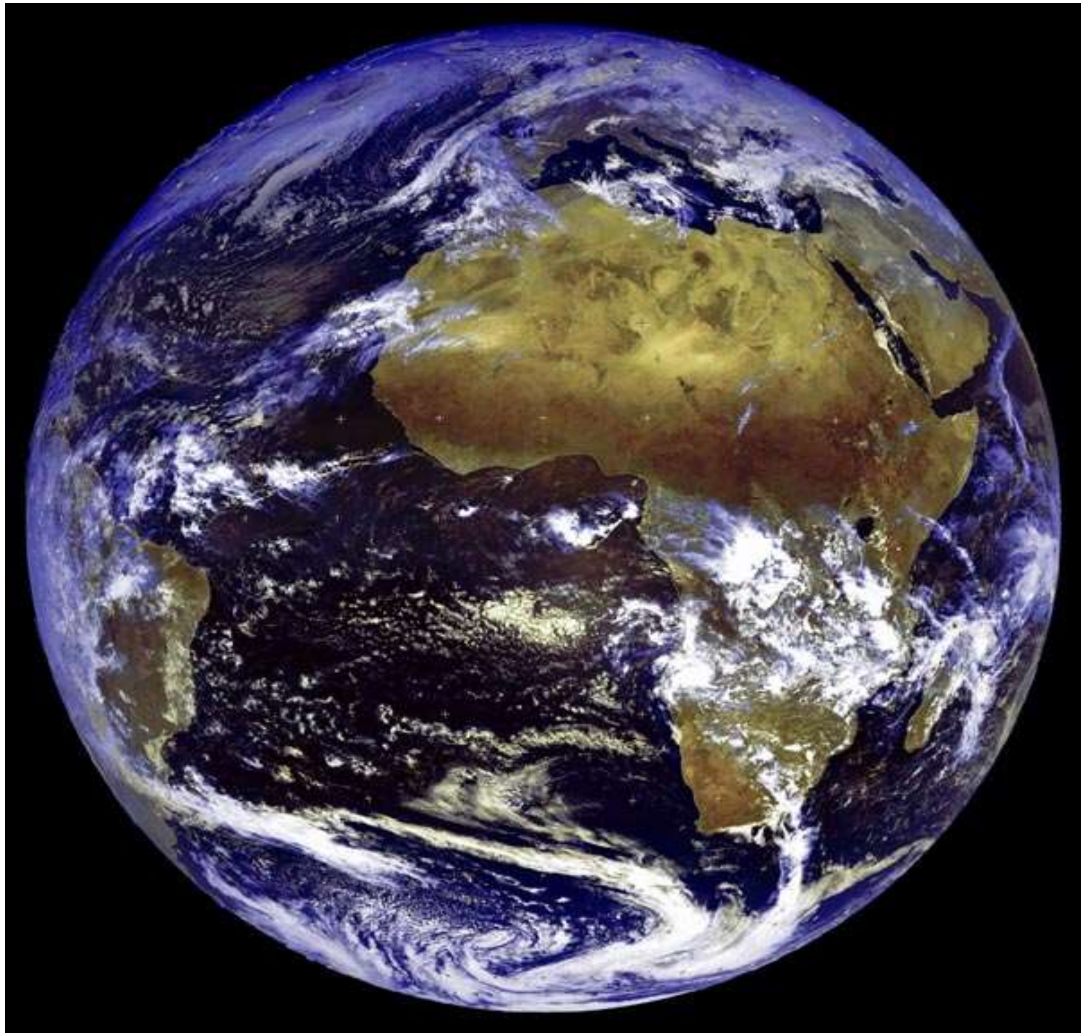
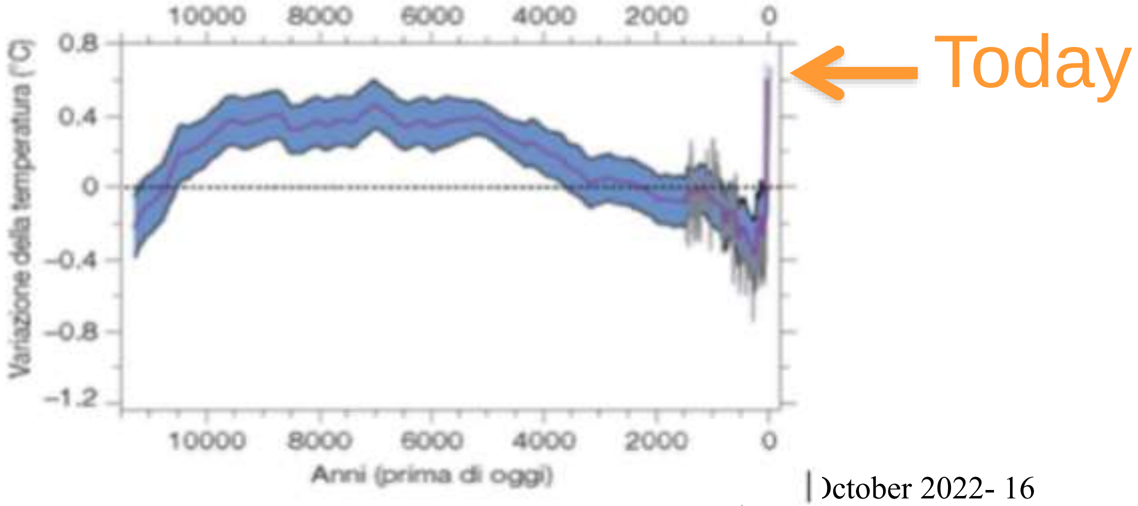


Marcott et al. 2013; Science

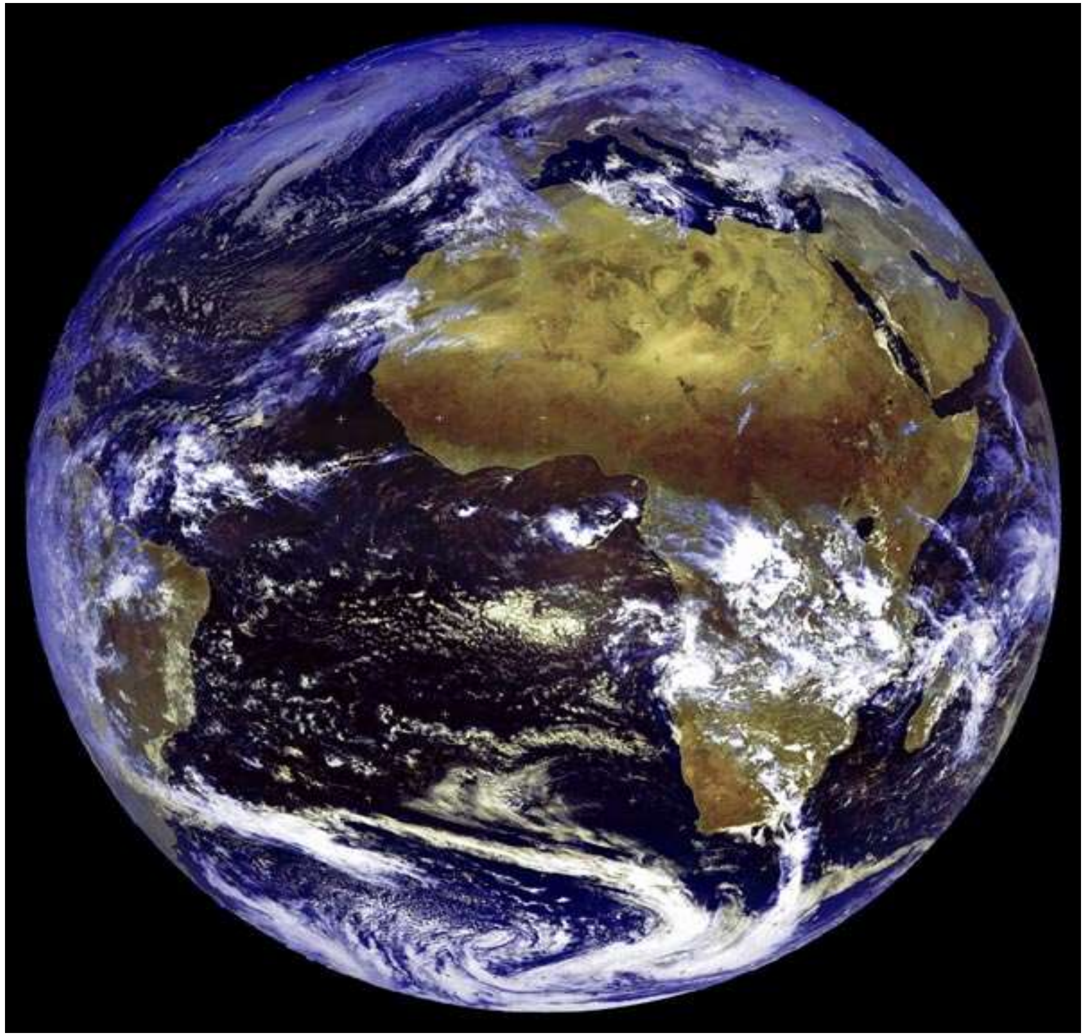


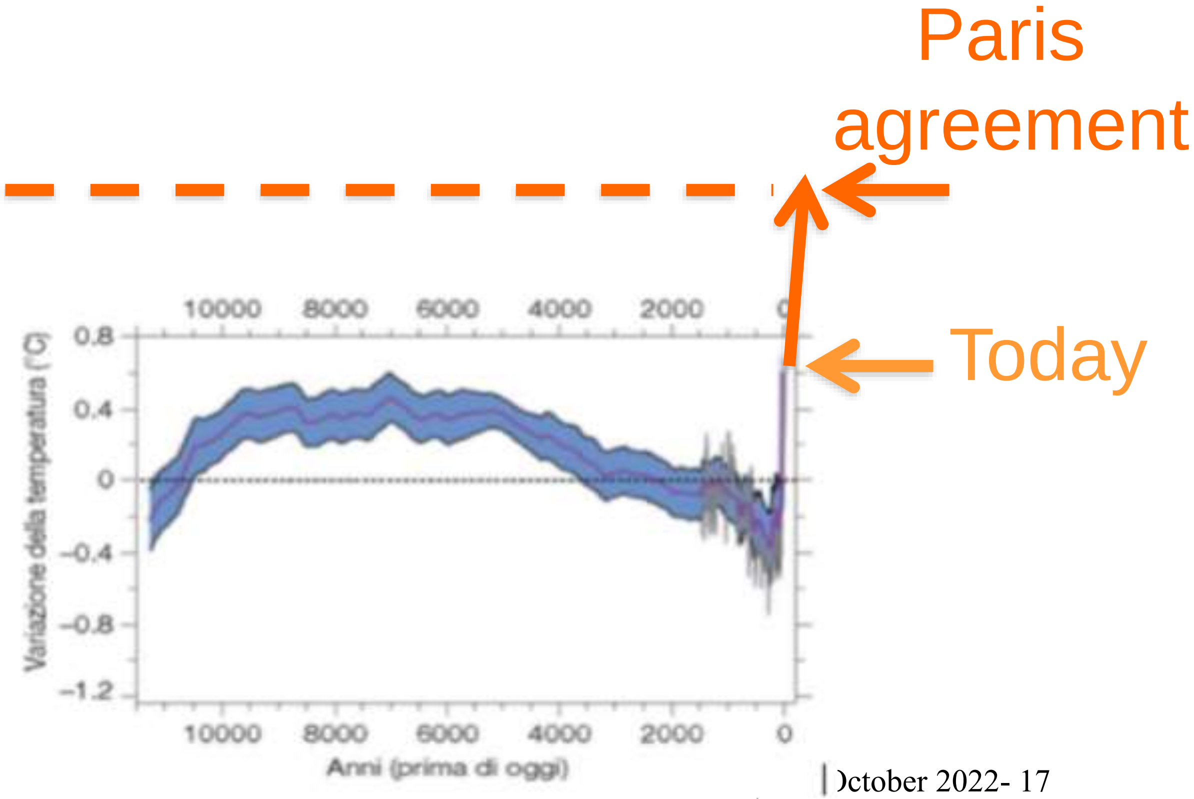
Now the planet has an anomalous “fever”



