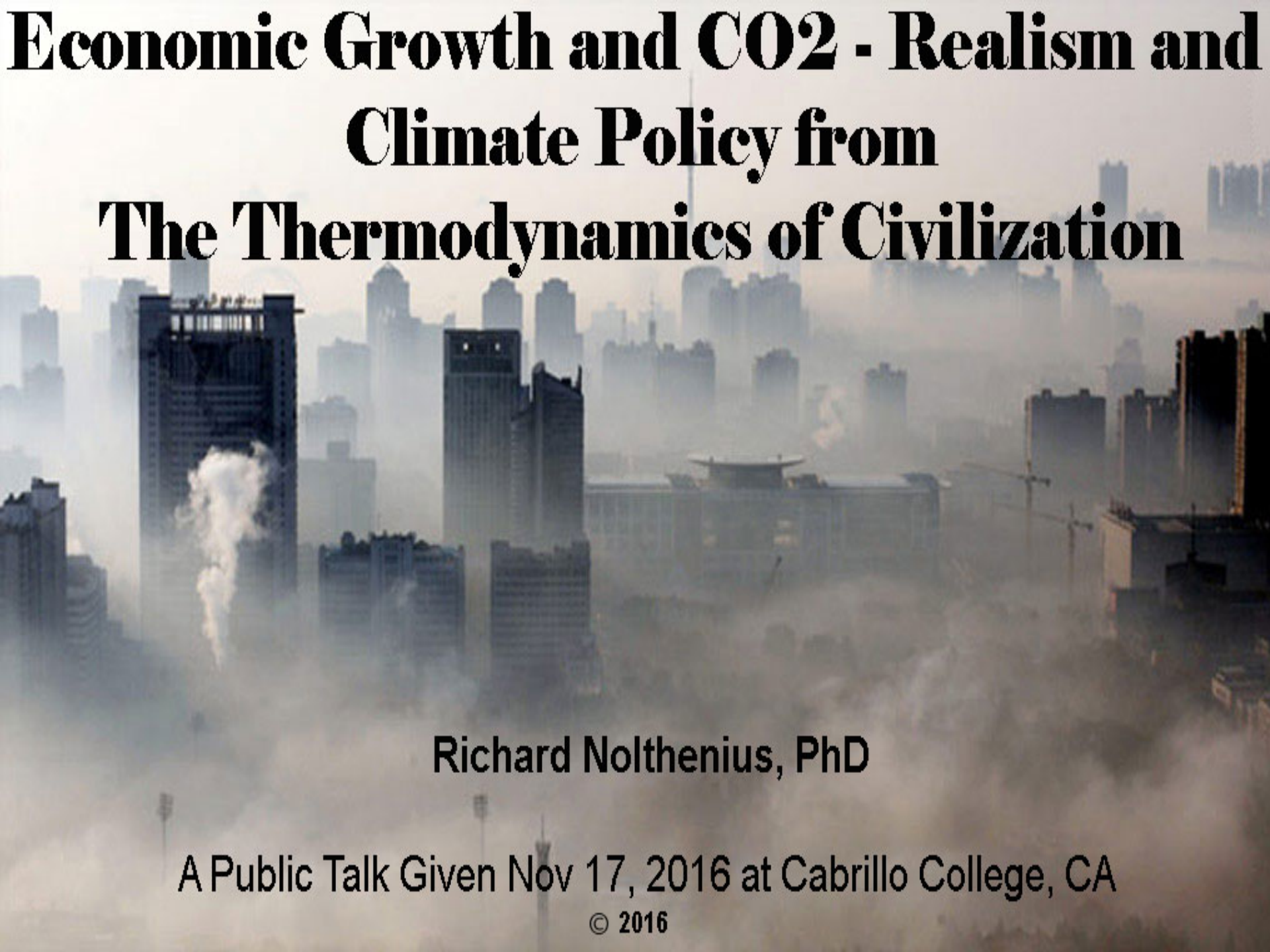
Economic Growth and CO2 - Realism and Climate Policy from The Thermodynamics of Civilization



