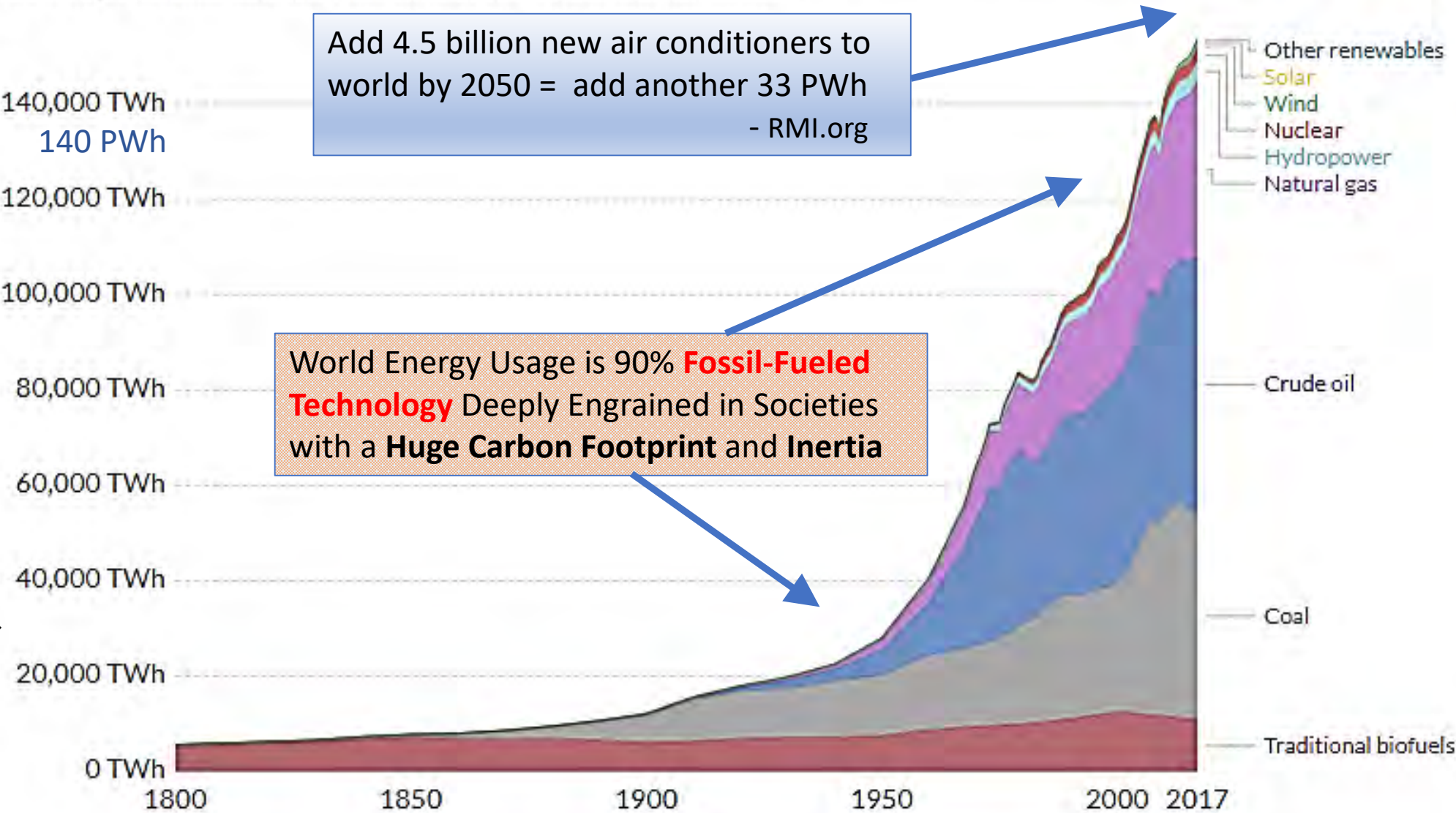


QUANTITATIVE CARBON DIOXIDE, TEMPERATURE, AND SEA LEVEL RELATION FOR THE FUTURE

Thomas Valone
Integrity Research Institute
Beltsville MD USA

Global primary energy consumption annually

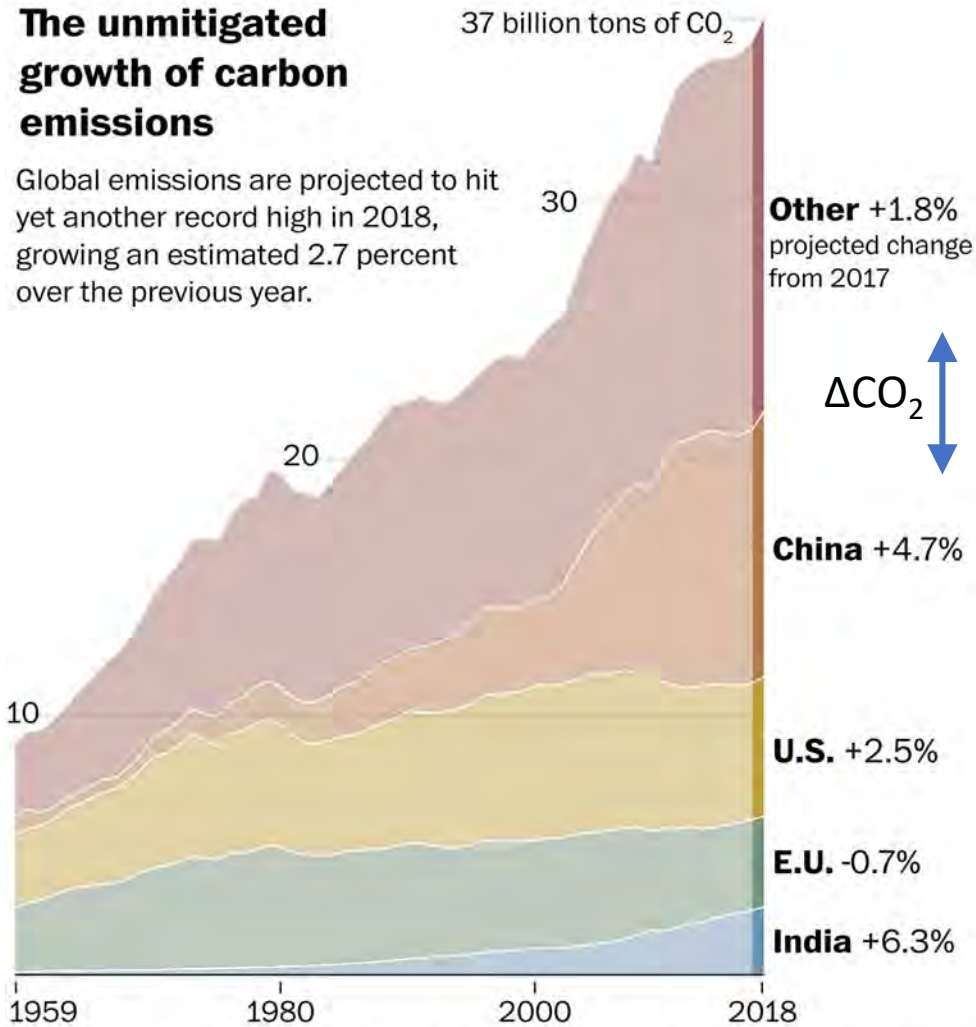
Global primary energy consumption, measured in terawatt-hours (TWh) per year. Here 'other renewables' are renewable technologies not including solar, wind, hydropower and traditional biofuels.



IEEE ISTAS 2019 CARBON EMISSIONS PER ANNUM

The unmitigated growth of carbon emissions

Global emissions are projected to hit yet another record high in 2018, growing an estimated 2.7 percent over the previous year.