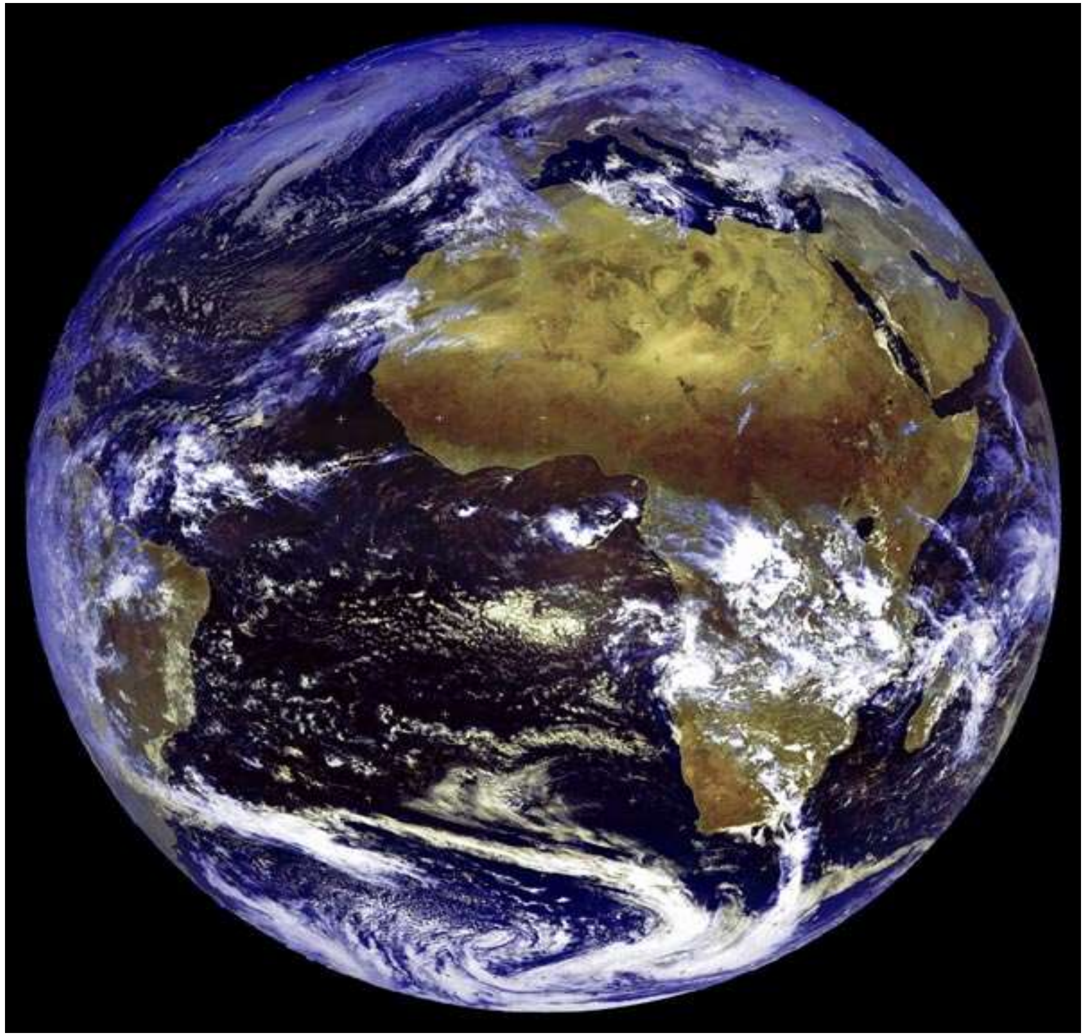


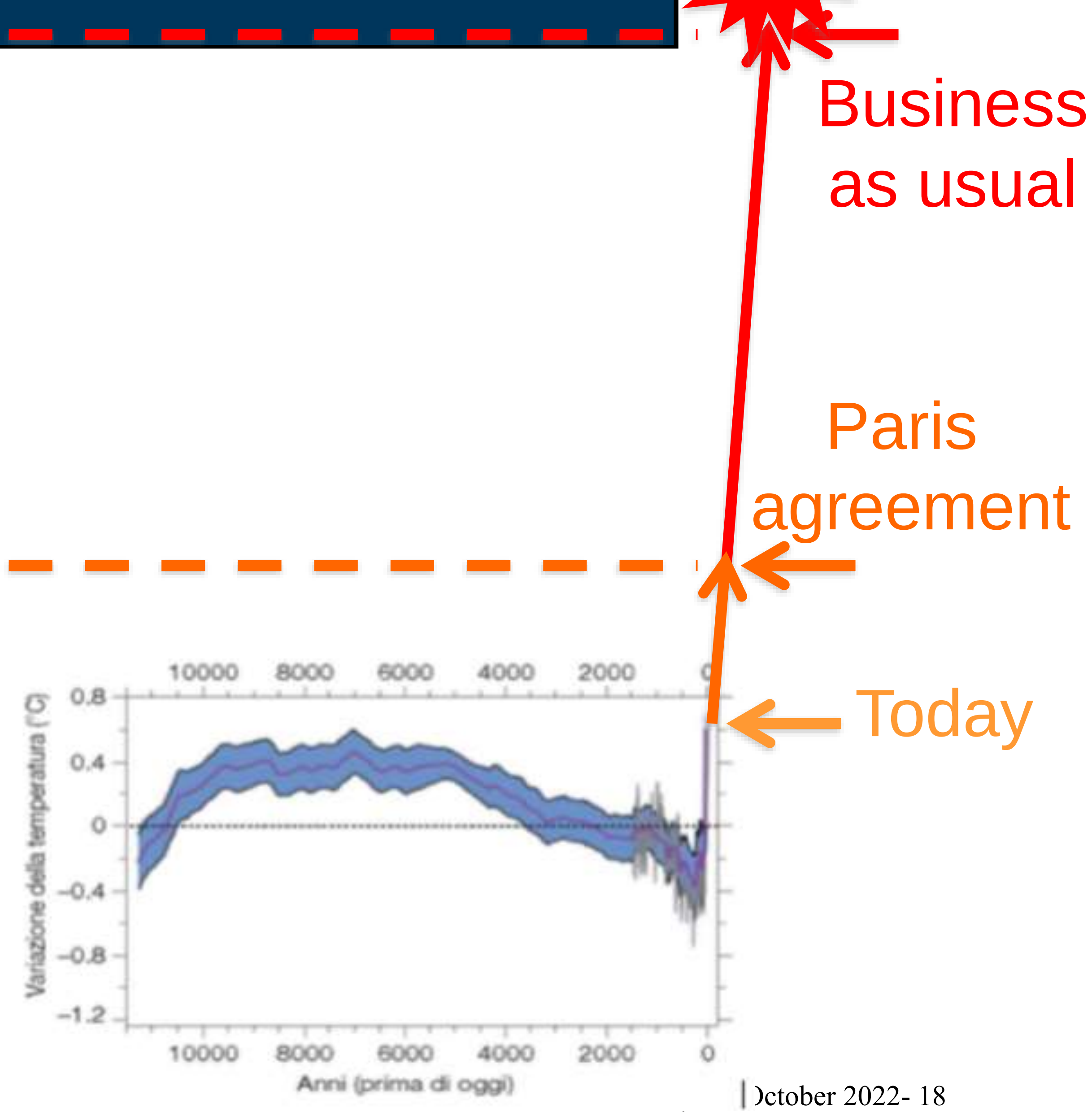
Which could grow in the future



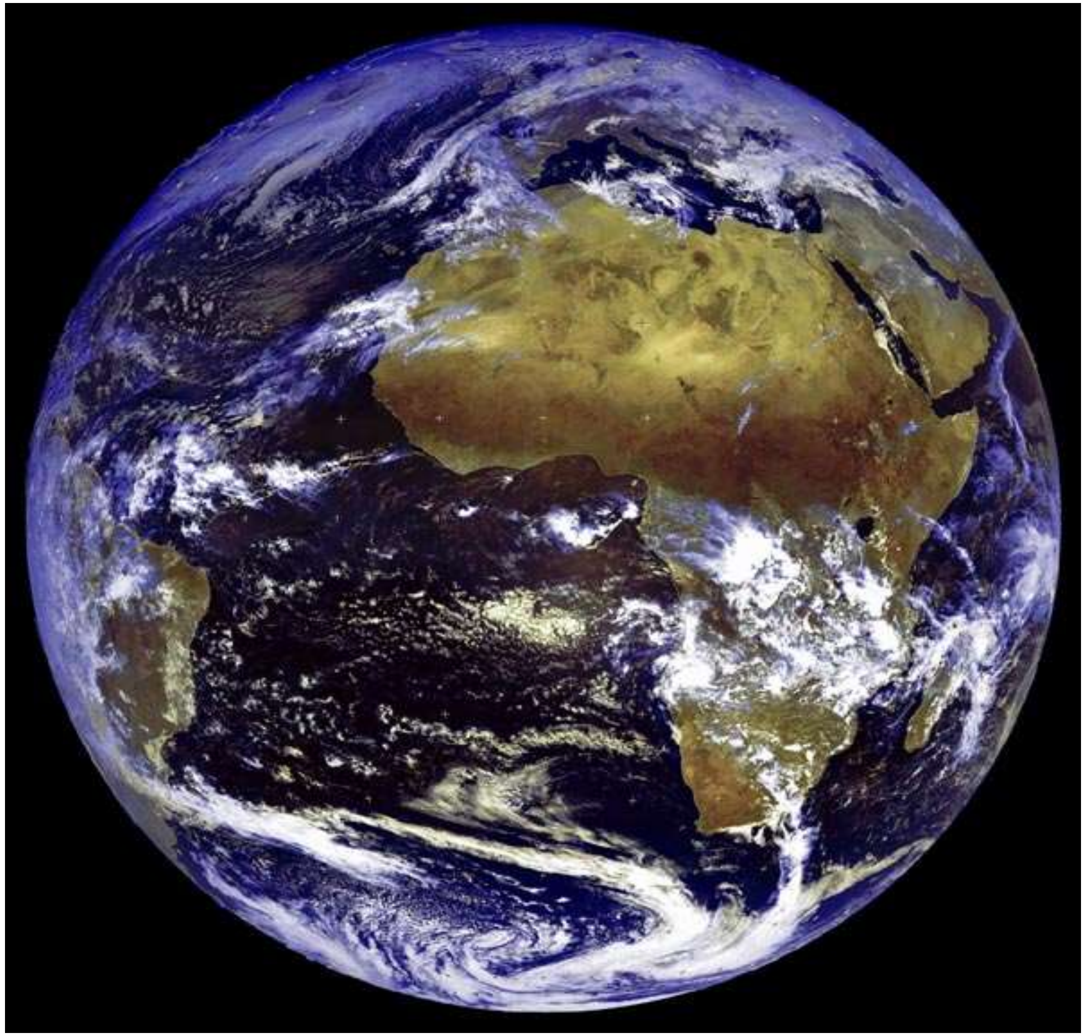


To the point of becoming a threat for society



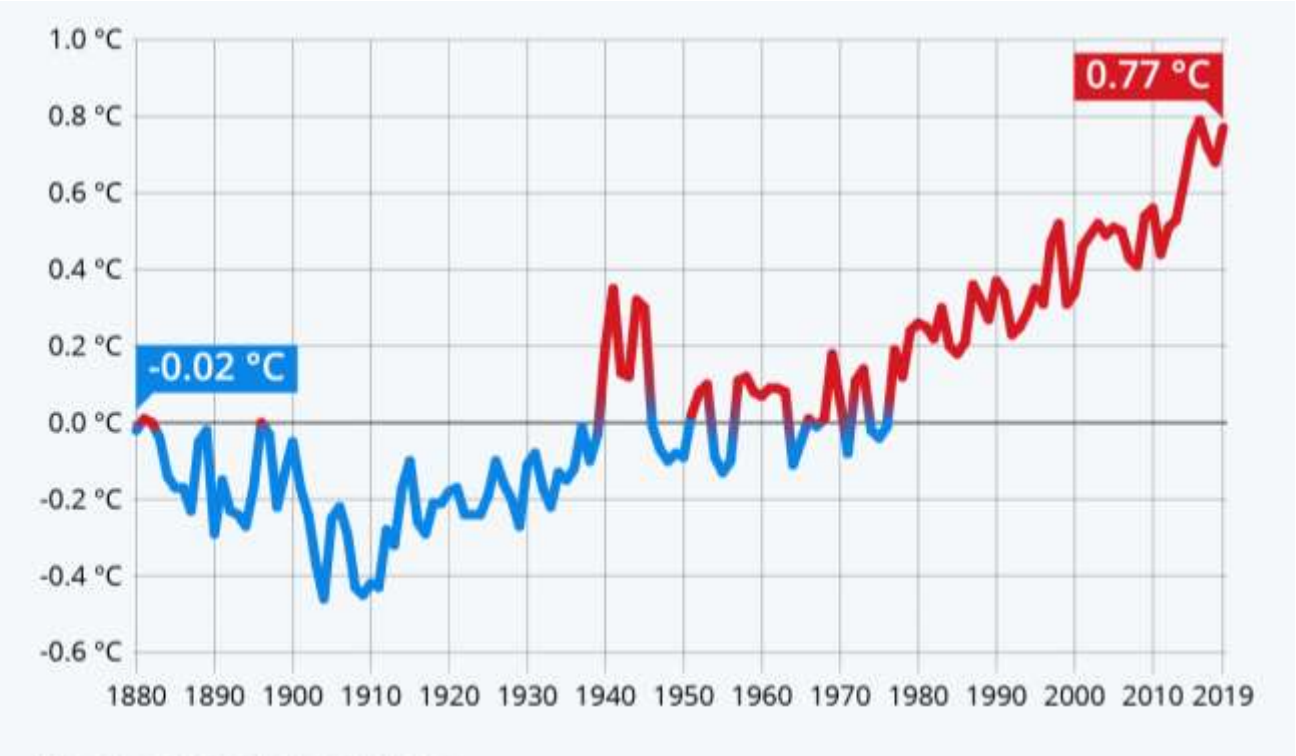


RCP8.5, at the end of 21 century, EURO-CORDEX



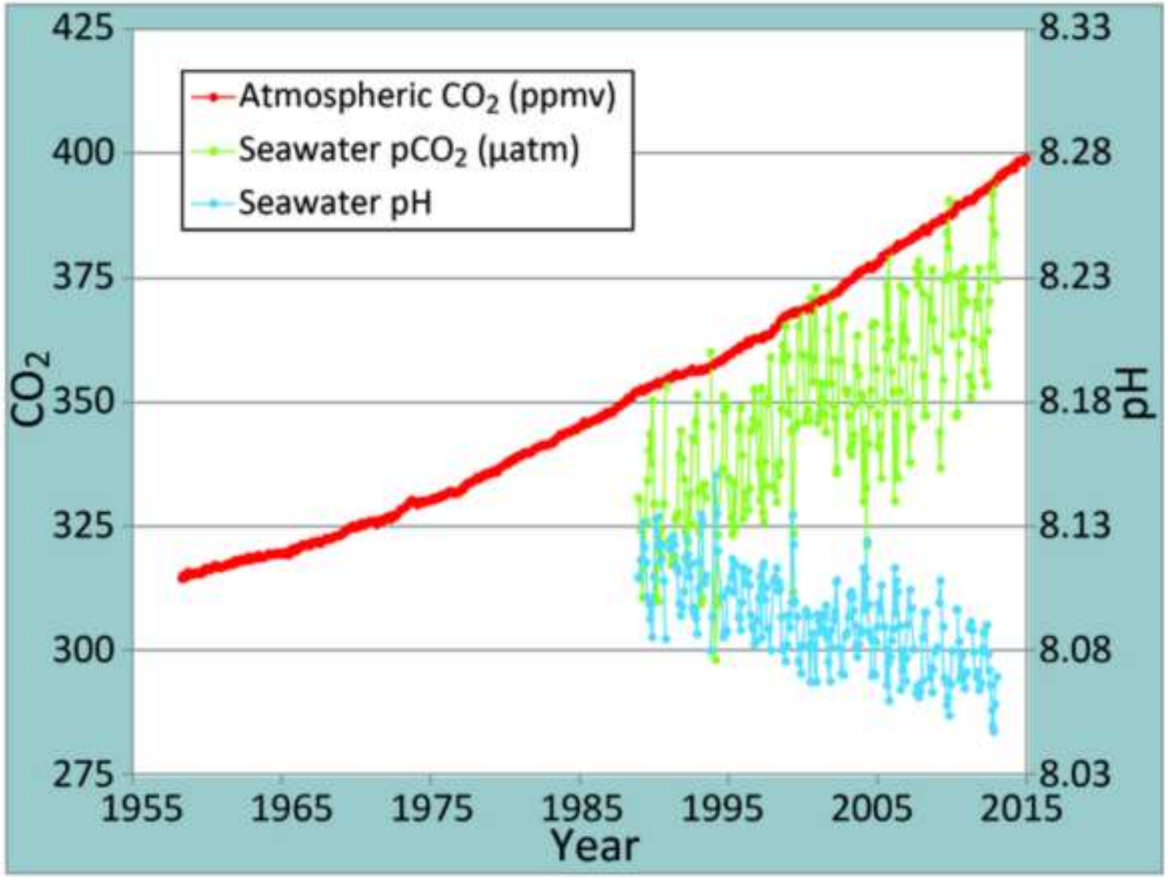
Oceans are heating up too

- Annual divergence of global ocean temperature from 20th century average (1880 – 2019)



Ocean surface temperatures
Source: NOAA National Centers for Environmental Information (NCEI)

- Ph and CO_2 concentration



Glacier melting

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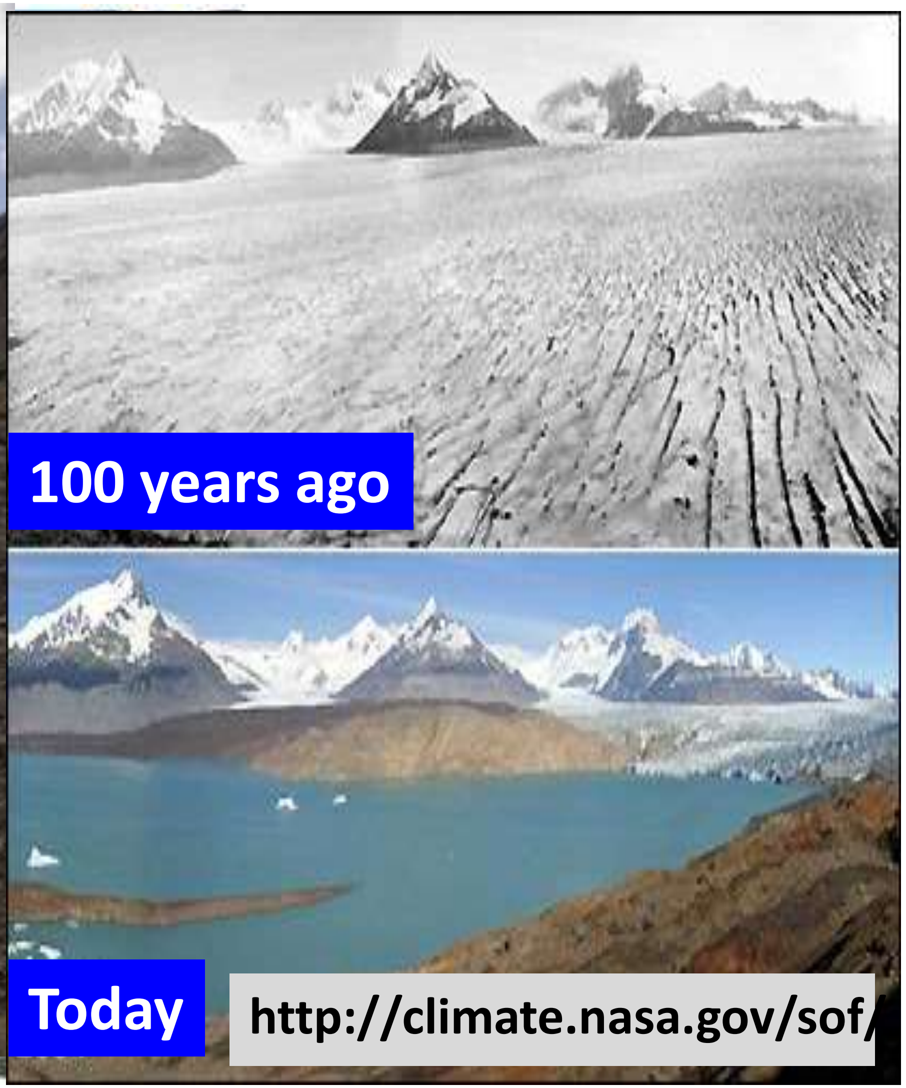

Permafrost melts

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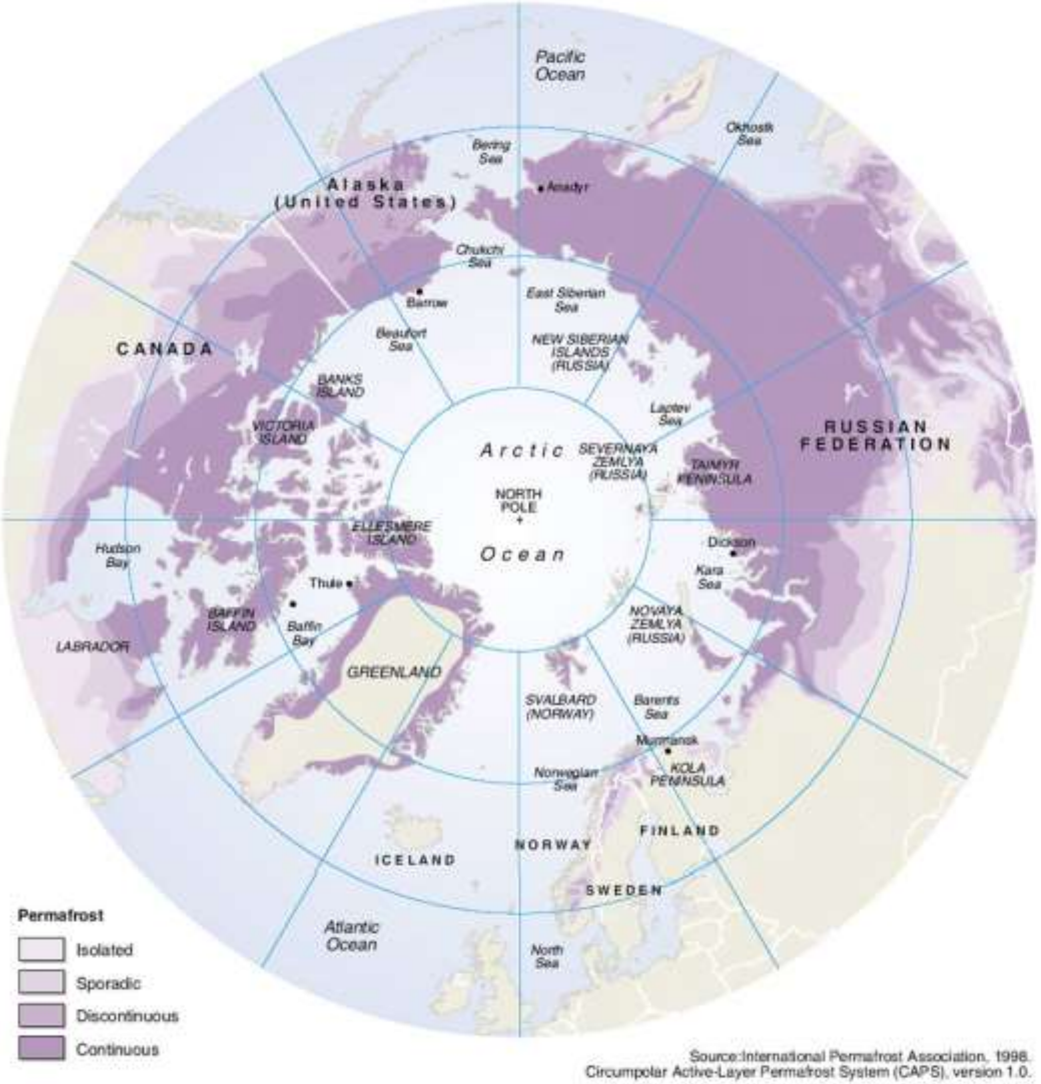
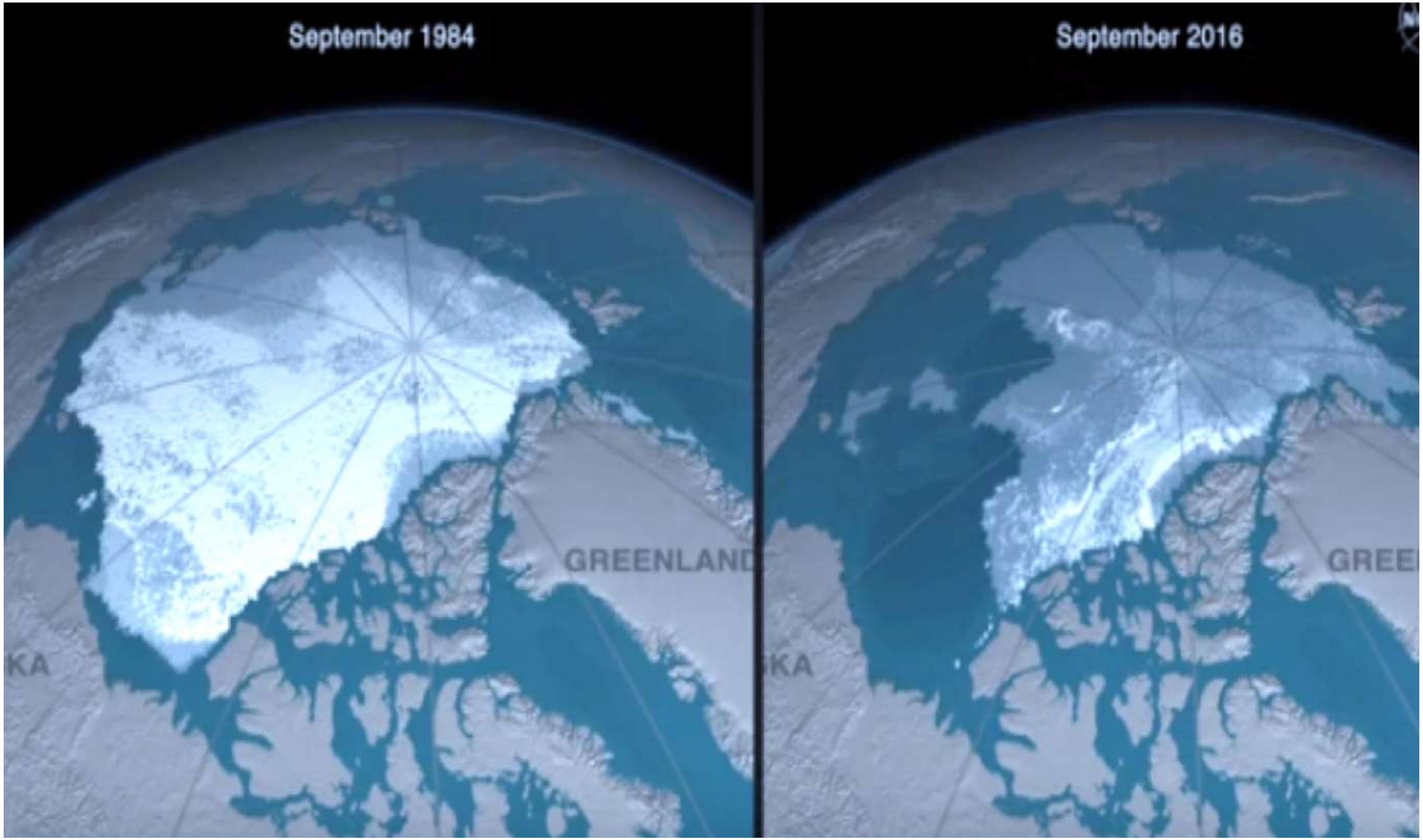