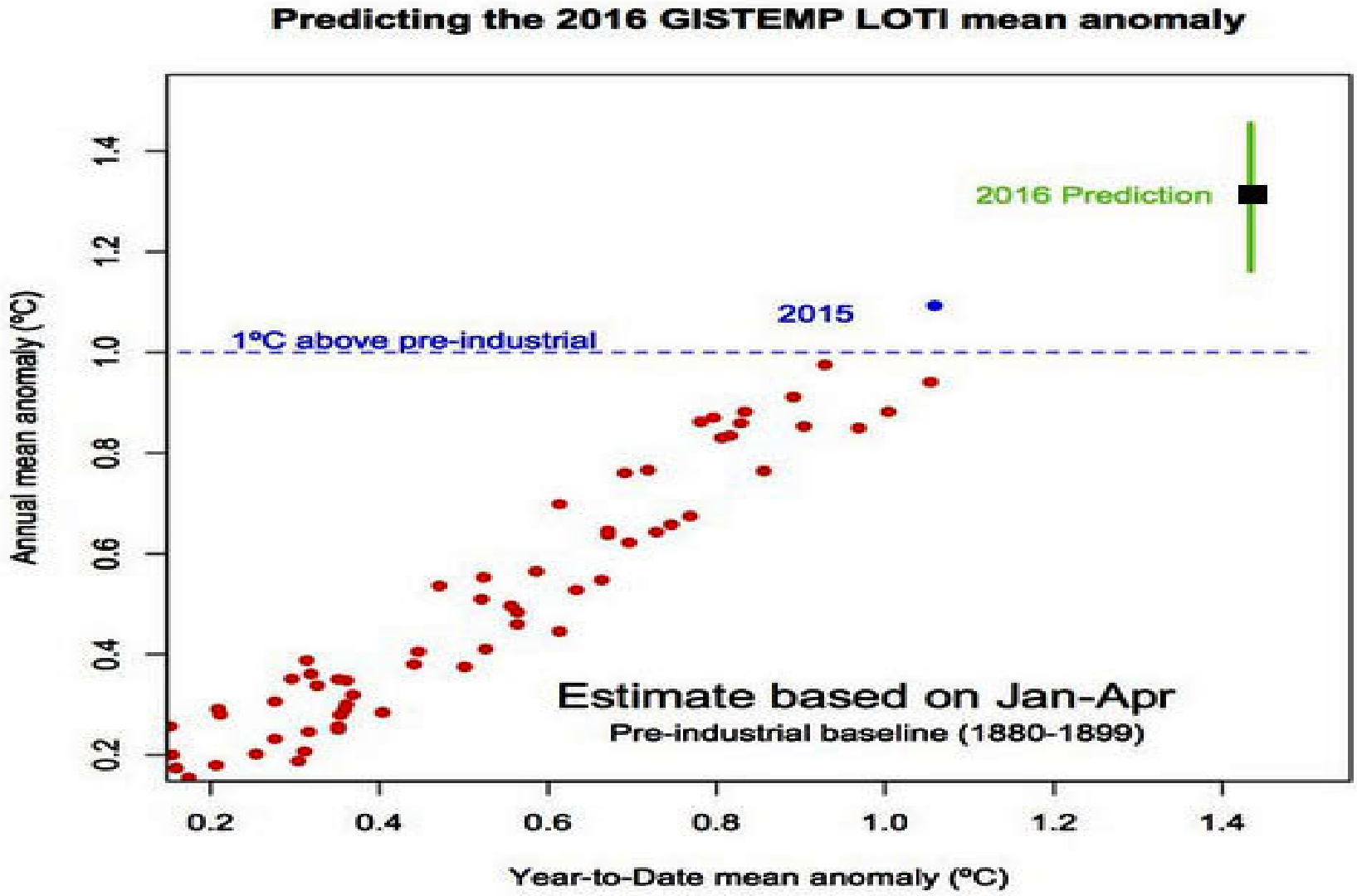
Richard Nolthenius, PhD

A Public Talk Given Nov 17, 2016 at Cabrillo College, CA

My Relevant Background

- M.S. in Aerospace ‘76 Univ. Az, thesis: developing numerical computer codes modelling non-equilibrium viscous fluid flow
- Thermal analyst, design for Atlas/Centaur rockets and space missions for General Dynamics in San Diego
- Thermal design lead for General Dynamics’ proposal for the International Space Station
- Stanford University PhD program in Applied Physics ‘78/‘79, but left for unrelated personal necessity to Los Angeles, finishing PhD in Astronomy at UCLA 1984. Grad research projects included:
- -- Application of chaos theory to bars in barred spiral galaxies, numerical simulation development
- -- First application of new technique “Smoothed Particle hydrodynamics” to stellar disruption around black holes
- -- Dissertation; novel use of ANOVA techniques to merge discrete star Doppler data with nuclear dispersion measures to make consistent dynamical models of disk galaxies and spheroid galaxies, with application to the Andromeda system. Planetary nebulae observational work at Kitt Peak National Obs.
- Post doctoral fellowship at Steward Observatory, galaxy clustering dynamics of Cold Dark Matter models and observational galaxy cluster data
- **UC Santa Cruz Astronomy**, lecturer in late ‘80’s and ‘90’s. Part of the Joel Primack - led Dark Matter team modelling numerical evolution of Primack’s Cold+Hot Dark Matter theory and confronting with observations, and with Sandra Faber *et al.* team defining the emerging Fundamental Plane describing dissipative stellar systems
- **At Cabrillo College** first (and only) Department Chair of Astronomy, wrote and distributed the RPHOT photometry software to observatories in ’90s, built Cabrillo Observatory with help from Cabrillo’s Construction Engineering Management students. CCD camera systems and software, astrophotography
- Member of the Ground Team for the NASA/JAXA Hayabusa asteroid mission to Australia in 2010, in charge of spectrophotometry of re-entry vehicle to evaluate heat shield performance.
- Switched major focus to climate science in 2010, developed course **“Astro 7 – Planetary Climate Science”** whose main focus is current Earth climate change – physical science, engineering options, policy, confronting climate denialism, psychopathologies, and the Thermodynamics of Civilization