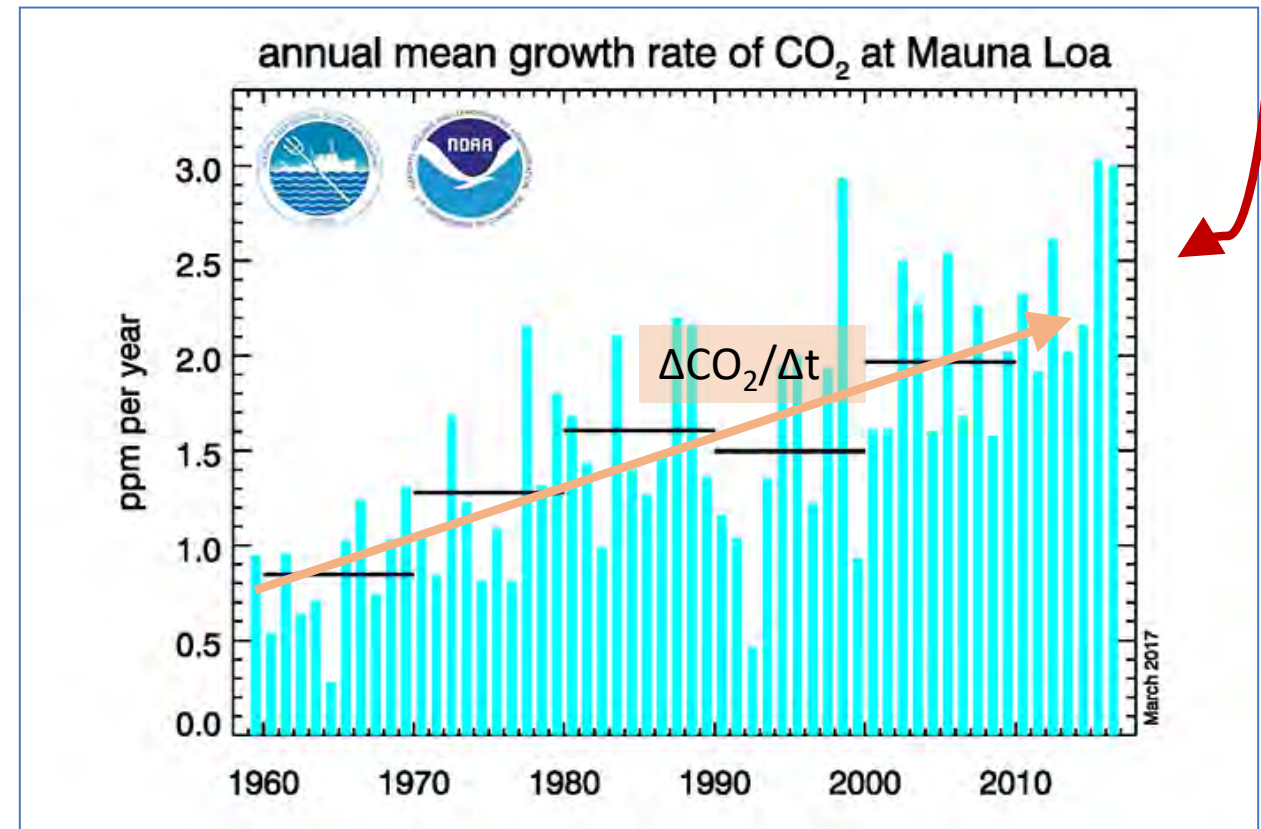


Figures show emissions from fossil fuels and industry, which includes cement manufacturing but not deforestation.

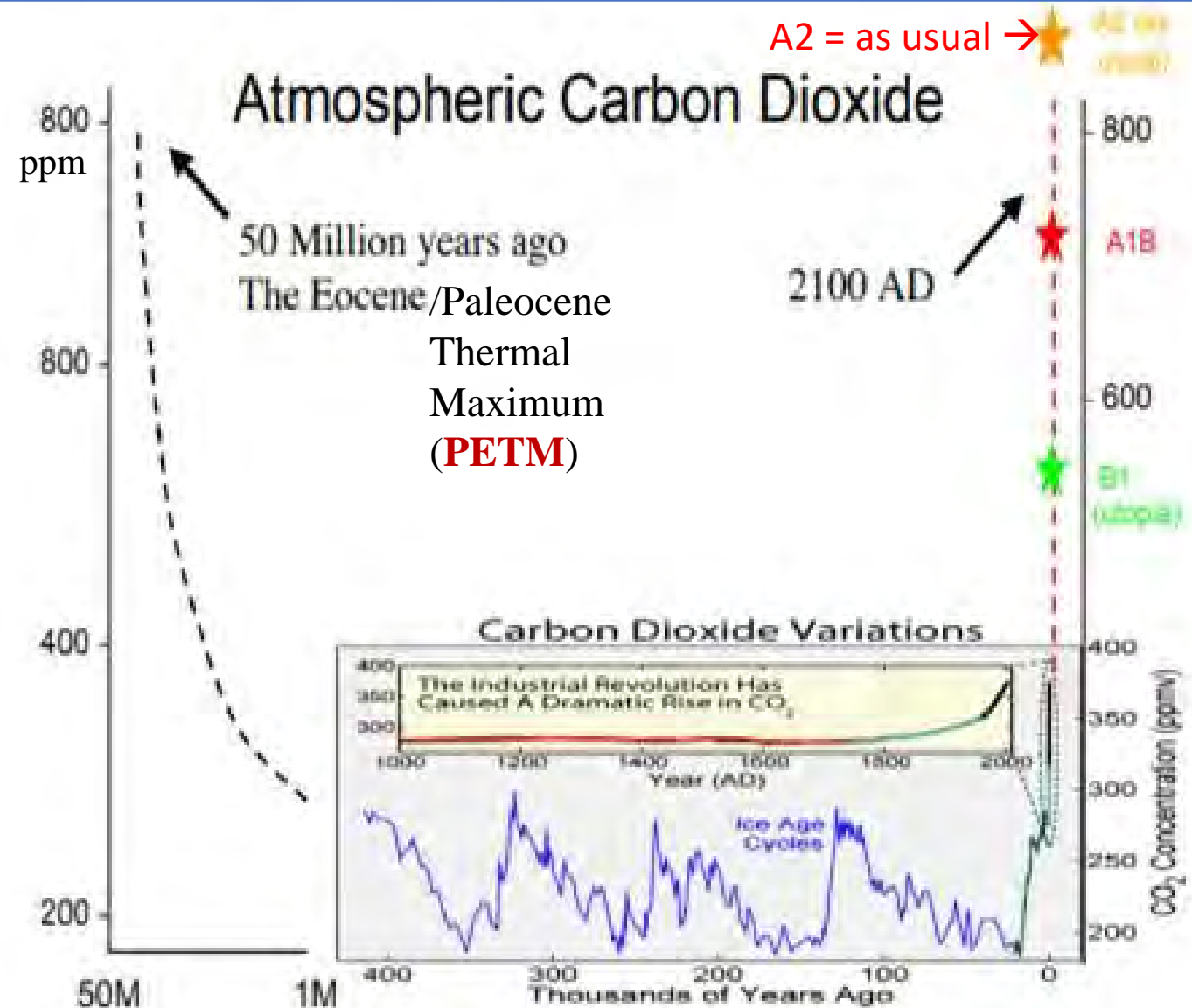
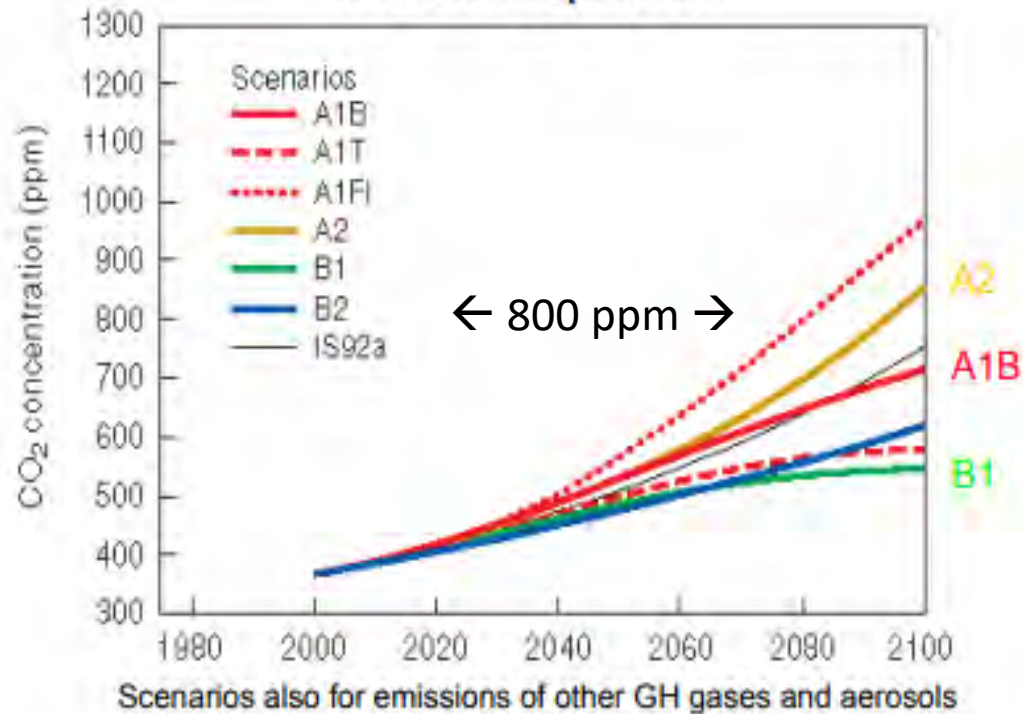
Source: Global Carbon Project

