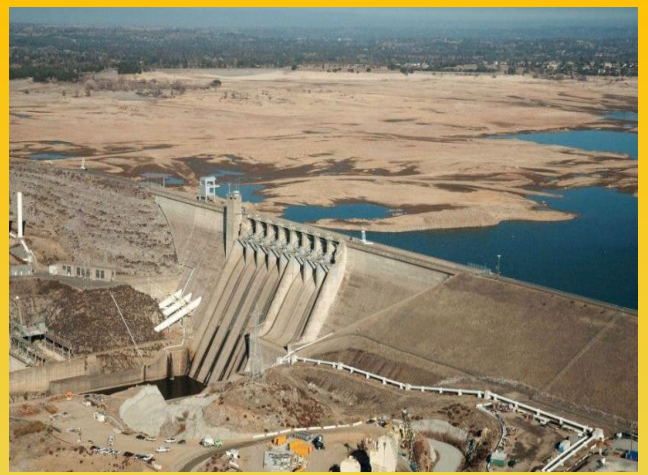

Huffpost

The Guardian

techexplorist.com

Linden
ENERGY HOLDING, INC

The Acceleration of Climate Change and the Complexity of the Energy Transition

Ray Leonard

Linden Energy Holding

January 2023

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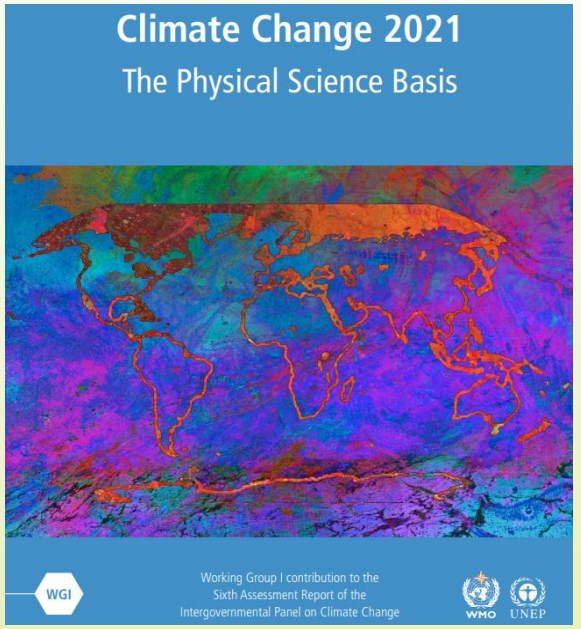
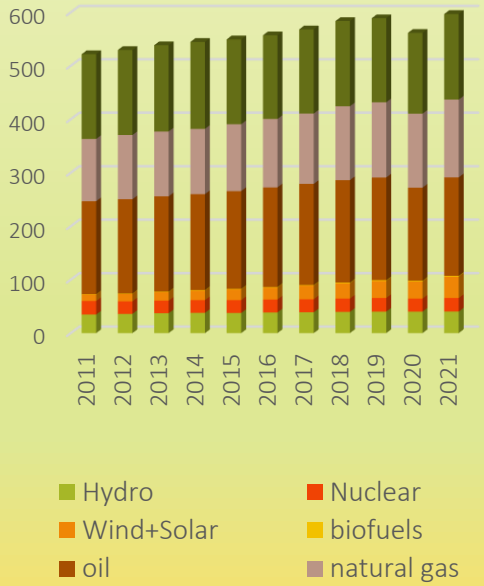
Climate Change is accelerating

- We already surpassed in 2021 the Radiative Forcing (RF) factor for 2030 predicted by IOCC Climate Change 2013
- This is due to cascading impacts and compounds events
- Based on IPCC Climate Change 2021, global temperatures will reach 1.5 degrees over pre-industrial time by 2030 and 2 degrees by 2050

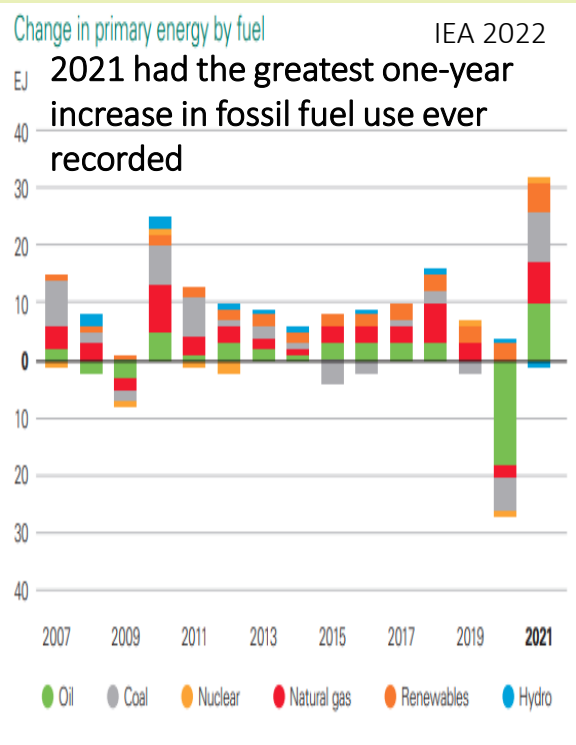


- Despite significant efforts, the energy transition has only made minimal progress in the past decade, with fossil fuel use only reducing from 88% to 85 % of energy sources
- The main sources of low carbon energy, hydro power and nuclear, are unlikely to increase in the coming decade
- The main drivers of rapid growth of wind and solar in the past decade; low energy costs and availability of critical minerals are now in question
- Geopolitical forces, while in the long term may support a shift away from fossil fuels, in the near term are supporting continued coal use

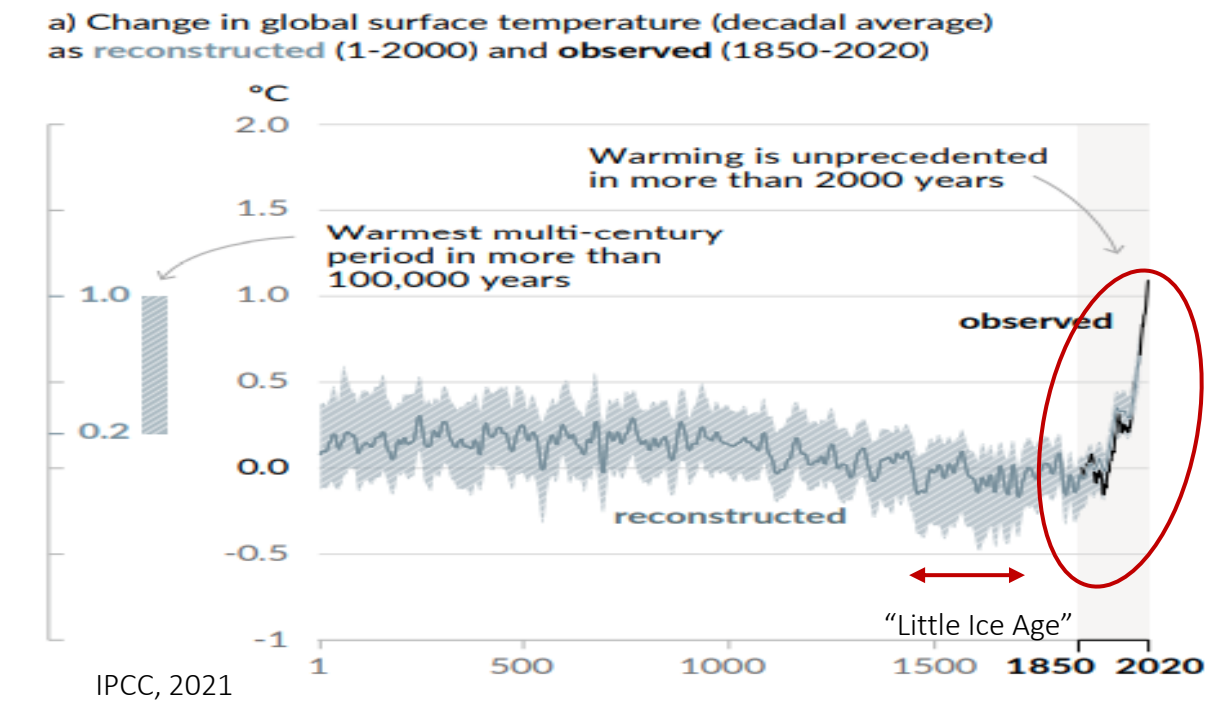
Total Energy consumption (exajoules)



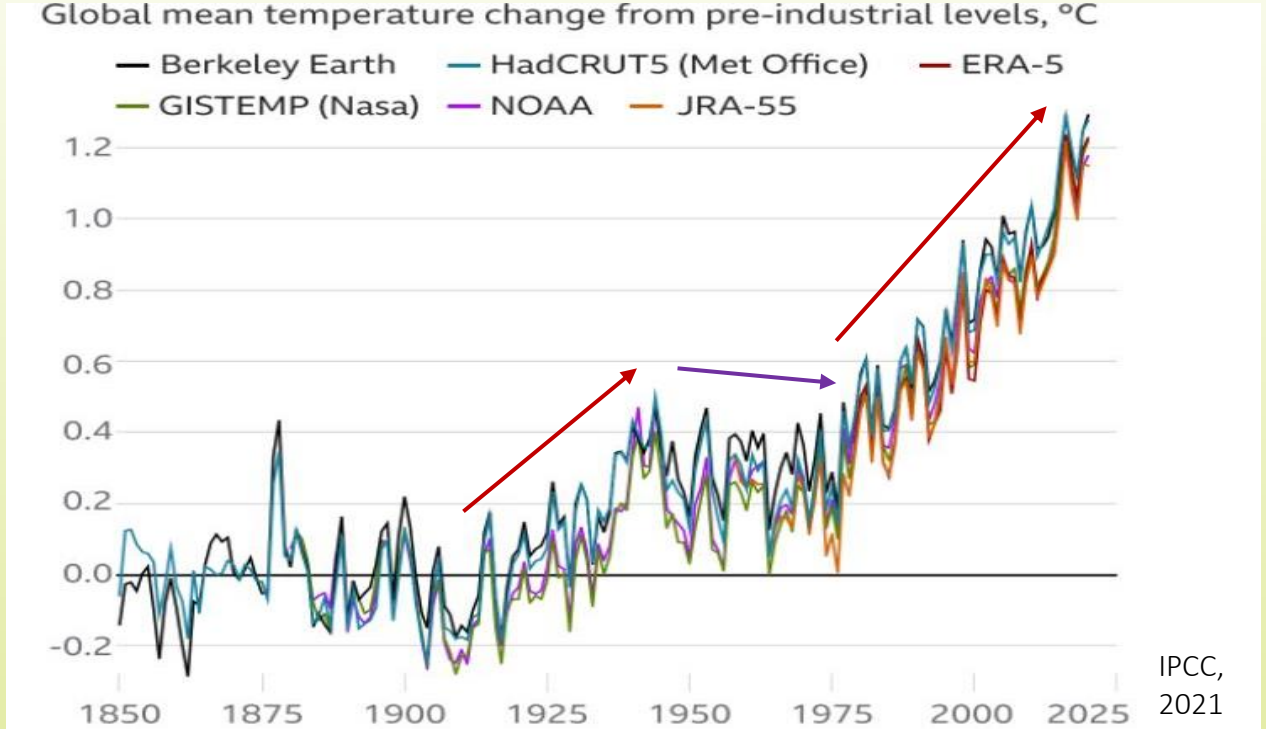
BP 2022 World Energy Review



Many factors have contributed to temperature change

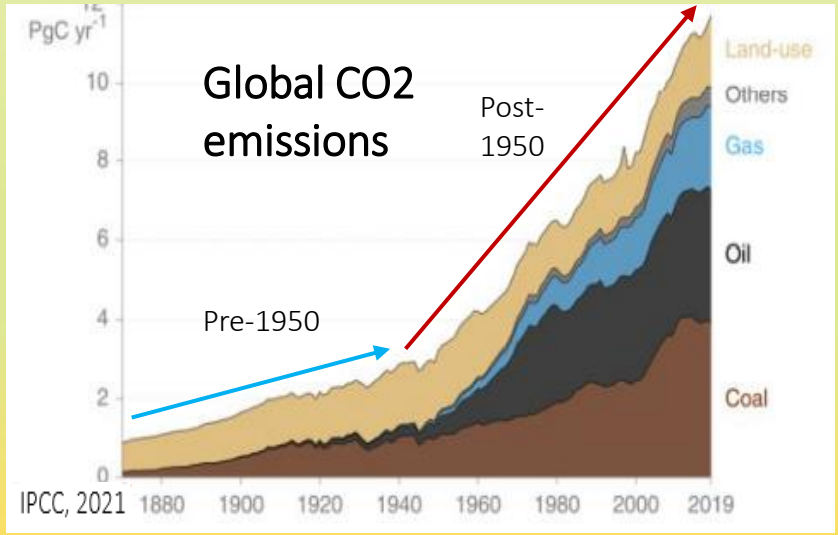


IPCC, 2021



IPCC, 2021

- Normal temperature variations can be 0.5 deg C/year
- Temperatures dropped over a 300-year period (1400-1700, or "Little Ice Age") due to reduced solar radiation
- Temperature rise of 1 deg C in past 40 years is far outside normal range of historical time



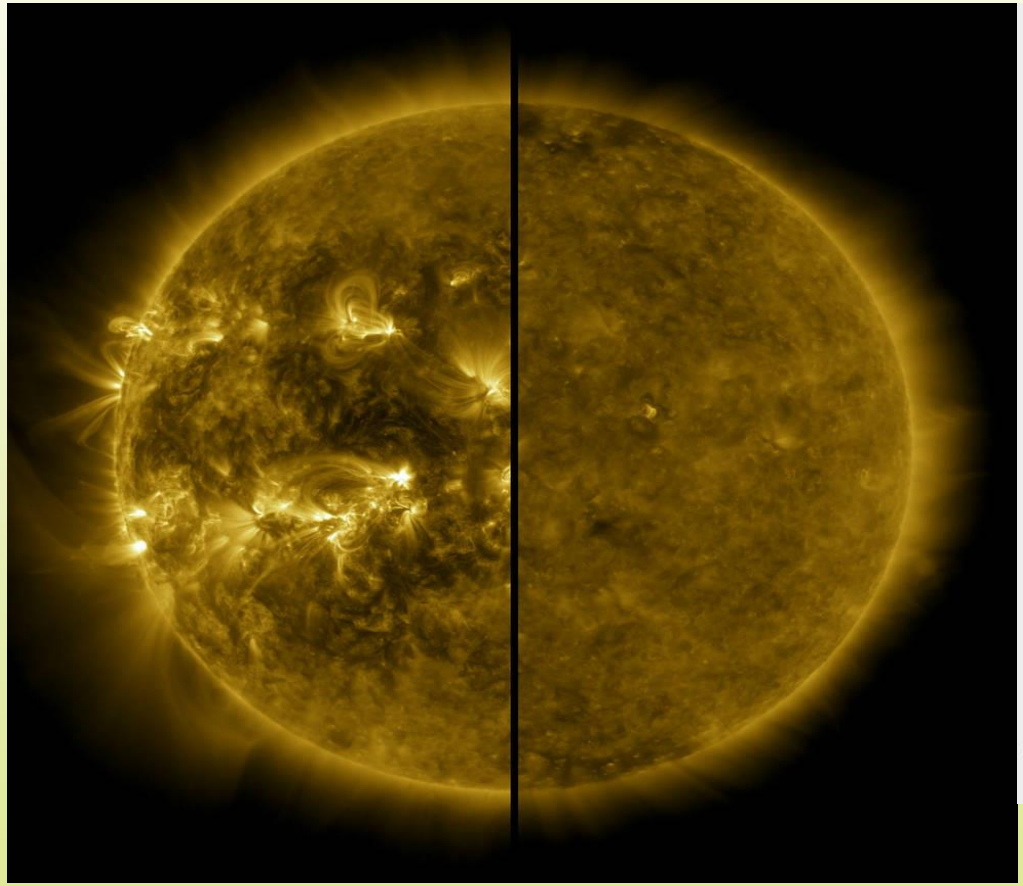
IPCC, 2021

Global temperatures in past 100 years have followed 3 trends:

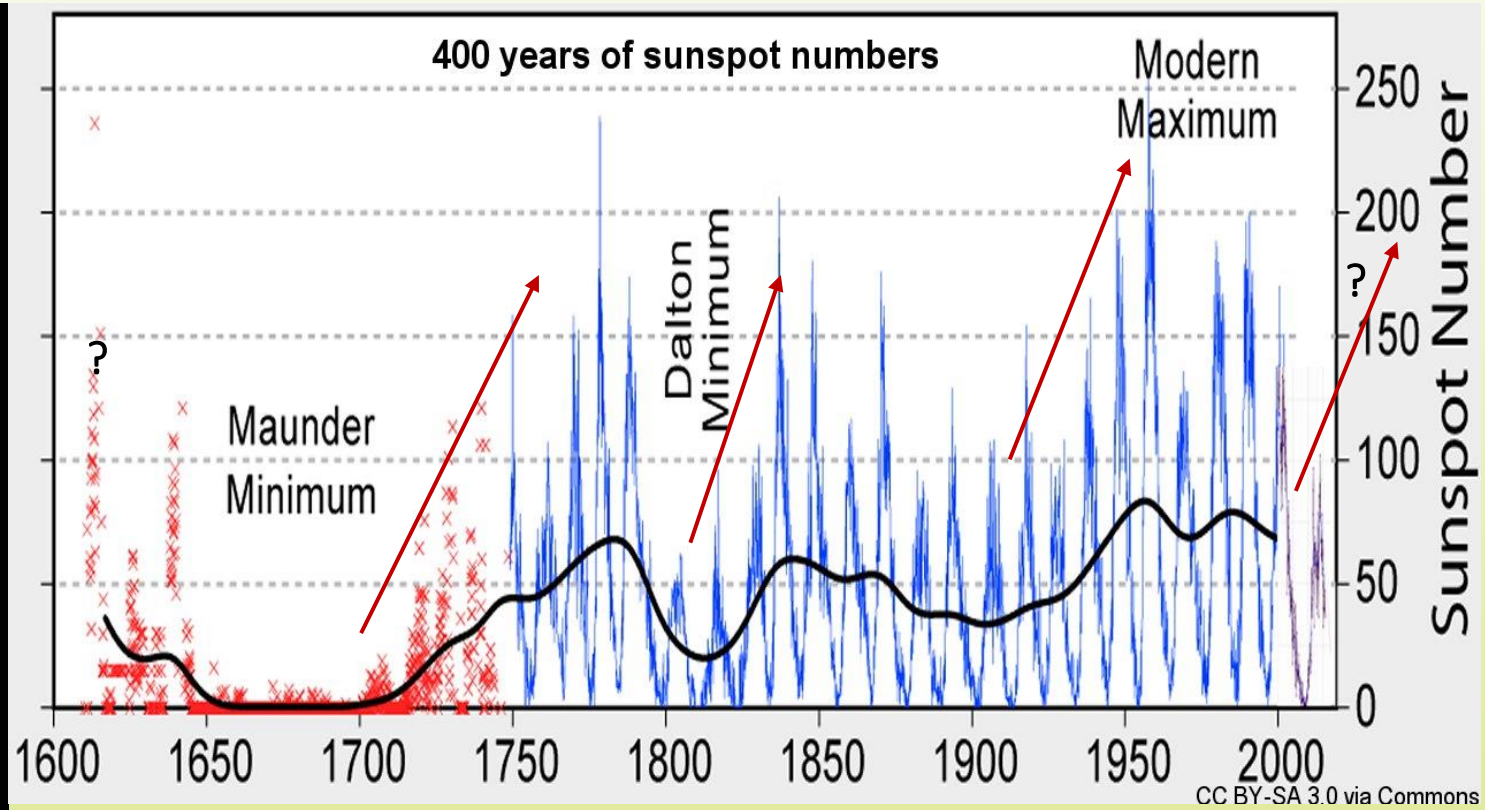
- 1910-1950: increase of 0.5 deg. C
- 1950-1980: temperature flat or slightly decreasing
- 1980-2020: increase of 1 deg. C

This is not consistent with CO2 emissions, which began rapid increase in 1950

Natural causes of temperature variation: Solar radiation



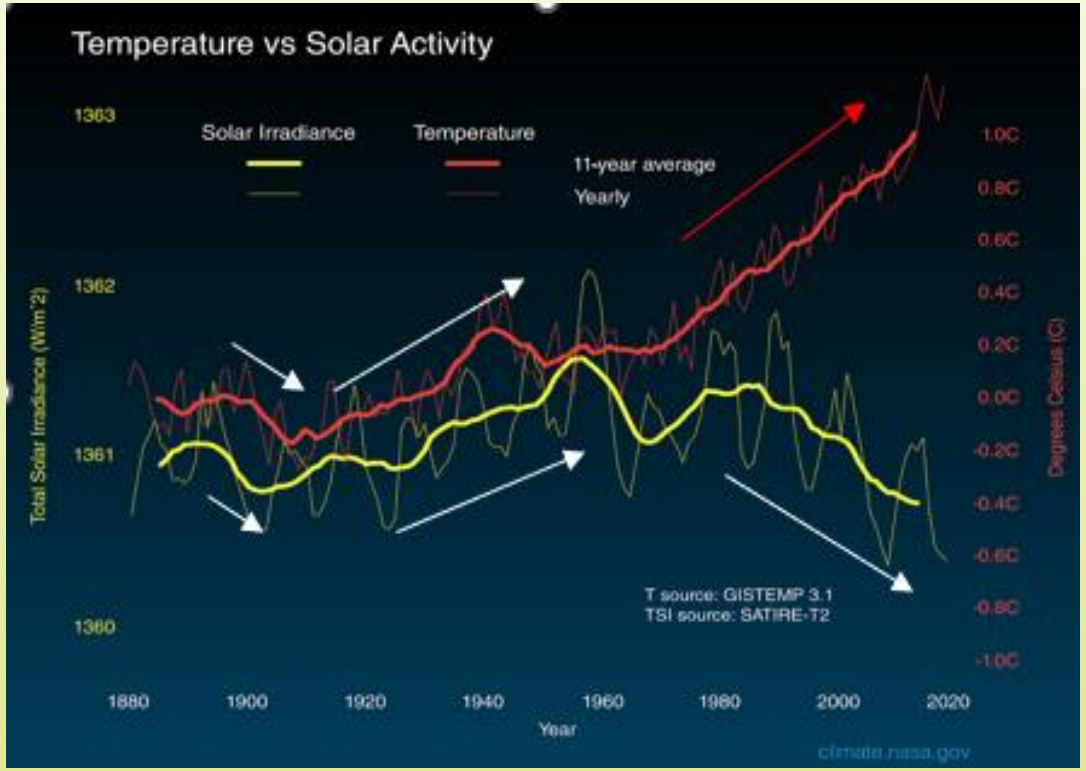
April 2014 and December 2018 Solar maximum and minimum (NASA)



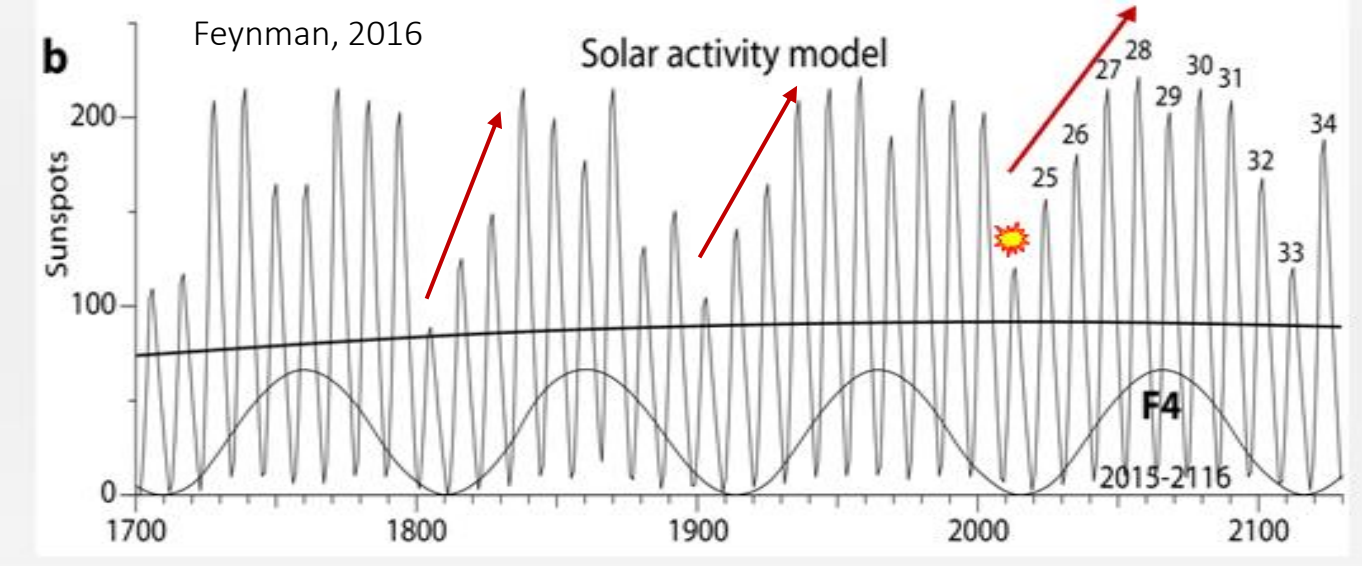
The sun has two seasons: calm and stormy. In the stormy season, solar radiation is increased, warming the temperature. The full cycle takes 22 years.