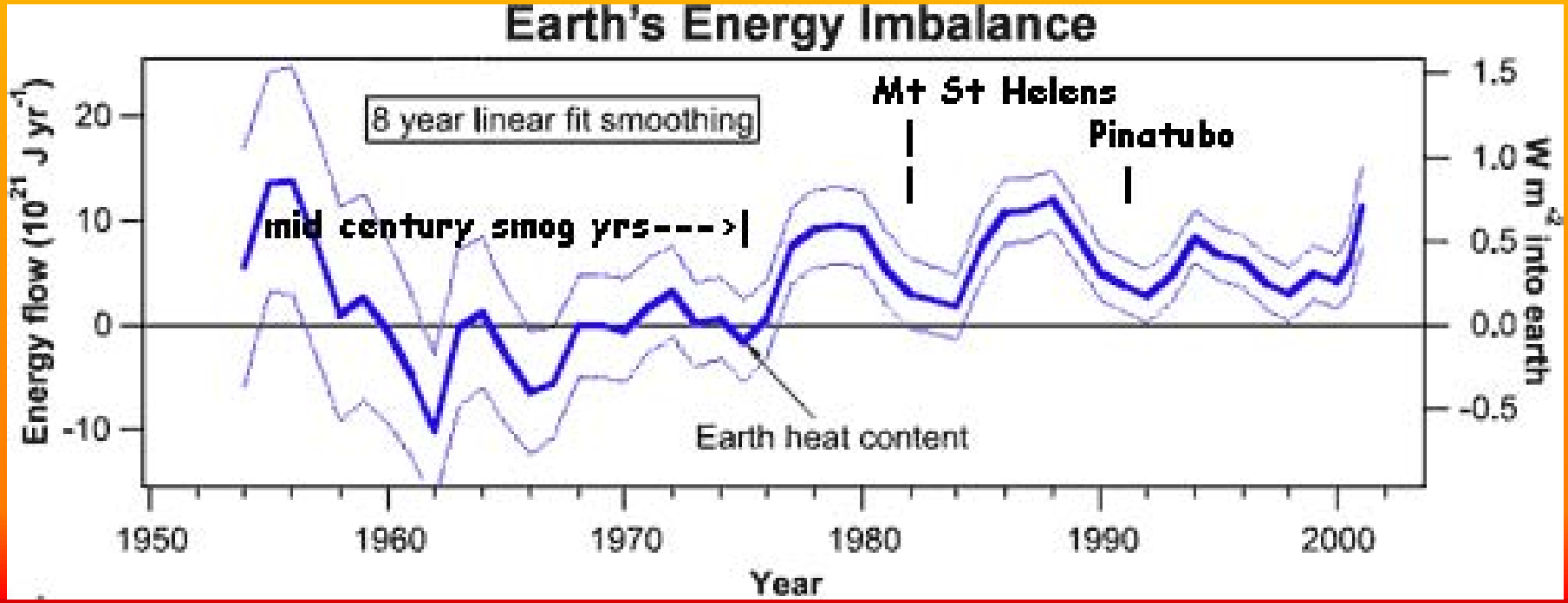
First, a Lightening Quick Summary of Our Predicament… we're already at +1.25 C above Pre-Industrial