Melting arctic ice caps



IPCC – 2021: Human activities affect all the major climate system components

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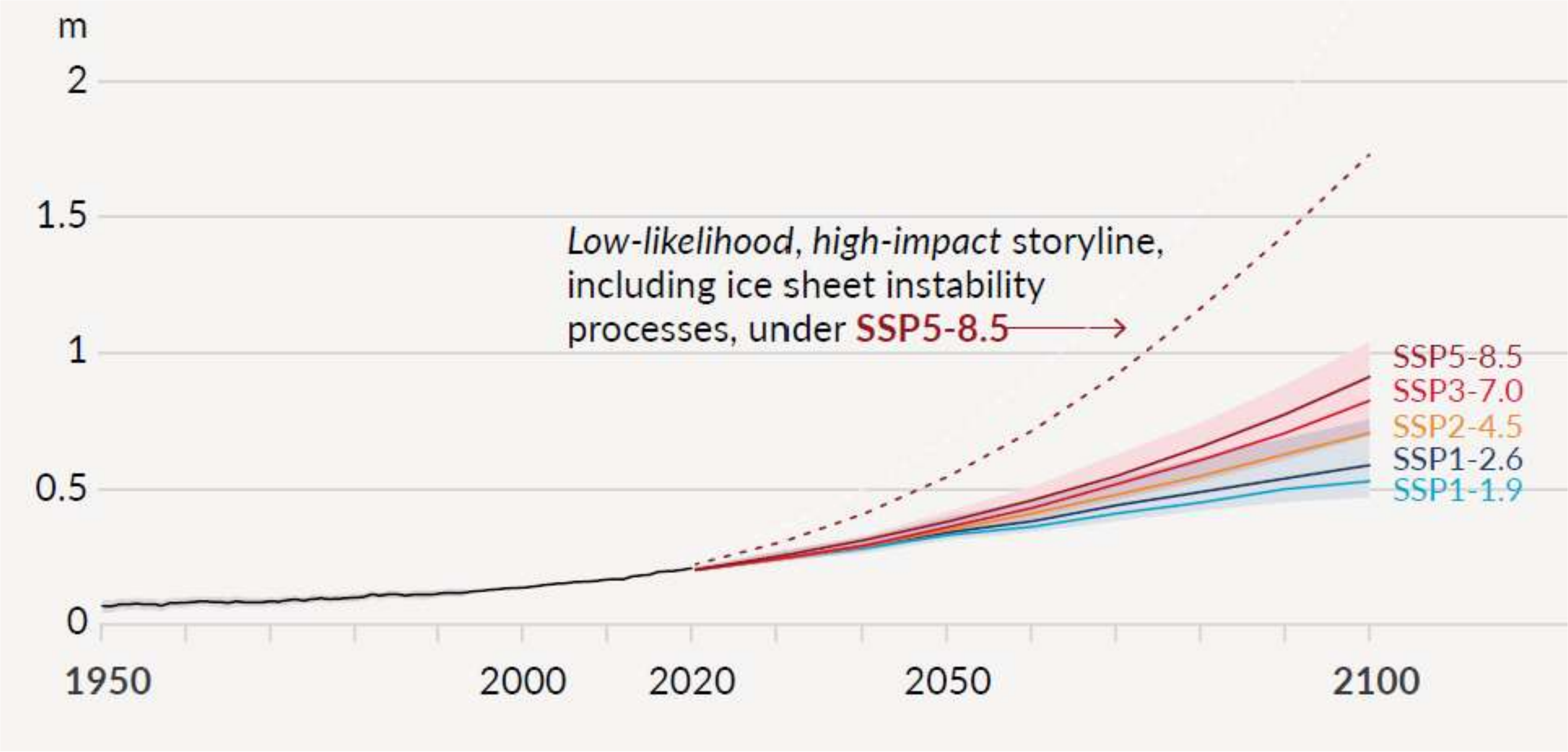
- Global mean sea level change relative to 1900: in 2300 will be from 2 to 7m (SSP5-8.5)



In 2100 part of the cost of the north Adriatic sea will be under water

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Predictions at 2200: Venice – Italy

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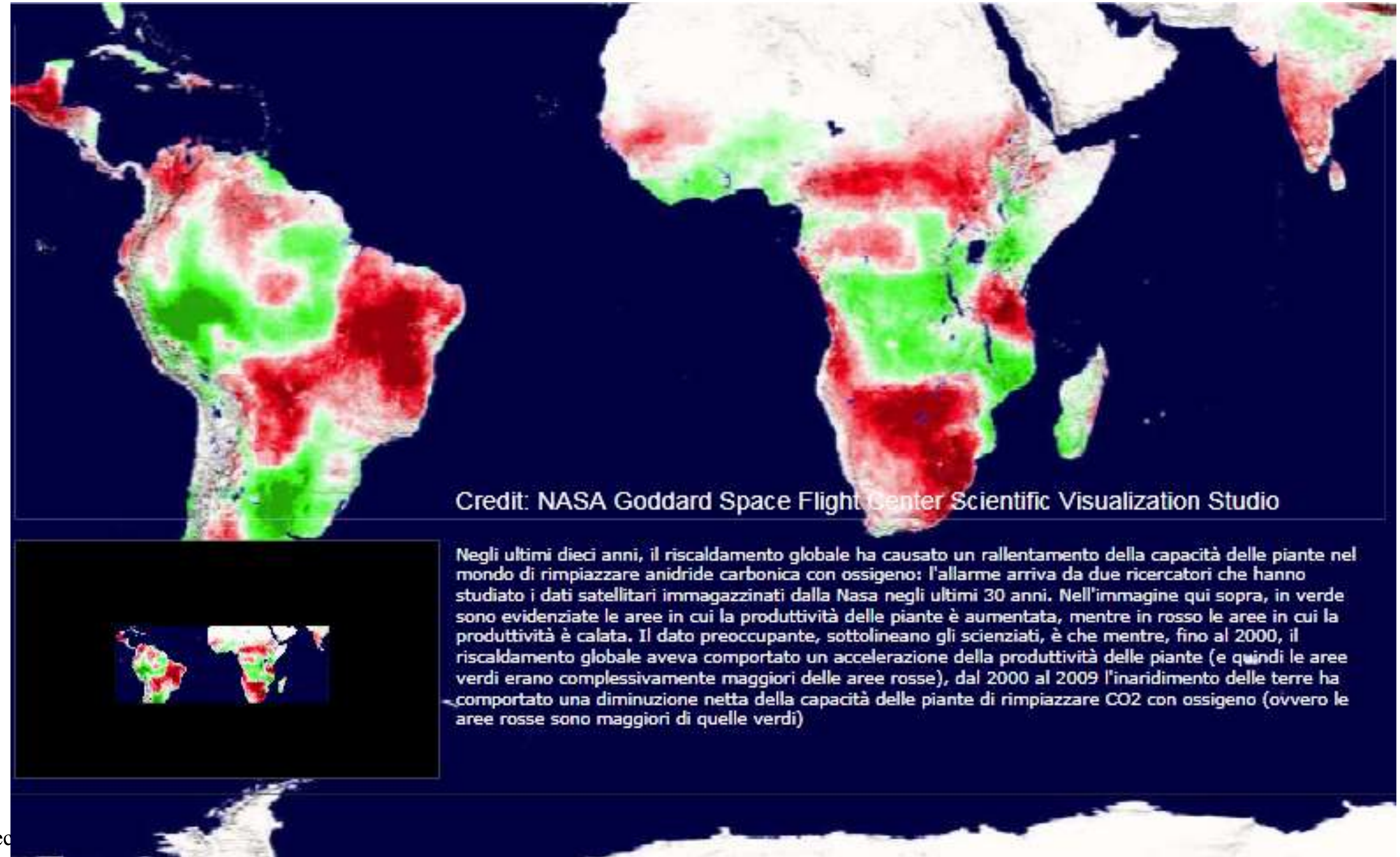
Plant productivity

- In GREEN increase of Productivity
- In RED decrease of Productivity



… and that’s not all about it!!!

nature

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NEWS | 15 October 2018

Climate change is about to make your beer more expensive

Extreme weather events are expected to reduce global barley production.

Outline of the talk

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  - Hydrogen as energy carrier
  - Hydrogen production processes: the colours of hydrogen
- Conclusions

A pioneer …. (an Hero !!!)

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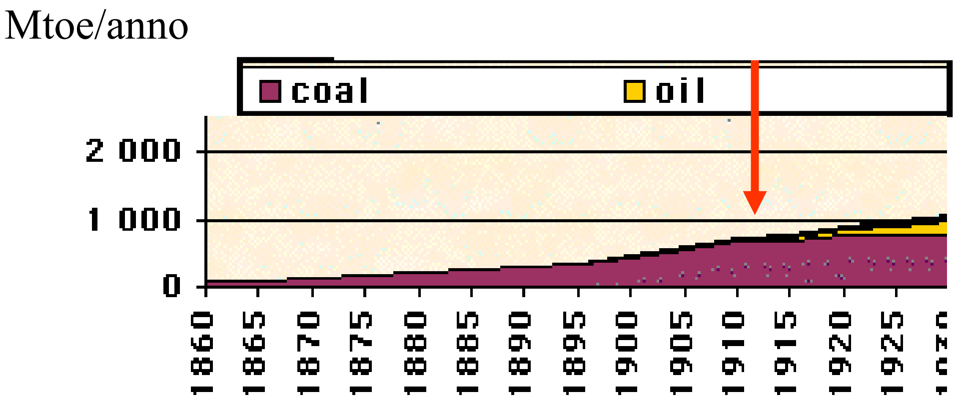
"…if our black and nervous civilization, based on coal, shall be followed by a quieter civilization based on the utilization of solar energy, that will not be harmful to progress and to human happiness."

1912
~ 1 TW



SCIENCE

FRIDAY, SEPTEMBER 27, 1912

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THE PHOTOCHEMISTRY OF THE FUTURE[1]

MODERN civilization is the daughter of coal, for this offers to mankind the solar energy in its most concentrated form; that is, in a form in which it has been accumulated in a long series of centuries. Modern man uses it with increasing eagerness and thoughtless prodigality for the conquest of the world and, like the mythical gold of the Rhine, coal is to-day the greatest source of energy and wealth.

1912 is an important year….

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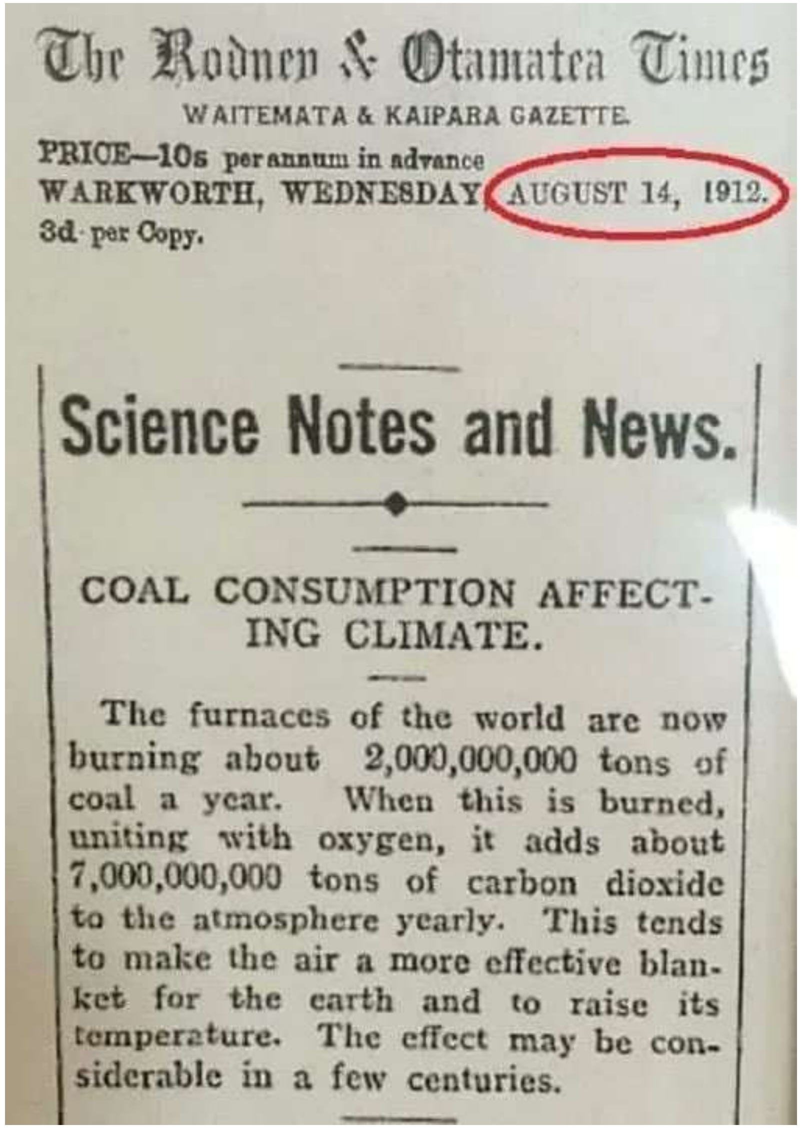
- “The furnaces of the world are now burning about 2,000,000,000 tons of coal a year,” the article reads. “When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries."



The Rodney & Otamatea Times

WAITEMATA & KAIPARA GAZETTE.

PRICE—10s per annum in advance
WARKWORTH, WEDNESDAY AUGUST 14, 1912.
3d. per Copy.

Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.

But after 1912 … no good news!