We have been able to measure the cycles in detail for about 400 years by counting sunspots. Direct measurement by satellite after 1960 verified solar radiation assumptions. However, not all stormy cycles are of the same intensity; there is an approximate 100-year cycle with lows at the beginning of each century. The 0.5 degree C temperature increase in the first half of the 20th century was mostly caused by increased solar radiation.

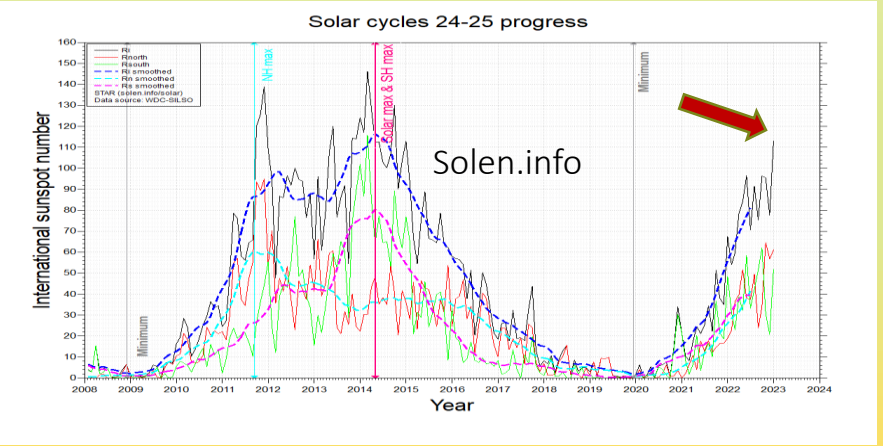
Solar radiation moderated the temperature rise in the past 40 years but will add to it in the next 40 years



In the past, an increase and decrease in solar radiation was mostly consistent with temperatures, but after 1980, the decreased radiation only moderated the temperature rise

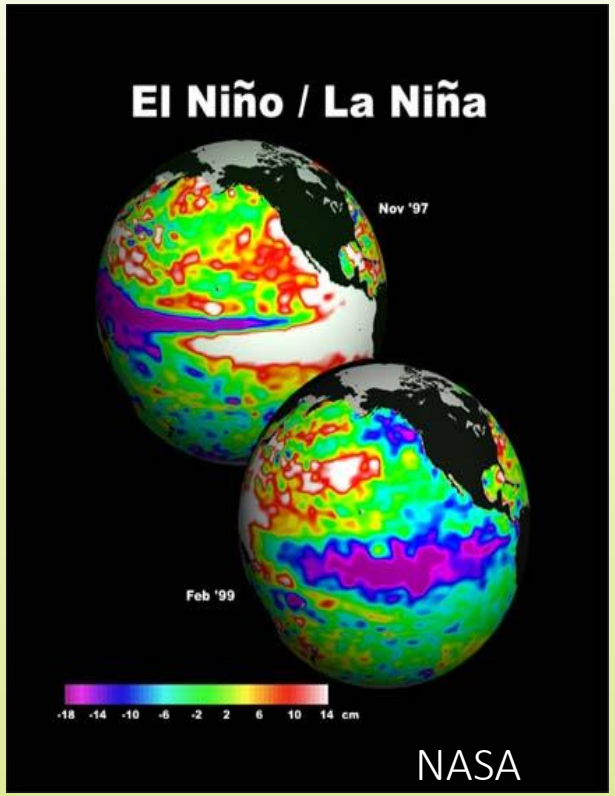


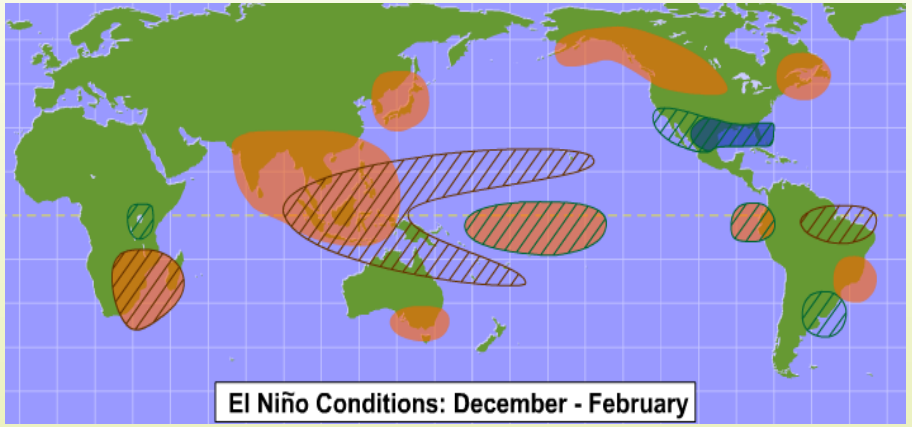
Unfortunately, solar activity will rise through the next 40 years adding up to 0.5 degrees C to other factors in the temperature rise

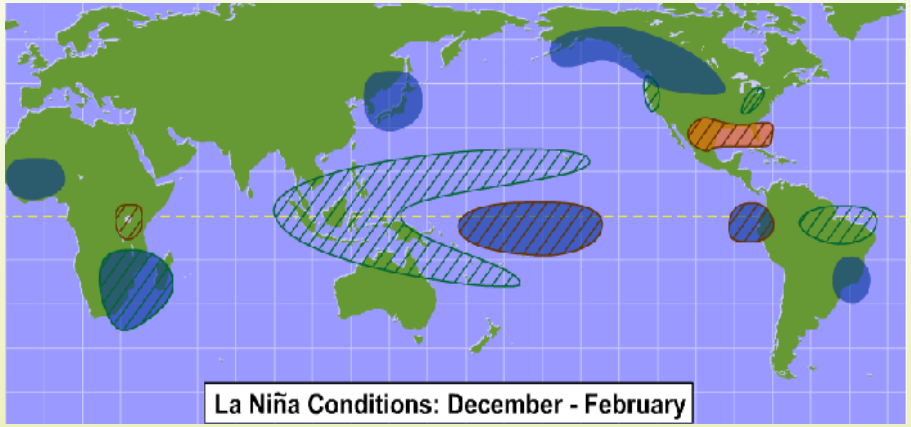


Solar cycle 25 may be exceeding levels at this point of the previous cycle supporting the historical trend and will contribute to increased temperatures after 2022

Natural causes of temperature variation: Ocean Currents



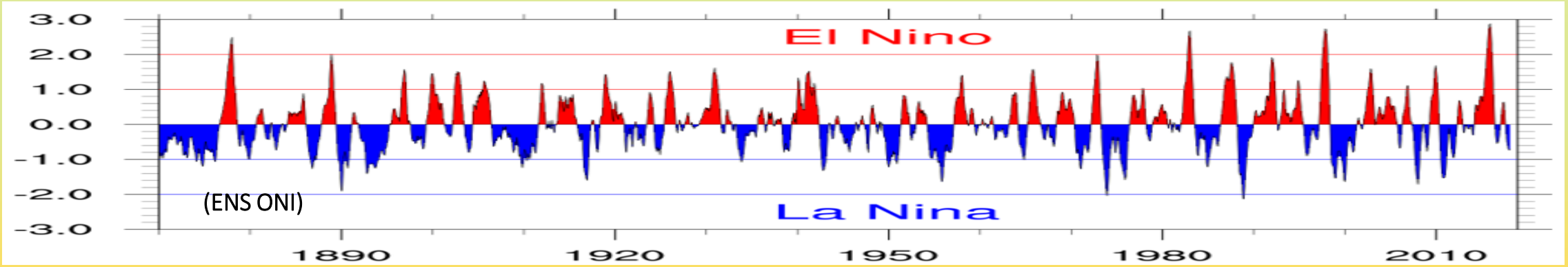




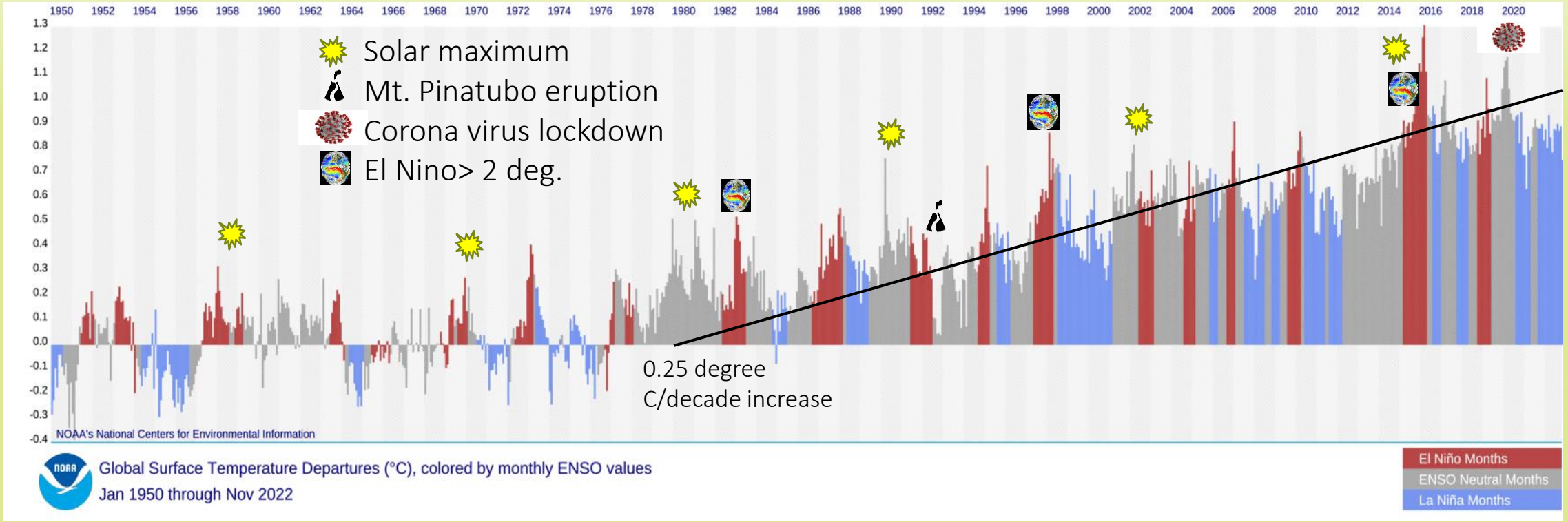
NOAA, Penn State

warm cool dry wet

- The most consequential current is the ENSO system: warming of the Pacific current (El Nino) results in mostly warmer and drier weather, while La Nina, a cooling current, cooler and wetter weather
- The Enso cycles have been recorded for 150 years. Cycles are unpredictable with currents sometimes lasting 3-5 years
- *Each ENSO deg. C warming or cooling causes a global temperature variation of .15 degree C on average*
- With the warming ocean due to climate change, El Nino cycles are predicted to become more extreme. The three warmest cycles ever recorded occurred in 1982, 1998 and 2015/6



Solar radiation and ocean currents explain some but not all post-1980 temperatures changes



Through 1980 temperature variability could be largely explained by solar radiation and ocean currents. However, after that point, a steady temperature increase due to atmospheric factors needed to be added.

If an El Nino occurs during the upcoming solar maximum of 2023-2026 the world will likely experience a temporary increase in global temperature greater than 1.5 degrees C above pre-industrial level

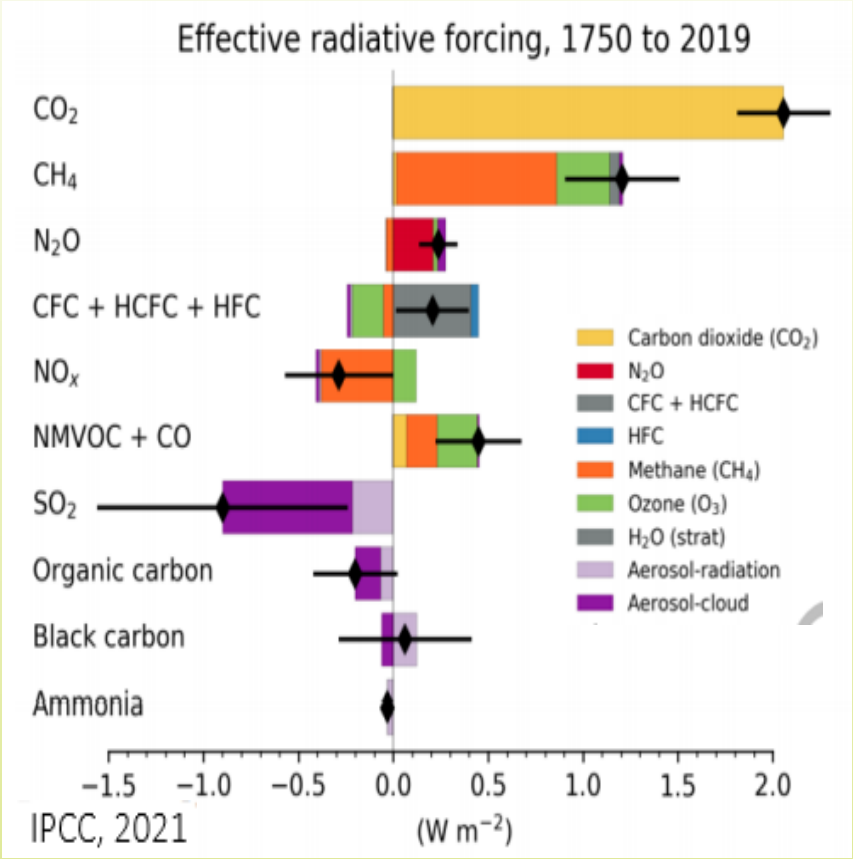
1980

2015/6

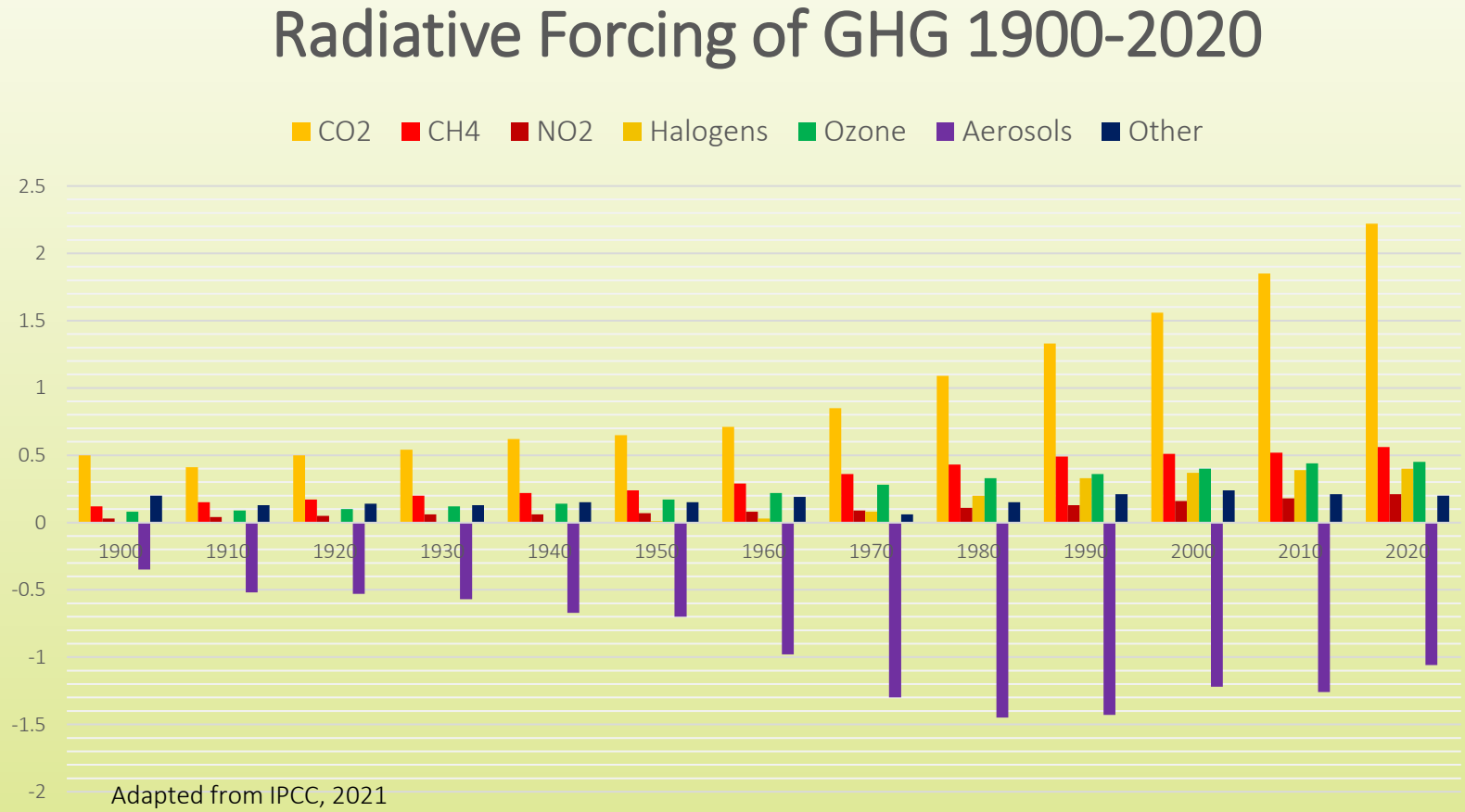
2023–2026

A combination of record breaking El Nino at time of near solar maximum likely caused extreme temperature records to be set in 1H 2016

Greenhouse gases and the Atmosphere: It's not just about CO2

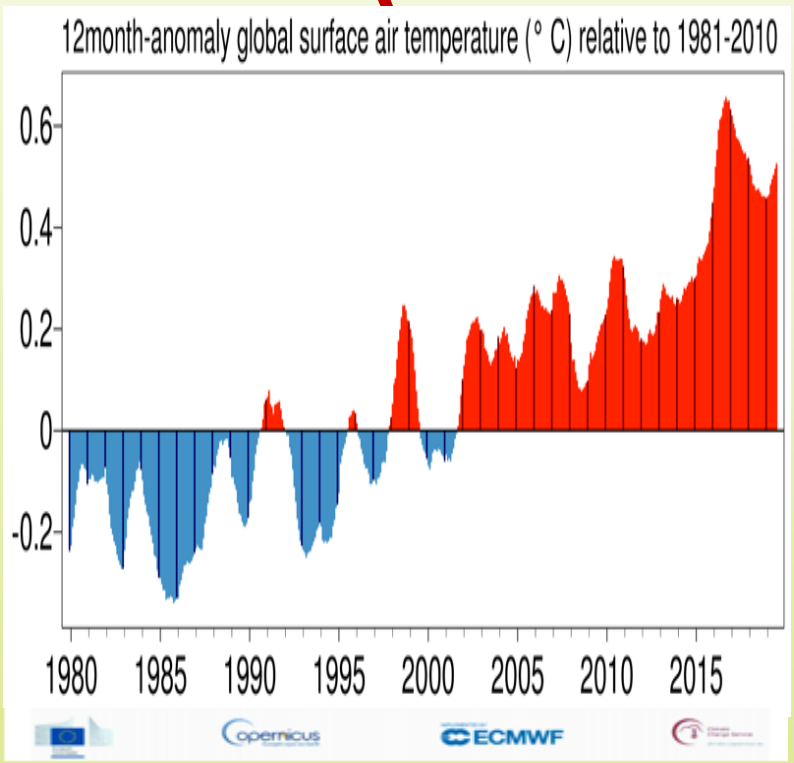


Radiative forcing (RF) is the change in energy flux in the atmosphere due to natural or human caused climate change in watts/meter. RF increase of 1750-2020 is +2.79. This surpasses the level predicted for 2030 in the 2013 IPCC report.

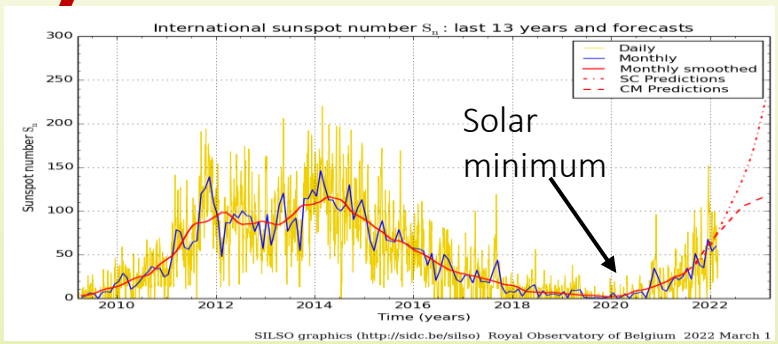


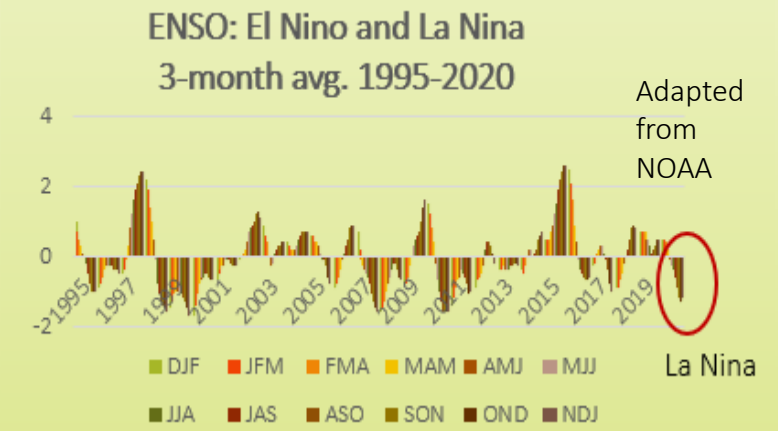
- Most important factors have been addition of CO2 in the atmosphere (+) mostly due to combustion of fossil fuels and aerosol pollution (-) from the same process
- From 1900-1990, these two factors largely cancelled each other out
- Increase in other GHG's increase 250% from 1950-1990
- After 1990, pollution (aerosol emission) dropped in Europe and USA replaced in part by pollution in Asia

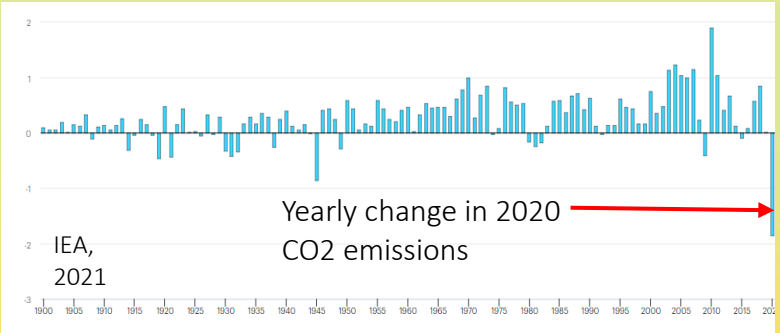
2020 demonstrated the effect aerosols (or lack of) have on temperatures



After the record shattering 2016, temperatures dropped in 2017-2019 by 0.2 deg. C.





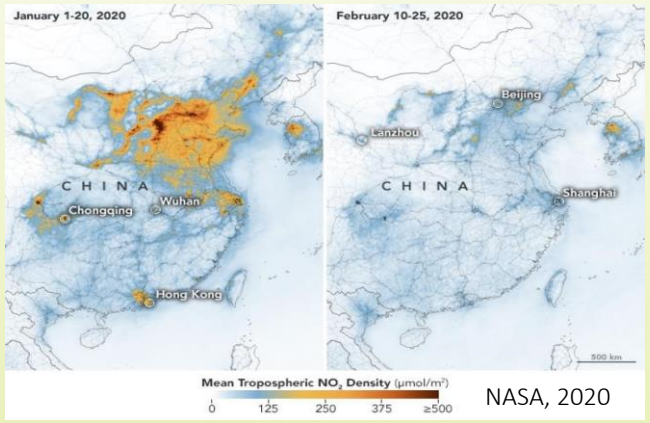


2020 should have been a cool year

- The sun was at the minimum of its cycle
- The ocean current was La Nina
- CO 2 emissions had the one-year greatest drop since records have been kept

1H 2020 tied 2016 as warmest year in historic time!