Temperatures as of Nov. 2016



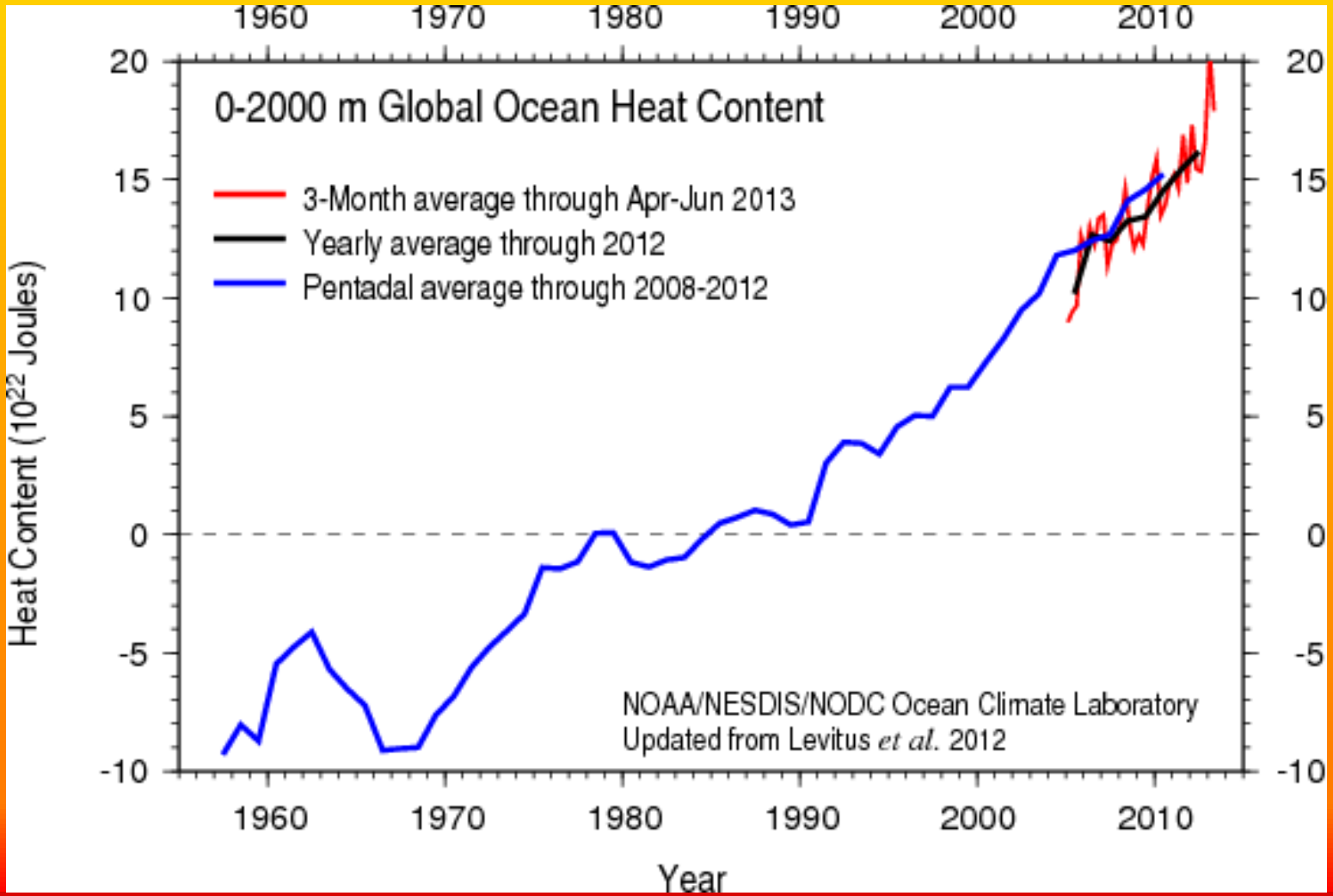
Even If We End ALL CO2 Emissions…Global Temperatures will Not Go Back Down