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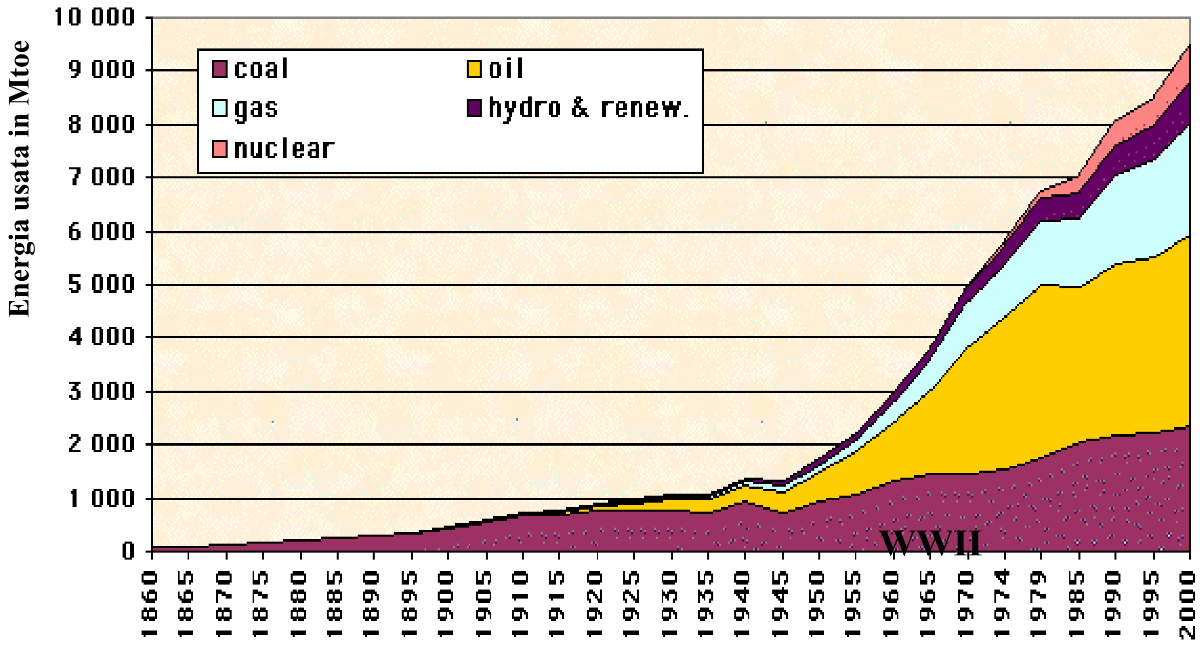
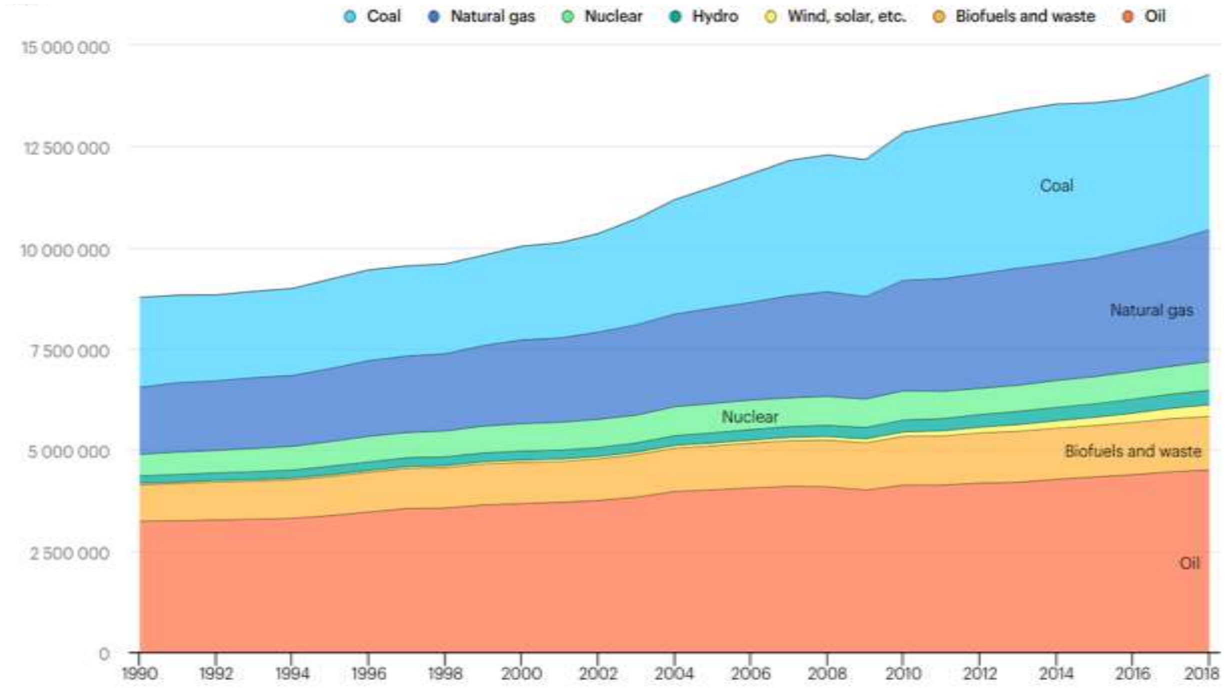
Nel 2000 12.3 TW



1 Mtoe/anno ~ 1.3GW

Nel 2018 19 TW

Total energy supply (TES) by source, World 1990-2018



.. .and for the future … ?

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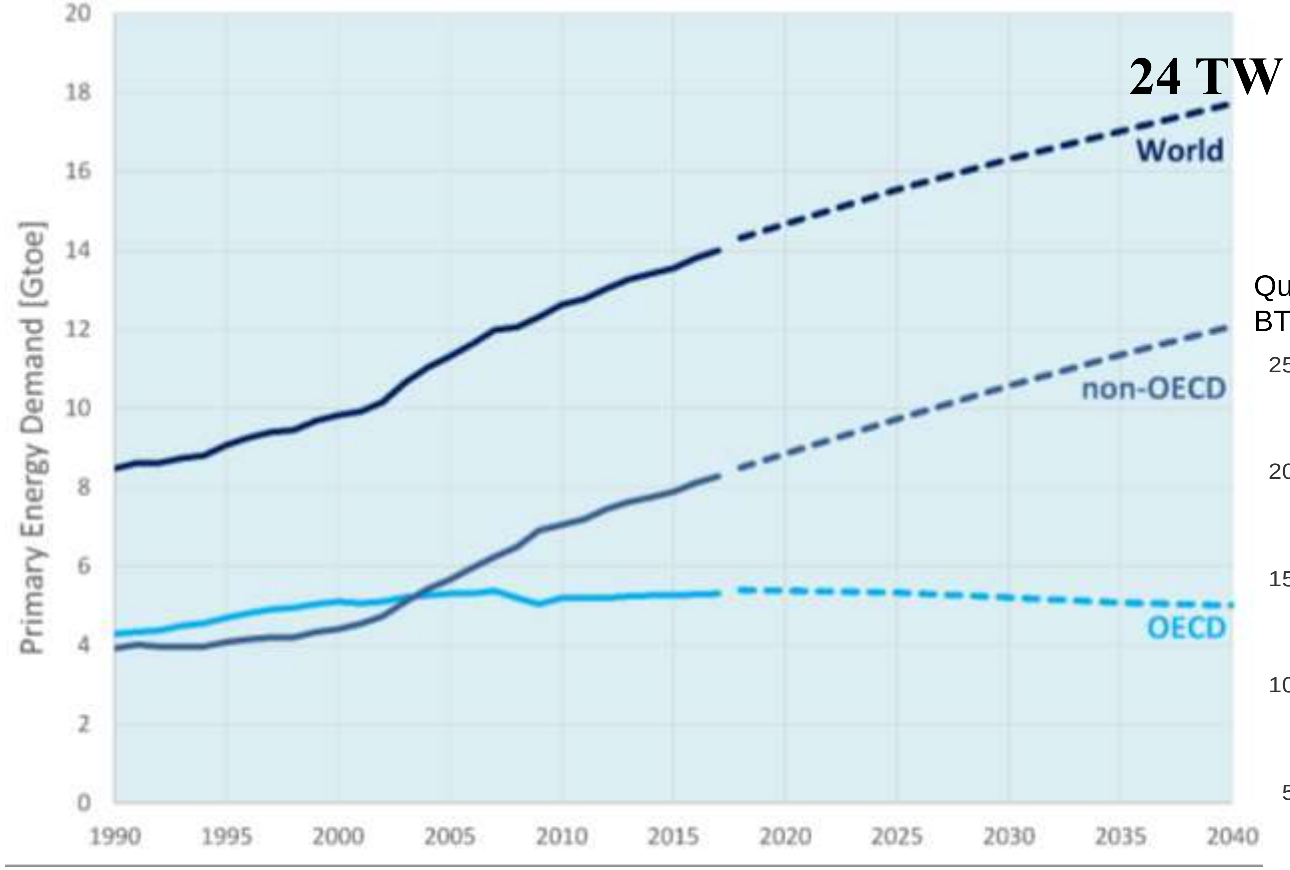
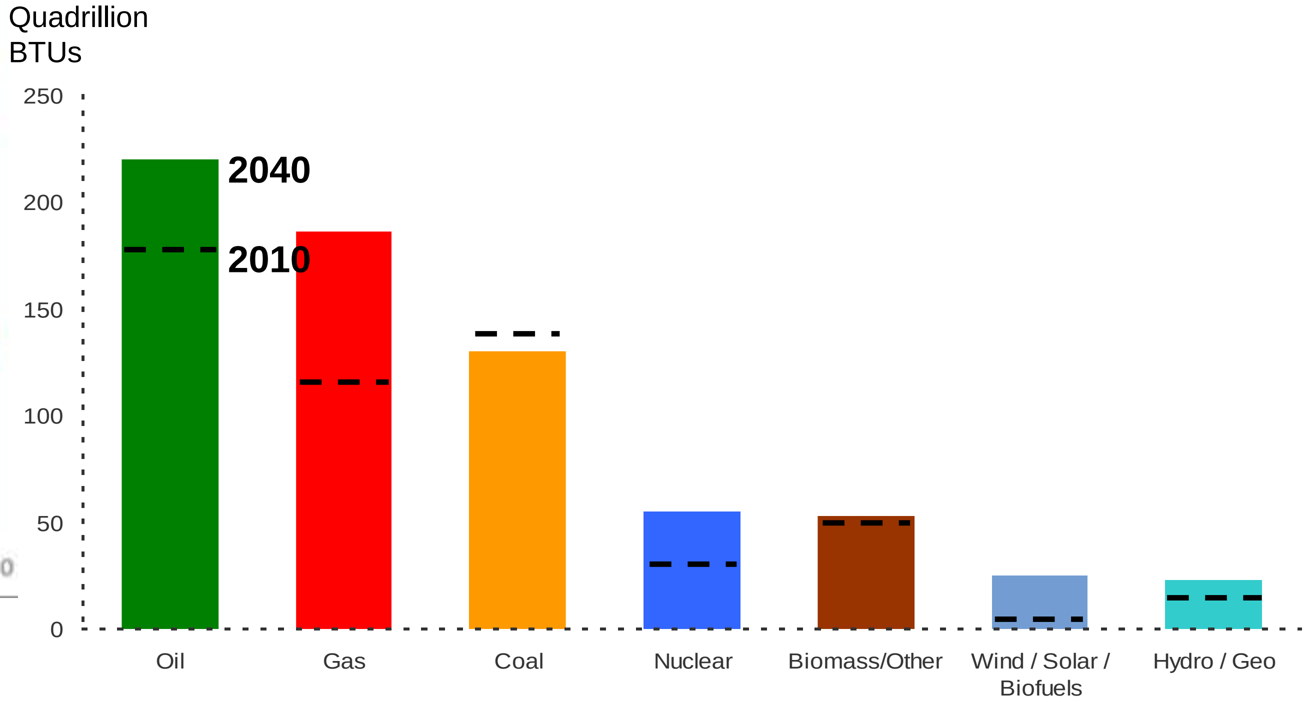
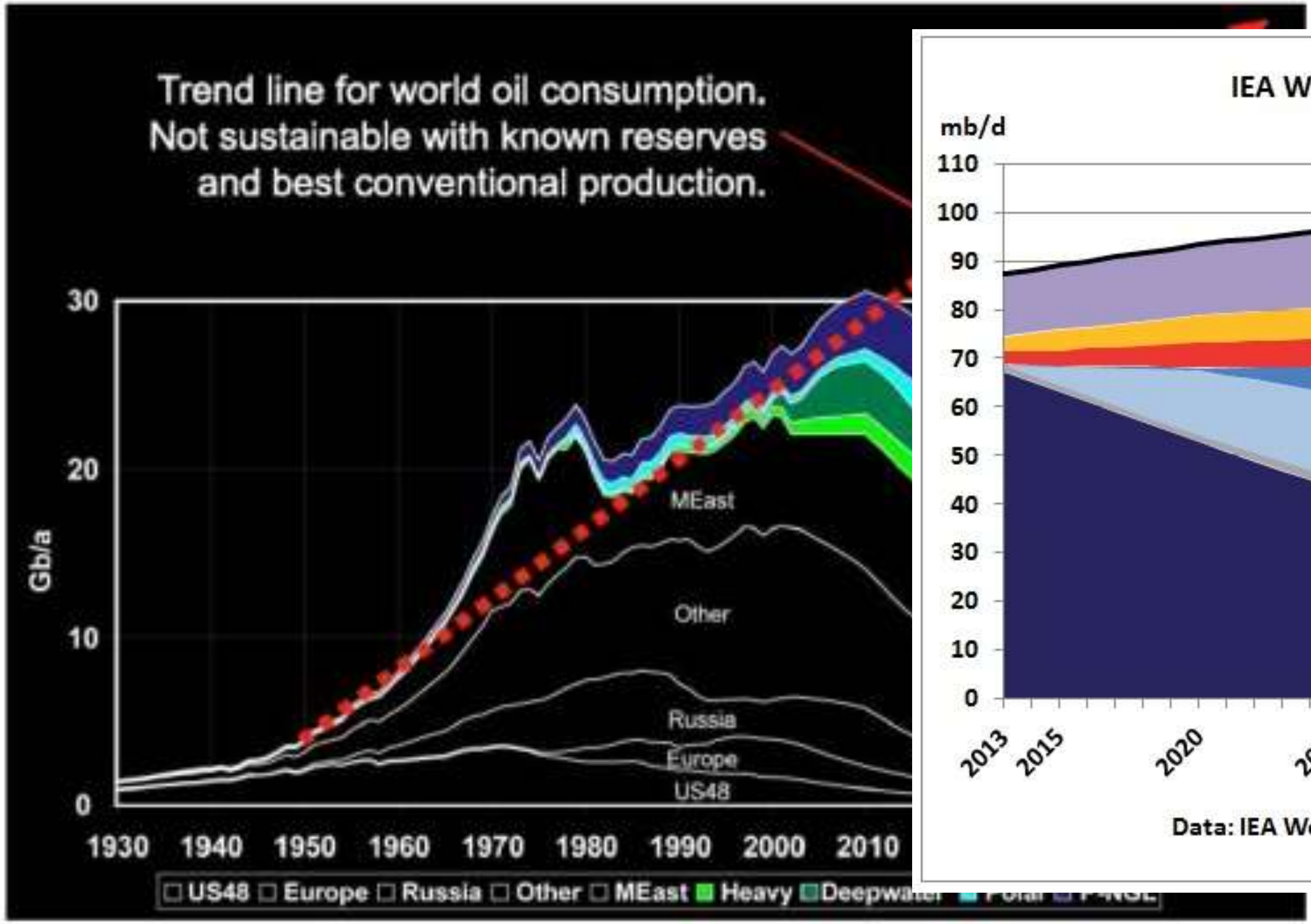
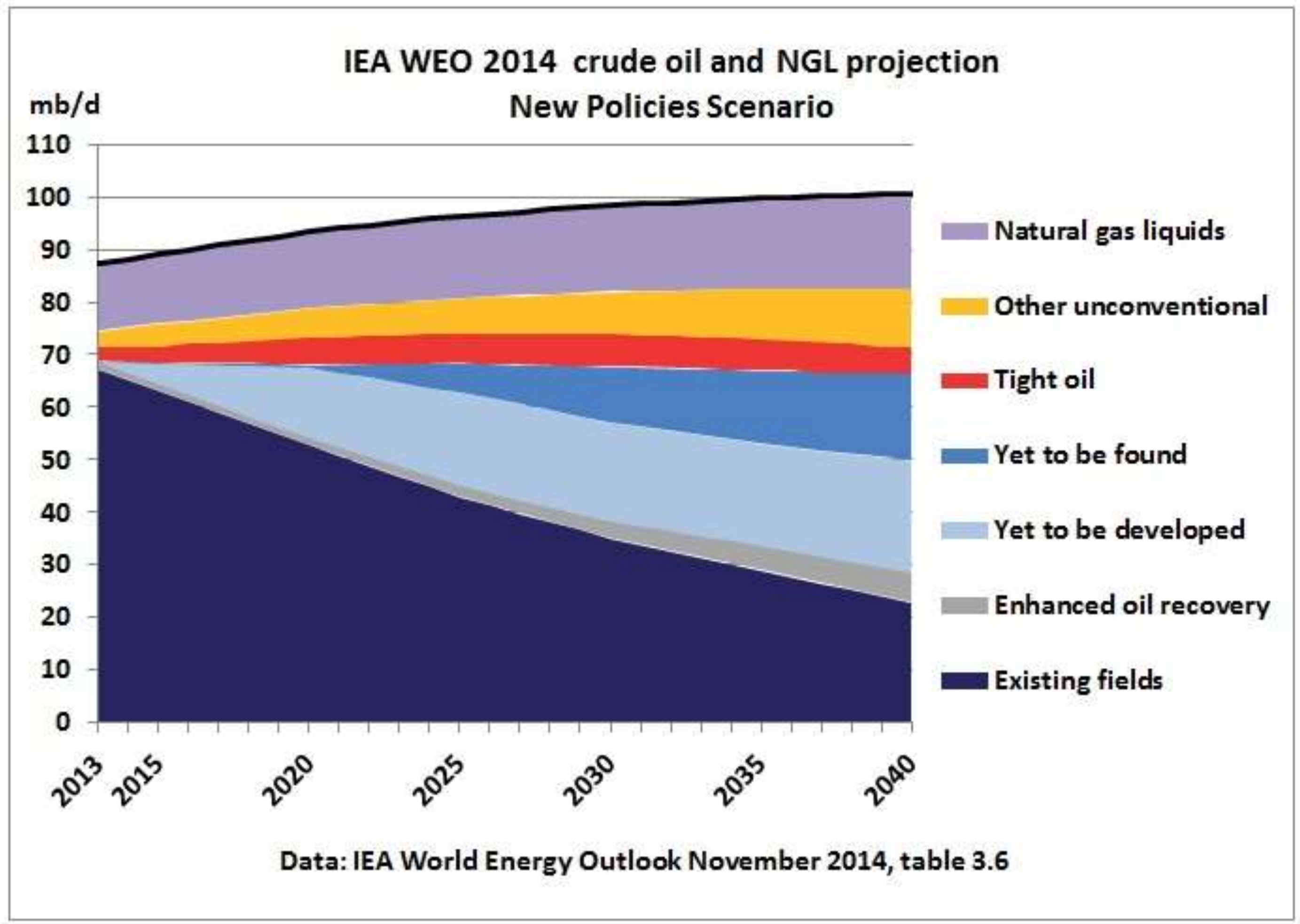




Source: The Outlook for energy: a view of 2040, Exxon

Fossil fuels production: projection





The energy system is inefficient !!!