During 1H 2020, due to Covid lockdowns, world stopped polluting!

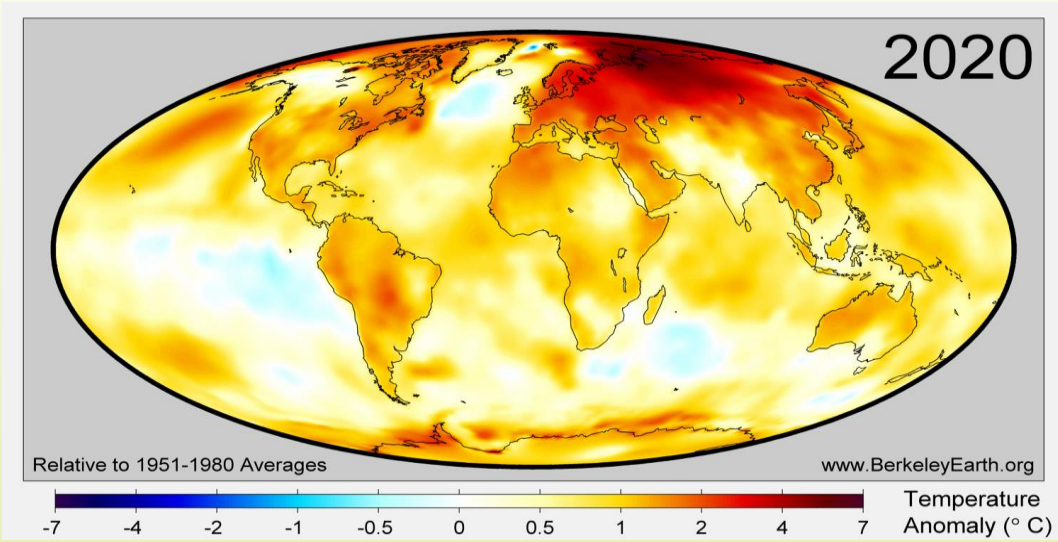


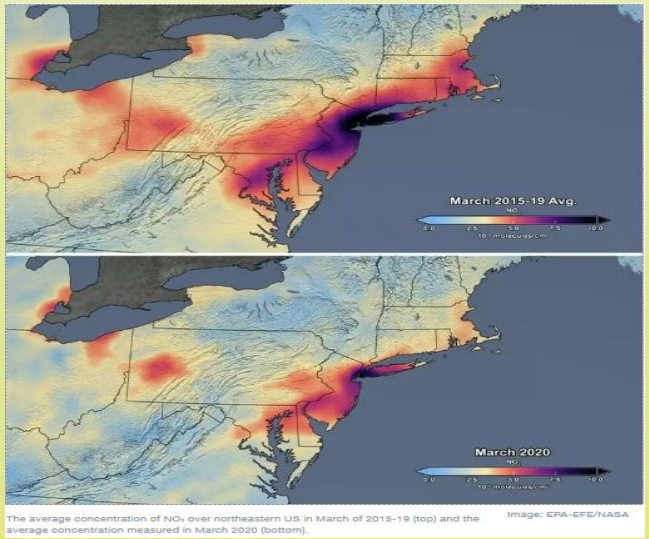
NASA, 2020

CHINA Jan 2020 vs Feb 2020

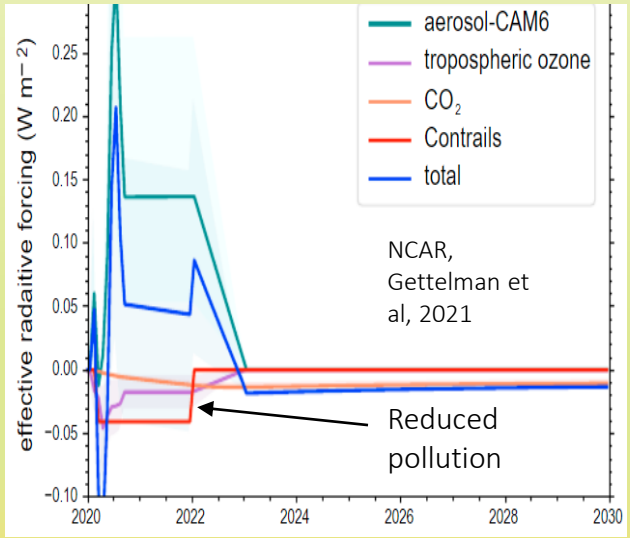
Reuters, 2020

INDIA New Delhi
Jan 2020 vs Feb 2020

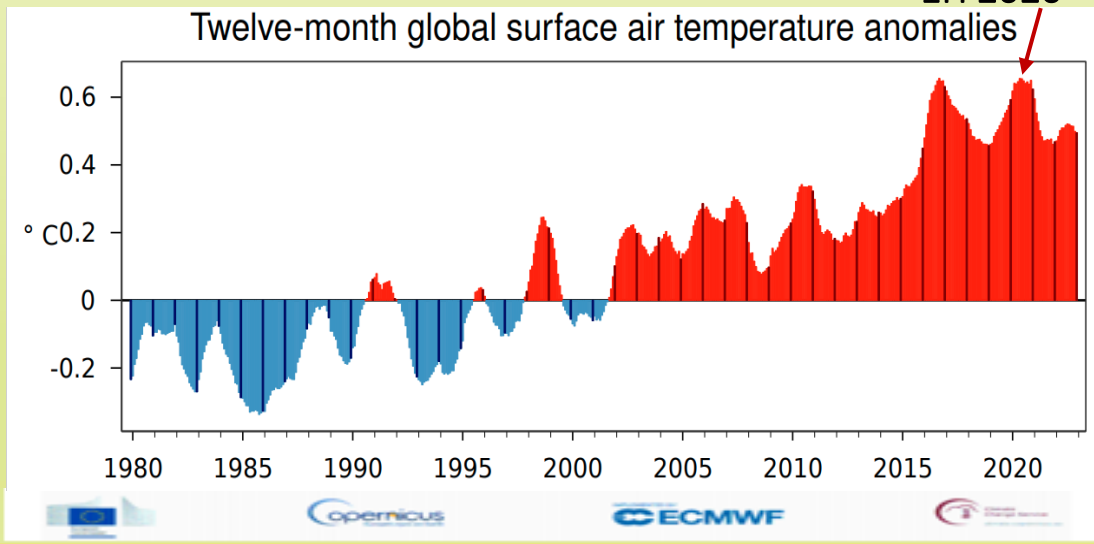




Northeast USA:
March 2019 vs March 2020

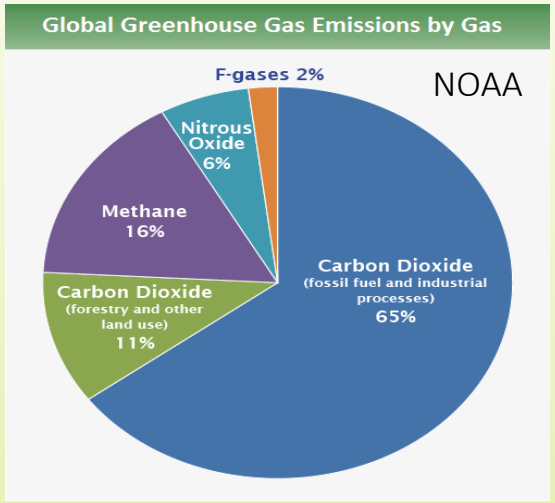


Increased RF due to lack of pollution



Record high temperatures, especially 1H 2020.
Temperatures dropped in 2021

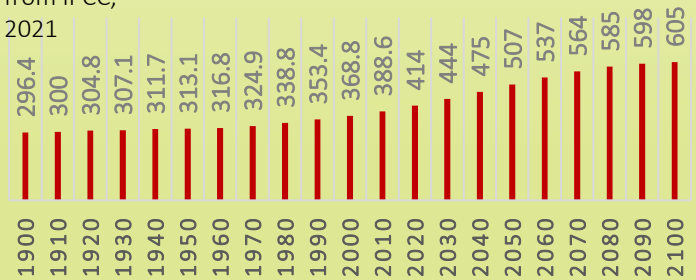
CO2 emissions: past and future



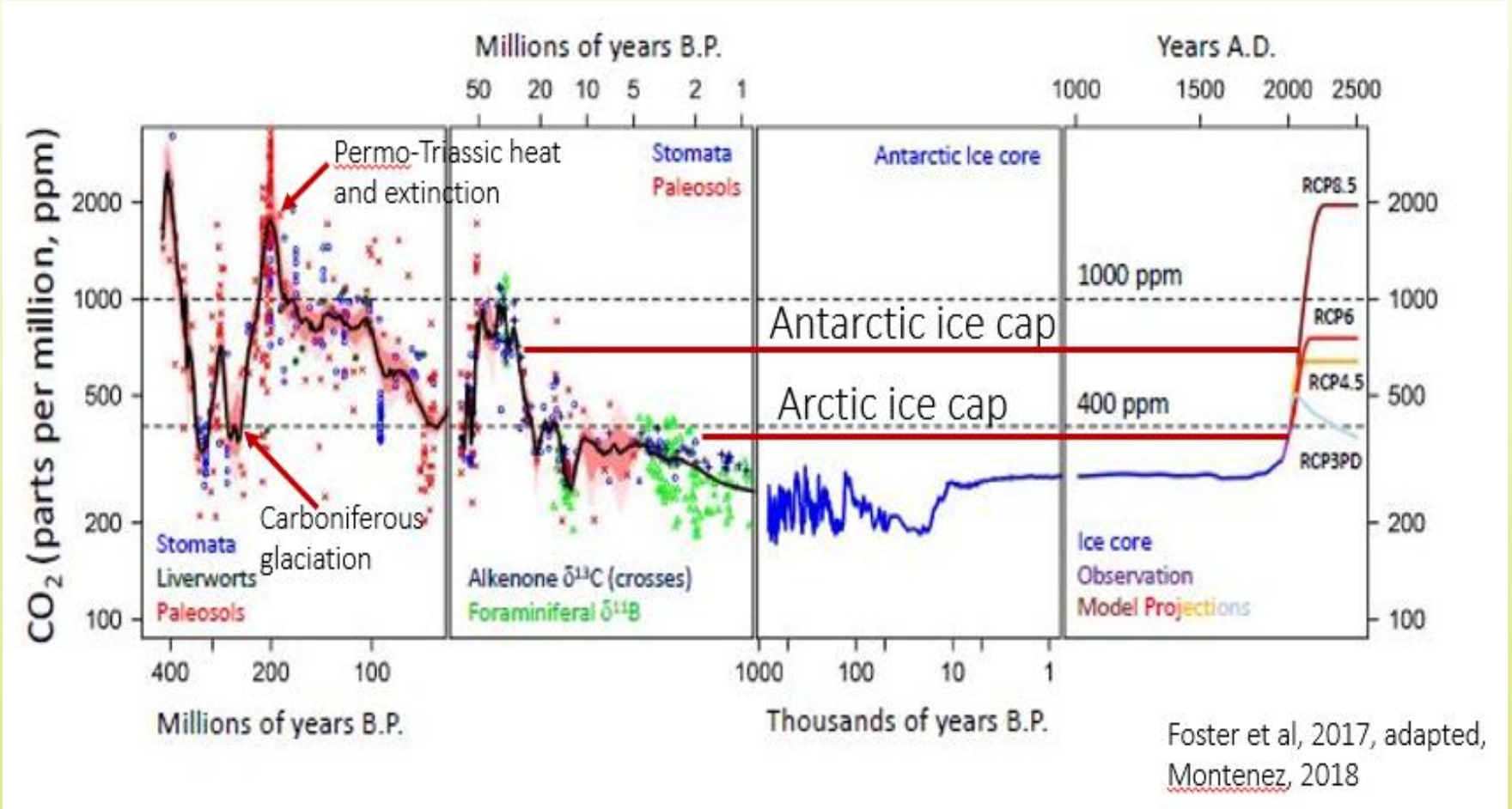
CO2 forms 76% of greenhouse gases.
80% of emissions come from fossil fuels.

ATMOSPHERIC CO2 (PPM) IN SP 4.5 SCENARIO

Adapted from IPCC, 2021



CO2 levels, at 420 ppm in 2022, will double in 21st century to level not seen in 30 million years

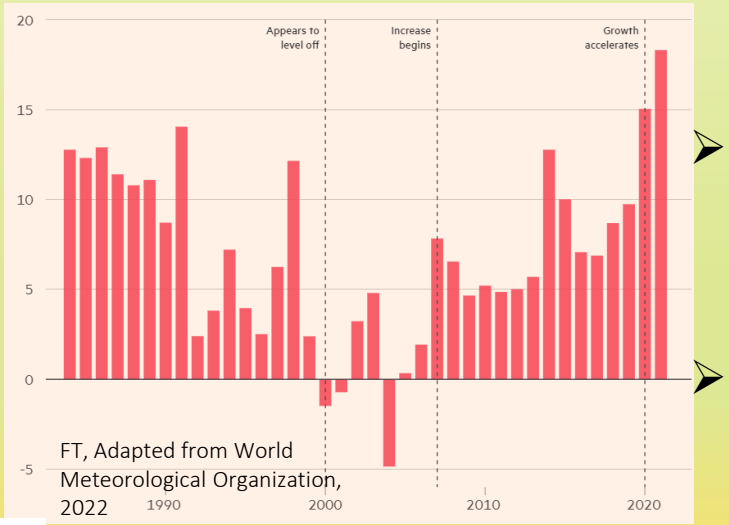


CO2 levels in geologic history can be estimated from the fossil and geochemical record. Actual measurement in ice cores of the past million years have verified the methodology. The formation of the Antarctic and Arctic ice caps, as well as the Carboniferous glaciation corresponds to the lower CO2 levels .

Methane Emissions: rising and out of control?

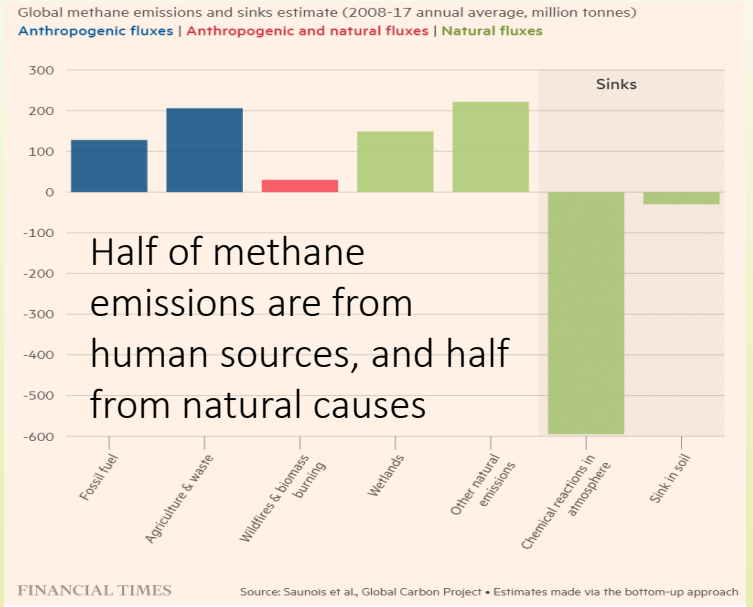
	CO_2	CH_4
2021 global mean abundance	415.7±0.2 ppm	1908±2 ppb
2021 abundance relative to 1750[a]	149%	262%
2020–21 absolute increase	2.5 ppm	18 ppb
2020–21 relative increase	0.61%	0.95%
Mean annual absolute increase over the past 10 years	2.46 ppm yr^{-1}	9.2 ppb yr^{-1}

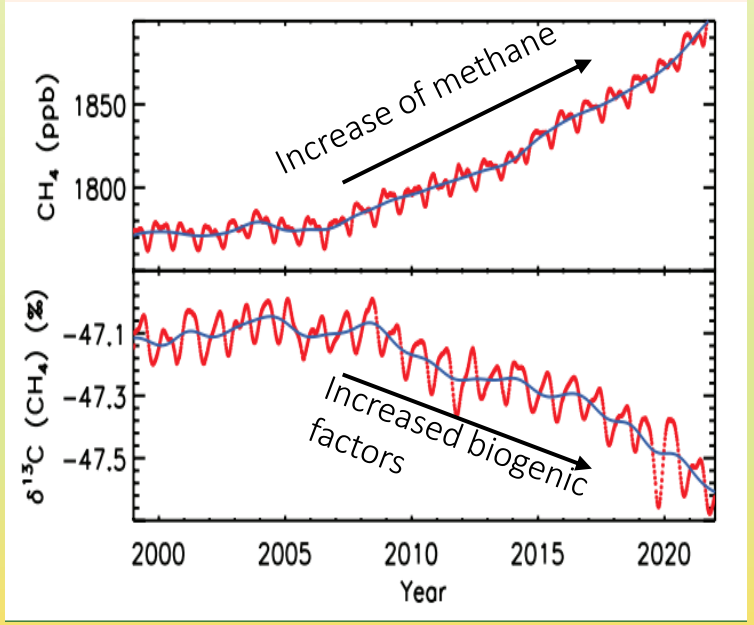
World Meteorological Organization, 2022



FT, Adapted from World Meteorological Organization, 2022

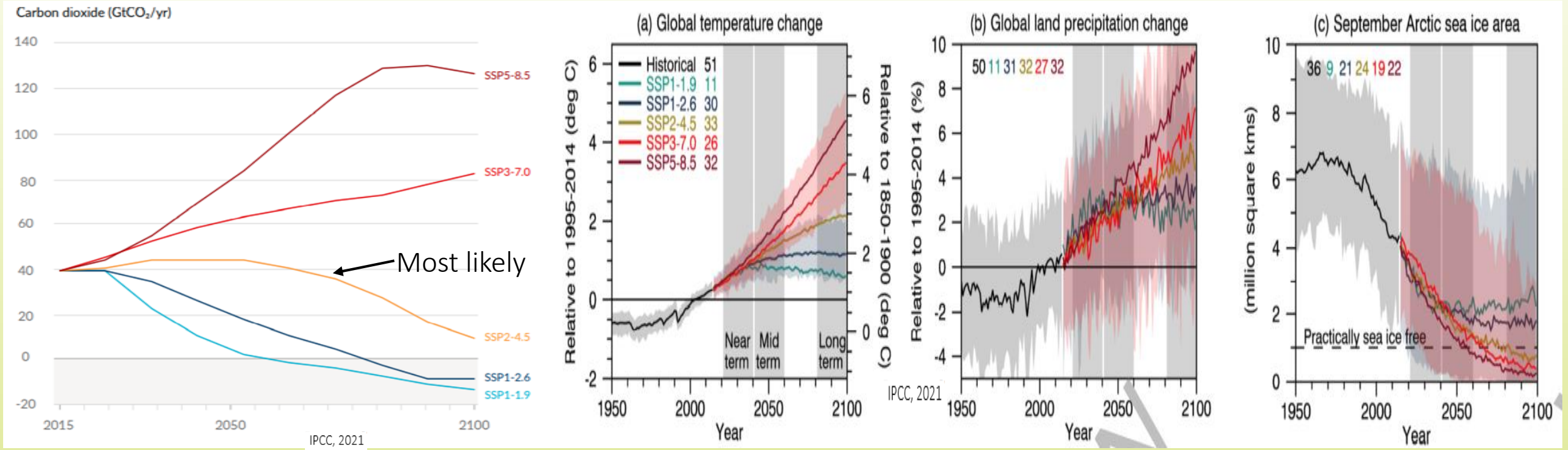
- Methane is more powerful GHG than CO2: 80X in short term, 25X in long term
- Methane emissions have risen almost twice as fast as CO2 since pre-industrial time and increased from 10% to 16% of overall GHG content
- Only half of methane emissions are from human related causes, and 40% of that from fossil fuels (20% net, 13% from oil and gas, 7% from coal)
- Methane additions almost ceased 2000-2007 but have steadily increased since that time
- In 2020, despite largest drop in CO2 emissions ever recorded, methane increase was highest in >40 years
- Influence of climate change: Melting of permafrost and increased precipitation in certain equatorial and northern wetlands regions resulting in higher methane emissions
- Source of methane emissions can be detected from isotope fraction: since 2008, increasing fraction from biogenic (non-human) sources





World Meteorological Organization, 2022

The 2021 IPCC report presents five potential scenarios for the rest of the 21st century, however, not all are realistic



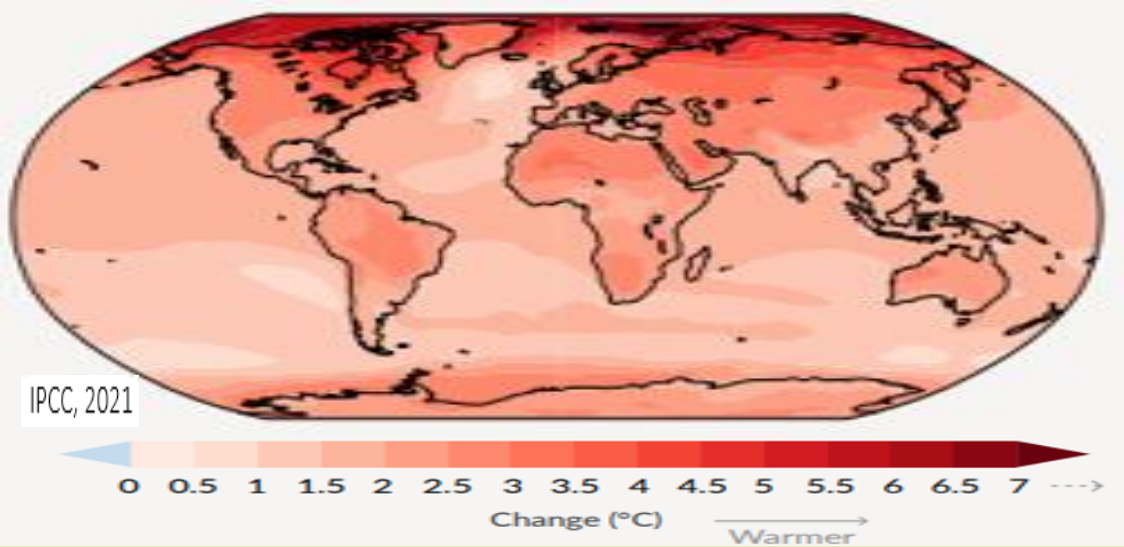
The IPCC admits in the report that the two high and low scenarios are unlikely. In fact, being able to move from the constant increase in carbon emissions to a plateau then decline after 2050 would be a significant achievement. Moving the decline closer to the present (beginning 2025) in SSP1-2.6 is a "stretch" goal.

