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

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185 PWh = 630 Quads* (Petawatt-hours and Quadrillion BTUs)
*EIA projection to 2020

33 PWh = 100 Quads*
*US consumption 2018

A 50% increase in this energy demand is expected by 2050 - EIA 9/24/19

Add 4.5 billion new air conditioners to world by 2050 = add another 33 PWh
- RMI.org

World Energy Usage is 90% **Fossil-Fueled Technology** Deeply Engrained in Societies with a **Huge Carbon Footprint** and **Inertia**
**CARBON EMISSIONS PER ANNUM**

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

**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.

- China +4.7%
- U.S. +2.5%
- E.U. -0.7%
- India +6.3%
- Other +1.8%

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

Source: Global Carbon Project

**annual mean growth rate of CO₂ at Mauna Loa**

Source: JOHN MUYSKENS/THE WASHINGTON POST
Paleoclimatology – Geo Past is Key to Future

Graphs from University of Washington

A2 = as usual

800 ppm

PETM

Paleocene Thermal Maximum

IEEE ISTAS 2019

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Temperature Variation Range is about 10 °C
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!
NOAA states, “CO₂ levels are at the highest concentrations in over 400,000 years” →

Earth’s Last 400,000 Year Climate History

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

CO₂ and the “Omery Climate Beast”

How might today’s human-caused increases in atmospheric concentrations of carbon dioxide affect the distribution of sunlight reaching Earth? Yet, scientists believe, has been enough to set in motion changes in ocean that raise and lower temperatures, launch and end ice ages, and trigger rapid changes in sea level. What is coming now? Carbon dioxide—the number one greenhouse gas—has much more power to affect Earth’s temperature than the orbital changes do. And just, for the past 100 years, humanized sea levels. Carbon dioxide concentrations by 100 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 10 and 35 meters higher than they are today. He predicts a more wetter world 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 PALMER

MIT’s Technology Review
July/August, 2006
Jim Hansen’s Table of Vostok data points for 400,000 years

CO₂ and the “Omnery Climate Beast”

This composite of the past 400,000 year earth history proves CO₂, world temp, and sea level are lockstep, close-correlated

Baseline:

0 m Sea Level = 290 ppm CO₂ = 15°C World Temp

CO₂, Temp, Sea Level are inextricably correlated and track each other always in lockstep

Break in graph

Projected Sea Level Rise 80 meters max

KEY: 10 ppm CO₂ = 0.5°C = 10 m sea level rise

Graph annotations by Thomas Valone, PhD, PE – updated 2019
Hansen Formula for CO₂, Temperature, and Sea Rise

\[ \pm \frac{1}{(20 \text{ ppm CO}_2) = \frac{1}{1 \degree \text{C}} = \frac{20}{1} \text{ m sea rise}} \]

- 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
Expected Sea Level RATE of rise is about **2.5 meters per century**, from last interglacial period (New Sci., July 6, 2019, p. 39)

**London, circa 2150**

**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 compared to raw climate model projections. Observationally-informed projections are more accurate and closely match historical climate data.

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.

Mass Extinction

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 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.

Western Colloid Fluid – Cool Roof System
- High Reflectivity
- Reduces energy costs by 30%

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.
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.


Can we stabilize CO₂ to 350 ppm or lower?

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.

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, ...
Net Zero Emissions by 2050
Energy Innovation: Policy & Technology LLC
www.EnergyInnovation.org

“Negative Emissions Technologies and Reliable Sequestration: A Research Agenda”
www.NAP.edu/25259

FREE download (PDF)

Wishful Thinking for a Quick Reduction by the National Academies Press
“Pulling CO₂ out of the air and using it could be a trillion-dollar business”


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
Carbon Engineering – very low-carbon fuels, powered by renewables, using CO$_2$ 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 CO$_2$ 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