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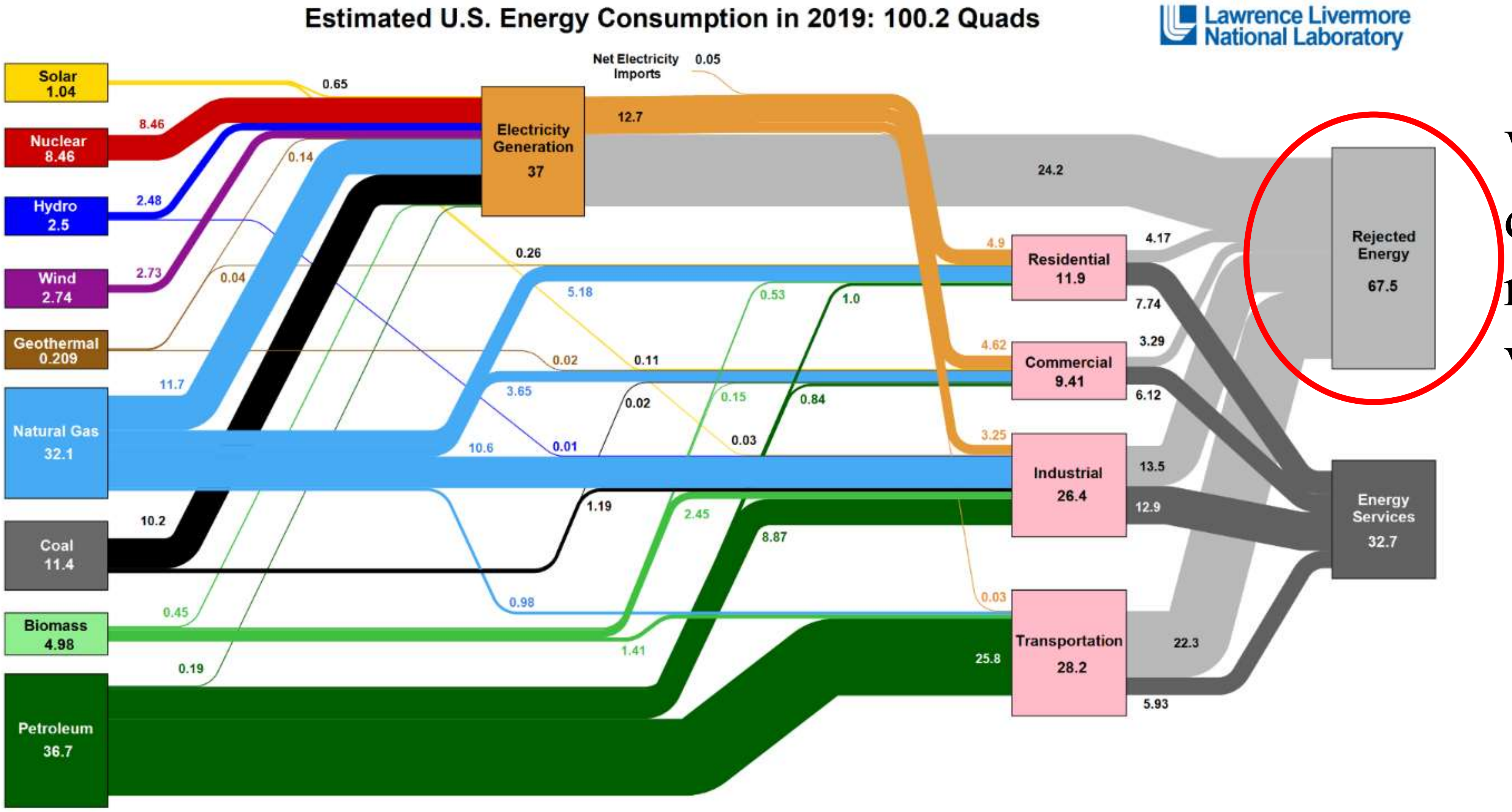


Source: LLNL March, 2020. Data is based on DOE/EIA MER (2019). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

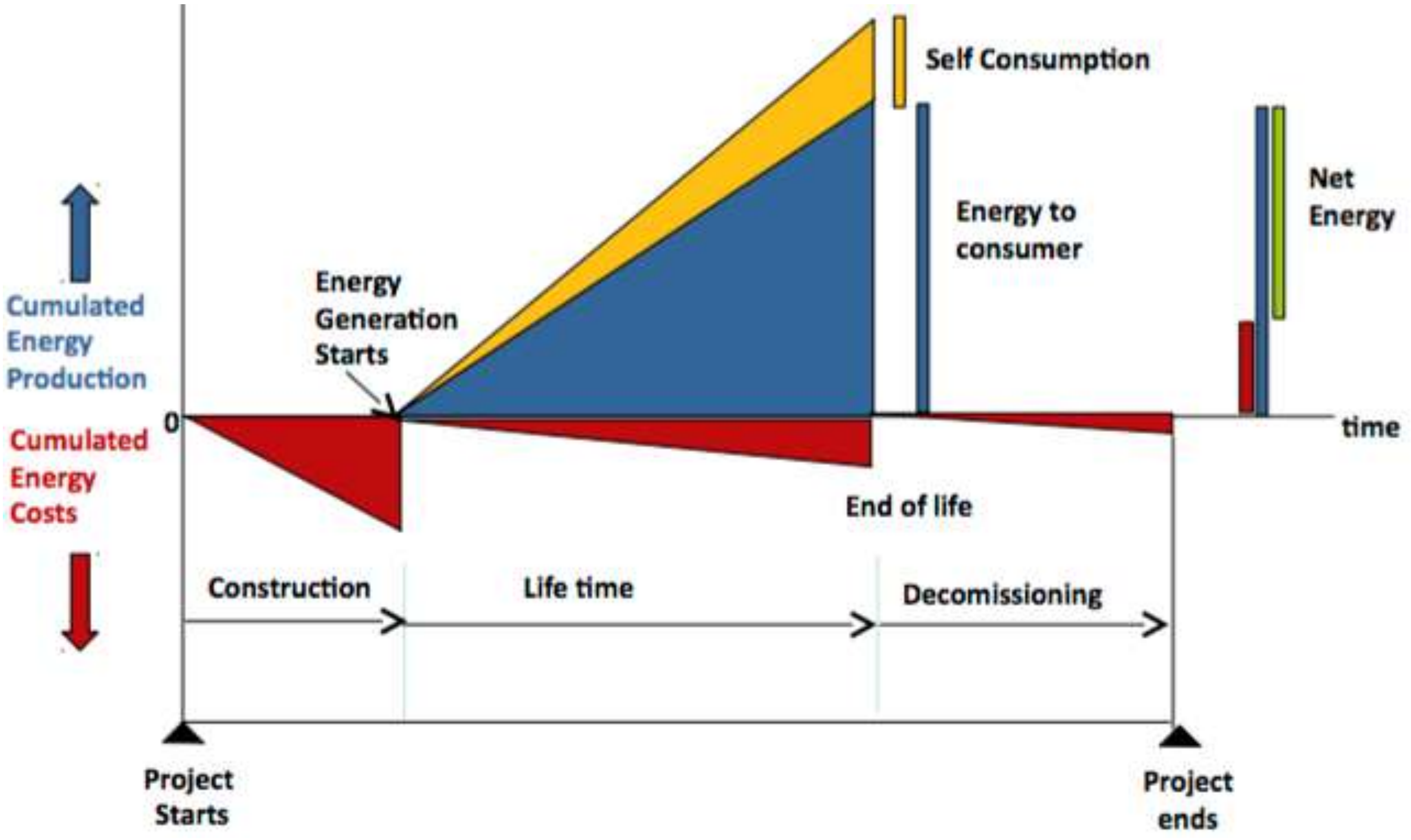
Working on demand reduction is very sensitive

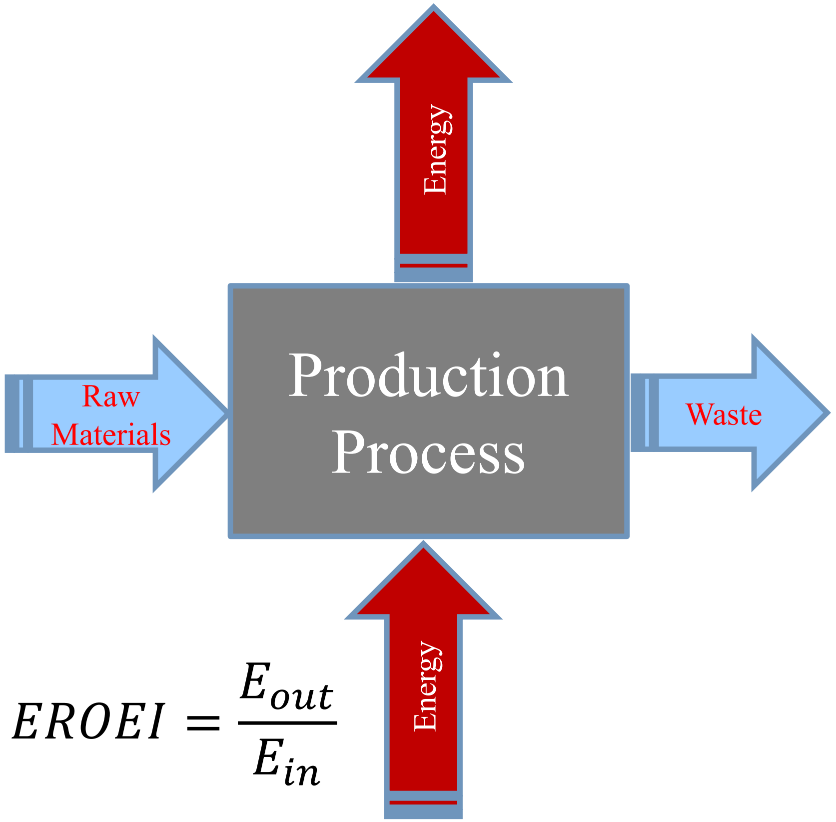
Indicators for decision makers

- Energy returned on energy invested EROEI and derived indicators (ESOEI – EROC)
- Levelized cost of energy – LCOE - LCOH
- Life Cycle assessment - LCA

Energy returned on energy invested (EROEI)

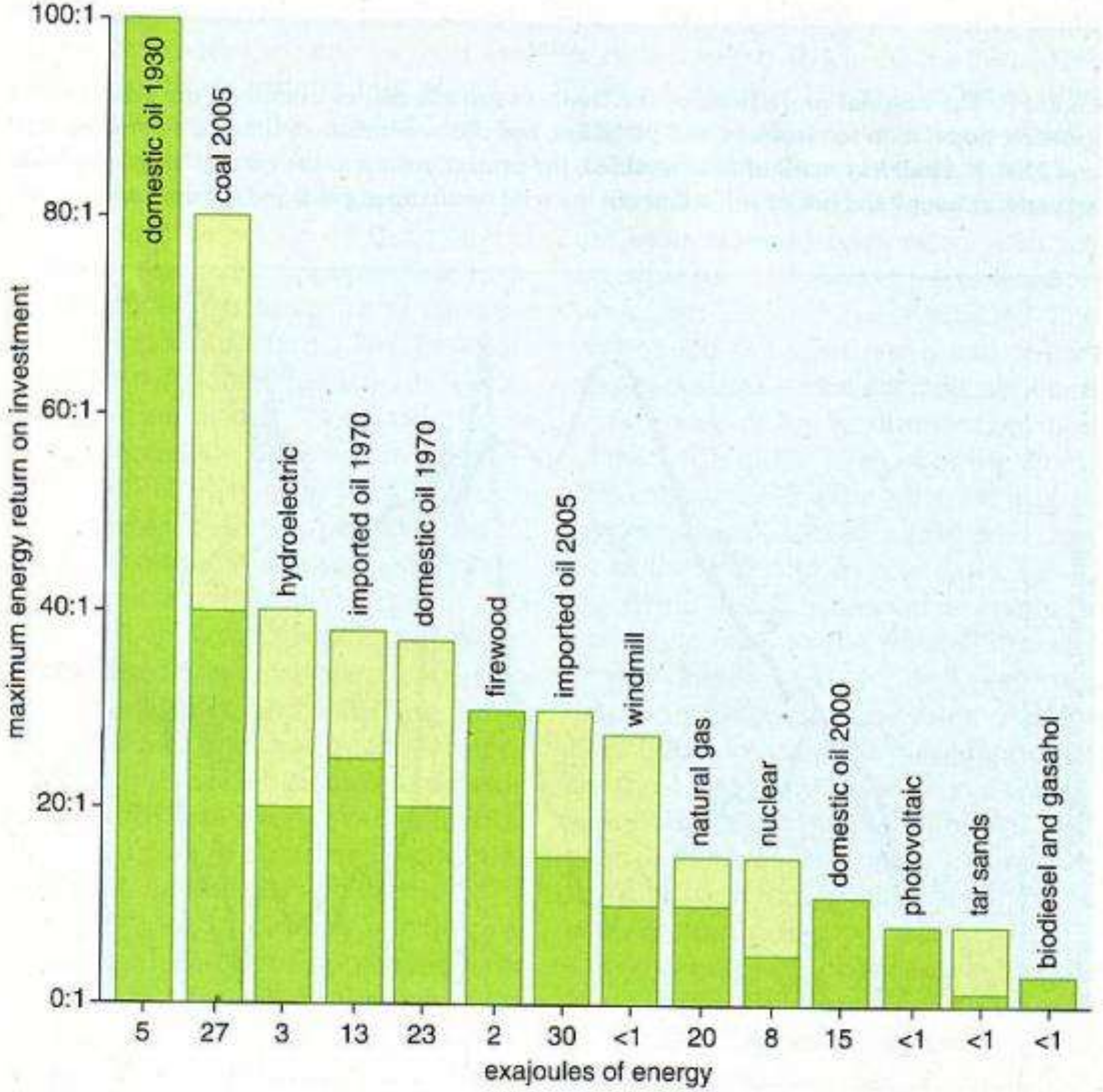
EROEI=

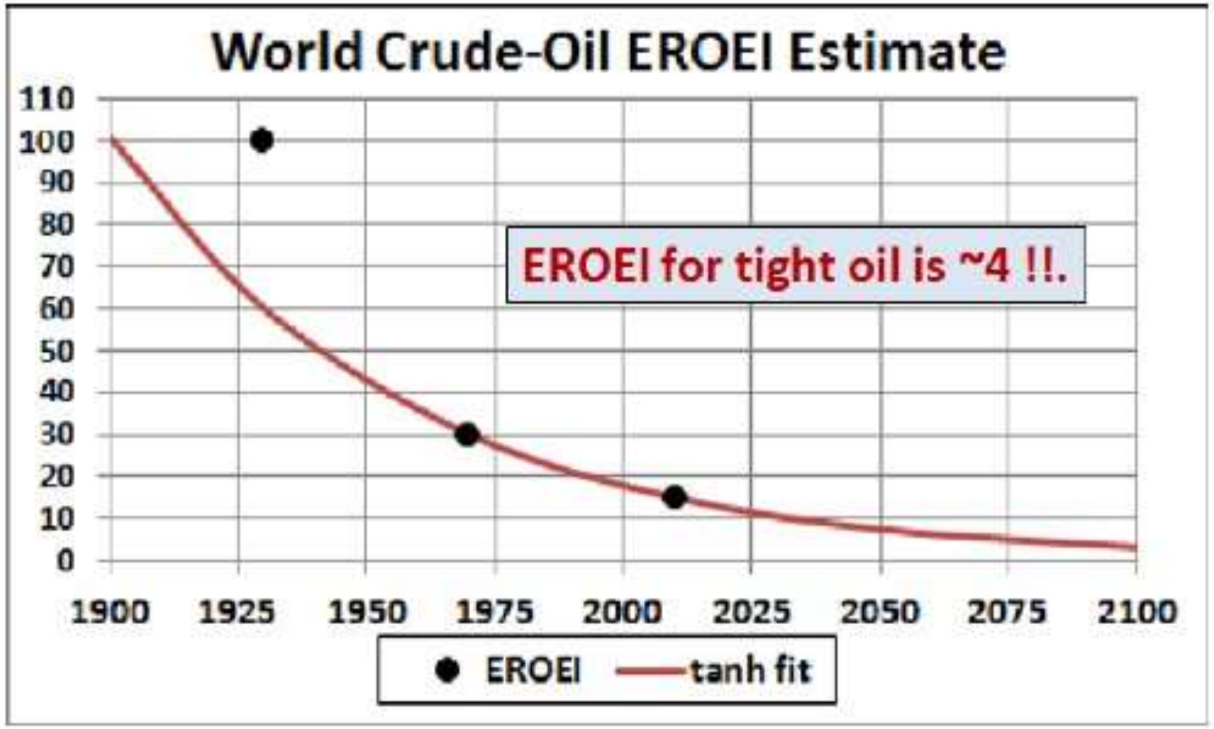




$$EROEI = \frac{E_{out}}{E_{in}}$$

Energy returned on energy invested (EROEI)





Source: C.A.S.Hall, J.W.Day Jr., "Revisiting the Limits to Growth After Peak Oil", Am. Sci. 97 (2009) 230

EROEI: recent data and time trends

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Table 1 | Comparison of mean EROIs for different energy sources

	Energy source		Optimistic EROI	Optimistic net energy percentage
Coal	Thermal		46:1	98
	Electricity		17:1	94
	Electricity with CCS		13:1	92
Oil	Thermal		19:1	95
	Electricity		7:1	85
Gas	Thermal		19:1	95
	Electricity		8:1	88
	Electricity with CCS		7:1	86
Biofuels & waste	Solids	Thermal	25:1	96
		Electricity	10:1	90
	Gases and liquids	Thermal	5:1	80
		Electricity	2:1	50
Nuclear			14:1	93
Hydroelectric			84:1	99
Geothermal			9:1	89
Wind			18:1	94
Solar PV			25:1	96
Solar thermal			19:1	95

Source: King et al, Nature Energy, 2018

Levelized cost of energy (LCOE)