Under most likely scenario (SSP2-4.5) the following would occur:

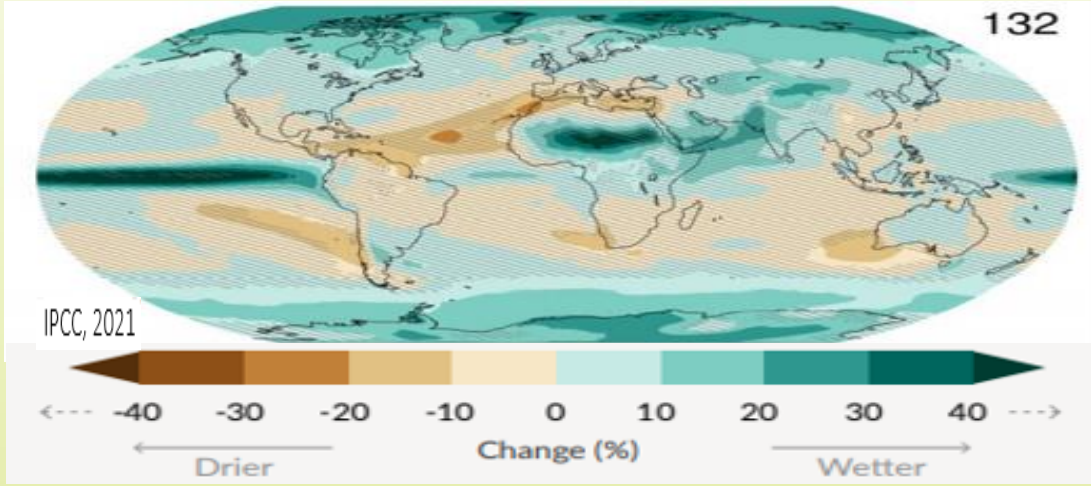
- ❑ Global temperature would rise to 2 deg. C relative to 1900 around 2050 and 3 deg. C by end of century
- ❑ It will be a wetter world in general, precipitation will rise 3% in first half of century, 5% by 2100
- ❑ The arctic will be mostly ice free by late summer by 2050
- ❑ **Through 2040, all scenarios have virtually identical results**

Lower emissions due to decreased burning of fossil fuels in SSP1-2.6 and 1.9 offset by reduced aerosols through 2040

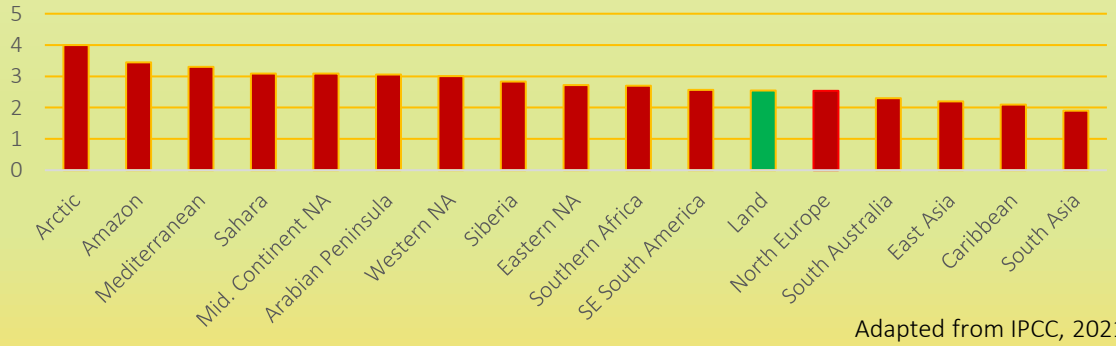
What will the world be like in 2050, with 2 deg. C temperature increase?



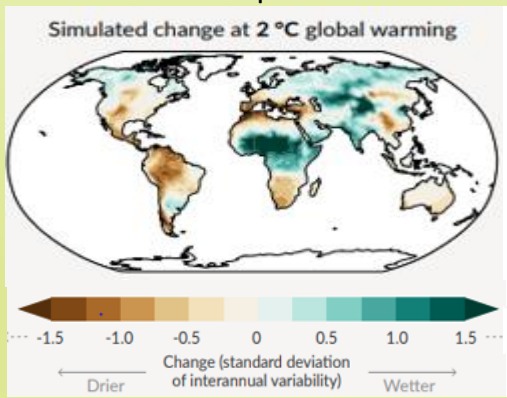
Temperature change at 2 deg warming



Precipitation change at 2 deg C warming



Adapted from IPCC, 2021



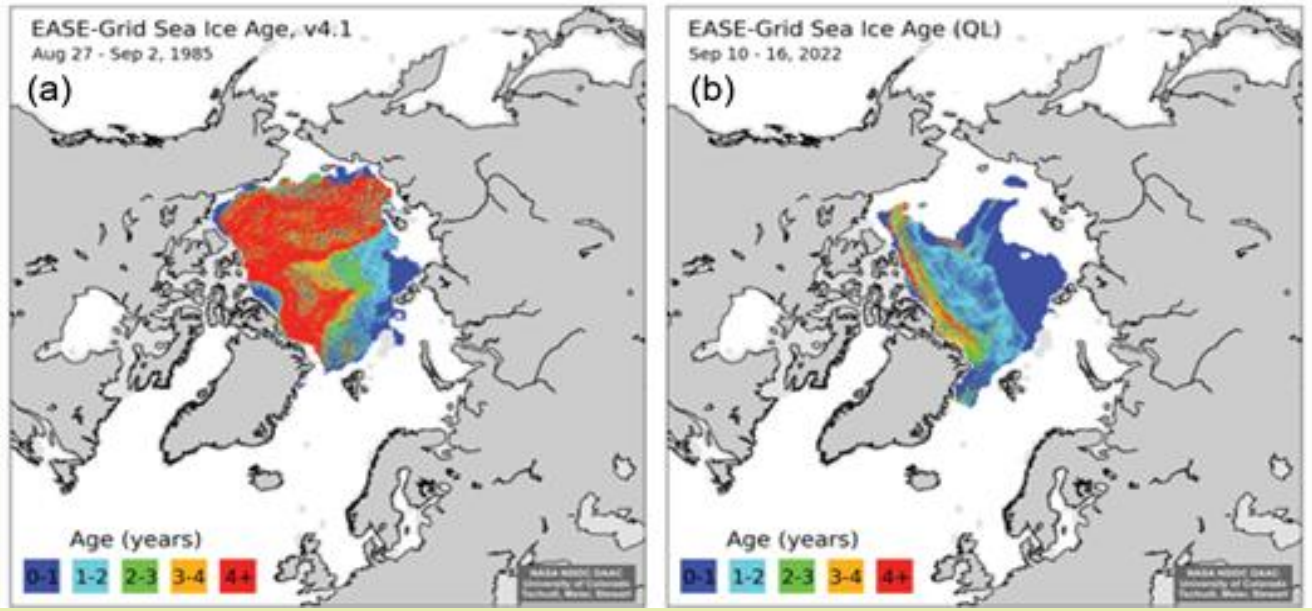
Change in soil moisture

Areas of predicted drought

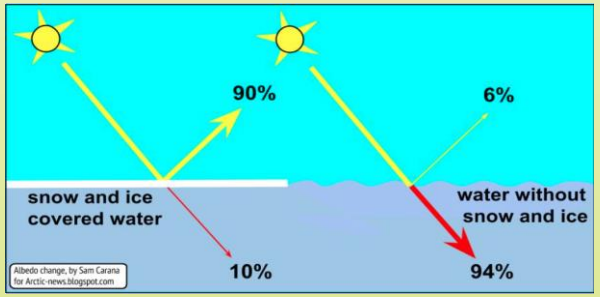
While land will average +2.55 deg C and ocean +1.64 C, the Arctic will warm the fastest

Combination of increased temperature and reduced precipitation will lead to serious drought in some areas

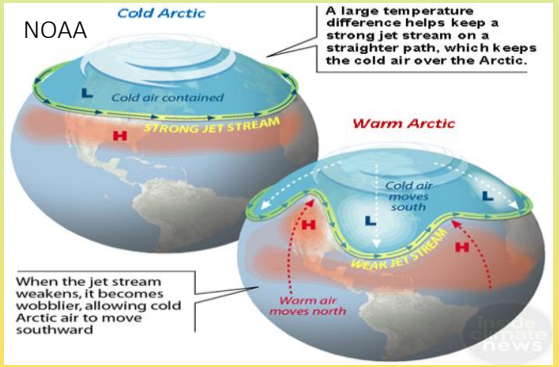
Arctic Amplification: Why it accelerates climate change

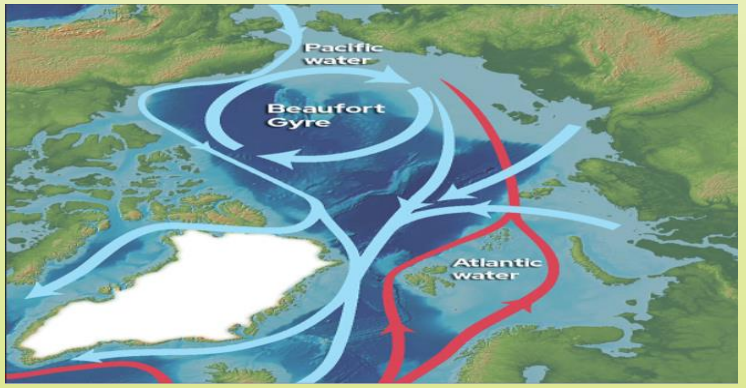


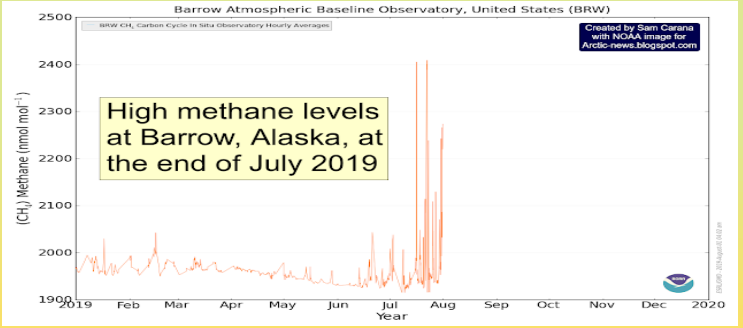
With Arctic temperatures rising at twice the rate of global temperatures, the northern polar cap is rapidly disappearing. Since 1985, the late summer ice cap has lost up to 50% of surface area and 70% of ice volume, including most multi-year ice. By 2040, only small area along the northern coast of Greenland and Canadian Arctic islands will remain during summer. This will accelerate climate change for the following reasons:



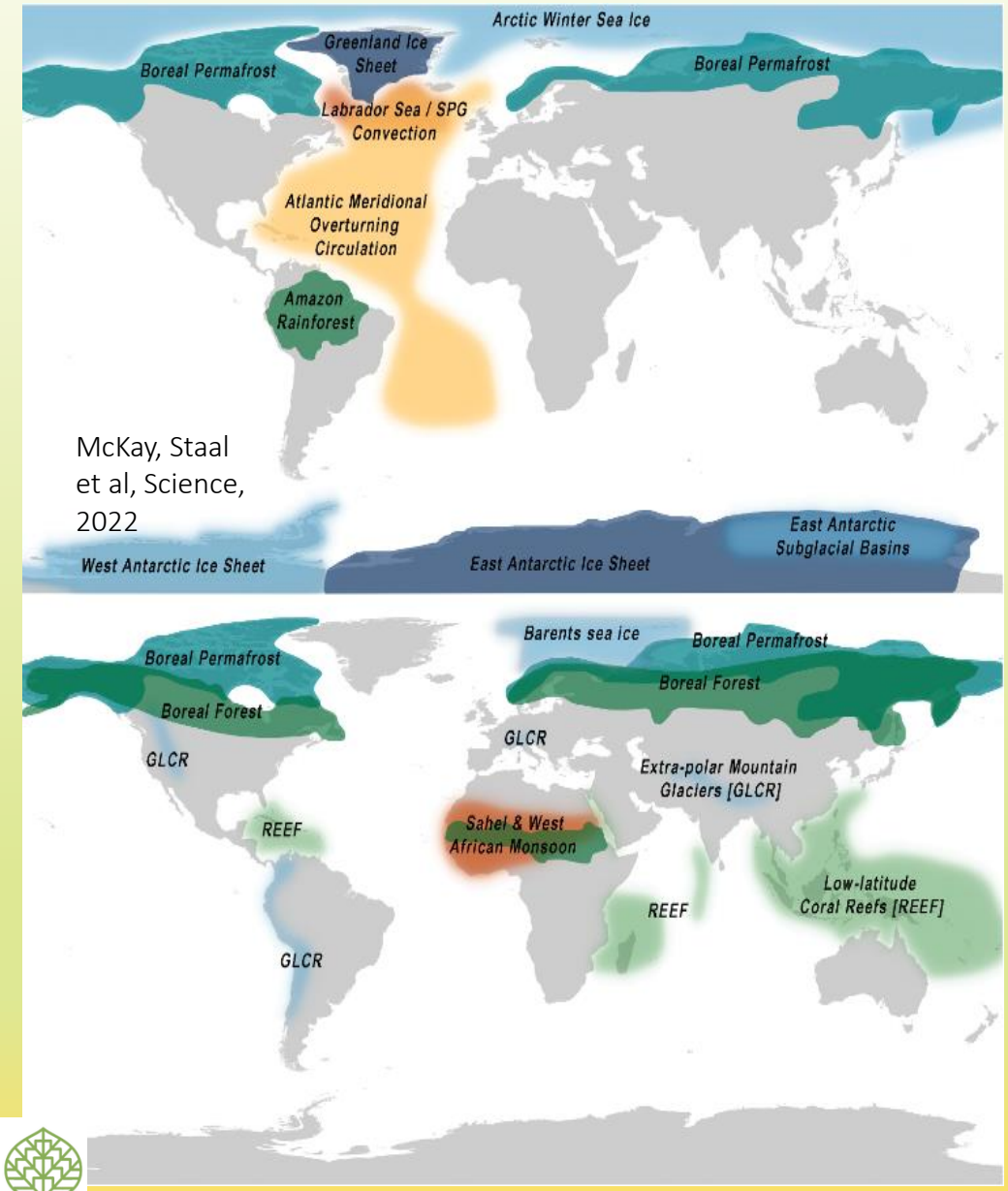
- Ocean absorbs 94% of heat, ice reflects 90%. Lack of ice cover will accelerate ocean warming which will increase melting
- Open Arctic summer will collapse Beaufort Gyre, resulting in increased flow of freshwater into North Atlantic, further weakening the Gulf Stream
- Reduced temperature differential weakens jet stream allowing warm air masses to high latitudes
- Increased melting of permafrost results in emission of large amounts of CO2 and methane into atmosphere







What are potential tipping points that could cause "catastrophic change"



McKay, Staal et al, Science, 2022

deg. C: Amount of temperature increase above pre-industrial time needed for tipping points to occur

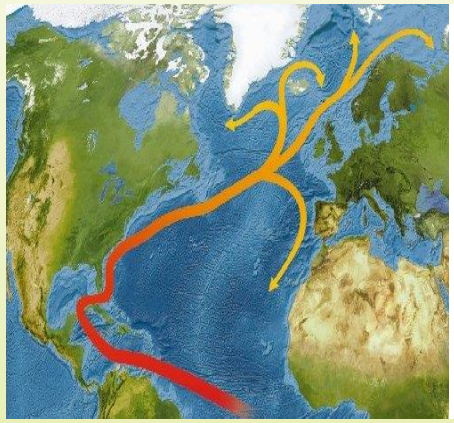
Global Tipping Points

- Arctic Sea ice: tipping point (**1.1 deg. C**) passed for summer sea ice and will be mostly gone by 2050. Winter sea ice would disappear at **4.5 deg C**.
- Greenland Ice Sheet: **1.5 deg C**, but will take >1000 years to complete
- Labrador Sea Convection: **1.8 deg C**, may disappear by 2040
- Atlantic Meridional Overturn: Estimated **2.2-2.4 deg C**, possible by 2100
- Boreal Permafrost Collapse: **3.0 deg. C**, possible by 2100
- Amazon Rainforest dieback: **2.5-3.0 deg C**, possible by 2100
- West Antarctic Ice Sheet: **1.5 deg. C**, first glacier collapse possible by 2050
- East Antarctic Sub-Basin: **3.0 deg. C**, not imminent in this century

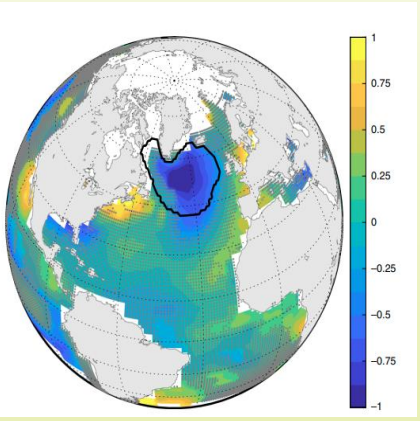
Regional Tipping Points

- Boreal Permafrost abrupt thaw: **1.5 deg C**, beginning by 2050 and continuing to 2100
- Barents Sea Winter Ice: **1.6 deg C**: gone by 2050
- Mountain Glaciers loss: **2.0 deg C**, most gone by 2070
- Sahel and W. African Monsoon (greening): **2.8 deg C**, around 2070
- Low latitude Coral Reefs die off: **1.5 deg C**, by 2030-2040
- Boreal Forest northern expansion: **2.5 deg C** (?), in 22nd century

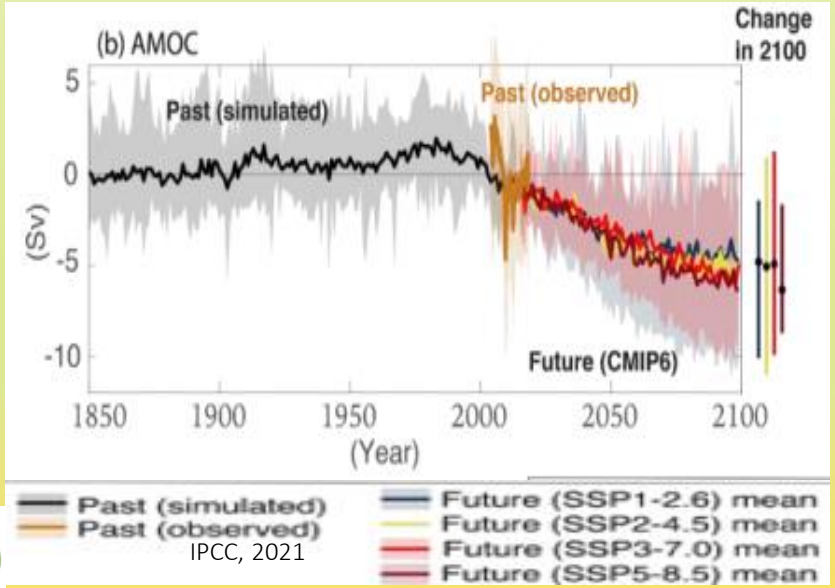
Overturning of Atlantic Meridian (Gulf Stream)



Gulf Stream Wikipedia

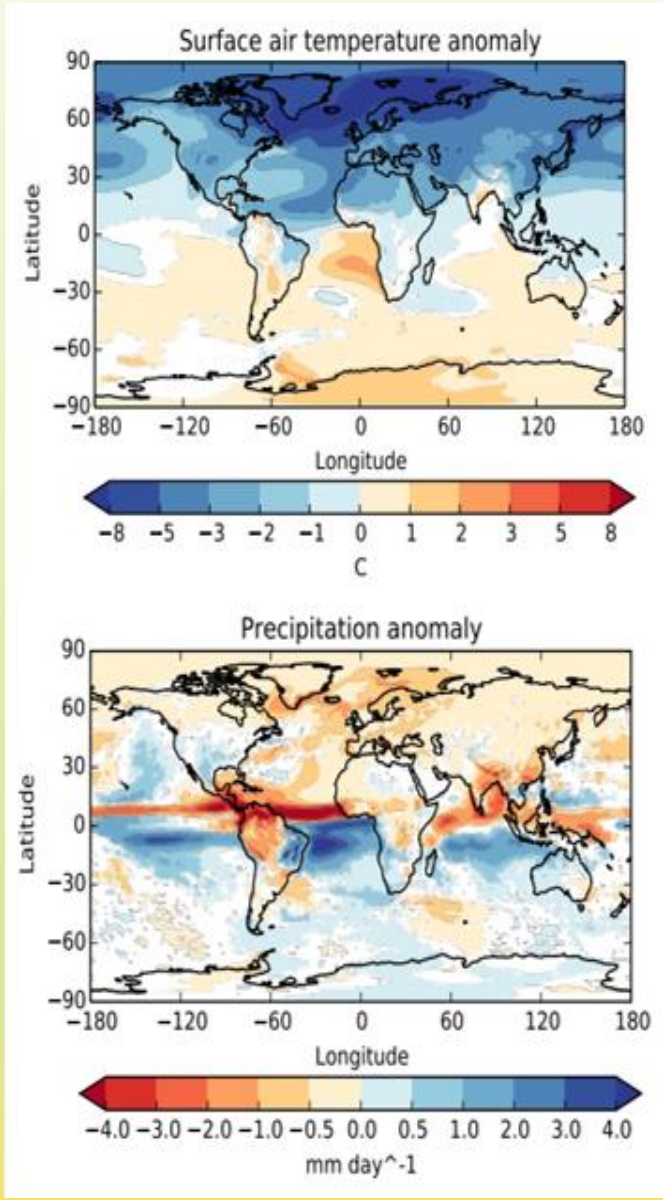


Trends in sea surface temperature 1909-2018 Deg. C (HadlSST and Kaplan)



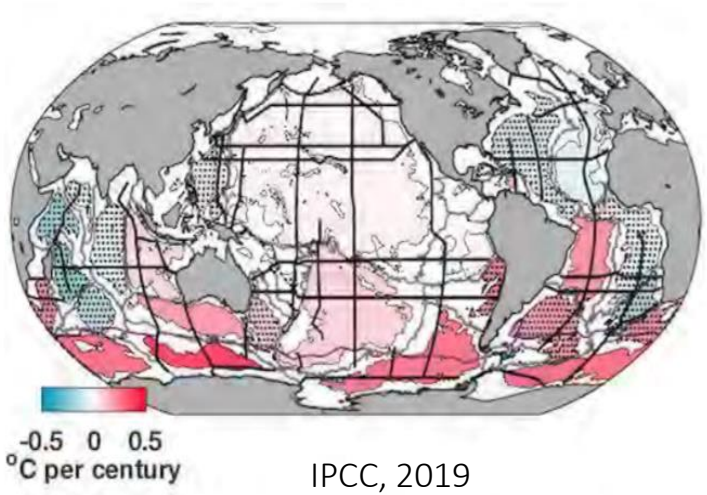
IPCC, 2021

- Increasing freshwater melt from Greenland and Arctic has weakened Gulf Steam by 15%
- This will accelerate under all scenarios and if it reaches 35-40% may overturn, radically changing global climate
- Heat transfer will slow, cooling N Hemisphere, warming S Hemisphere. Effects will be worldwide, especially precipitation.
- Dryas event occurred 13,000 years ago dropping temperatures in NW Europe and Greenland 5 deg C in 30 years

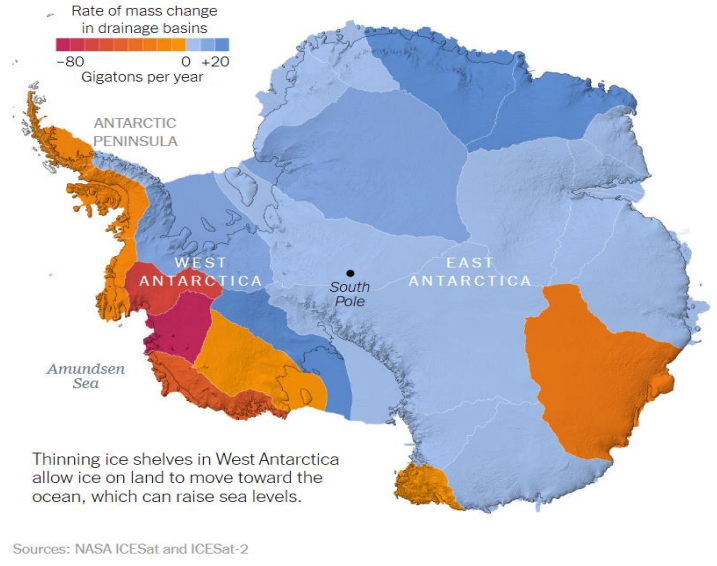


Jackson et al. 2015

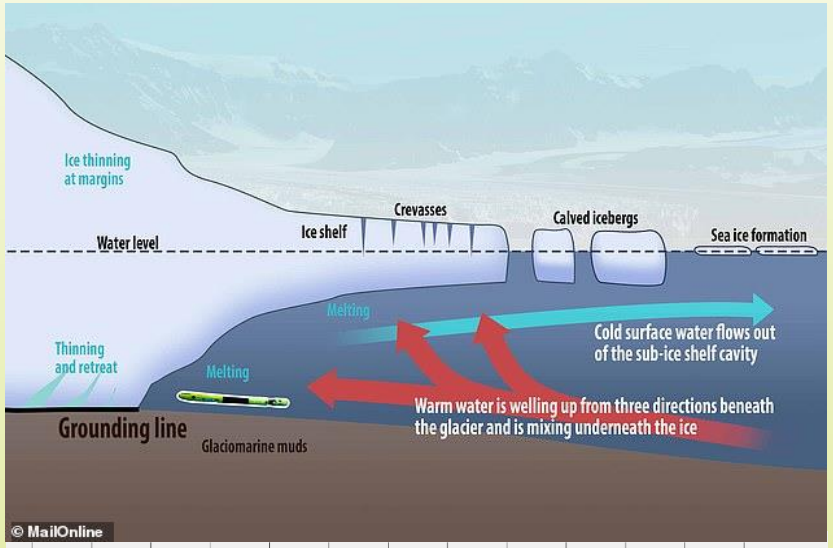
Breaking off of West Antarctic ice sheet