JOHN MUYSKENS/THE WASHINGTON POST

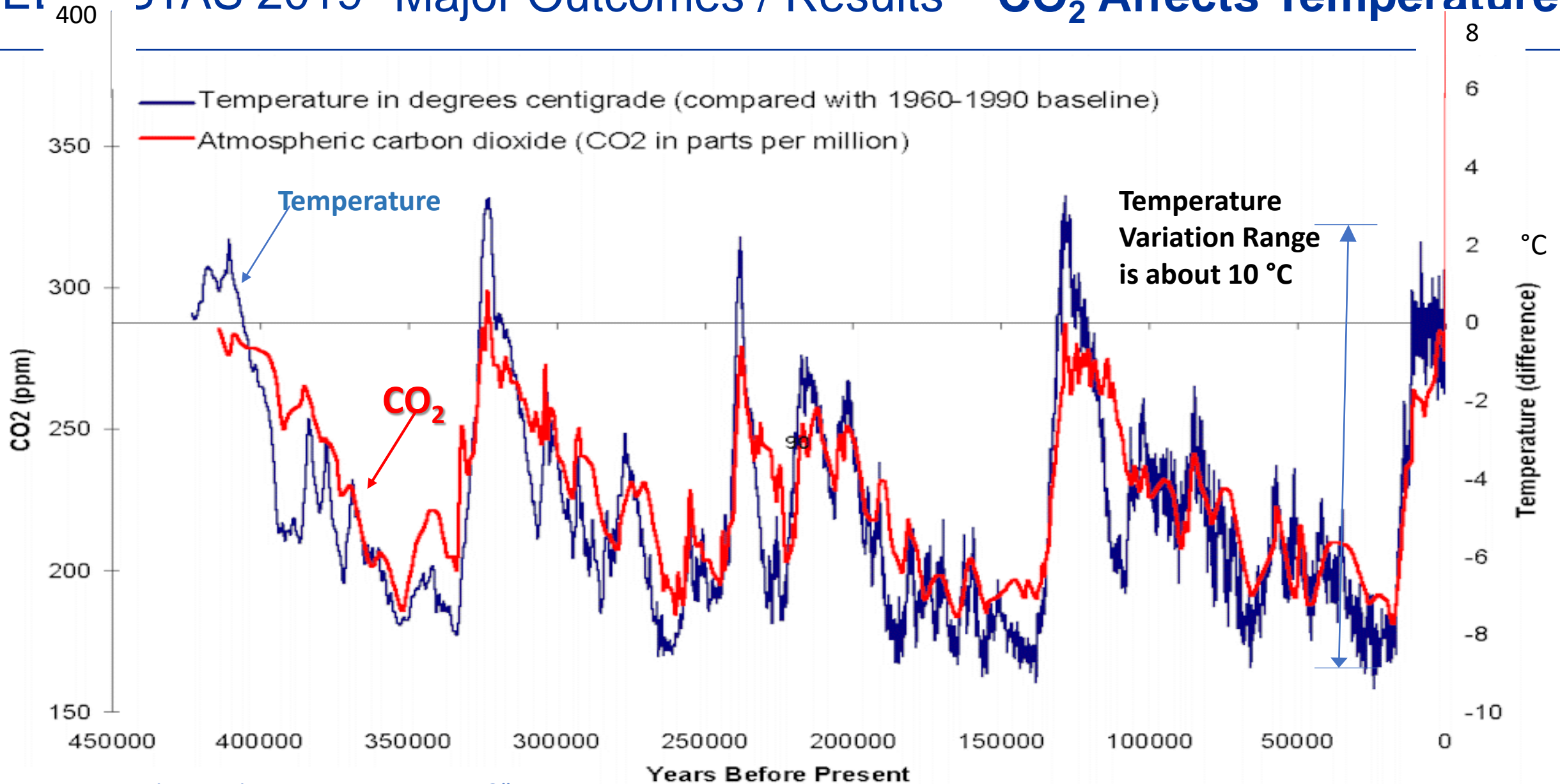
- CO₂ up to 40 gigatons per year worldwide rapidly *increasing rate*
- compared to 30 Gt/yr ten years ago



How much Carbon Dioxide will go into the atmosphere?



IEEE ISTAS 2019 Major Outcomes / Results – CO₂ Affects Temperature



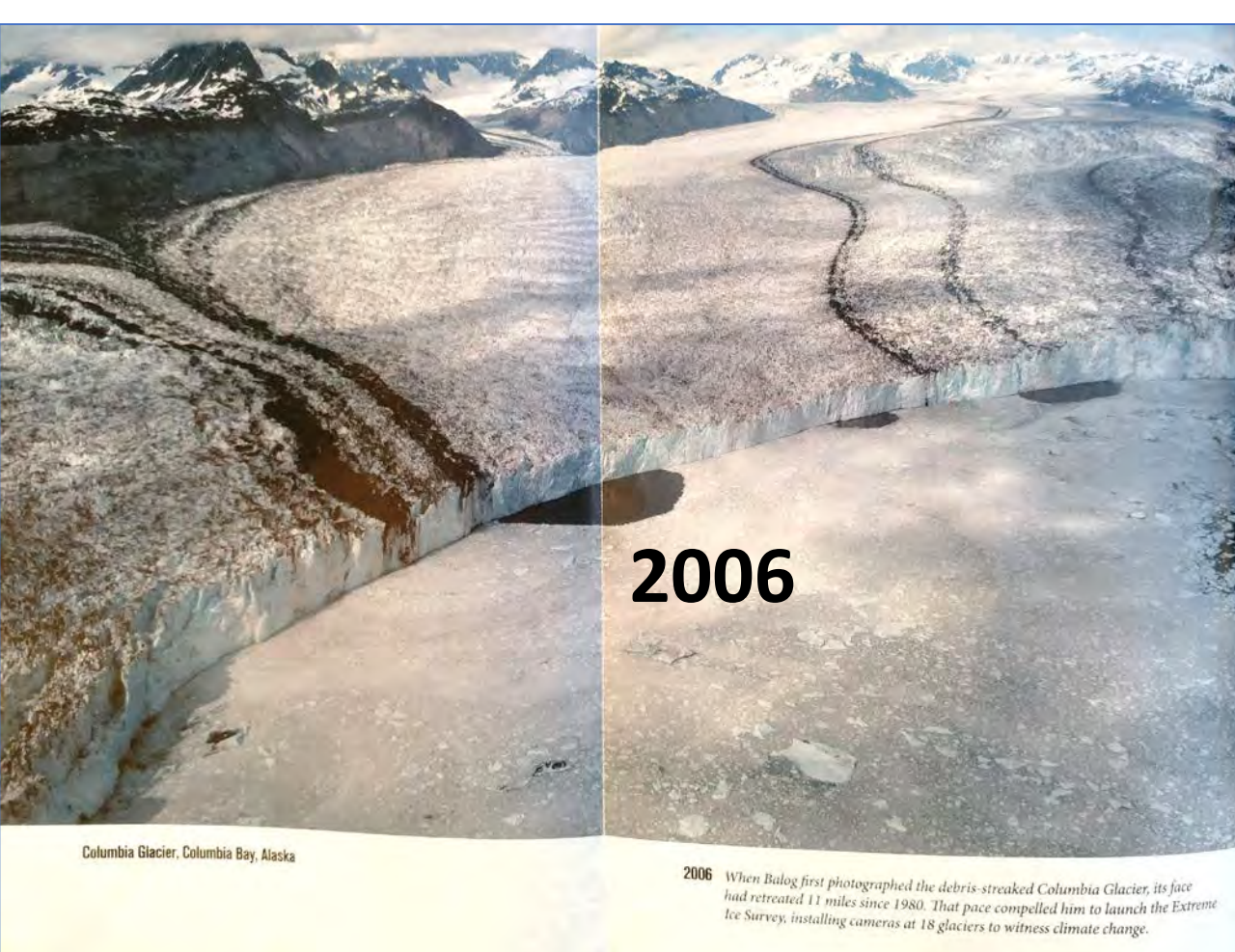
“Does CO₂ Correlate with Temperature History?” A. Watts, Wordpress.com, after Shakun, *Nature*, 2012