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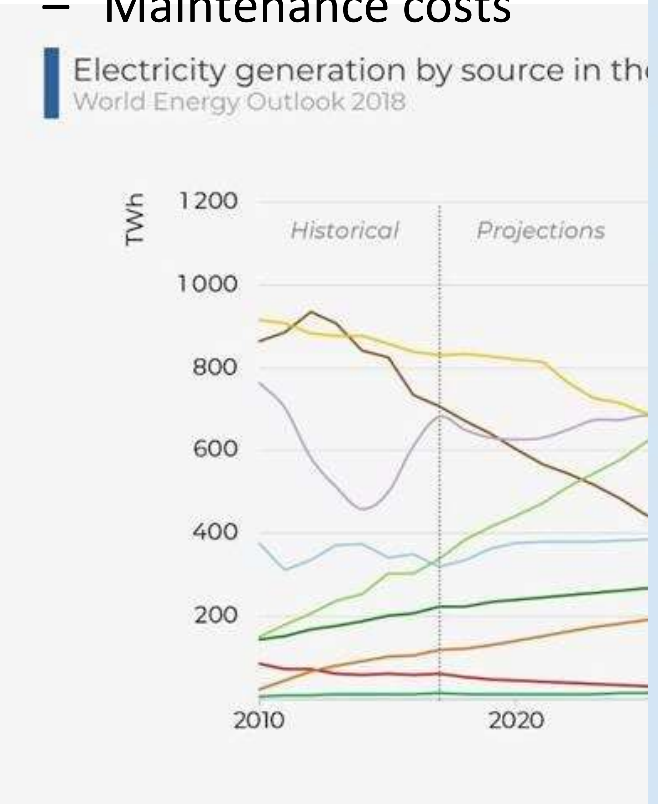
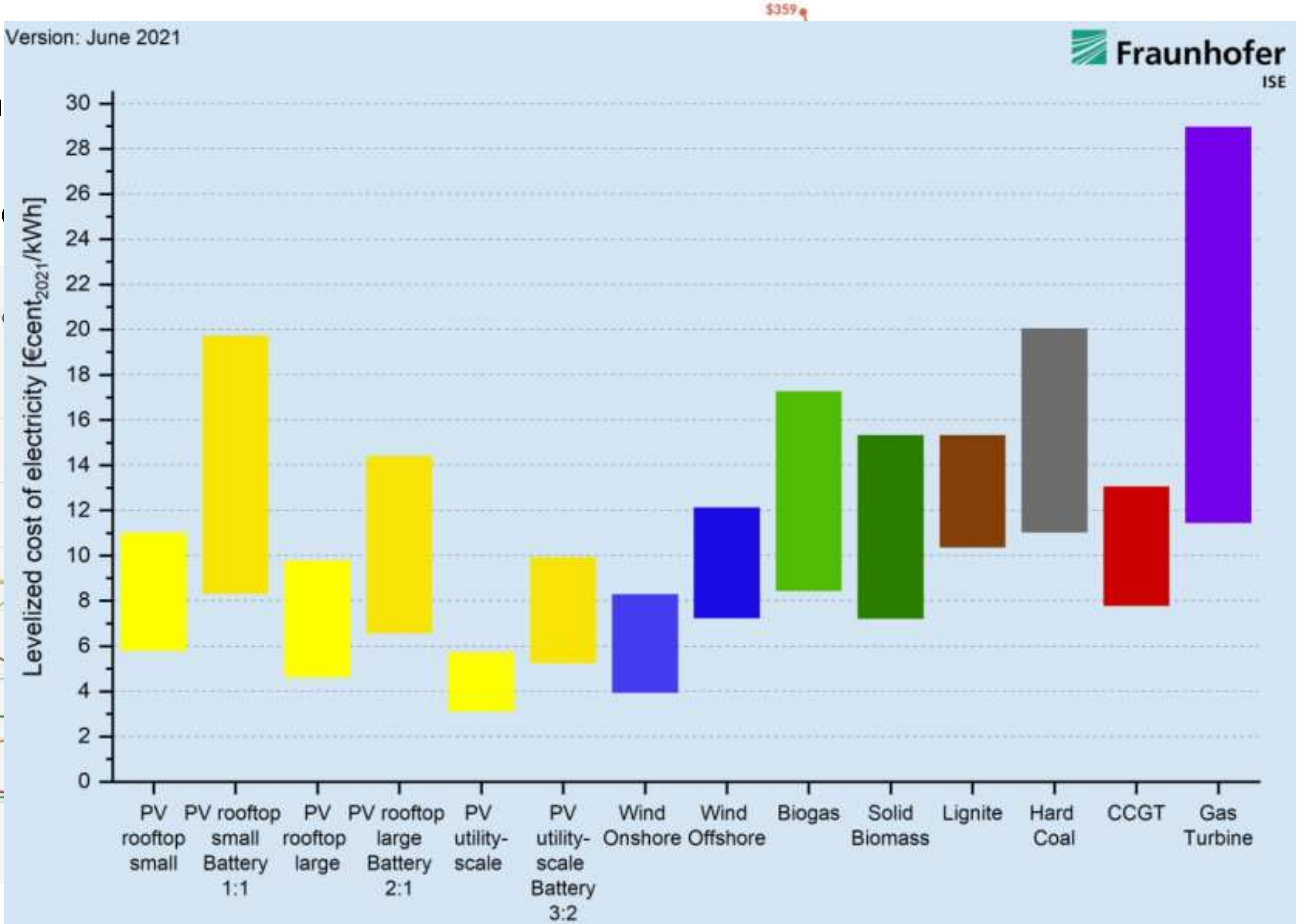
- Levelized cost of energy
  - depreciations of initial ca
  - Return of investment,
  - Operating costs, fuel, labo
  - Maintenance costs





Life Cycle Assessment - LCA

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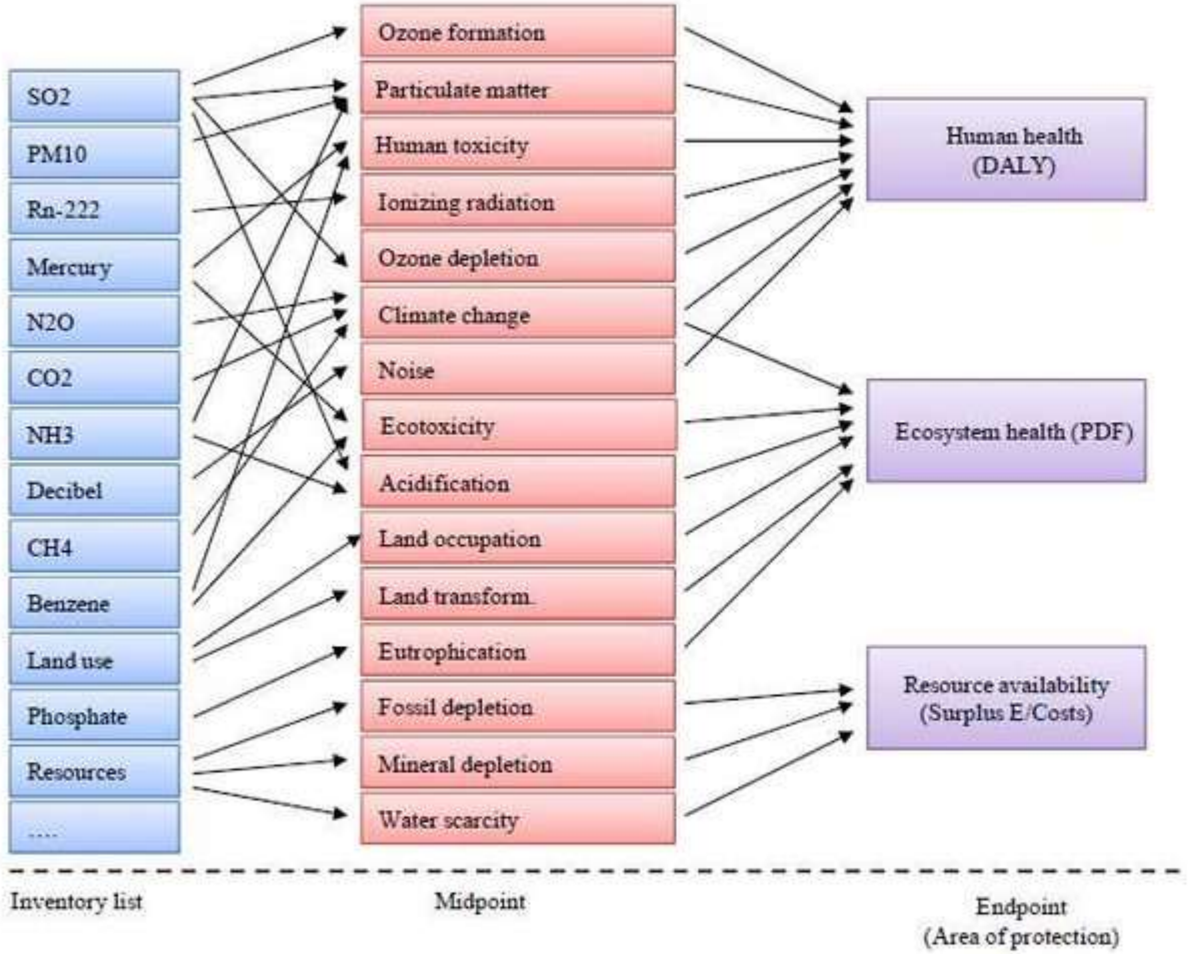
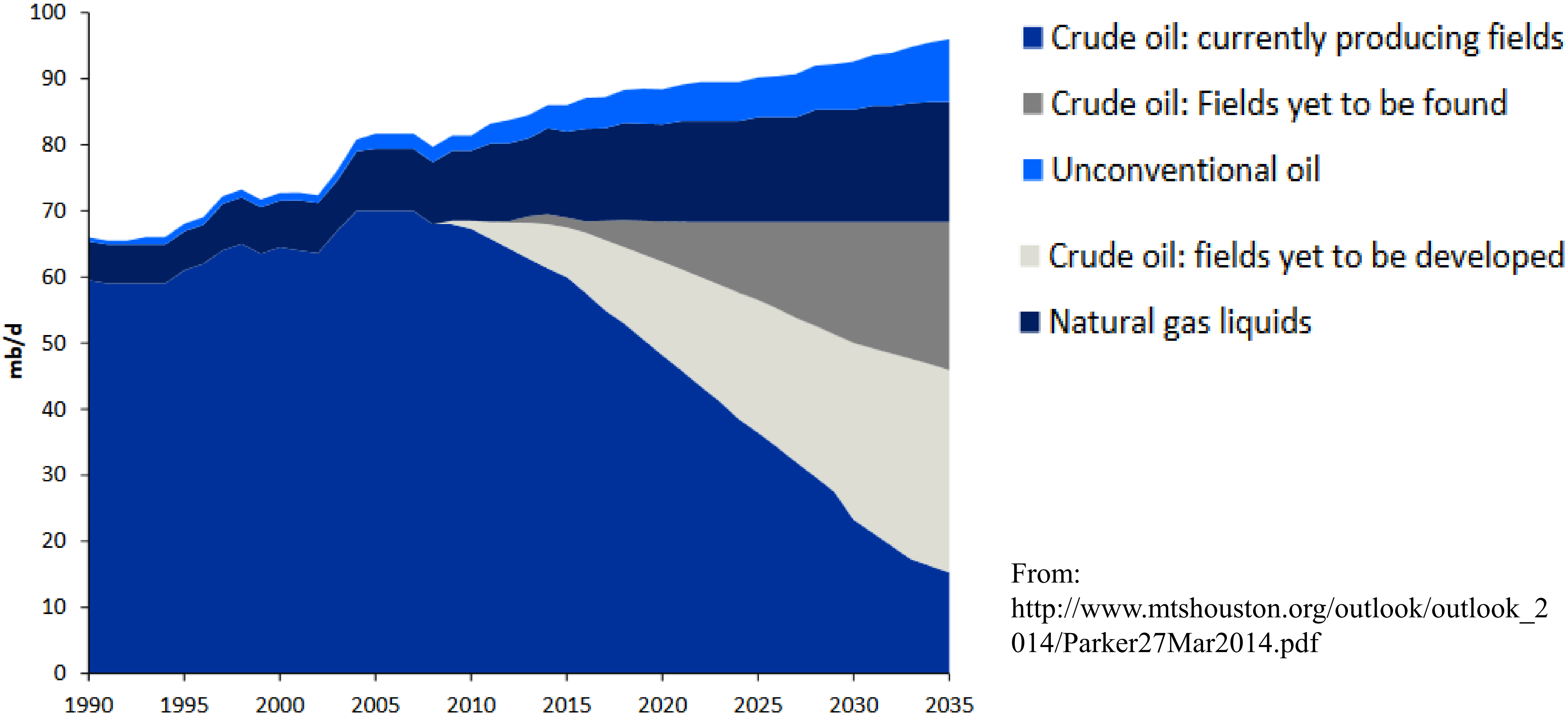
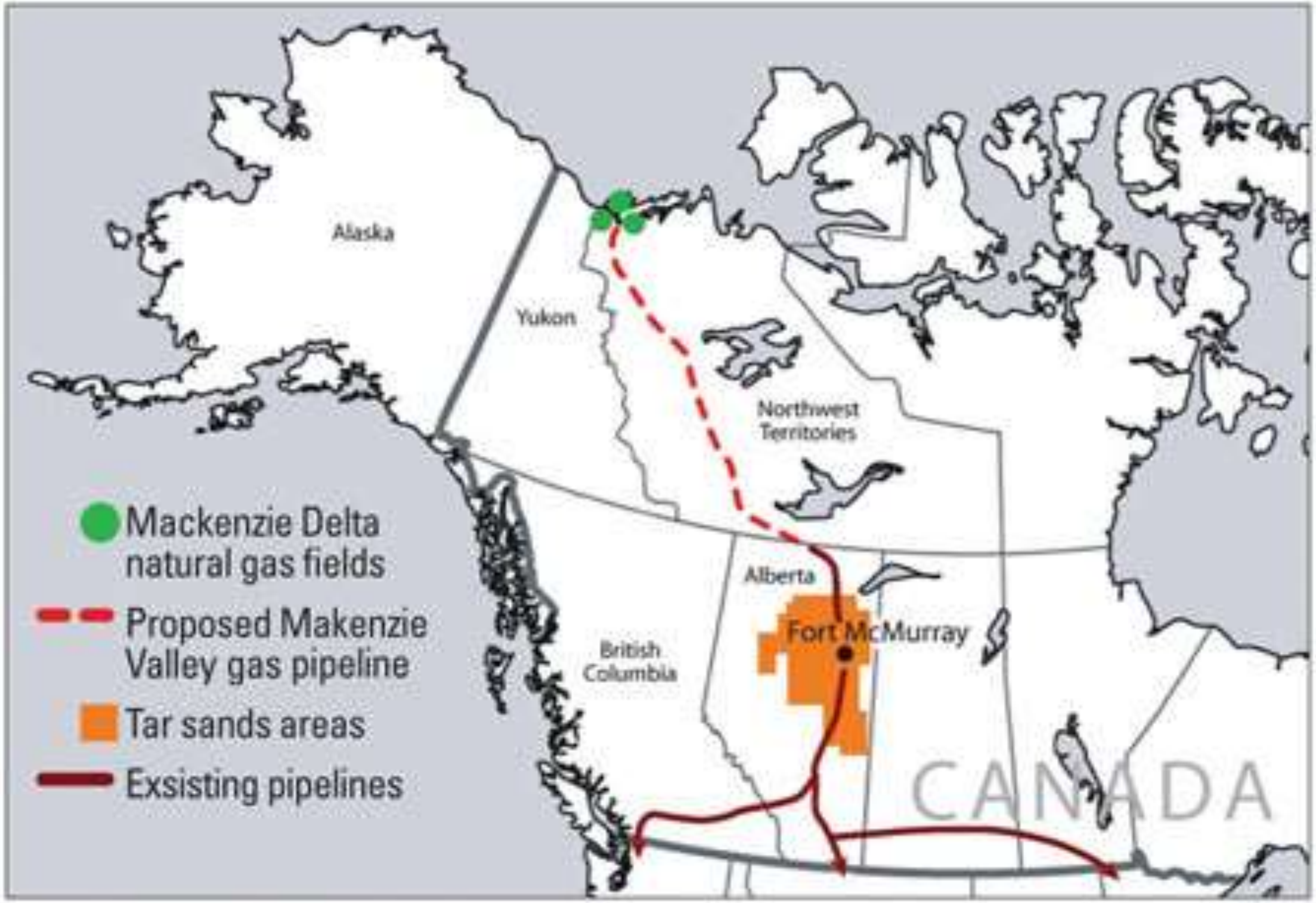


Oil production prediction



From:
http://www.mtshouston.org/outlook/outlook_2014/Parker27Mar2014.pdf

Non conventional fossil fuels
Tar sands, Alberta (Canada)



Huge quantity of land is necessary and …

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National Geographic Magazine, **March 2009**

… large treatment plants and …

National Geographic Magazine, **March 2009**

… large places for waste discharges.