- Instead they stay constant (Matthews and Weaver 2010, Port et al. 2012, and others)… or more likely and worse - continue to rise (Fredrich *et al.* 2016)
- In Leonardo DiCaprio's ***"Before the Flood"***, towards the end, the interview with astronaut Piers Sellers was unfortunately misleading. An early 2009 work by Lisa Sloan's team showed temperature changes from much later, higher levels than today, after instantaneous ending of all emissions, showing a very slight drop of a couple of tenths of a degree after centuries. But later work including integrated biology/climate modelling (but no permafrost melt), revises that – to NO change in temperatures.
- **Zero emissions do NOT lead to dropping temperatures. (see graph two slides ahead)**
- **Why?**

The reason is - offsetting climate forcings: The existing radiative imbalance (difference between the incoming solar heating and the outgoing radiant heat of Earth) of **0.6 watts/square meter** will continue to force temperatures higher. But atmospheric CO2 will drop (or not – see MacDougall *et al.* 2012 described in slides up ahead), still being absorbed by land and oceans, which applies a cooling forcing. Both effects have similar time scales and magnitude, in opposite directions, and cancel each other out



Further, 93% of our Greenhouse heating has been deposited into the oceans, where it will act like a massive warm bath with 700x the thermal capacitance of the atmosphere, preventing our atmosphere from cooling