IEEE ISTAS 2019 ALASKA Columbia Glacier ONLY SIX Years Apart

Columbia Bay, Alaska – Photographer James Balog, Nat. Geo. magazine: **Extreme Ice Survey of 18 Glaciers**

The most extreme: Columbia Glacier is losing one mile every three years – so two miles of loss are shown below.

Since 1980, this glacier has lost height equal to the Empire State Building!



Earth's Last 400,000 Year Climate History

credit: Dr. Jim Hansen, NASA Goddard Inst. for Space Studies

CO₂ and the "Ornery Climate Beast"

How might today's human-caused increases in atmospheric concentrations of carbon dioxide and other greenhouse gases change the planet? The past provides clues. Geological records show that in the past 400,000

years, atmospheric concentrations of carbon dioxide, average Earth temperature, and sea levels have risen and fallen roughly in tandem, in 100,000-year cycles paced by slight oscillations in Earth's orbit. These oscillations

affect the distribution of sunlight, hardly affecting the total amount reaching Earth; yet, scientists believe, this has been enough to set in motion chains of events that raise and lower temperatures, launch and end ice ages, and trigger vast changes in sea level.

What's coming next? Carbon dioxide—the number one greenhouse gas—has

much more power to affect Earth's temperature than the orbital changes do. And in just the past 150 years, humankind has boosted carbon dioxide concentrations by 32 percent. NASA planetary scientist Jim Hansen says that if we continue to increase greenhouse-gas emissions, temperatures will rise between 2 and 3 °C this century, making

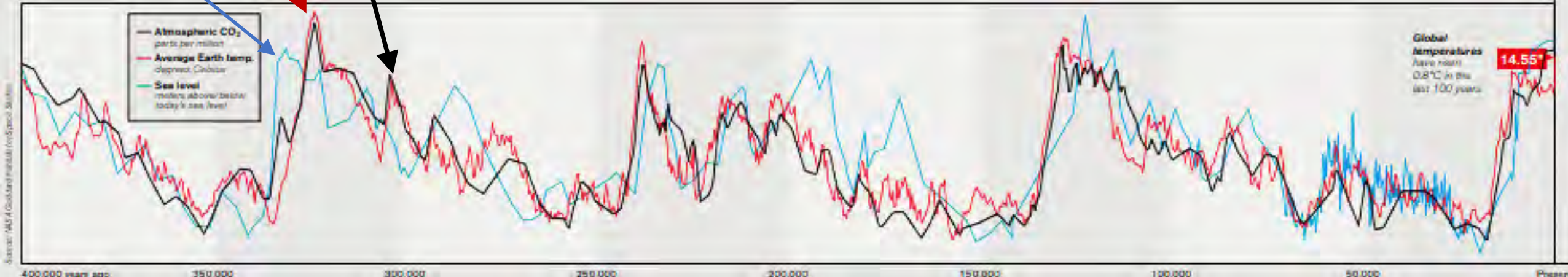
Earth as warm as it was three million years ago, when seas were between 15 and 35 meters higher than they are today. His predictions bear weight partly because he can verify his methods: using geological records, he has calculated past temperatures, and his results closely match the measured temperatures shown here. DAVID TALBOT

377

Sea Level

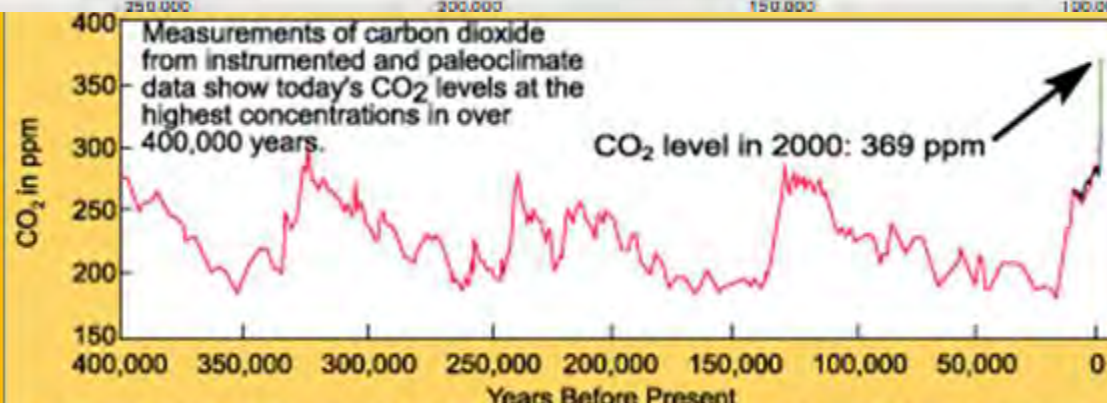
Avg. Earth Temperature

Atmospheric CO₂



NOAA states, "CO₂ levels are at the highest concentrations in over 400,000 years" →

On right is the same CO₂ data from ncdc.noaa.gov



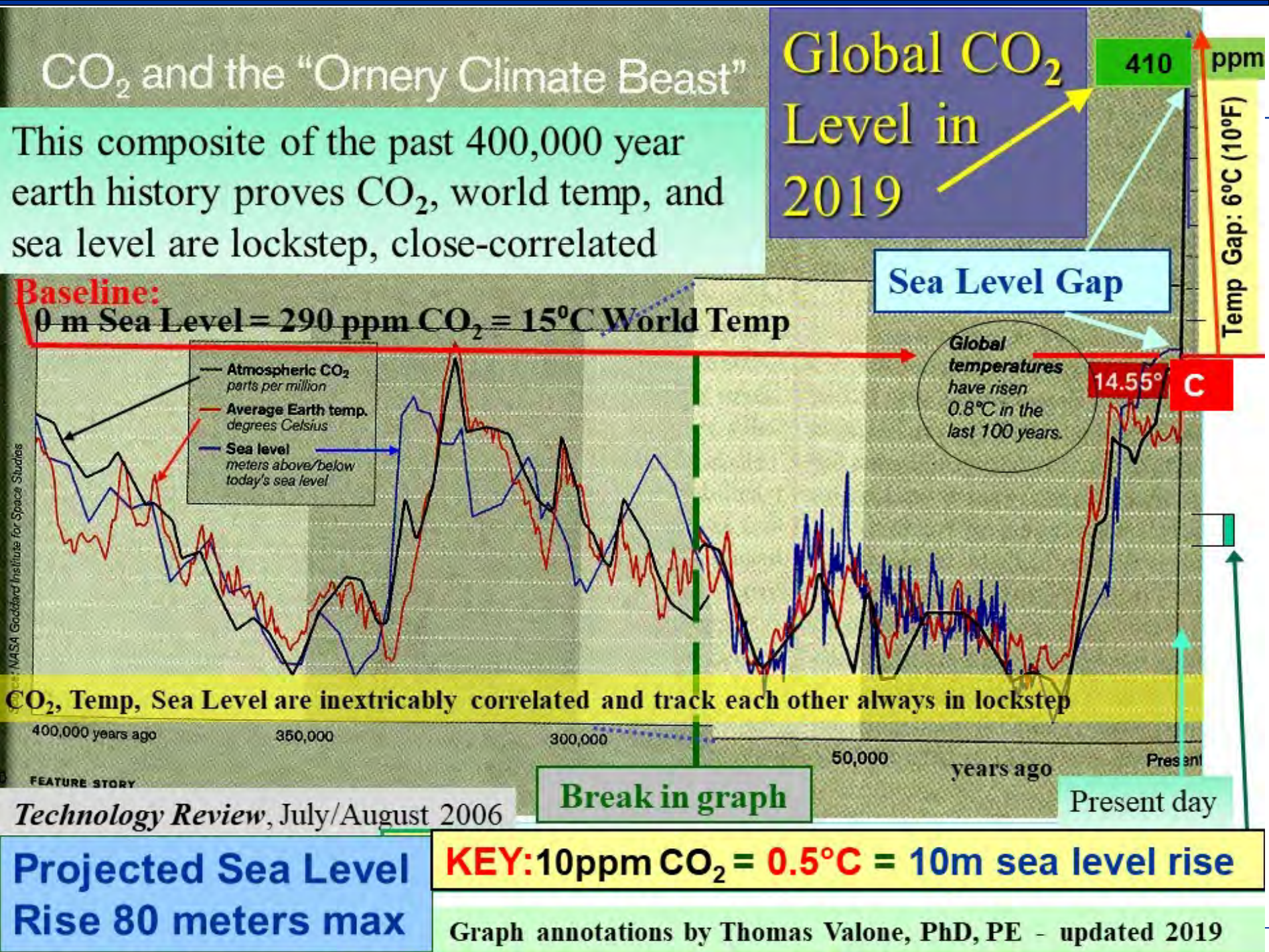
Source: Modified from Bernois et al., (1999), A. Indemichie et al. (2000), D.M. Etheridge et al. (1998), C.D. Keeling et al. (1996)