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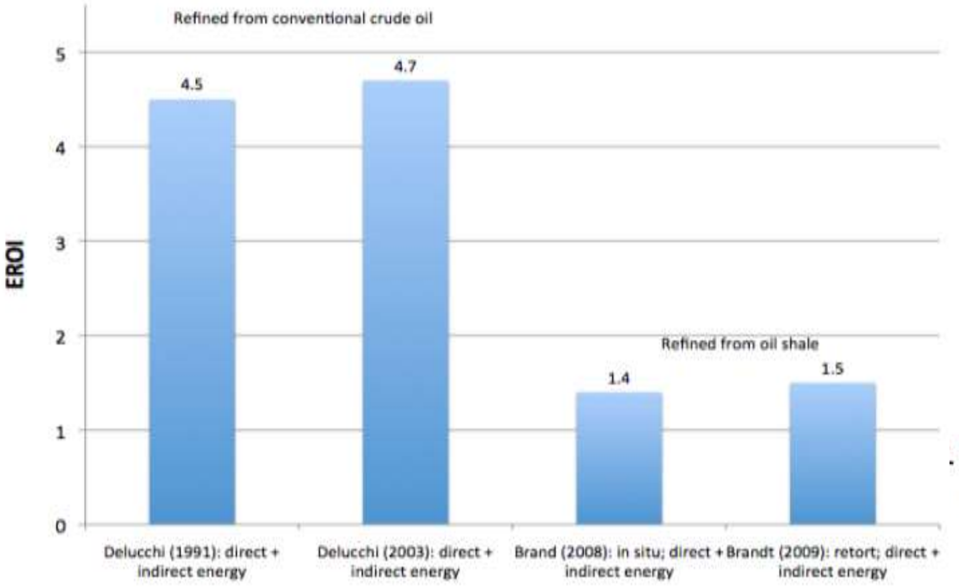
National Geographic Magazine, **March 2009**

Unconventional fossil fuel: Shale oil & Gas problems and risks

Average production trend per x well , ***Bakken formation*** **Montana, USA**



5459

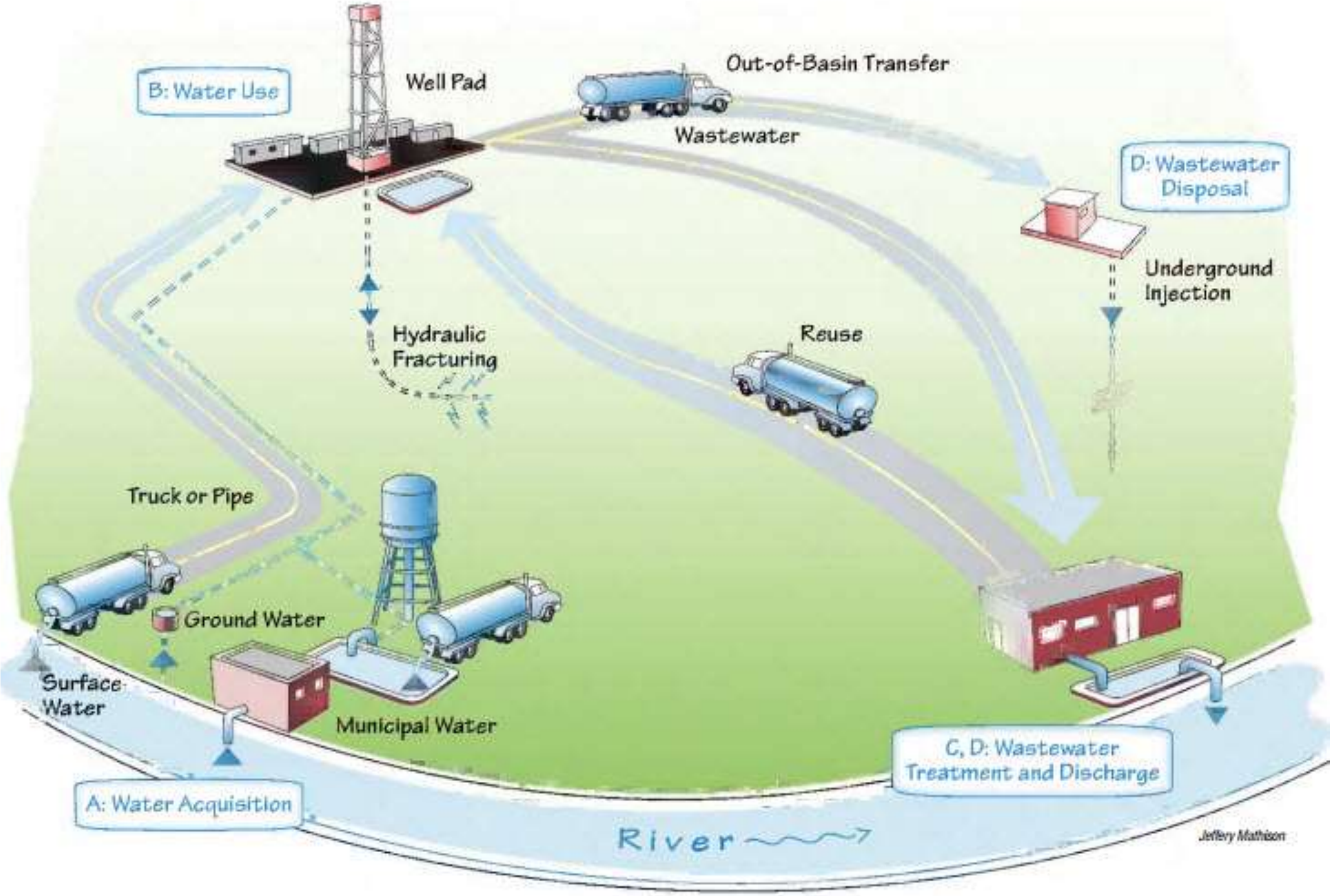
Fracking: water consumption

- Water consumption per frack: average 5 Mil gallons (=20 Mil liters)
  - Water volume equivalent to 15 Olympic water pools
  - 400 – 600 incoming trucks
  - 200 – 300 outgoing trucks

Average Water Volumes for Drilling and Hydraulic Fracturing of Shale Gas Wells

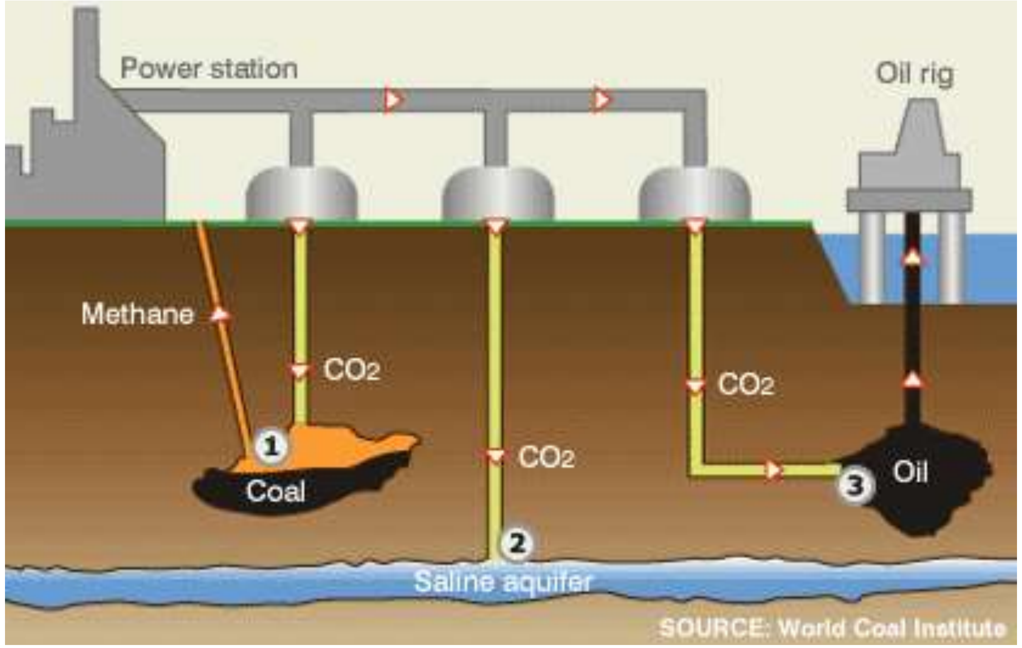
Unconventional development	Average fresh water volume for drilling	Average fresh water volume for fracturing	Average salt water volume for fracturing
Barnett	250,000 gallons	4,600,000 gallons	
Eagle Ford	125,000 gallons	5,000,000 gallons	
Haynesville	600,000 gallons	5,000,000 gallons	
Marcellus	85,000 gallons	5,600,000 gallons	
Niobrara	300,000 gallons	3,000,000 gallons	
Horn River (Apache)	250,000 gallons	negligible	8 to 12,000,000 gallons

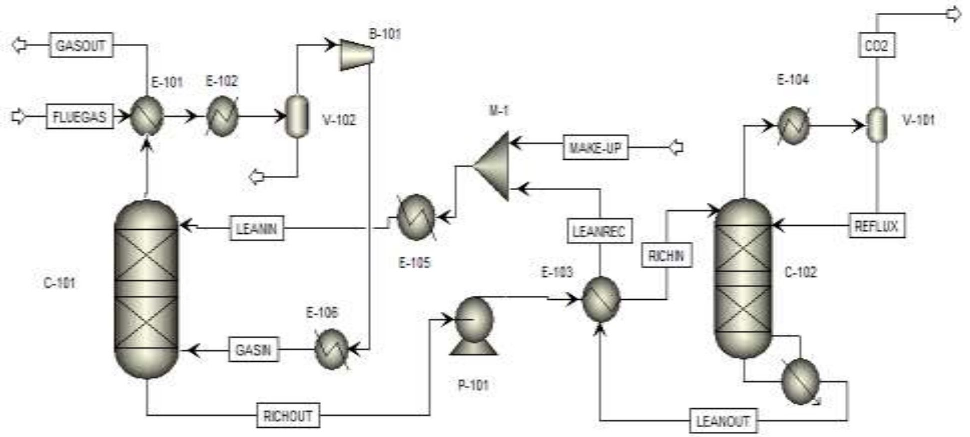
From King 2011 (in press)



Carbon Capture and Sequestration (CCS)

- CO_2 produced is captured with a suitable solvent and stored in exhausted oil fileds





Carbon Capture and Sequestration (CCS)

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- CCS facility of **Petra Nova**
  - Coupled with a coal power station at Parish Generation Station in Texas,
  - It is **out of service since 2 years**
  - **It is not economically sustainable**

The Silliness of Carbon Capture and Sequestration

By Benjamin Zycher
June 27, 2022

THE VOICE FOR CLEAN CAPITALISM
Corporate Knights
SINCE 2002

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CLIMATE CRISIS

Most carbon capture and storage projects are failing, researchers say

A report found that 13 flagship carbon capture and storage projects only captured one-ten thousandth of the 36 billion tonnes of CO2 emitted in 2021

BY MITCHELL BEER
SEPTEMBER 2, 2022

Most popular new power-generating technology installed: 2021

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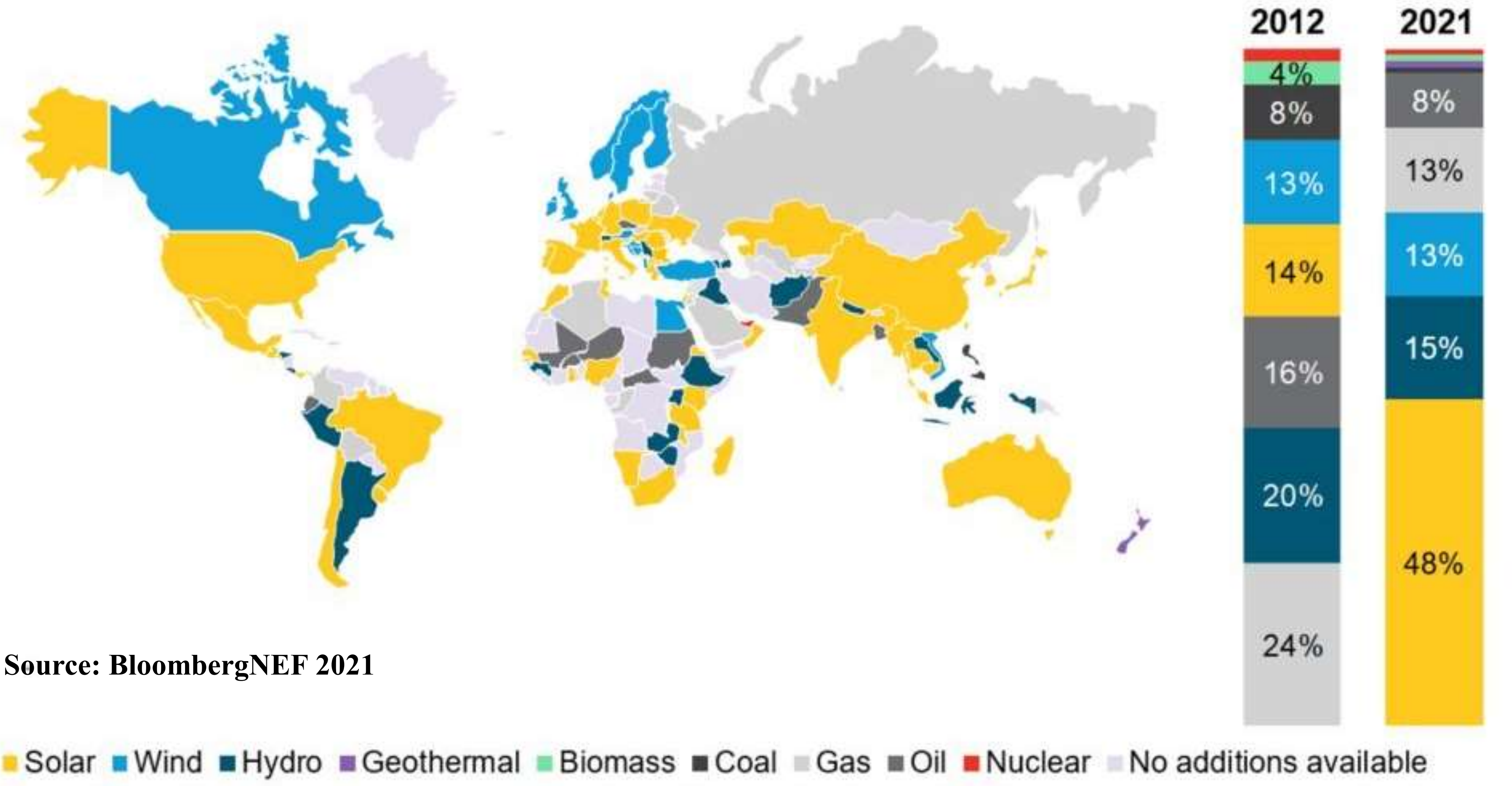

Source: BloombergNEF 2021

Outline of the talk

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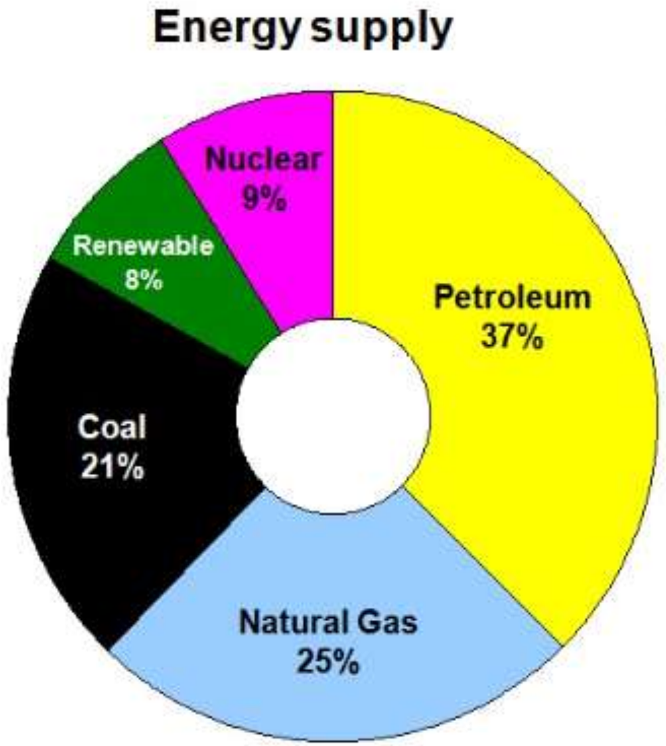
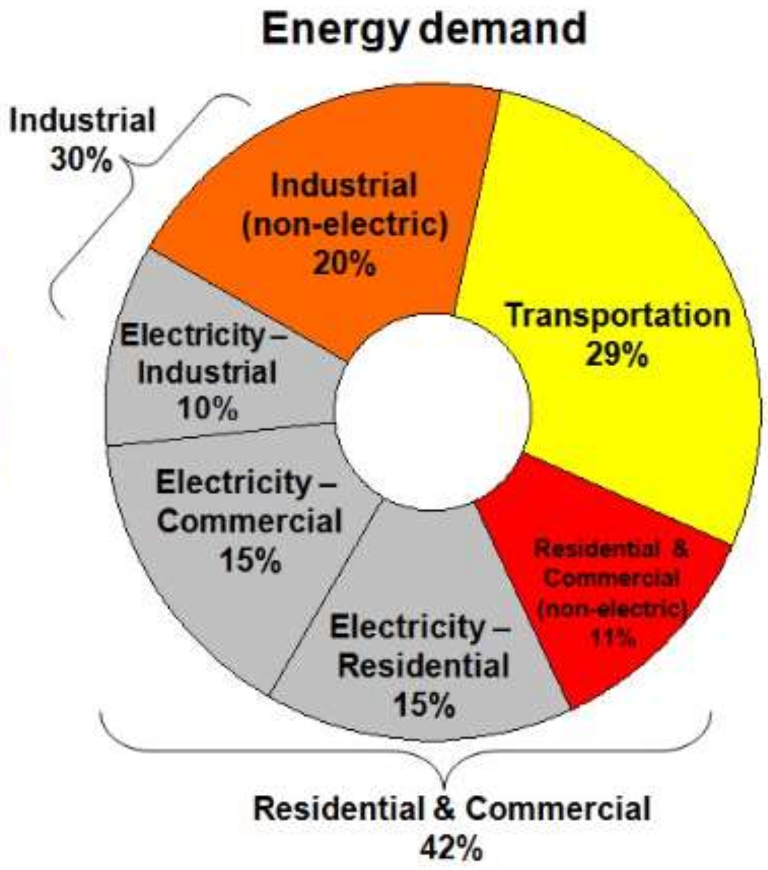
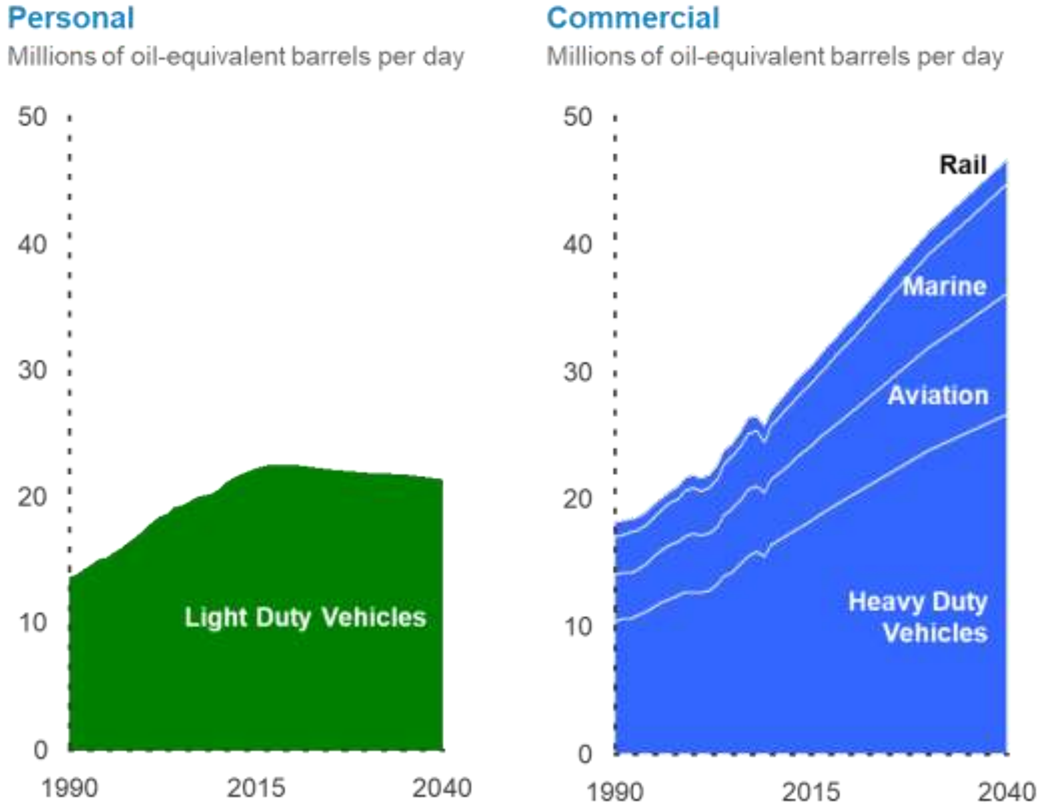
- Global warming: an environmental emergency
  - The perfect storm: John Beddington and other “weathermen”
  - CO_2 concentration in the atmosphere
  - Effects of global warming
  - Why we should act quickly
- The energy system: the main cause of global warming
  - Energy sources: past, present and future
  - Indicators for helping decisions on energy production
  - Non conventional fossil fuels
- Energy for transportation
  - Hydrogen as energy carrier
  - Hydrogen production processes: the colours of hydrogen
- Conclusions