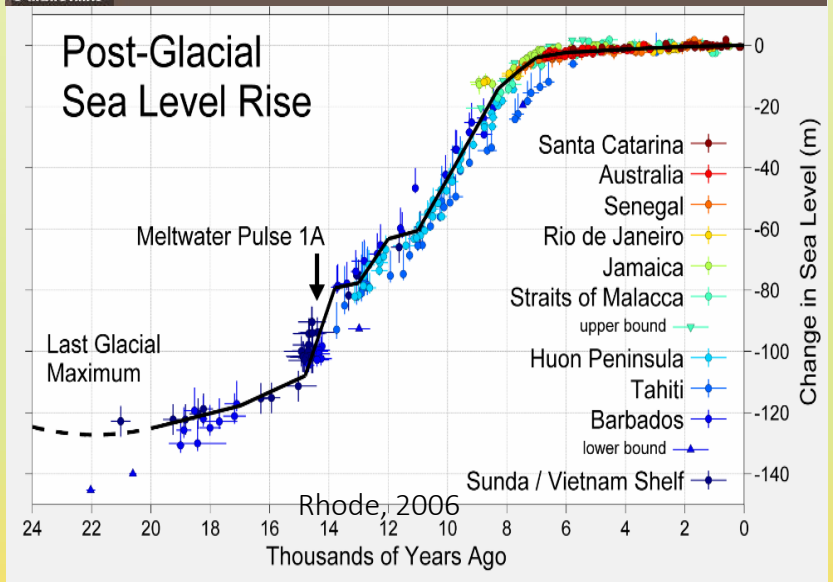


IPCC, 2019

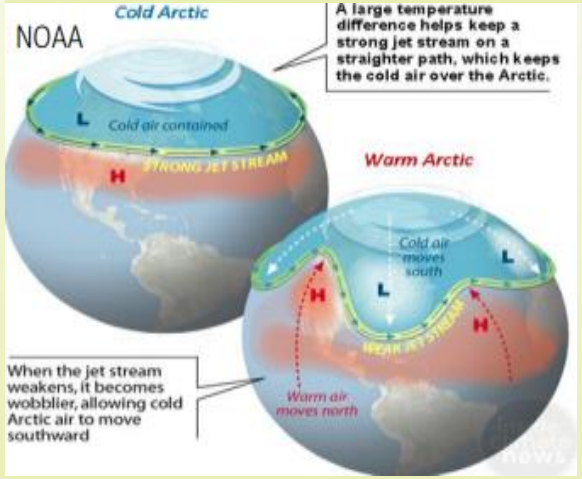


- Most of increased deep ocean heat is transferred by currents to southern ocean surrounding Antarctica
- Most of Western Antarctica is ice
- Melting due to increased air temperatures and warm currents are making West Antarctic glaciers increasingly unstable
- Breaking off of ice sheets could cause magnitude increase in rate of level rise as happened 14,600 years ago, raising sea level 18 meters in 500 years (one meter/28 years)

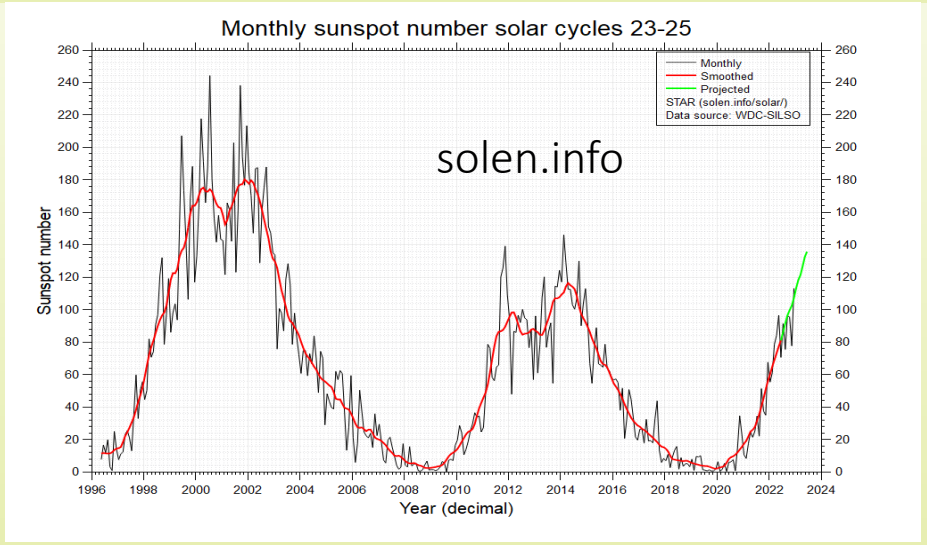


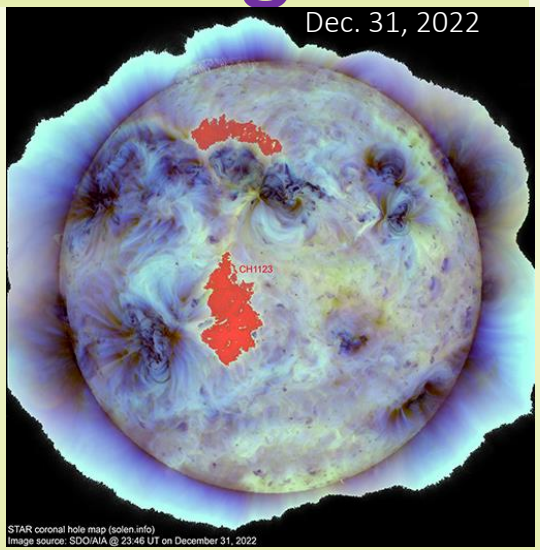


The temperature in 2023 will be heating up: factors moderating temperature rise since 2016 are ending

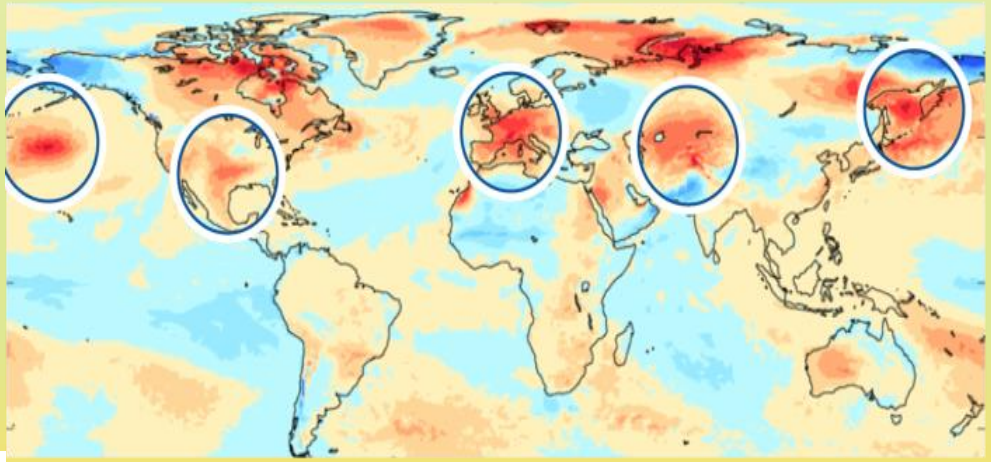


As the jet stream weakens, heat domes in northern hemisphere are becoming more common. During week of July 18, 2022 multiple occurrences.





Solar cycle 25 may be on track to resemble Cycle 23, rather than 24, and should have an impact on increasing temperature in 2023



Graphic: Ian Bott Source: Met Office
© FT

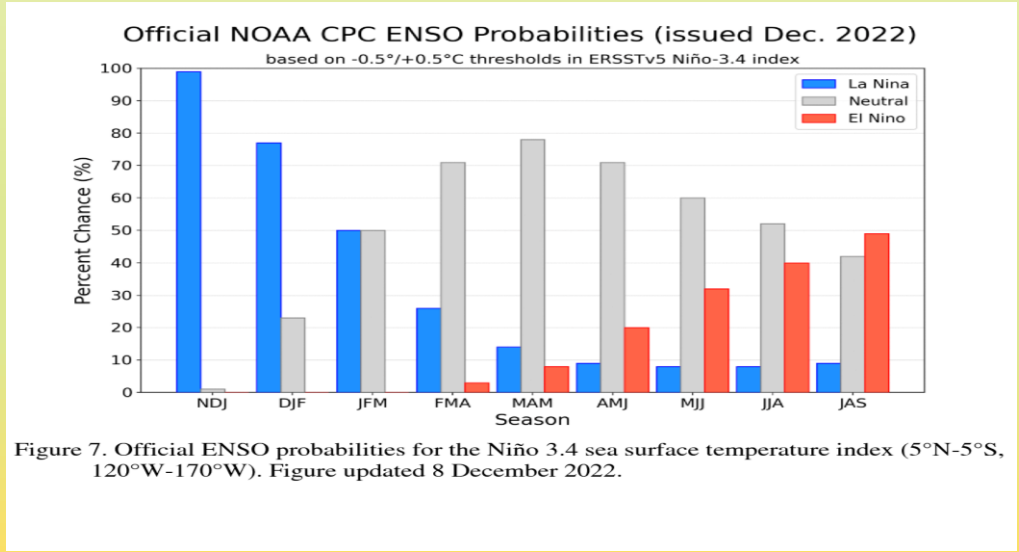
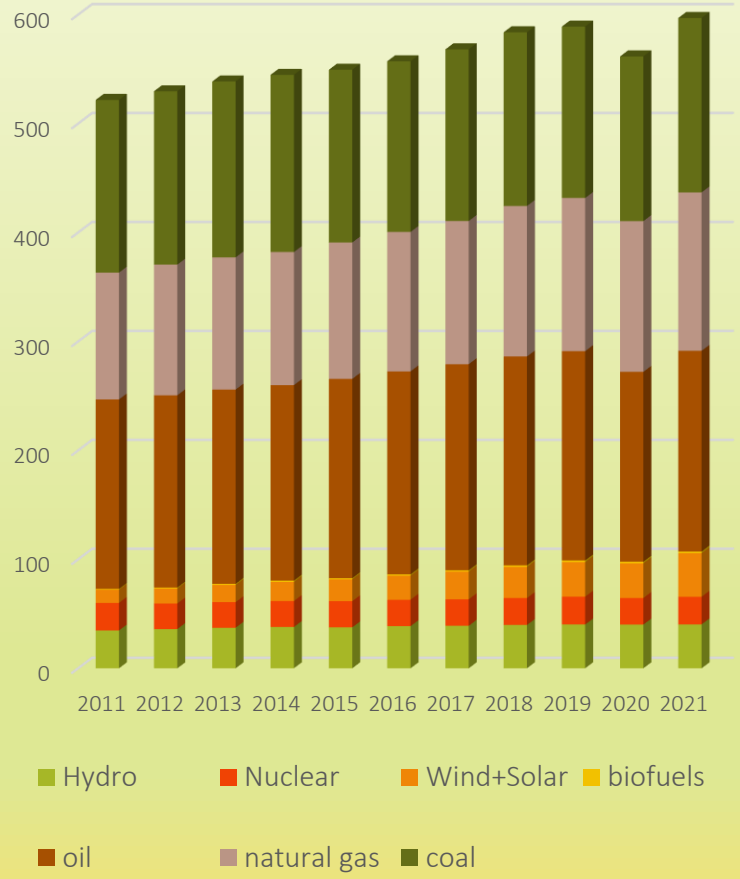


Figure 7. Official ENSO probabilities for the Niño 3.4 sea surface temperature index (5°N-5°S, 120°W-170°W). Figure updated 8 December 2022.

We have had three years of La Nina. NOAA model predicts ENSO shift to neutral and then El Nino (and higher temperatures) in 2023.

The results of the energy transition in the past decade were limited putting the ambitious targets for 2050 in doubt

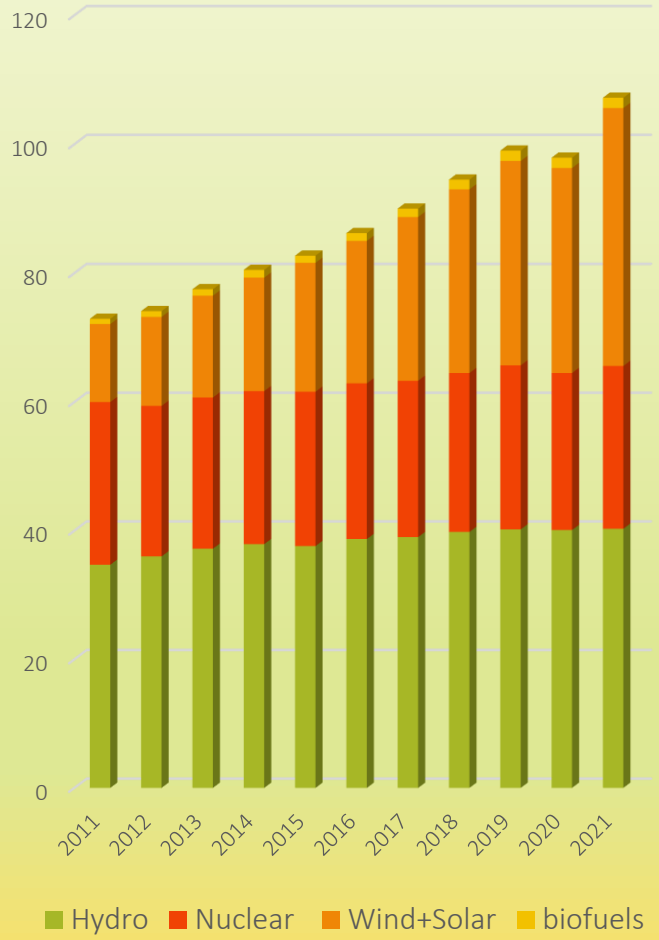
Total Energy consumption (exajoules)



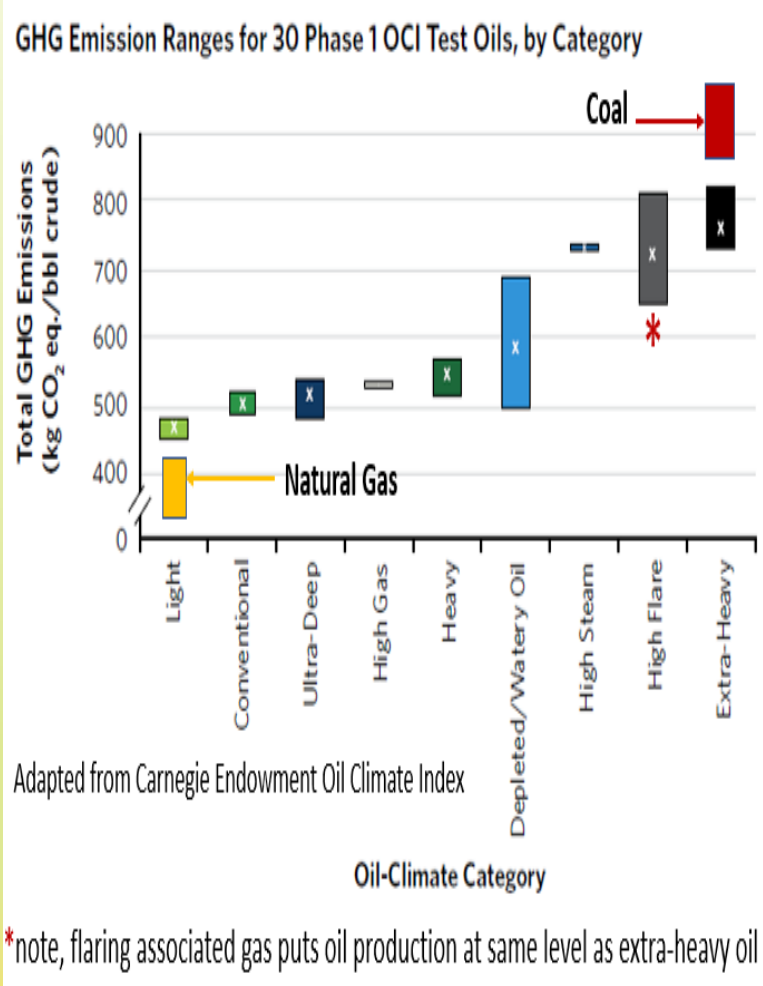
BP 2022 World Energy Review

- Despite intensive efforts, low carbon energy sources only increased from 12.3% to 15.3% in the past decade
- In 2021, 60% of low carbon energy came from hydropower and nuclear which had virtually no increase in the past few years and has little prospect for increasing in the coming decade
- Wind plus solar share increased, but only from 2.6% to 6% of total

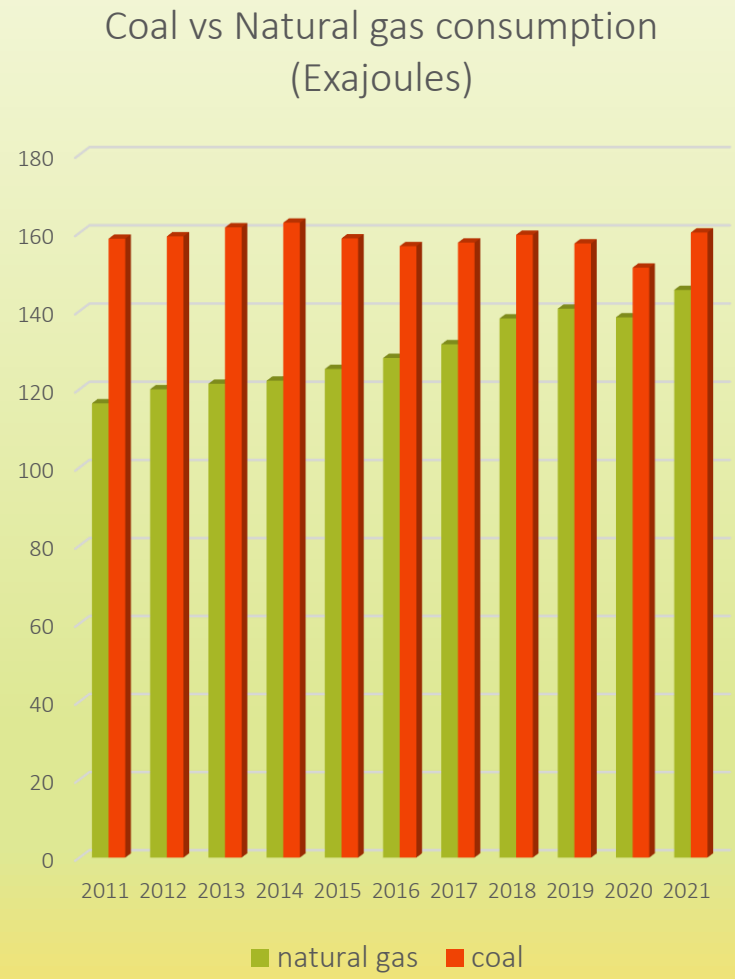
Low carbon energy production (Exajoules)



CO2 emissions increased, but only at half the rate of energy increase

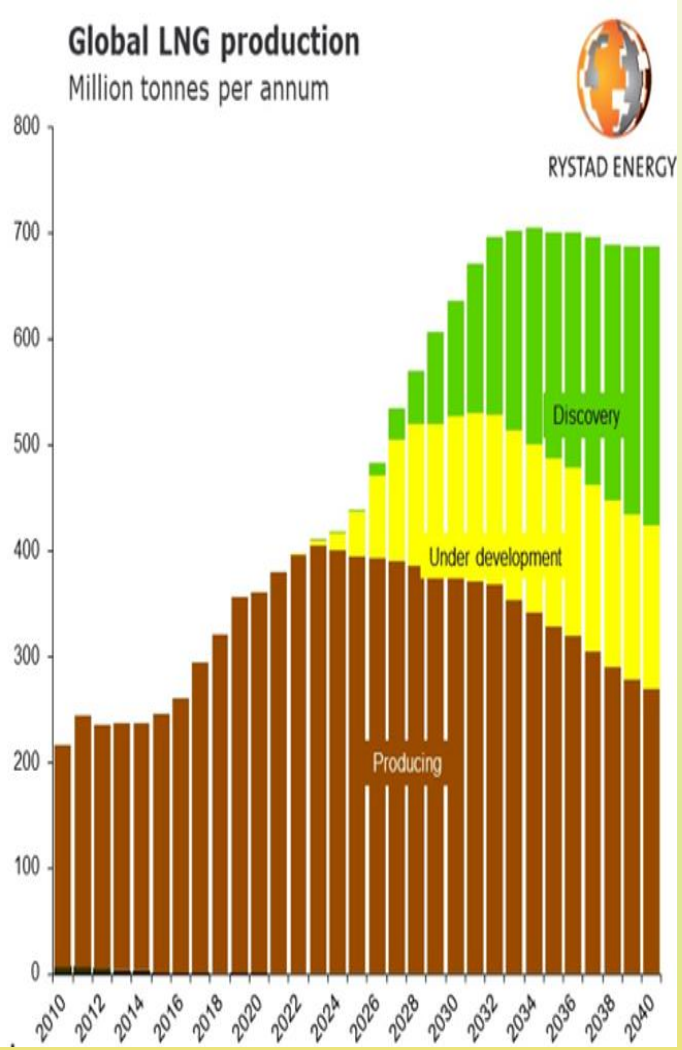


- World energy use continued to increase in past decade at 1.3%/year, with 70% of the increase supplied by fossil fuels
- However, during this period, CO2 emissions rose only 0.6%/year or about half of the rate of energy growth.
- Two major reasons for this were (1) increase of solar + wind power and (2) increase of 25% in natural gas consumption vs. no increase in coal consumption
- CO2 emission from gas is only approximately half the amount compared to coal per unit of energy produced

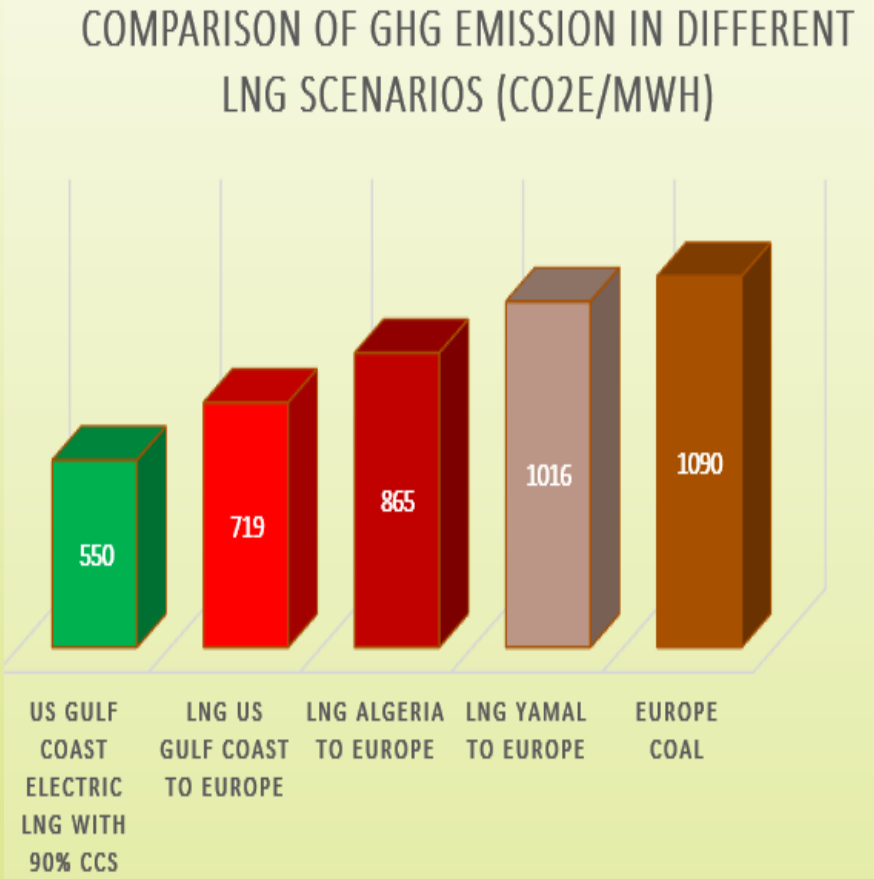


BP 2022 World Energy Review

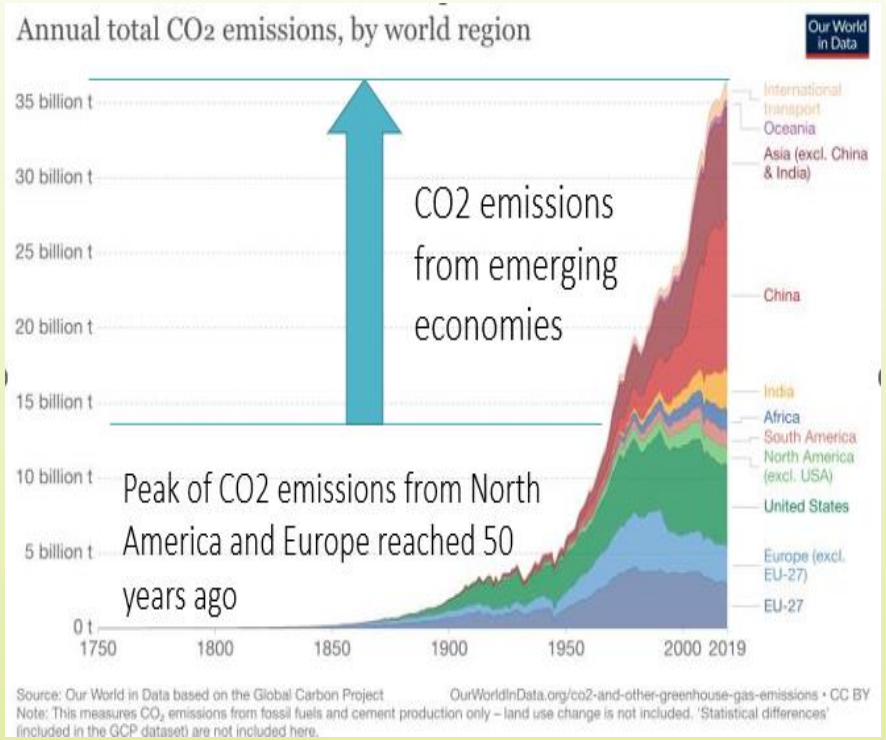
What will be the role of LNG in the coming decades? Does it decrease GHG emissions?