MIT's
Technology Review

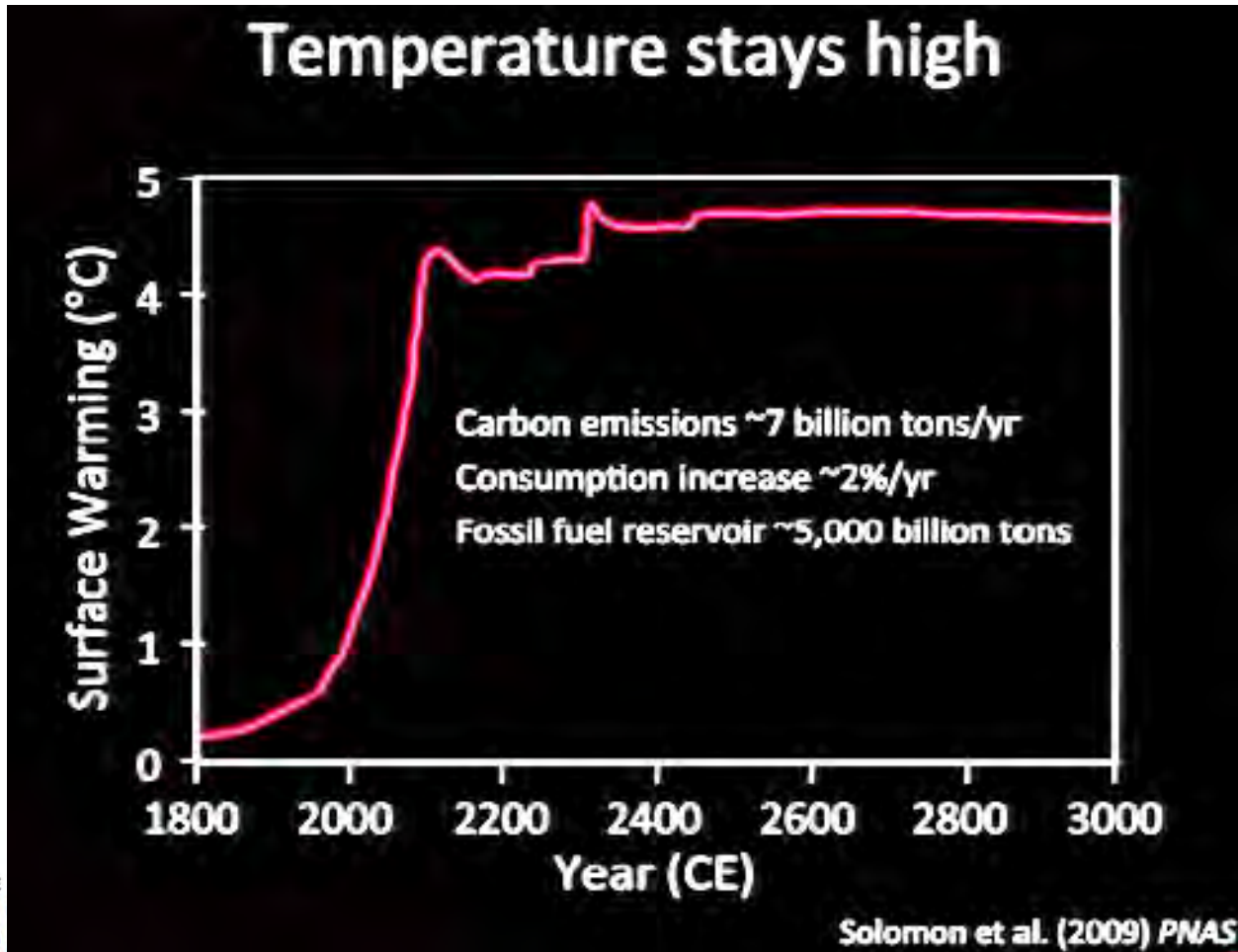
July/August, 2006

Jim Hansen's Table of Vostok data points for 400,000 years

Carbon dioxide p.p.m.	Average Earth temp. °C	Sea level meters
300	15.5	10
290	15.0	0
280	14.5	-10
270	14.0	-20
260	13.5	-30
250	13.0	-40
240	12.5	-50
230	12.0	-60
220	11.5	-70
210	11.0	-80
200	10.5	-90
190	10.0	-100
180	9.5	-110
170	9.0	-120



+/- (20 ppm CO₂ = 1 °C = 20 m sea rise)



- Formula becomes nonlinear past 500 ppm CO₂ as global temperature response lessens
- In 2009, Dr. Solomon (NOAA) projected 4 – 5 °C by 2100, assuming a CO₂ **peak at** around 2100 – wishful thinking 7→11 Gt
- Hansen's Formula prediction of **6 °C by 2100** will continue to increase if business as usual 2100s

In 100 years, the atmospheric CO₂ will reach 500-1000 ppm, which was last experienced during the EOCENE (55 to 36 million years ago)



The Eocene climate was warm, even at high latitudes:

- palm trees flourished in Wyoming and Antarctica was a pine forest
- crocodiles lived in the Arctic
- deep ocean temperature was 55°F (today it is ~35°F)
- sea level was at least 300 feet higher than today

* Climate models with mid-range climate sensitivity simulate an Eocene that is much too cold compared to the fossil records