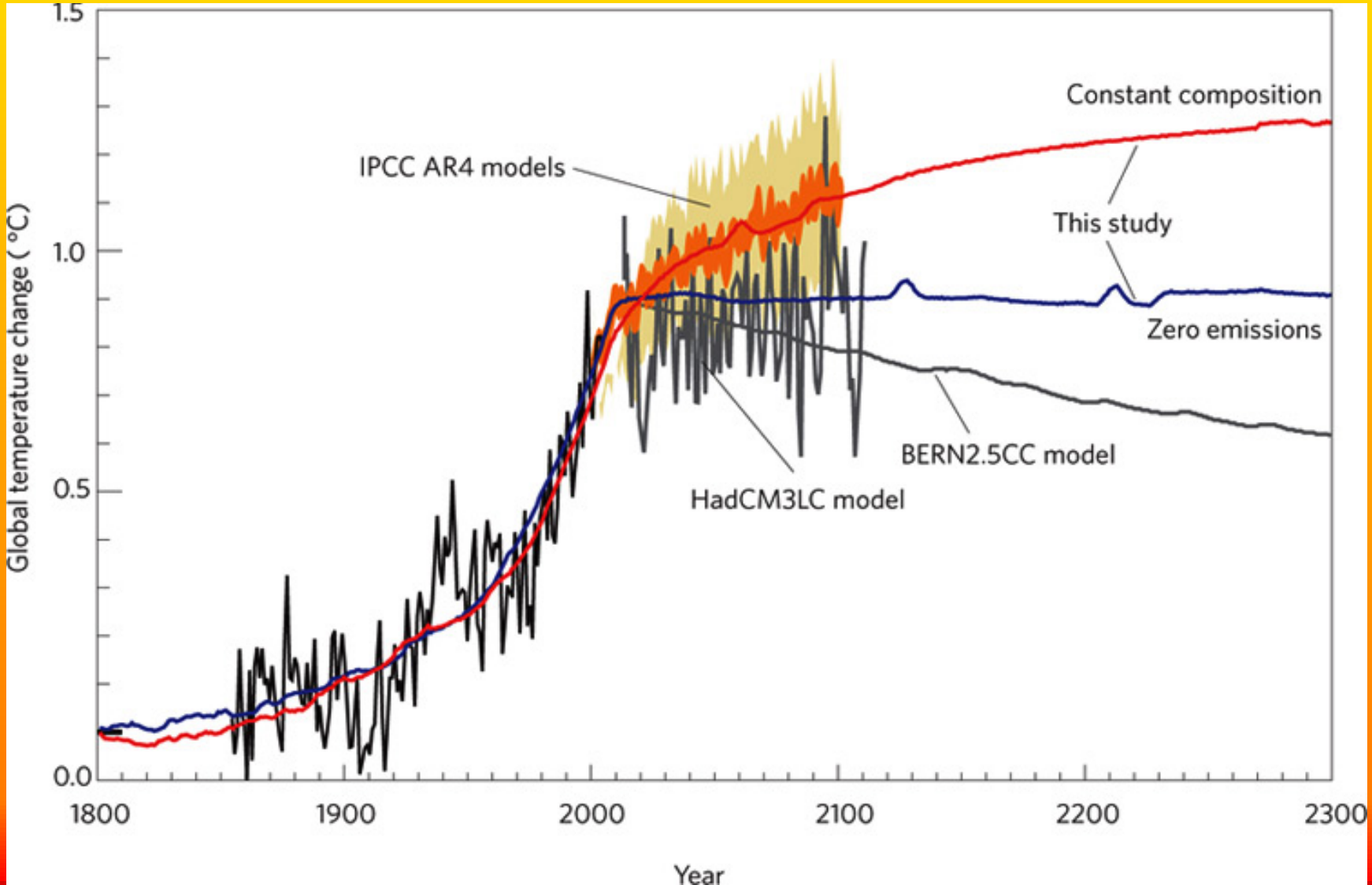


So… if we end Industrial Civilization tomorrow, we stay at about +1.25C above the Pre-Industrial Global Average. Is that Dangerous?