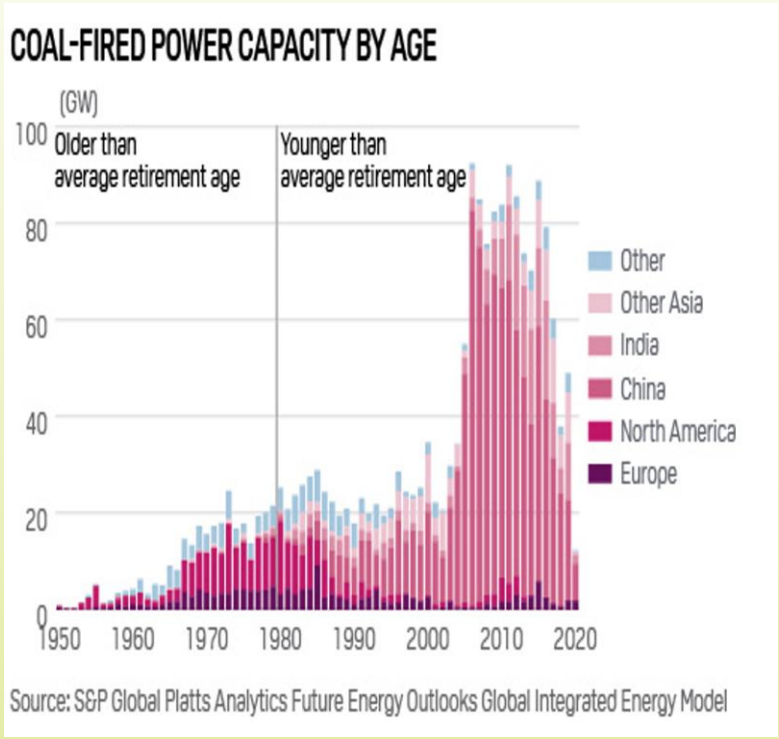


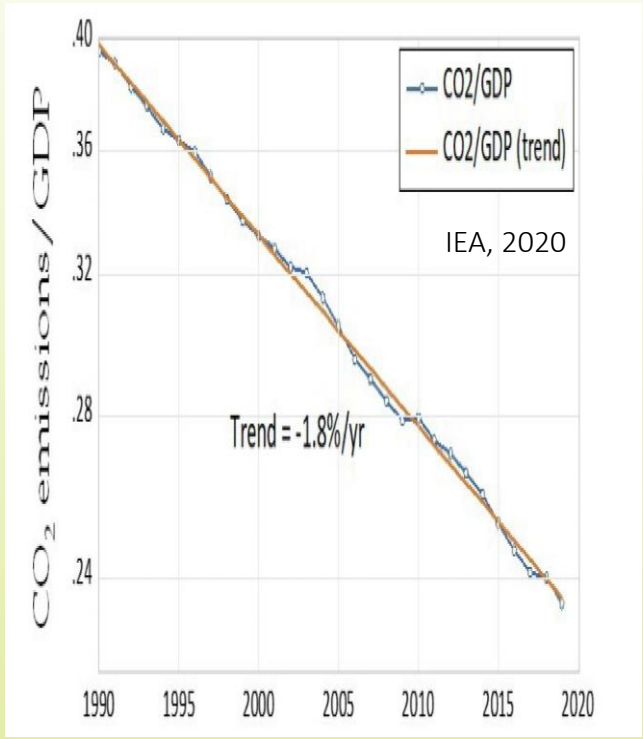
- Most of gas increase due to rise of liquified natural gas (LNG)
- LNG production doubled 2010-2020. It is projected to increase by another 75% by 2032.
- The USA and Qatar will provide >50% of the needed capacity increase
- **While gas produces less CO2 emissions, if enough methane is leaked in LNG process, there is no overall GHG benefit in LNG production compared to coal**
- **The 3% methane leak detected by satellite at Yamal LNG mostly negates GHG benefit of LNG at that facility**
- **US LNG has on average half that level of methane leakage**
- **Electric LNG with CCS is best solution**



The effort to reduce CO2 emissions faces serious difficulties in coming decades





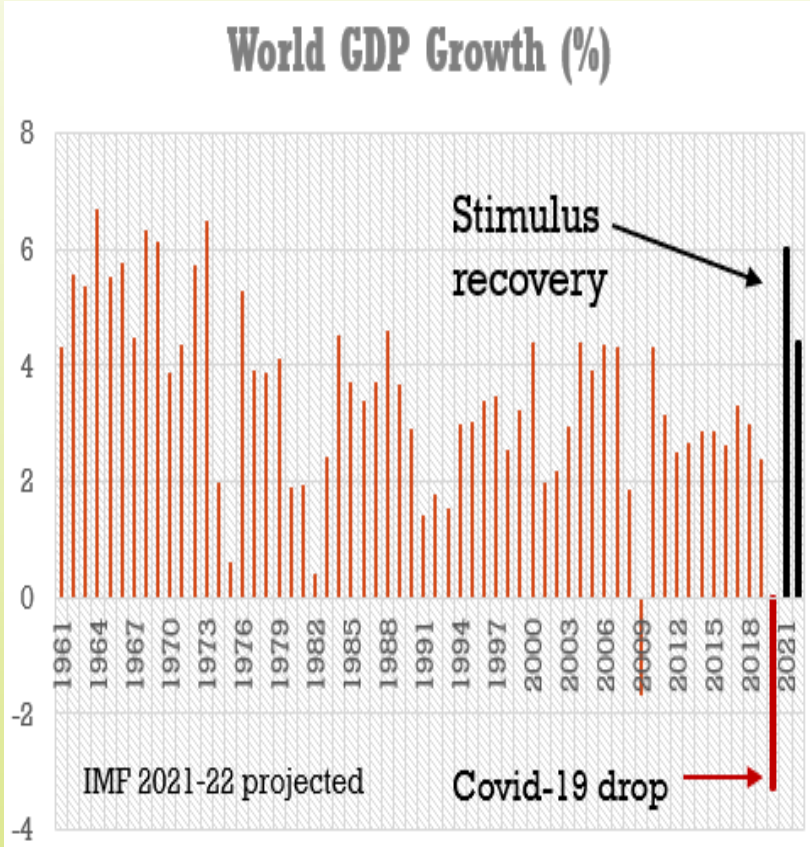


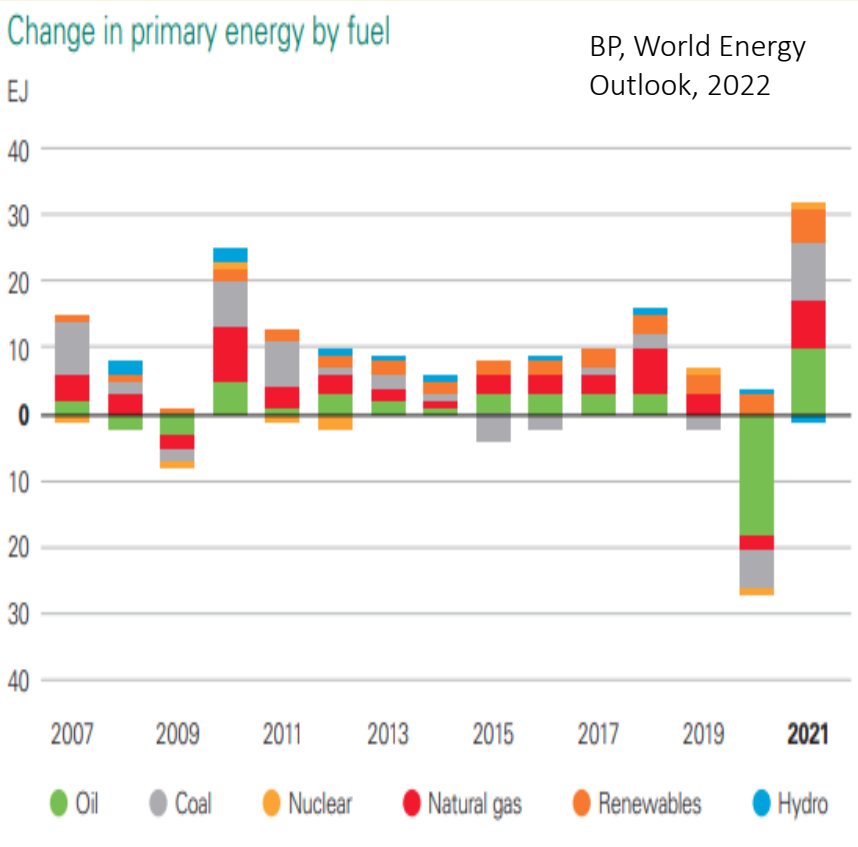
73% of current emissions come from emerging and developing nations, whose prime concern is improving living standards of their populations. They account for the entire growth of GHG emission of the past 50 years. If developed nations honor their pledges by 2030, they will be only 17% of emissions.

The developing nations depend on coal as a power source. Most of their coal plants were built since 2000 with a 40-year lifetime. This makes it unlikely that GHG emissions from coal will significantly decrease in the coming decades.

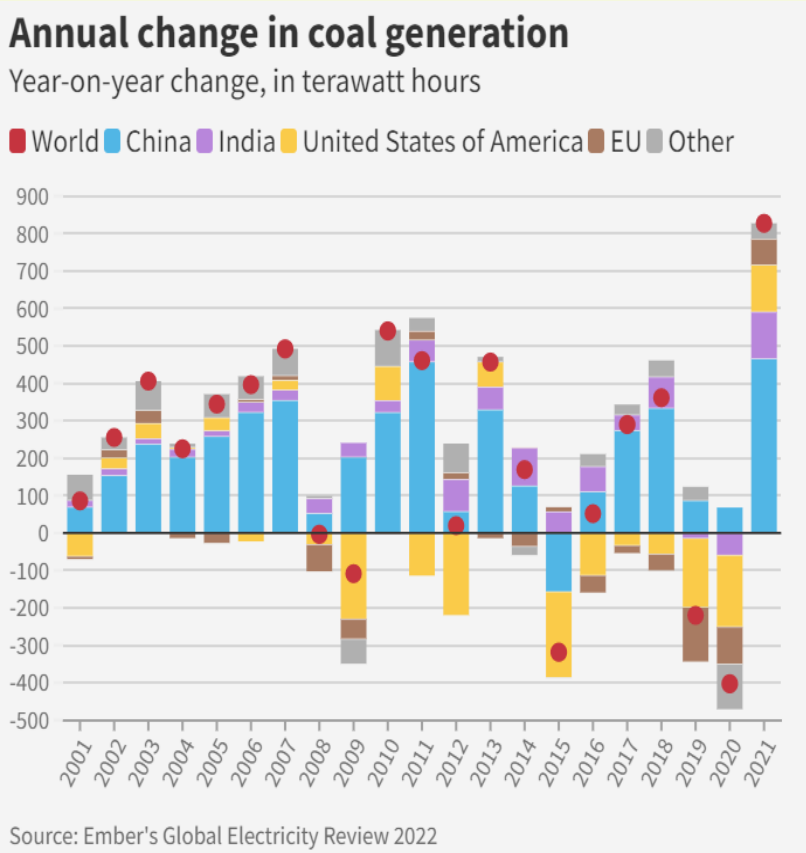
Despite the emergence of new technologies, growth of renewables and increased energy efficiency, the trend of ratio of CO2 emissions to GDP reduction has remained constant

Massive Economic stimulus is 2021 resulted in global economic recovery and record increase in energy demand





BP, World Energy Outlook, 2022

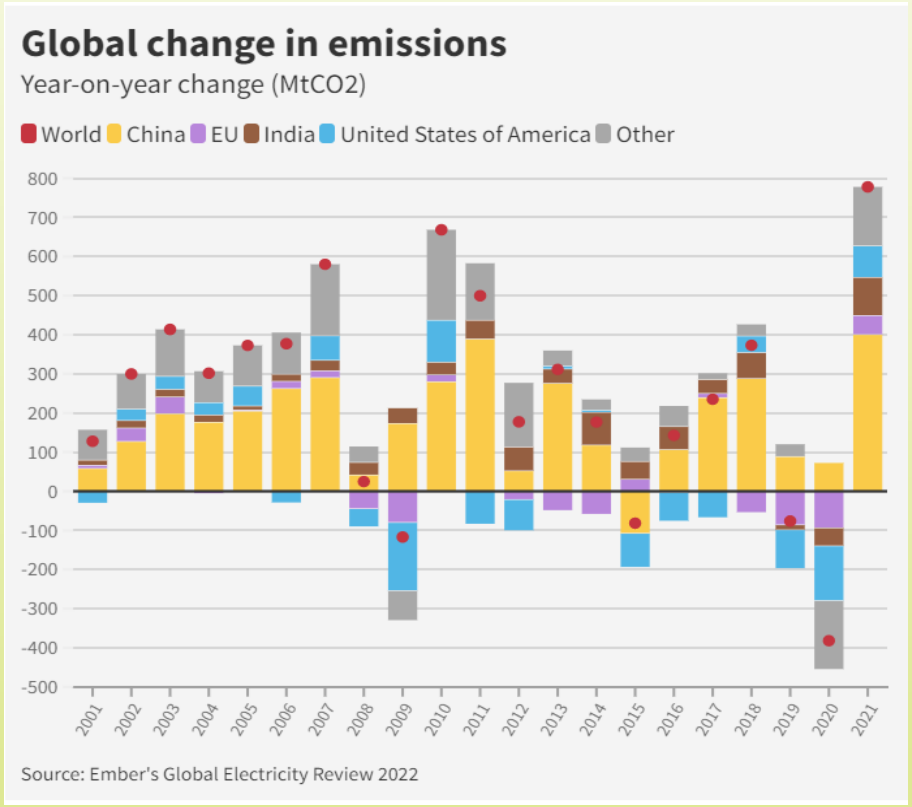


With massive stimulus, world economic growth of 2021 resulted in 6.1%, the highest percentage rise in 50 years

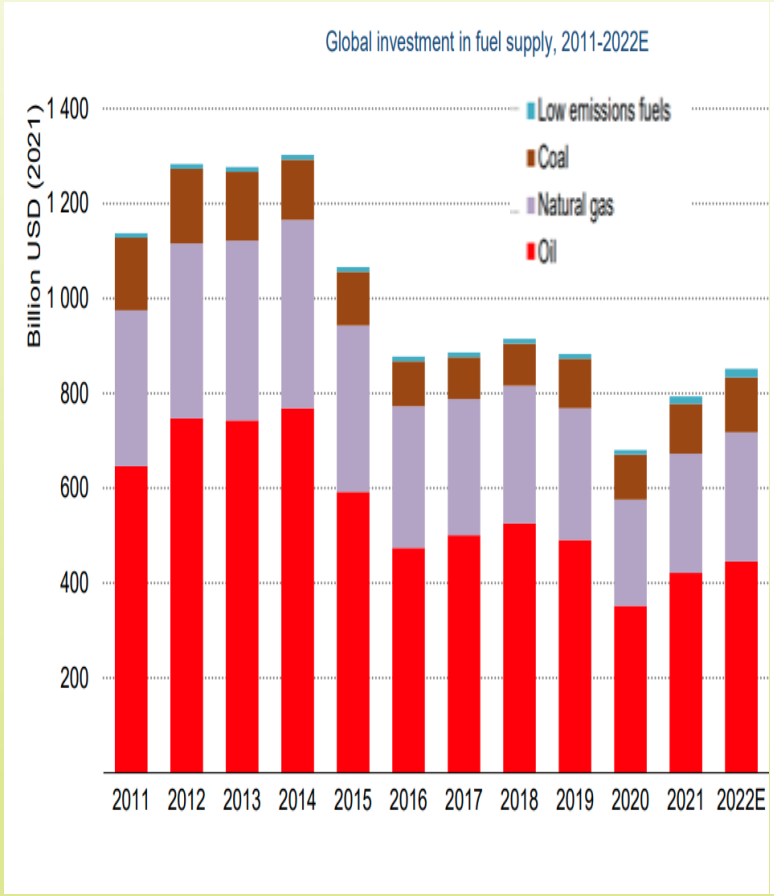
Not surprisingly, this growth resulted in greatest rise in energy use ever recorded, 80% from fossil fuels. Energy supplied by hydro power actually declined, due to drought.

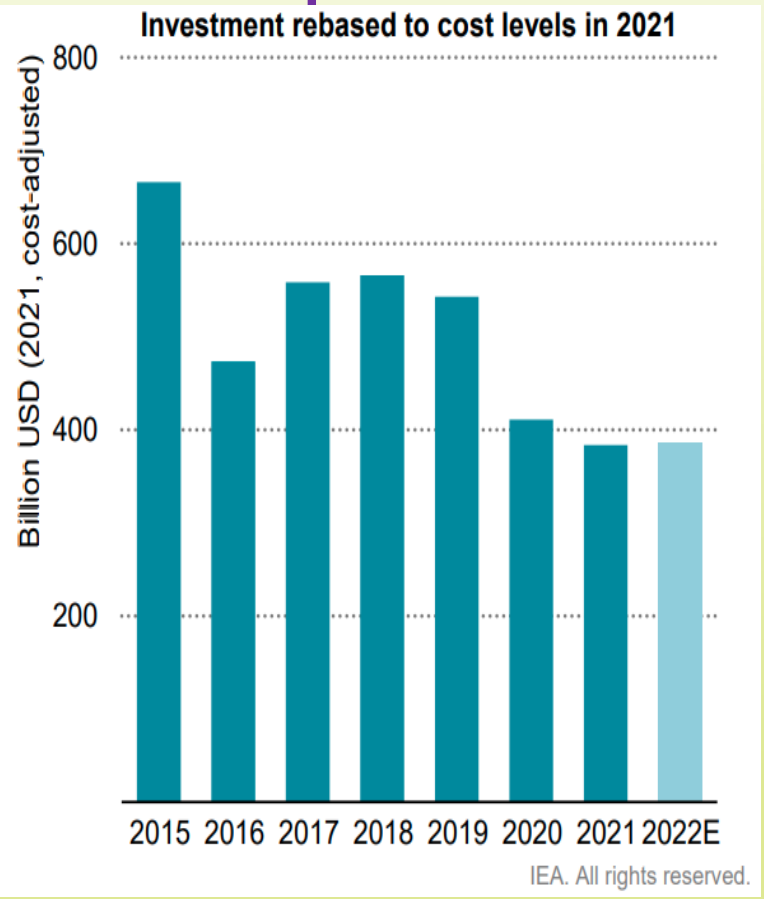
The annual increase in coal generation was the greatest ever recorded. 56% of the increase came from China.

This had two results: increase in CO2 emissions and increased fossil fuel prices

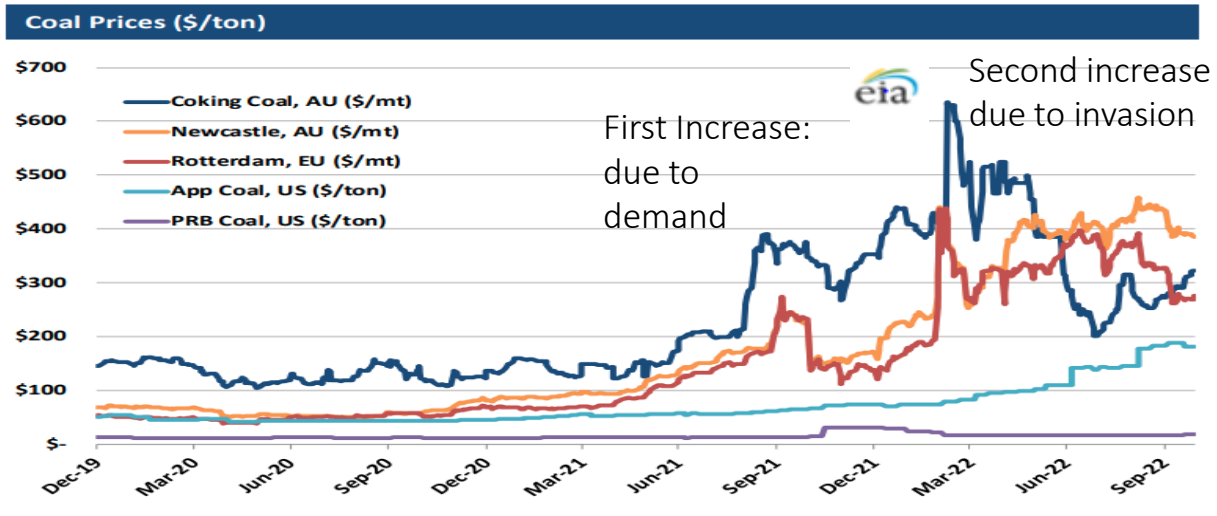


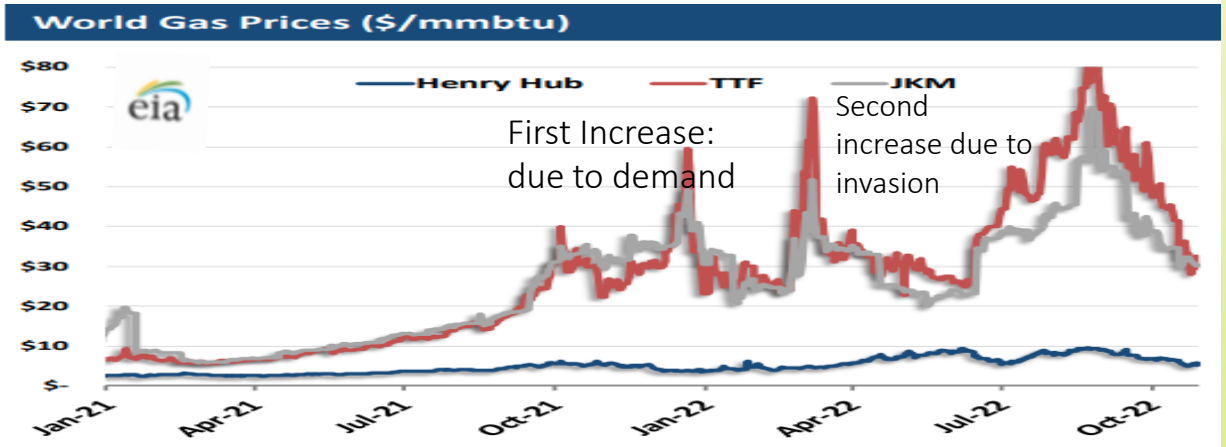
CO2 emissions from electricity generation increased by 800 Mt, double the decrease from 2020, making the 2030 CO2 reduction goals more difficult to meet

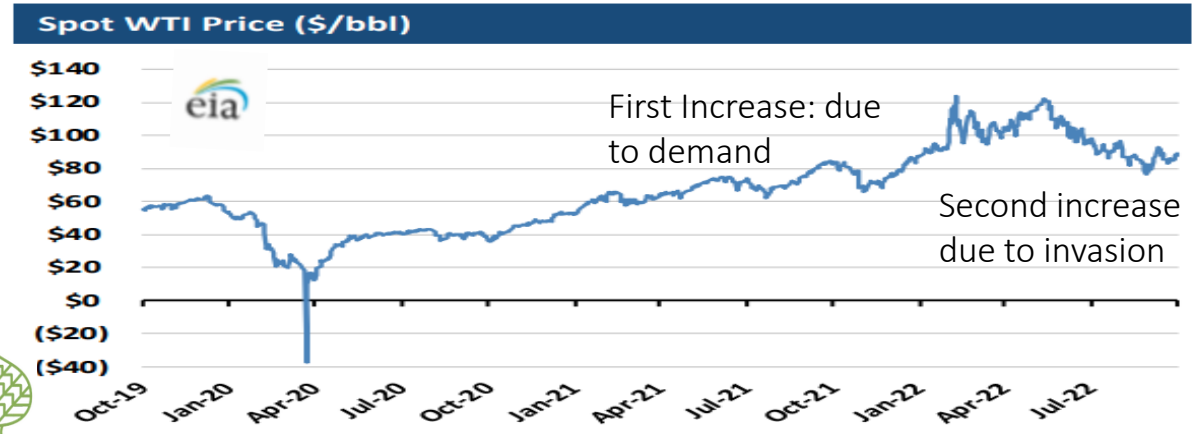




Since 2014, global investment in fossil fuels dropped to a low of 50% by 2020. It has increased in 2021/22 but only matching increased cost levels.