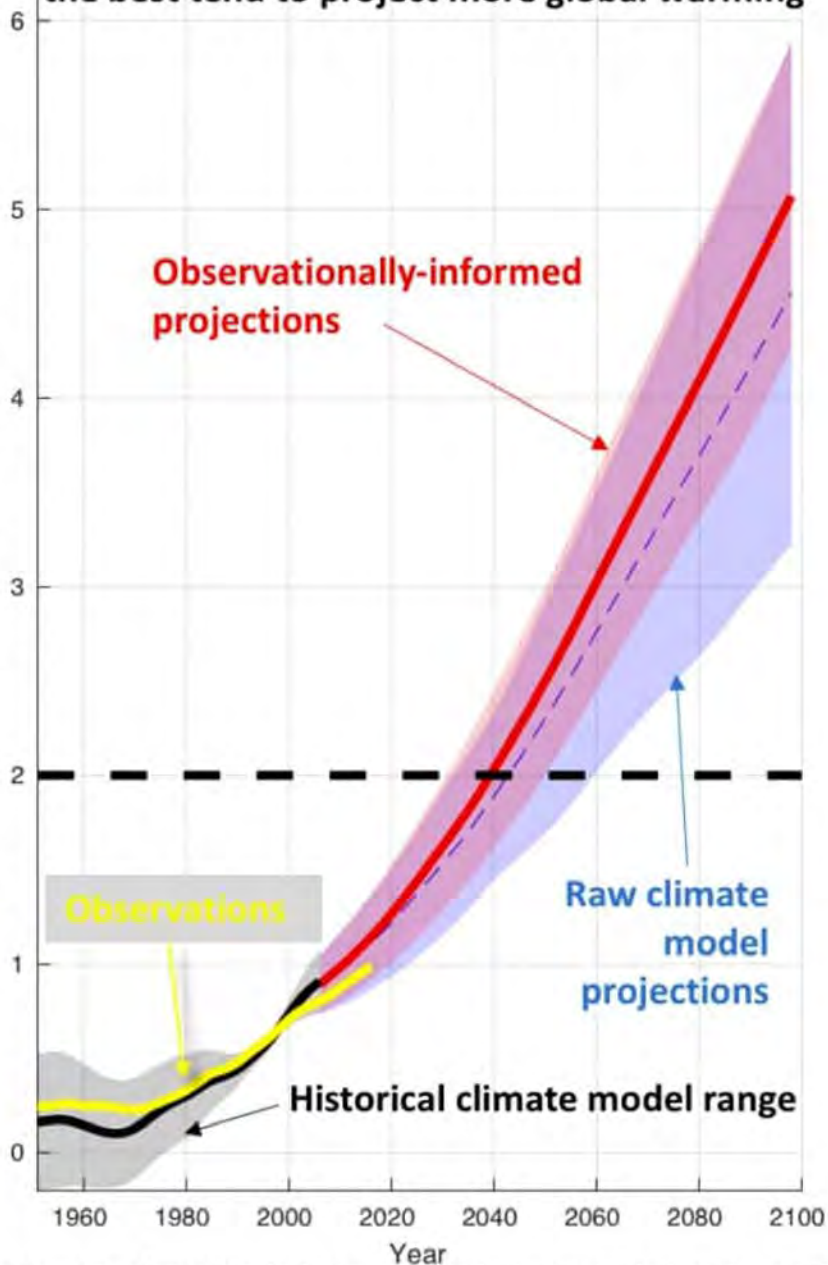
**University of
Washington**
Climate Change
Lecture Notes,
www.atmos.Washington.edu



RED = at sea level, **GREEN** = 4 – 5 m above sea level

Climate models that simulate the current climate the best tend to project more global warming

Global average surface temperature above preindustrial (C)



Comparison of raw and observationally-informed climate model projections from Brown and Caldeira (2017, *Nature*)

CNN

World

Africa

Americas

Asia

Australia

China

Europe

India

Middle East

United Kingdom

LIVE TV

Edition

Q

≡

11,000 scientists warn of 'untold suffering' caused by climate change



By Emma Tobin and Ivana Kottasová, CNN

Updated 3:24 AM ET, Wed November 6, 2019

Nov. 6, 2019 CNN

Latest numbers show at least 5 metres sea-level rise locked in

It's too late to stop the seas rising at least 5 metres and only fast, drastic action will avert a 20-metre rise, *New Scientist* calculates based on recent studies

SCIENCE ADVANCES | RESEARCH ARTICLE

MASS EXTINCTION

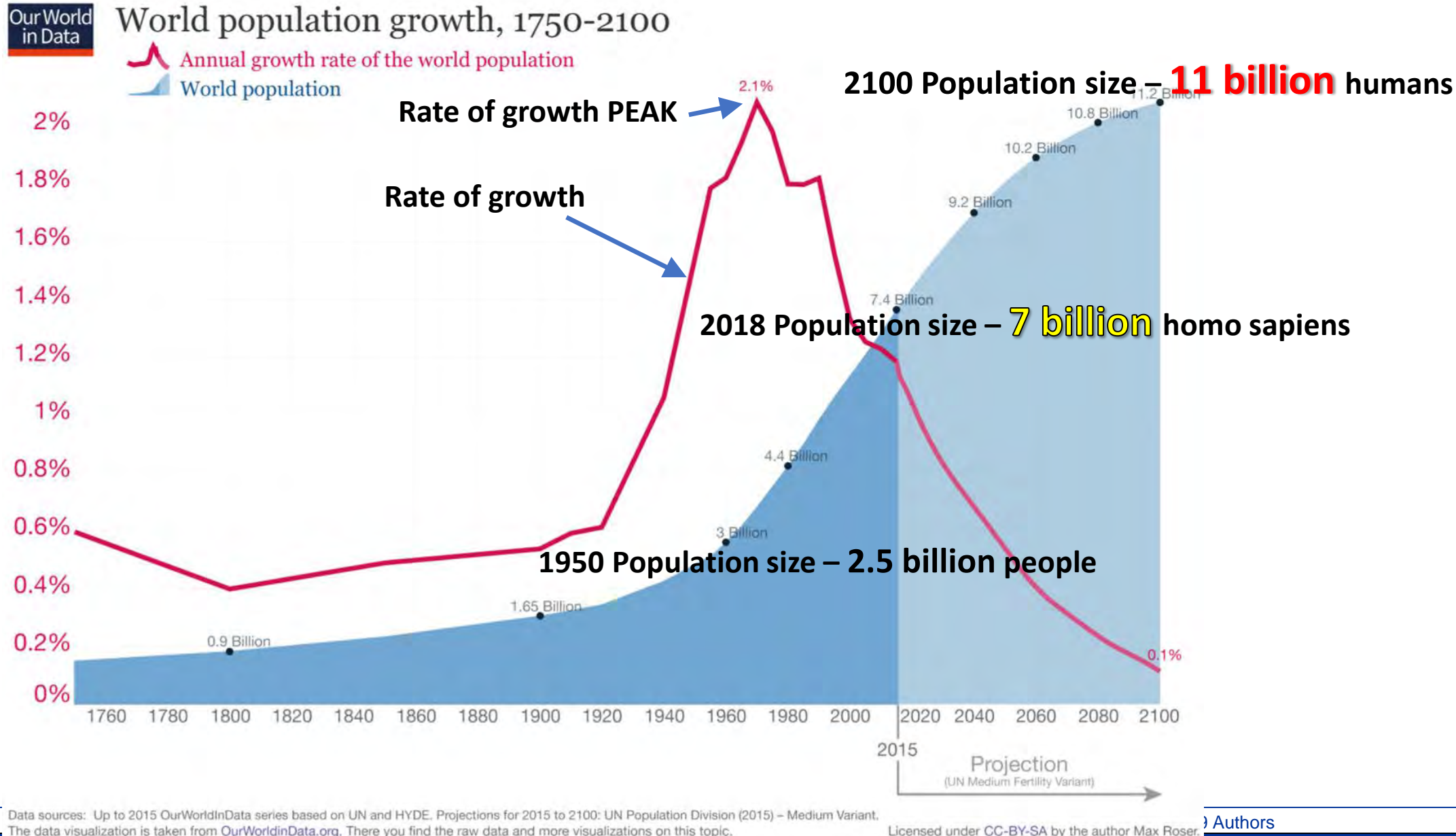
Rothman, *Sci. Adv.*, Sept., 2017

Thresholds of catastrophe in the Earth system

Daniel H. Rothman

The history of the Earth system is a story of change. Some changes are gradual and benign, but others, especially those associated with catastrophic mass extinction, are relatively abrupt and destructive. What sets one group apart from the other? Here, I hypothesize that perturbations of Earth's carbon cycle lead to mass extinction if they exceed either a critical rate at long time scales or a critical size at short time scales. By analyzing 31 carbon isotopic events during the past 542 million years, I identify the critical rate with a limit imposed by mass conservation. Identification of the crossover time scale separating fast from slow events then yields the critical size. The modern critical size for the marine carbon cycle is roughly similar to the mass of carbon that human activities will likely have added to the oceans by the year 2100.

Global **population** has tripled (3x) since 1950; CO₂ **emissions** have quadrupled (4x); and global **energy** demand has quintupled (5x), all in the same time period.



Phase Change Materials

Absorb and release energy naturally - without consuming energy.

Phase change insulation is a vital adaptation technique for the immediate future and beyond. **InsolCorp** leads the industry with **InfiniteR** insulation only one centimeter thick has **100 BTU/ft²** of energy storage, **314 Watts/m²** of energy.