Energy for transportation







Source: The Outlook for energy: a view of 2040, Exxon

Electrolysis to produce hydrogen, … fuel cell to use it

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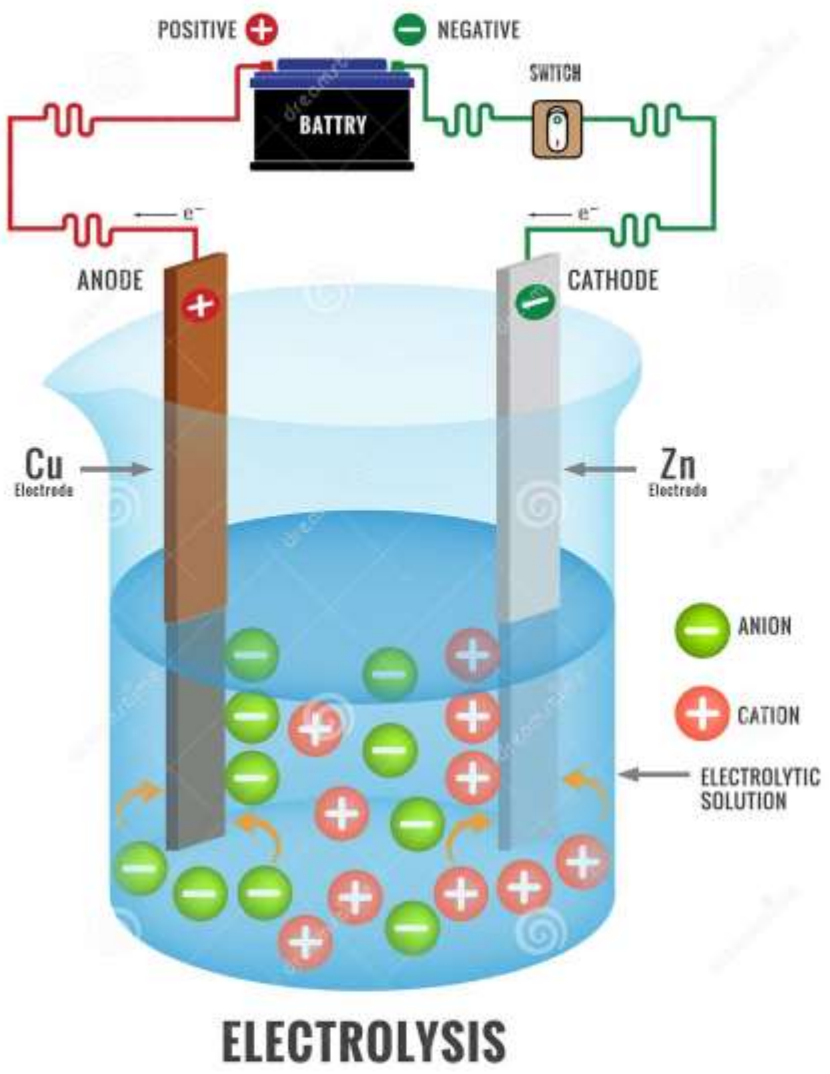

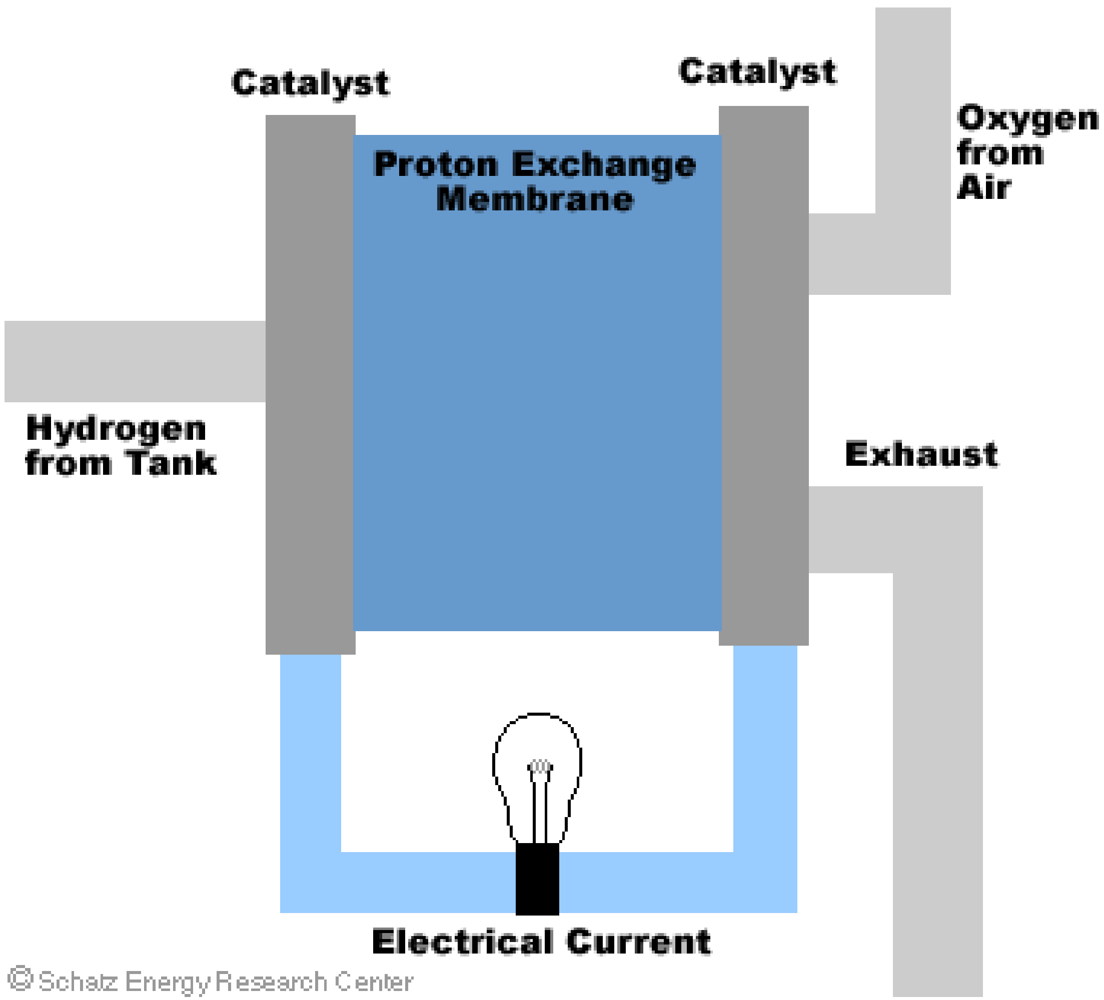

Fuel cells for automotive industry

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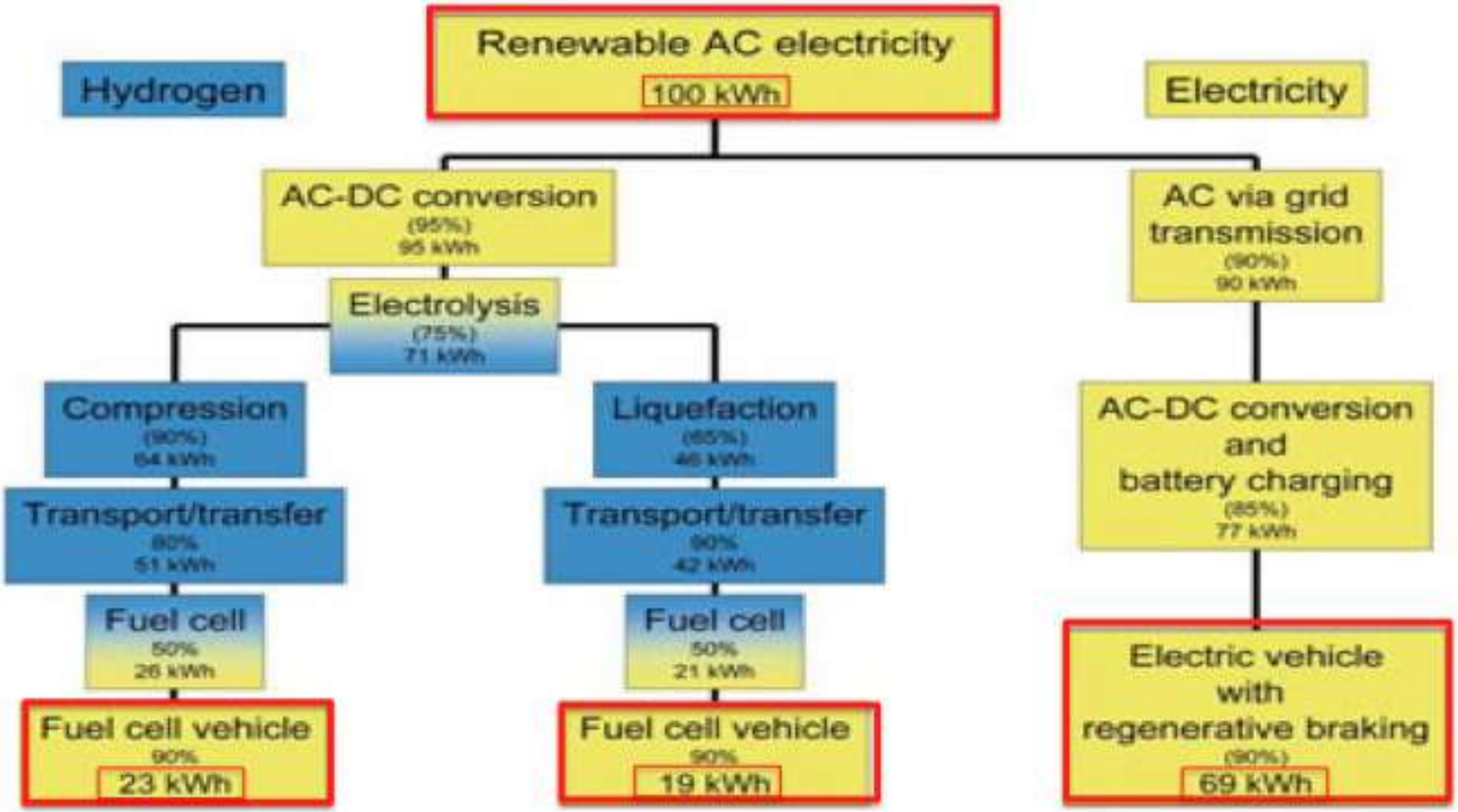
H_2 and heavy logistic

Battery or Hydrogen for automotive?
Toyota vs. Tesla



Battery vs. Hydrogen for trucks – long distance

trips up to 400 km is 62%of EU truck activity

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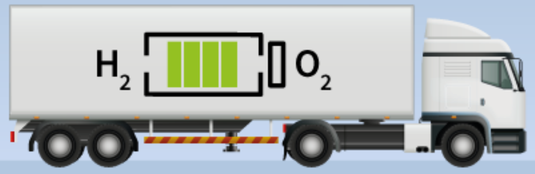

Parameters	Fuel cell electric truck	Battery electric truck
	2030	
Total cost of ownership over first 5-year user period (based on France)	**€ 459 k**	**€ 393 k**
Vehicle purchase costs	€ 139 k	€ 167 k
Annual renewable fuel costs[1]	€ 38 k	€ 22 k
Cost parity with diesel without subsidies	**Mid 2040s**	**Early 2030s**
Economies of scale with cars	**Low**	**High**
Max range without refuelling / recharging	**1200 km**	**800 km**
Refuelling / recharging time (full)	**10-20 minutes**	**8 hours (overnight)** **60 minutes (opportunity)**
Net payload loss (weight)[2]	**None**	**None**

Better →

An alternative to a future based on hydrogen

Type:
Horse Front Drive

Specifications:

bio-propulsion	
displacement:	15 ccm
fuel economy:	0 l
horsepower:	1 hp
V_{max}:	20 mph
cruising range:	20 miles

Options:
navigation system
full air conditioning

Emissions:

CO_2	=	380 g/mile
CH_4	=	1,6 g/mile
particles	=	800 g/mile
low-emission		

Hydrogen color spectrum

GREEN HYDROGEN

Hydrogen produced by electrolysis of water, using electricity from renewable sources like hydropower, wind & solar. Zero carbon emissions are produced.

GREY HYDROGEN

Hydrogen produced using fossil fuels such as natural gas. This accounts from roughly 95% of the hydrogen produced in the world today.

BROWN HYDROGEN

Hydrogen extracted from fossil fuels and created through coal gasification.

BLUE HYDROGEN

Grey or brown hydrogen with its C02 sequestered or repurposed.

PINK/PURPLE/RED

Hydrogen obtained by electrolysis through an atomic current using nucle-ar power.

YELLOW HYDROGEN

Hydrogen made through electrolysis with solar power.

WHITE HYDROGEN

Hydrogen produced as a byproduct of industrial process.

TURQUOISE HYDROGEN

Hydrogen produced from natural gas using the molten metal pyrolysis tech-nology.

Hydrogen production cost for different technology options in 2030

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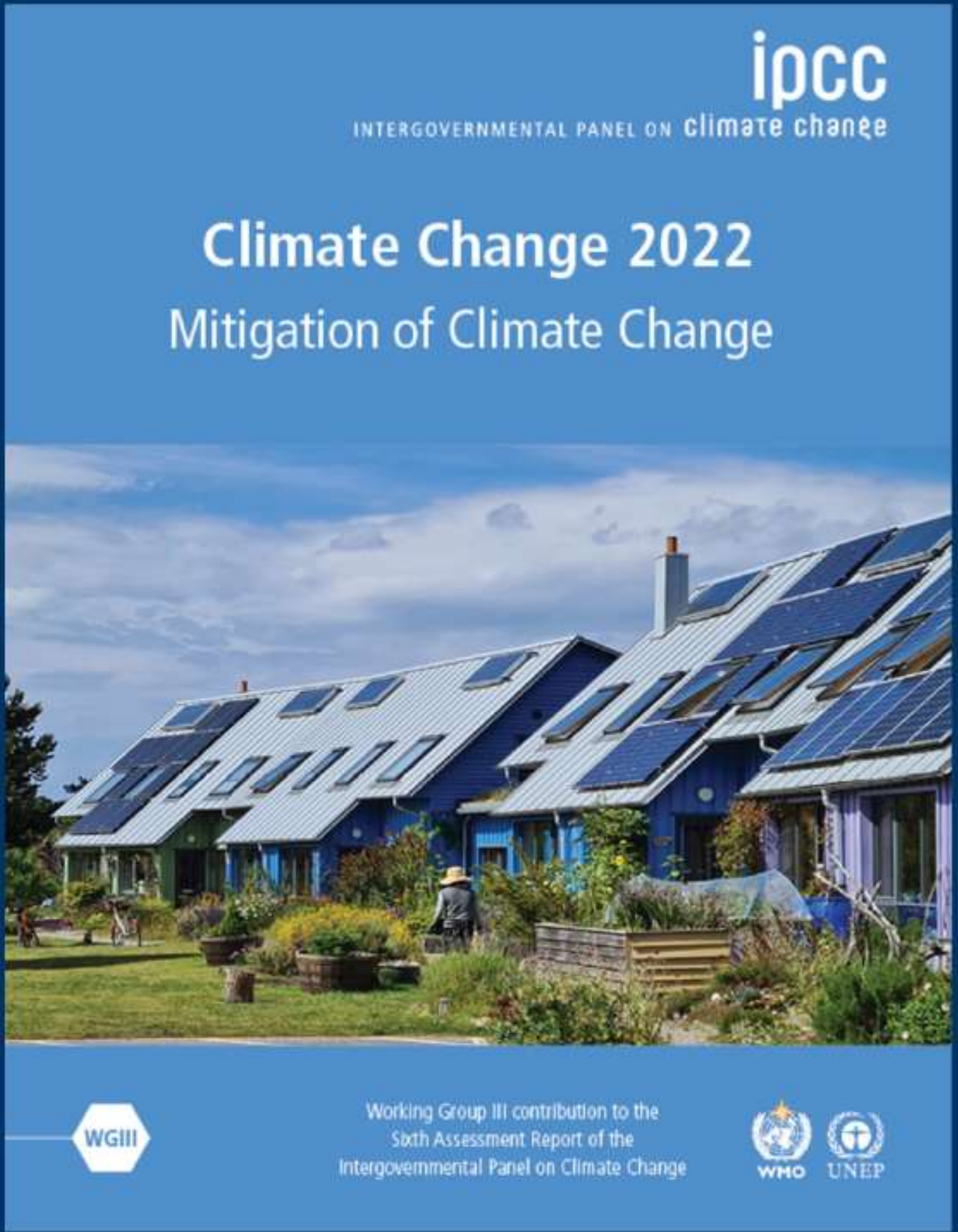
Sixth Assessment Report
WORKING GROUP III – MITIGATION OF CLIMATE CHANGE

“The evidence is clear:
The time for action is now



The end of stone age

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“The Stone Age didn’t end because the world ran out of stone …. And

… The Oil Age will not end because we run out of oil! “

Don Huberts

Shell Hydrogen

We are in trouble!!