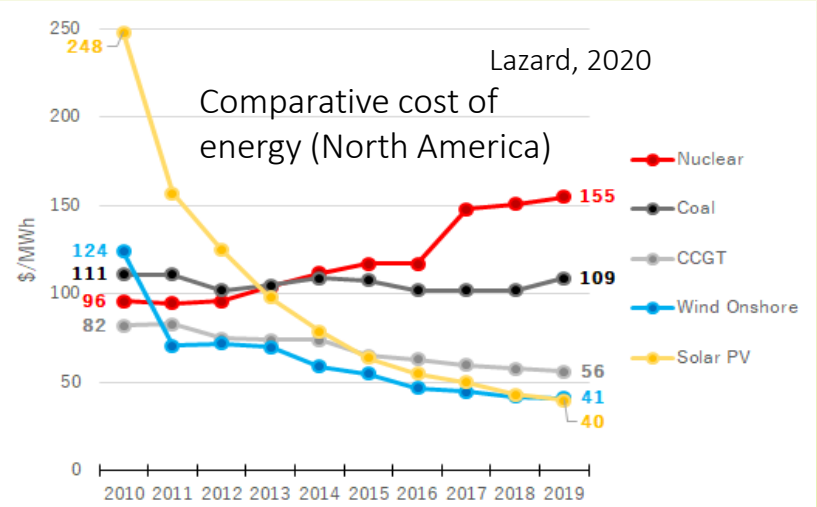


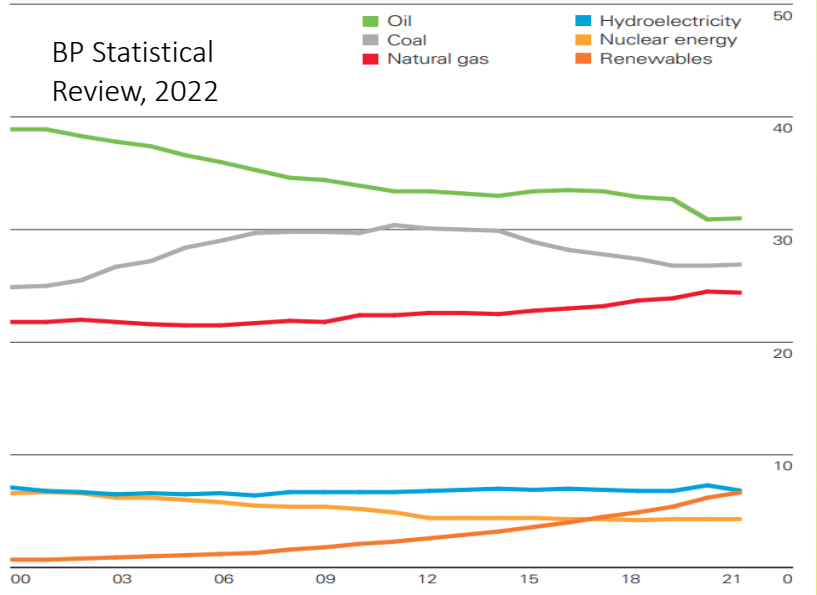


The world suffered two energy price increases due to fossil fuel shortage: in 2H 2021 due to increased demand and in February 2022 due to Russian invasion of Ukraine

- Coal prices: Prices in Europe and Asia tripled in late 2021 and then doubled again after February 2022. Appalachian (USA) coal prices tripled after Russian invasion, mostly due to export to Europe.
- Gas prices: Prices in Europe and Asia tripled due to shortages in late 2021. With increased volatility, they have hit historic highs twice after the Russian invasion and reduced of pipeline flows. US prices, although at lower level, doubled in late 2021 and have increased another 50% in 2022.
- Oil Prices: World prices gradually doubled from $40 to $80/bbl. in 2021 due to recovering demand. They increased 50% following Russian invasion but have gradually declined to $90/bbl. with Russian oil sold below $60/bbl. mostly substituted in Asian for European markets.

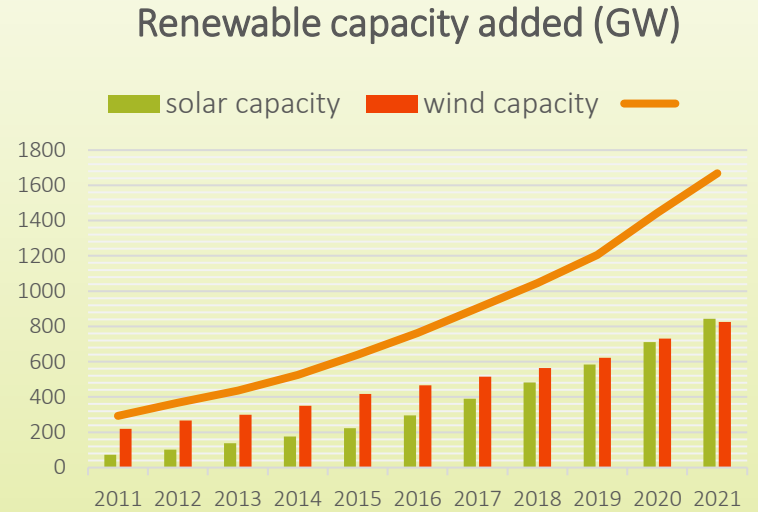
The challenge facing wind and solar



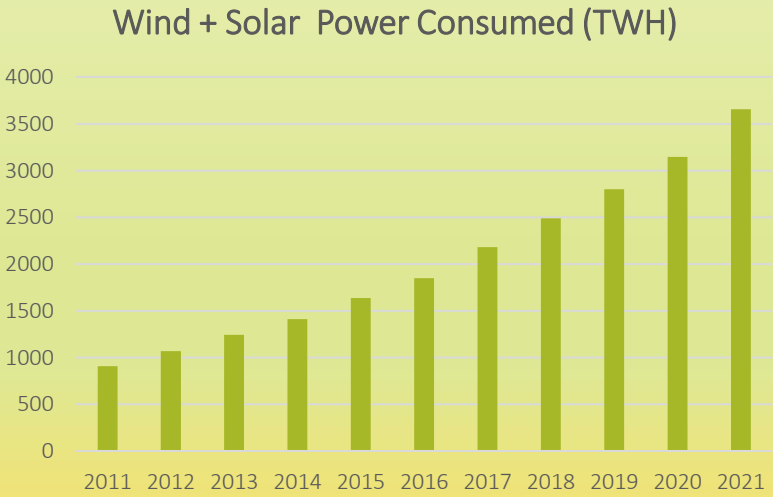


The past decade was very favorable for development of wind and solar power

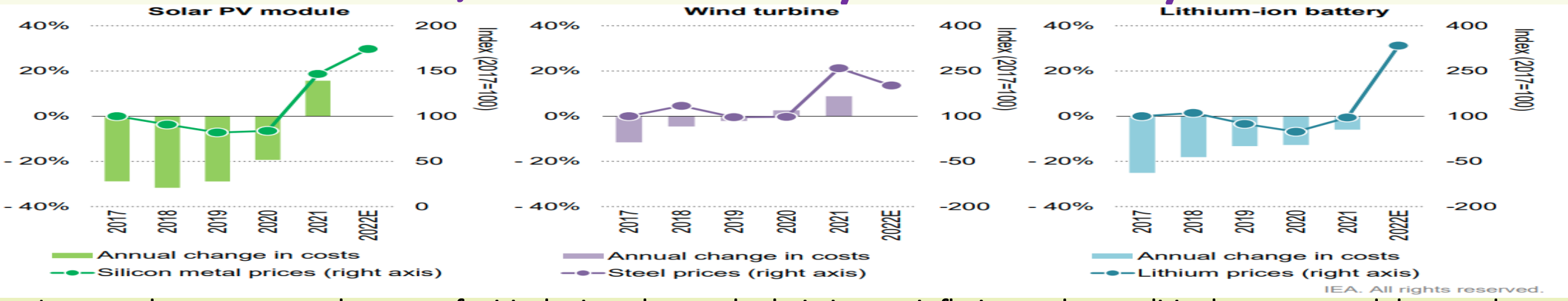
- Supported by low energy costs, improved technology and subsidies, wind and solar power became cost competitive with gas and preferable to coal and nuclear from 2010 to 2019.
- Installed capacity grew by 570% and consumption by 400% in a 10- year period.
- Wind and solar combined share of world primary energy consumption increased from 2.6% to 6%.



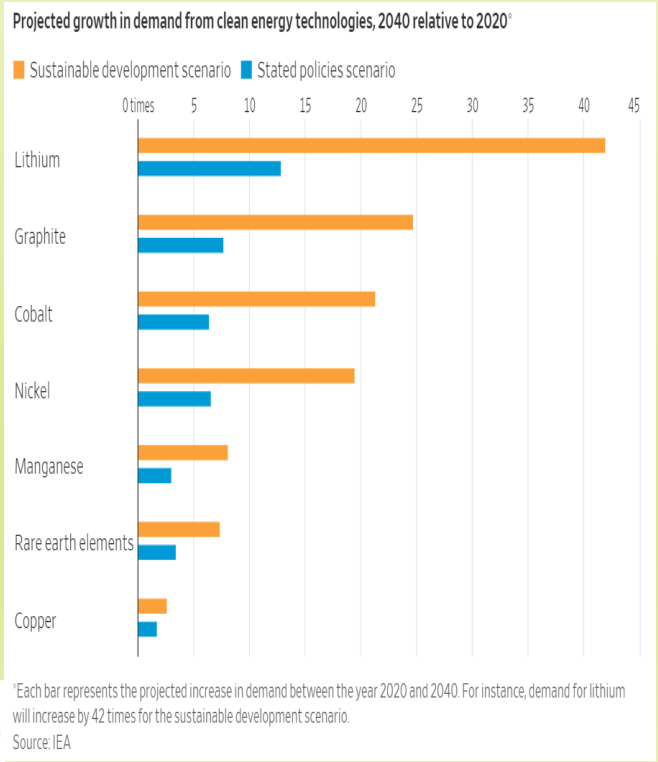
Adapted from BP Statistical Review, 2022



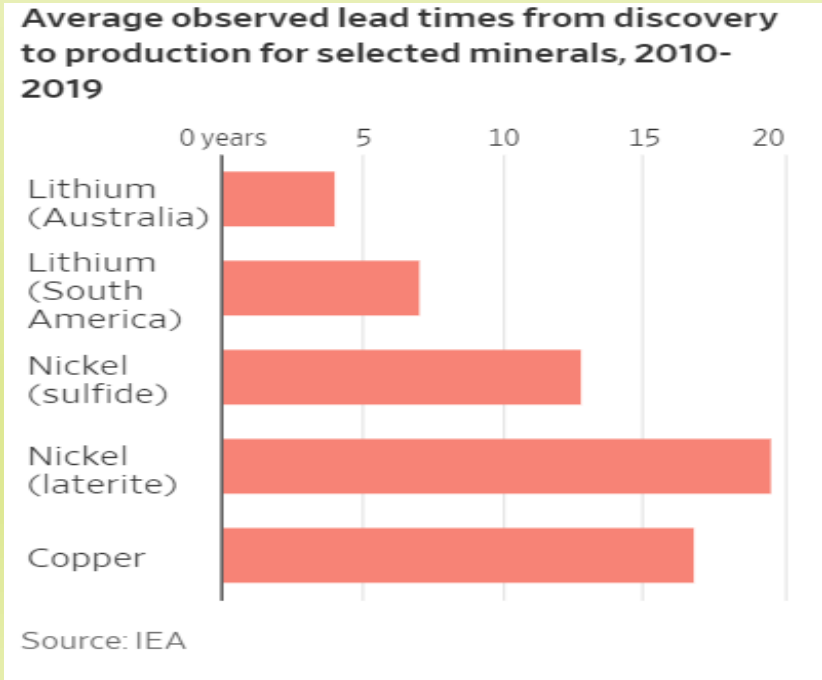
These conditions, unfortunately are unlikely to continue



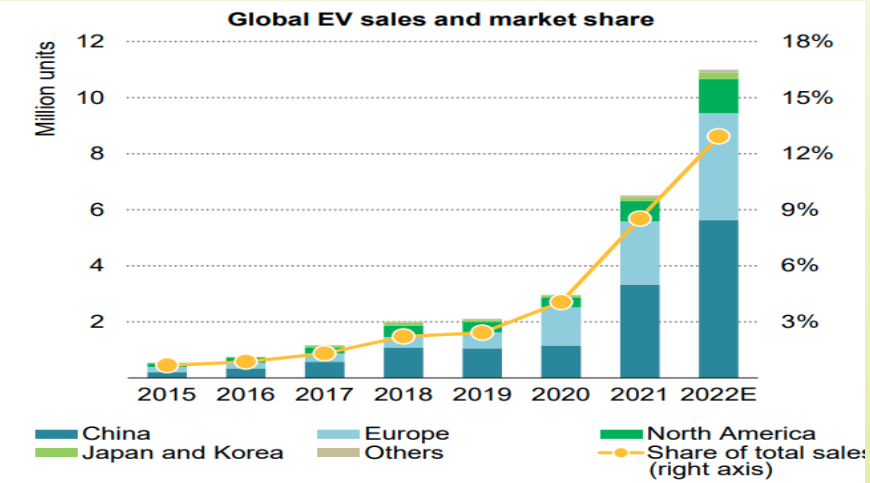
Increased energy costs, shortage of critical minerals, supply chain issues, inflation and geopolitics have reversed the trend

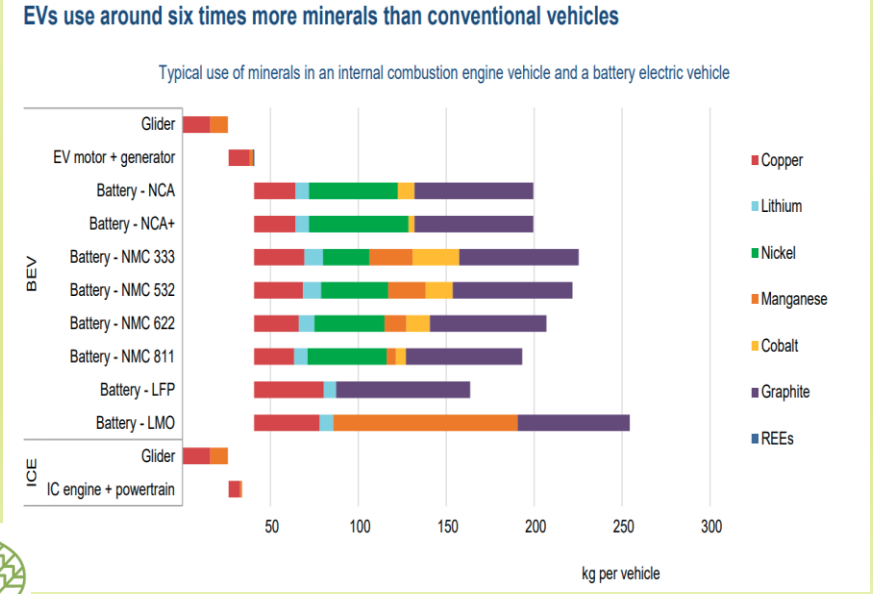


- Increase in critical mineral production needs to be in multiples, not percentages
- Lead time for new production projects is 5-15 years
- Russia has been major supplier for many of critical minerals, but geopolitics will prevent their rapid growth supply
- World contains the critical minerals, but supply growth will be gradual, not supporting exponential growth needed for net zero or even 50% drop in emissions by 2050



Transition to Electric Vehicles (EV's) illustrates complexity of energy transition

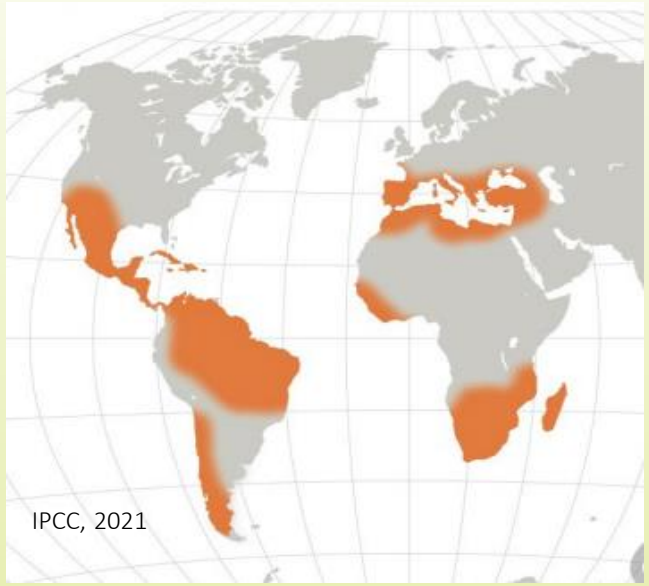




- 40 MMBO/D is used for road transport; shift to electric vehicles is key to reduction in oil GHG emissions
- EV's use six times more critical minerals than internal combustion (IC) engines
- EV sales show consistent 40% increase per year, reaching 13% of global sales in 2022, mostly in China and Europe
- Demand for critical minerals outpaced supply in 2021, with increased sales of EV's biggest single factor. This has resulted in significant price rise in critical minerals leading to increased purchase cost of EV's.
- 50% of EV's are sold in China. Two thirds of electrical power in China is generated by coal. EV's in China have a higher GHG footprint than new efficient internal combustion (IC) vehicles.
- Electricity cost increased significantly in Europe, EV second largest market. At current prices, EV's are as expensive to operate as IC vehicles
- With increased battery costs, EV's significantly more expensive than IC vehicles. Increased sales supported by government subsidies in developed economies and China. The rest of the world cannot afford these subsidies.

Current rate of EV sales growth, needed for rapid energy transition, is probably not sustainable

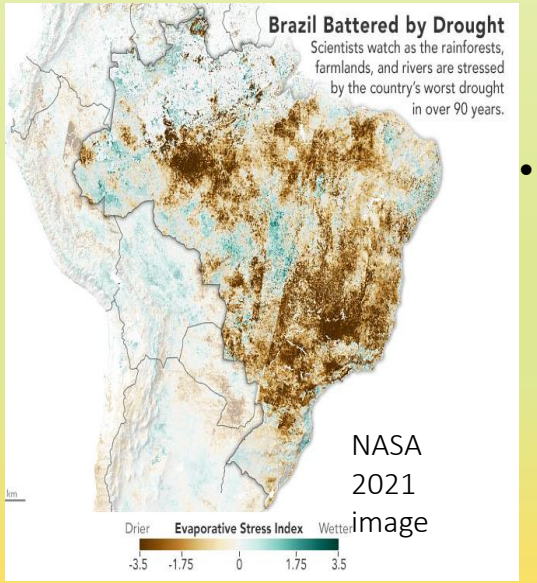
Climate change will affect reliability of hydropower



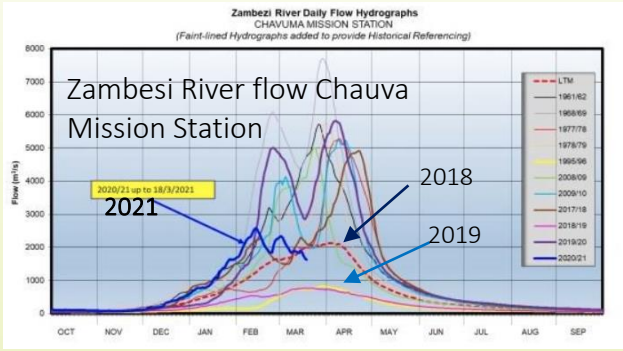
Areas of drought in 2050 with +2 deg. C temperature increase

- South America receives 52% of electric power from hydroelectric plants, highest proportion of all continents
- Italy and Turkey receive 21% of power from hydro electricity
- Western US and Southern Africa are already suffering from reduced hydro power due to lowered precipitation and drought

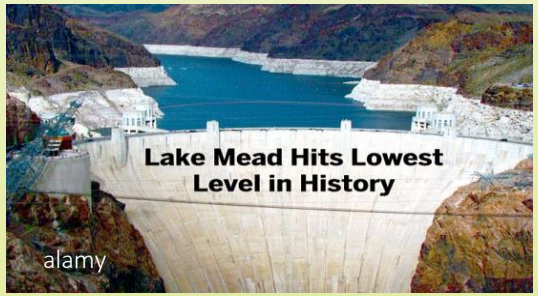
Hydropower currently accounts for 40% of renewable electricity power. However, climate change will put at risk many of the world's major hydroelectric projects:



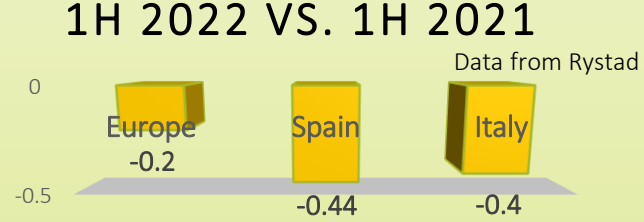
NASA 2021 image



Unprecedented drought reduced flow of Zambesi river and loss of power generation in Africa largest hydroelectric plant

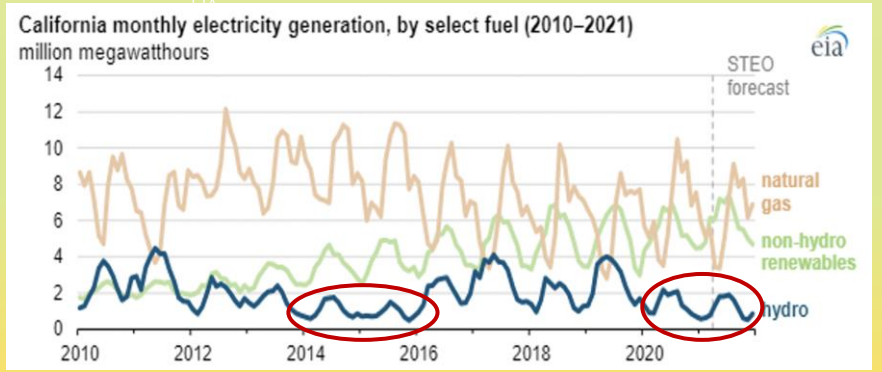


Drought and reduced snowpack puts largest US hydroelectric dam in question

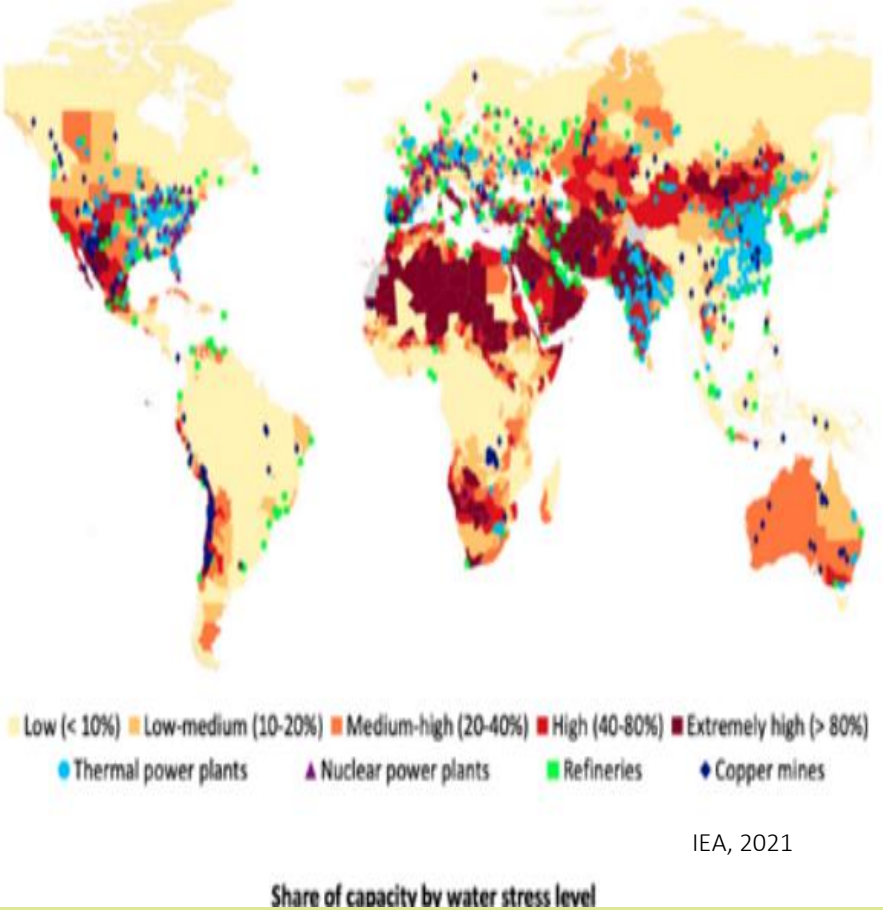


During energy crisis, Europe hydropower power drops 20% due to drought in 2022 with Mediterranean nations hit hardest