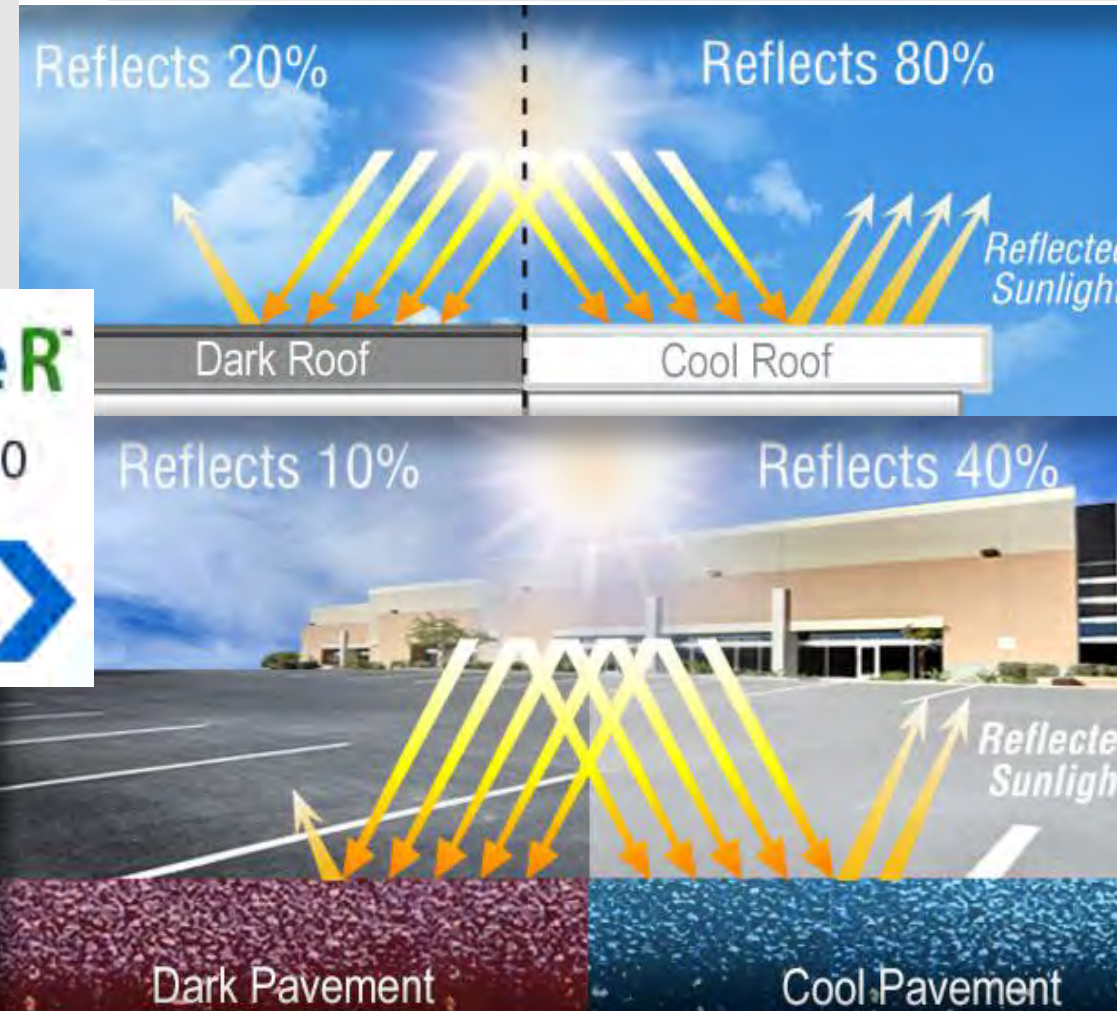


Choose you preferred TEMPERATURE for the phase change. It will **maintain that temperature INDOORS (+/- 2 °F)** while the outdoors swings wildly with 100 °F hot and 20 °F cold.

Like ICE, it freezes and thaws at the chosen TEMPERATURE above.

Western Colloid Fluid – Cool Roof System

- High Reflectivity
- Reduces energy costs by 30%



How to make a carbon tax popular

Politicians are cautious but a survey of 3000 people in the US found **attitudes to it are positive** if the money raised goes toward renewable energy or is redistributed to people as a rebate.

-Sci. Adv., Sept., 2019 doi.org/dbqd

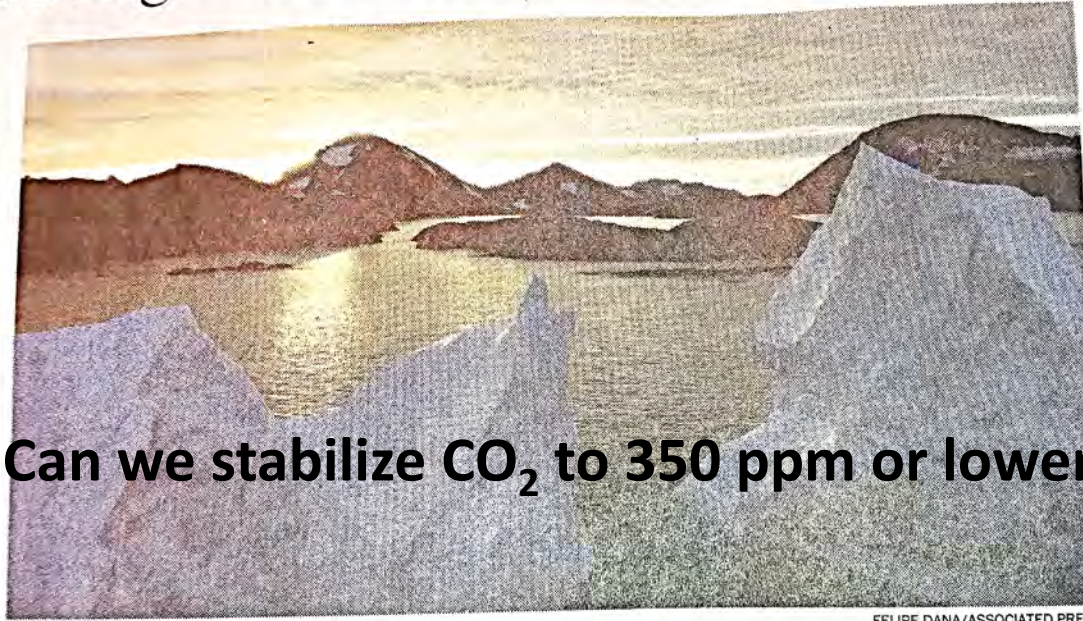
World needs a huge carbon tax by 2030 to limit climate change, IMF says

BY CHRIS MOONEY
AND ANDREW FREEDMAN

A global agreement to make fossil-fuel burning more expensive is urgent and the most efficient way of fighting climate change, an International Monetary Fund study found on Thursday.

The group found that a global tax of \$75 per ton by 2030 could limit the planet's warming to 2 degrees Celsius (3.6 degrees Fahrenheit), or about double what it is now. That would greatly increase the price of fossil-fuel-based energy — especially from the burning of coal — but the economic disruption could be offset by routing the money raised straight back to citizens.

"If you compare the average level of the carbon tax today, which is \$2 [a ton], to where we need to be, it's a quantum leap," said Paolo Mauro, deputy director of the fiscal affairs department at



Can we stabilize CO₂ to 350 ppm or lower?

FELIPE DANA/ASSOCIATED PRESS

The IMF found that a global fossil-fuel levy of \$75 per ton by 2030 could limit the planet's warming, which has drastically affected Greenland, above — to 2 degrees Celsius.

low to hold climate change to 2 degrees, noting that he had expected the figure to be closer to \$100 per ton, given the world's high emissions path.

Gernot Wagner, who studies climate policy at New York University, agreed. He co-wrote a paper published Monday arguing that a carbon price should gradually be reduced to account the costs of damage from global warming.

"If one takes climate uncertainty seriously, numbers rise much higher still," Wagner said in an email.

Most economists and policymakers have designed carbon tax policies that start relatively low and ramp up quickly over time. Proponents say it would minimize economic hardship for consumers and companies for their past choices while changing future decisions such as purchases of polluting equipment or automobiles.

The Nobel Prize-winning

that analysis.