- Brazil suffering severest drought in century reducing hydropower
  - Drought reduces California peak hydroelectric power output by 50%



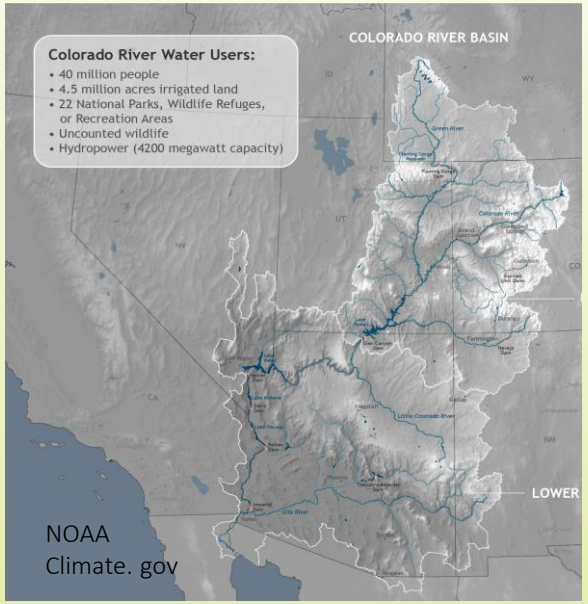
Lack of water due to climate change has major implications

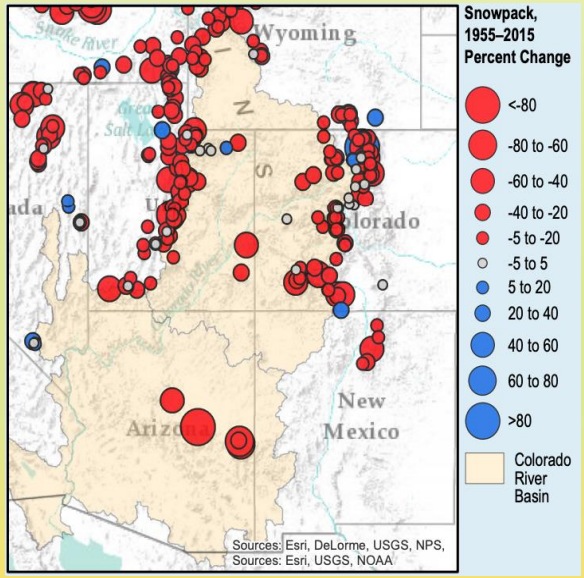


IEA, 2021

Lack of water will affect power generation in both fossil fuels industry and low carbon energy, as well as the production of critical minerals

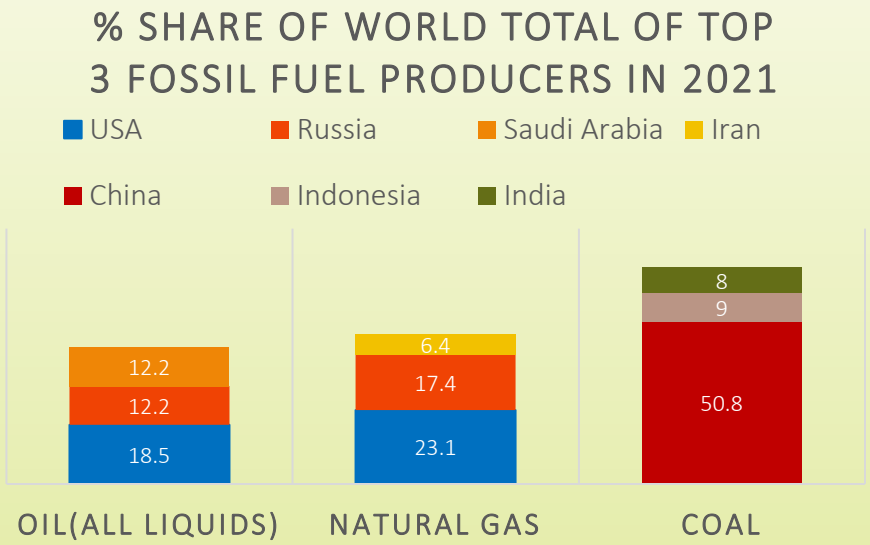
China accounts for 30% of worlds hydropower and depends on melting glaciers on Tibet Plateau that will be gone by the end of this century for much of water supply



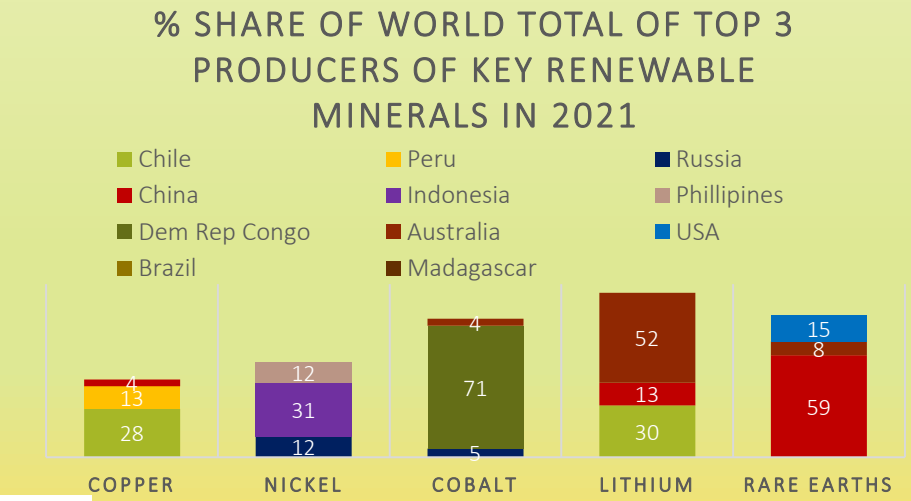


Colorado River (USA) supplies water to 40 MM people and 4.2 GW hydropower. Much of source of water (snowmelt) has disappeared in last 50 years leading to severe water shortages and reduced hydro power generation.

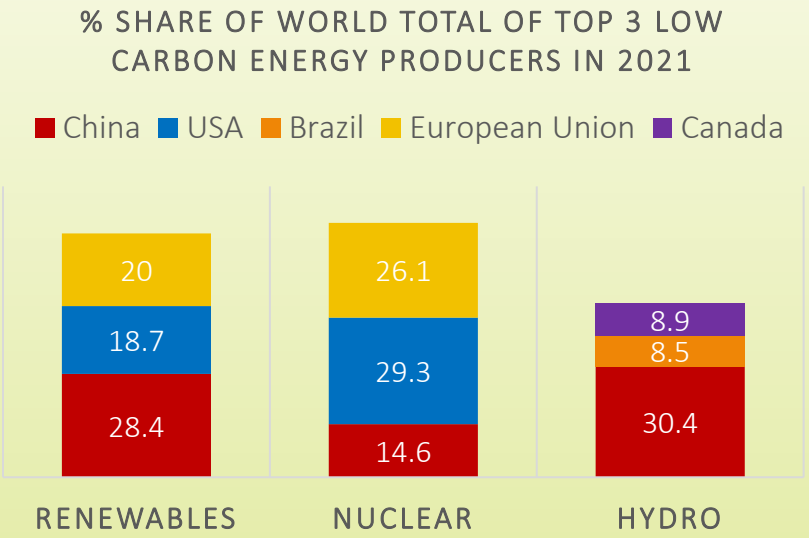
Transition from fossil fuels to renewable energy will shift control of resources and processing

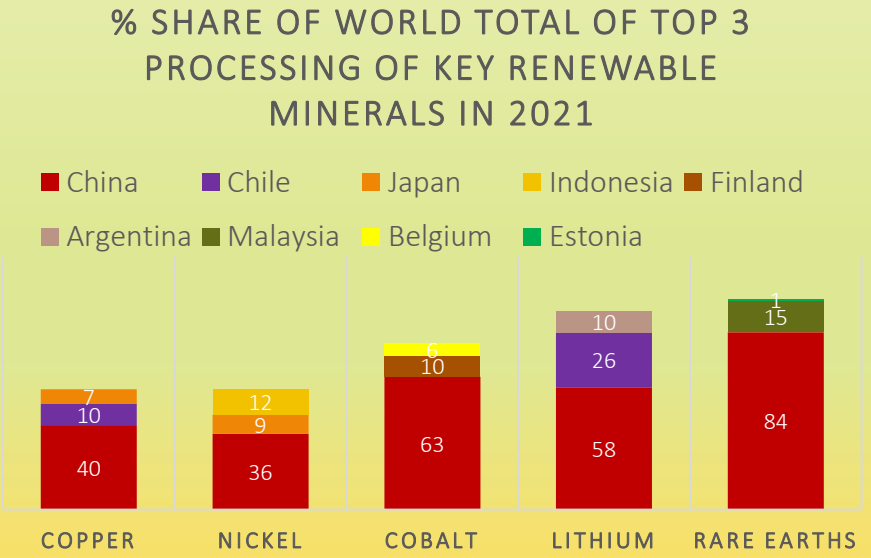


- USA is largest producer (and consumer) of oil and gas by a significant margin
- China is the largest producer of coal (and consumer) by a large margin
- China has largest share of hydro but it is at risk due to melting glaciers and drought
- USA, EU and China generate 2/3 of world's renewable and nuclear energy production



- Key renewable minerals have diverse production base, with dominant positions in certain minerals by Australia, China and DRC
- USA has minimal production of key renewable minerals
- **China has established dominant position in processing of key renewable minerals**





Data from BP World Statistical Review 2022

Why it will be difficult to reduce CO2 emissions below current levels in the coming decade

Lack of International Cooperation: The 2016 Paris Climate Agreement has voluntary targets and no penalty for non-compliance. It has had minimal impact on emissions level outside of developed nations.

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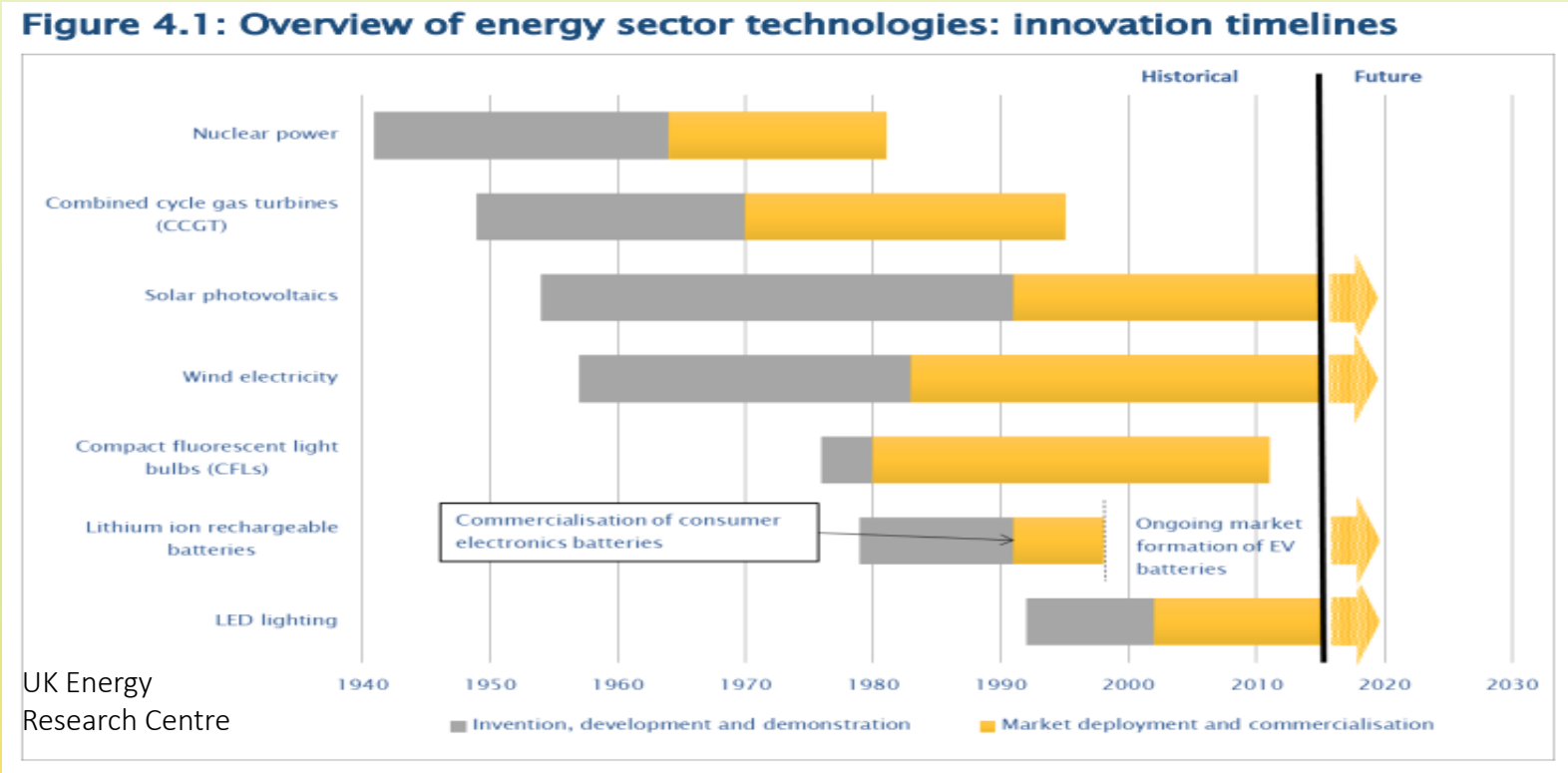
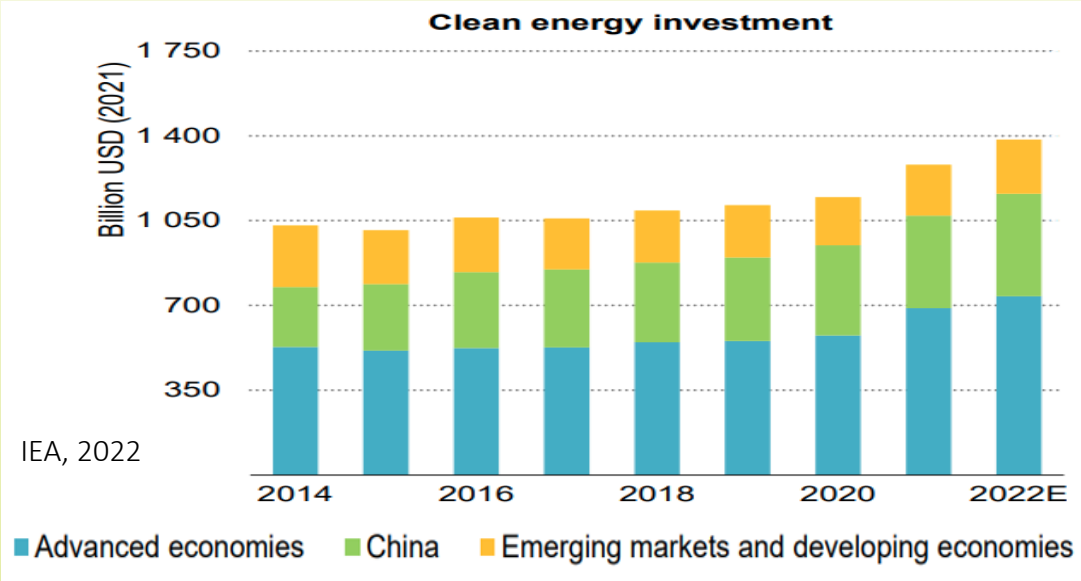
73% of current CO2 emissions are from developing nations who will be increasing emissions in the coming decade. Even if aggressive reduction targets are met for developed nations, it will not reduce overall level.



Pace of new technology development and commercialization:

- The technologies that have allowed developed nations to flatten emission levels have taken about 40 years from initial discovery to full commercial implementation.
- <u>Technologies needed to reduce overall emissions:</u> hydrogen, carbon capture and sequestration, nuclear fusion and direct air CO2 capture are known but not yet commercial on a large scale. It will take at 20-40 years for full commercial implementation.

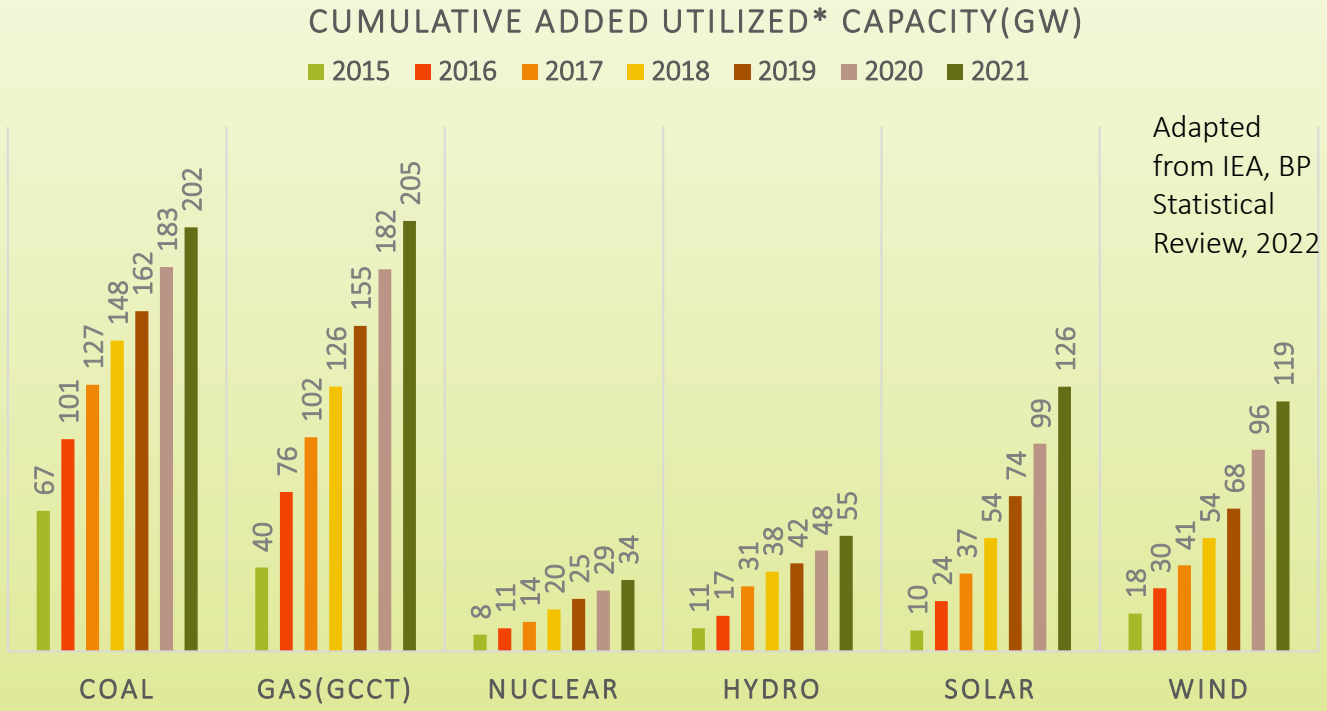
Recent investments and amounts are key to GHG emission levels in coming decade



IEA, 2022

Investment is not efficiently allocated

- 52% of investment is in developed economics with only 27% (and decreasing) portion of GHG emissions
- 28% of investment is in China, with 30% of emissions which is correct proportion
- Rest of emerging and developing world, with 47% of emissions receives only 20% of investment
- Most of 2021/2 investment increase is due to higher cost of energy, minerals and inflation

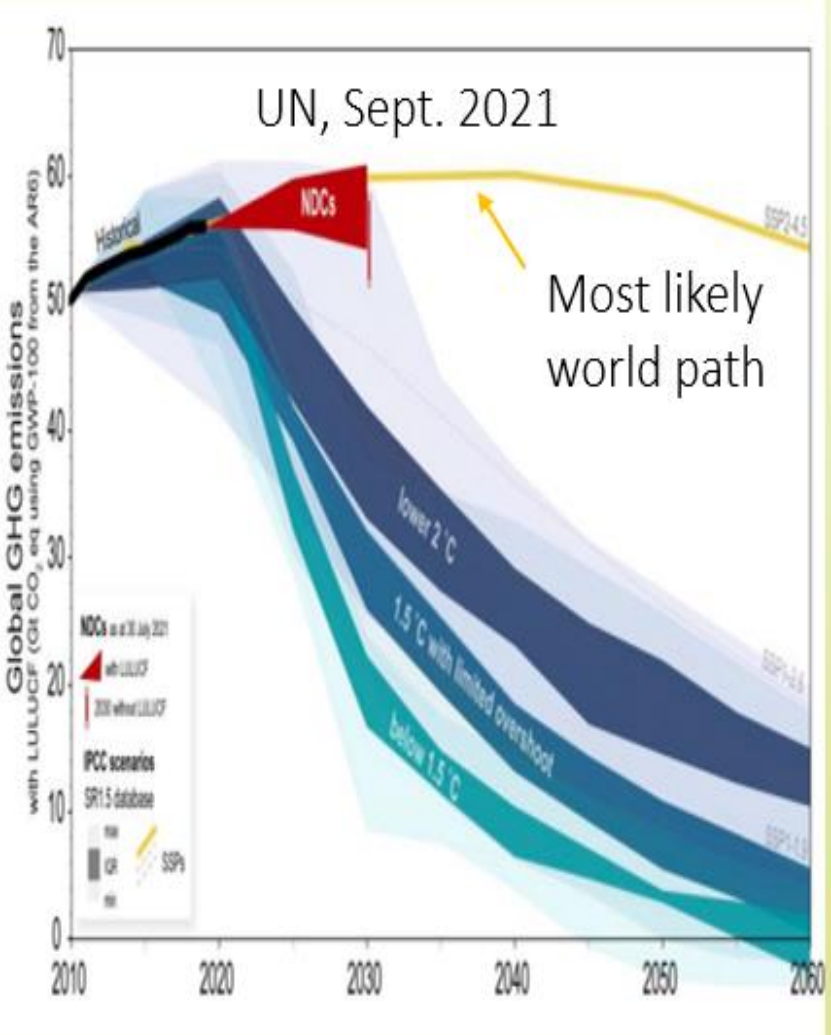


Adapted from IEA, BP Statistical Review, 2022

Taking into account actual utilization, 55% of installed new power capacity in 2015-2021 period was fossil fuel generated. ***However, share of low carbon added doubled from 31% in 2015 to 62% in 2021***

*nuclear 90%, coal 70%, GCCT 50%, Hydro 40%, Wind 25%, Solar 20%

The Reality of Climate Change and the Complexity of the Energy Transition: Hard Truths



Global CO2 emissions

- The world will reach 2.0 degree C above pre-industrial temperature by 2050. We need to prepare for the consequences.
- Under current world policies, we are heading for a temperature increase close to 3 degrees C by the end of the century. This greatly increases of the changes of catastrophic tipping points occurring in the second half of the 21st century.
- The GHG emissions of the developed nations are becoming only a small portion of the world total and any significant reduction will need to come through efforts in cooperation with developing and emerging nations
- Renewable power, while lower GHG emitting, has reliability limitations with high share of capacity and will not continue cost reduction. Renewables will likely continue recent growth rate rather than accelerated increase needed for near-term CO2 emission reduction.
- Rising energy prices due to underinvestment in fossil fuels and geopolitical concerns (Russian invasion of Ukraine) have increased focus on energy security and cost of developing low carbon energy complicating dealings with climate crisis