"The climate crisis and public/population to attack it is strong and unique even \$75/ton by 2030 too moderate a tax Komanoff, director of Tax Center, wrote response to the IMF report

Wash. Post,
Nov. 2019

economic political feasibility as well, might affect

ments of society a them more political such as by redirecting to people through direct dividend payments

It shows that 20's largest economies would raise energy average of 43 percent and 14 percent the countries corner

This reflects the notion that political burden particular would trigger a tax. France's tax diesel, for

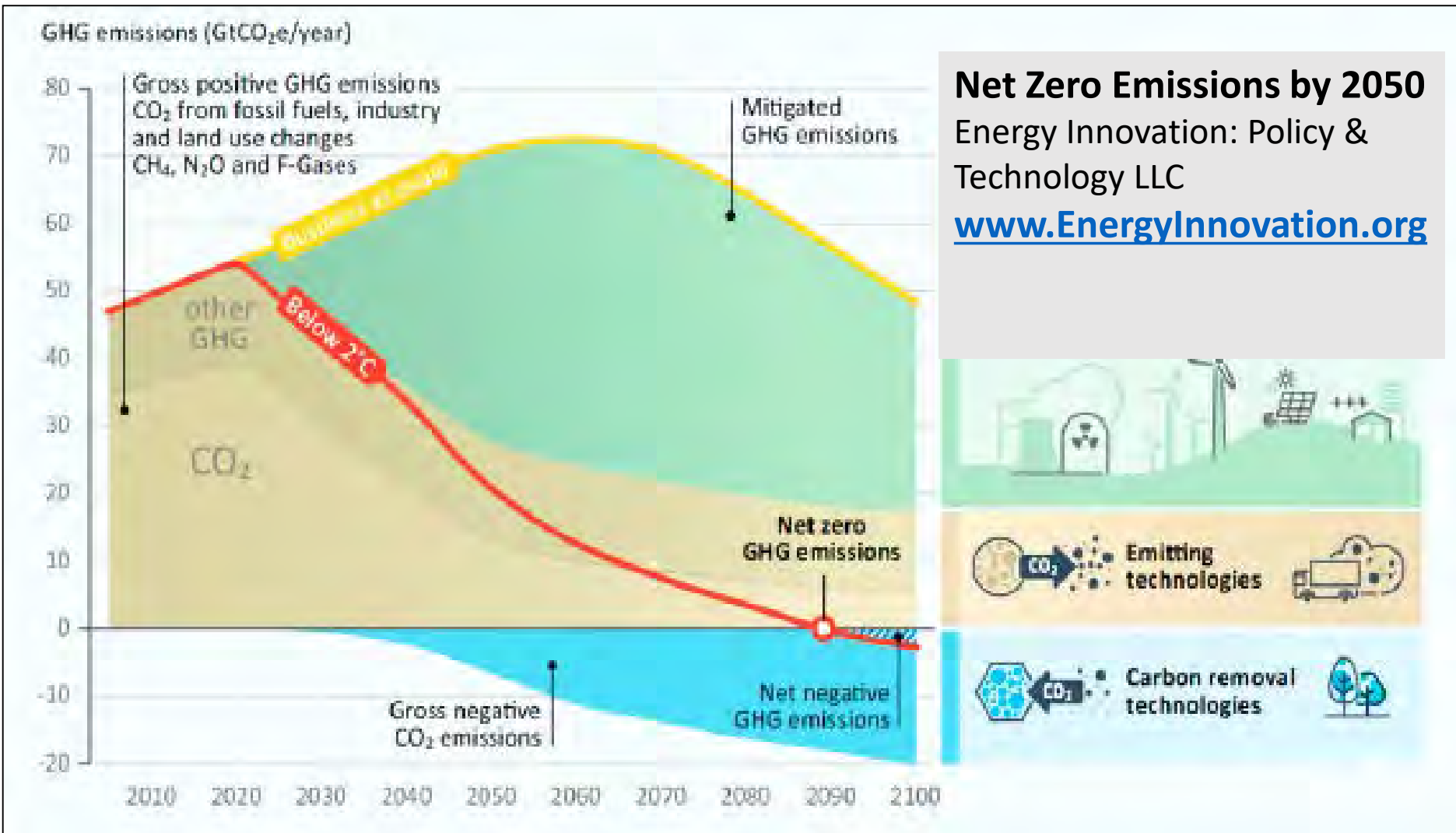
Young Evangelicals Welcome Bipartisan Carbon Tax Bill

Posted by Victoria Goebel

Sept. 26, 2019

Today, Representative Brian Fitzpatrick (R-PA) introduced the bipartisan Market Choice Act, an ambitious plan to incentivize a free-market transition toward clean, renewable energy. The bill will significantly drive down greenhouse gas emissions, direct most of the revenue raised toward much-needed infrastructure investment,

IEEE ISTAS 2019 Negative Emissions and Carbon Sequestration



**“Negative
Emissions
Technologies and
Reliable
Sequestration: A
Research Agenda”**
(2019) National Academies
Press

www.NAP.edu/25259

FREE download (PDF)

“Pulling CO₂ out of the air and using it could be a trillion-dollar business”

Put CO₂ to work making valuable products. www.vox.com/energy-and-environment

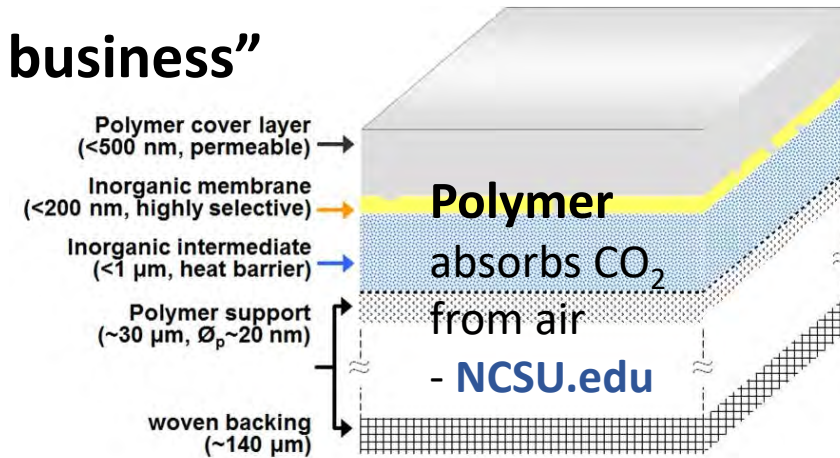
1 ppm CO₂ = 2 Gt Carbon = 7.77 Gt CO₂

THE HANSEN CHALLENGE

Can we REDUCE the CO₂ level to lower temperature? YES, it is reversible!

- Choose 350 ppm (+3 °C) as the target CO₂ level just to lower temperature
- Calculate gigatons (Gt) to remove in total if done today (a long shot)
- Take present 410 ppm – 350 ppm = 60 ppm which is equal to **466 Gt CO₂**
- However, *every year* an average of 5 ppm CO₂ or **+40 Gt/yr** will be added (in A2)
- Therefore, any **Global Carbon Reduction Program** will require CCS-CCU to invest enough to remove say, **100 Gt/yr for 10 years and 50 Gt/yr after**, until the hoped-for carbon emission rate peaks and a century later, the emissions slow down, level off, as population has done globally

[Carbon Engineering](#) out of Calgary, Canada →
Tested Direct Air Capture (DAC) for CCU, CCS



“A Process for Capturing CO₂ from the Atmosphere”

DAVID KEITH ET AL., JOULE, [VOLUME 2, ISSUE 8](#), P1573-1594, AUGUST 15, 2018

→ Estimates low cost can be around
\$100/ton of CO₂ presently
→ \$50 billion/yr for 50 Gt/yr @\$1/t

Carbon Engineering – very low-carbon fuels, powered by renewables, using CO₂ from the air, drawing **hydrogen** from electrolysis to produce hydrocarbons. The company calls the process “**air to fuels**,” or **A2F**, and it is targeting wide commercialization in 2021.

→ *SOLUTIONS to excess CO₂ need Gt CCS as well as these renewable, carbon-neutral fuels.*

HyTech is targeting a big market – diesel engines – the source of 50% of urban smog, especially in winter

Onboard electrolyzers are the game plan for turning existing → diesel engine fleet into **zero-emissions vehicles (ZEV)** by making them run on pure hydrogen.

-- **HyTech Power**, based in Redmond, Washington