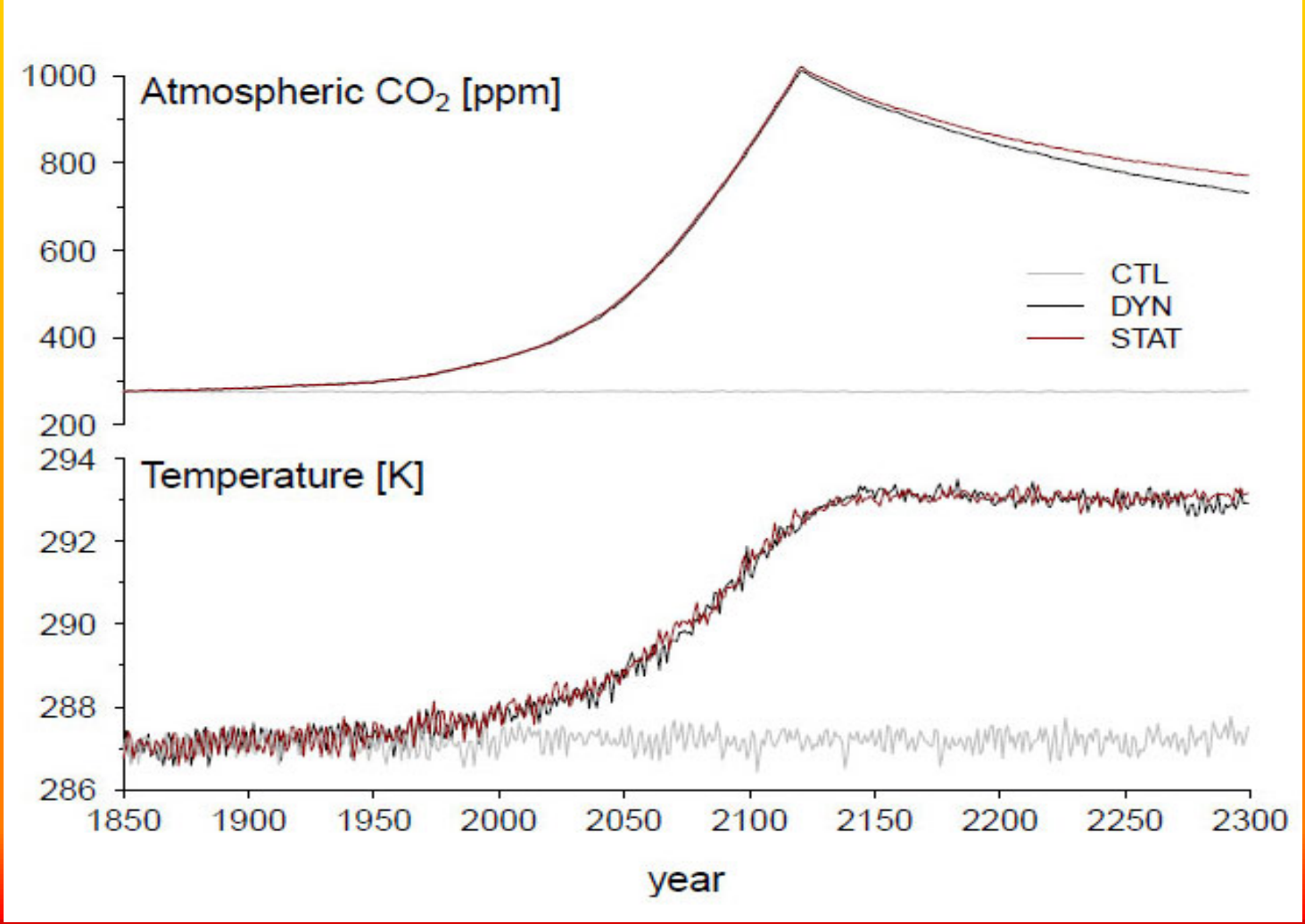
- **Yes!**

- "But Rick! I thought we could get to +2C before it was 'dangerous' "
- First, +2C is merely a round number proposed by economist William Nordhaus ~20 years ago as a target. It has no validity as a safe limit.
- It is fiercely argued for by policy people because of the investment they've made in years of political negotiations trying to find acceptable political solutions**. THAT is why you keep hearing about +2C. Roll your eyes when you hear the popular media claiming +2C is the safe limit.**
- Climatologist and Goddard Institute former head Dr. James Hansen has studied the implications and calls **+2C "A prescription for disaster**" (see his work summarized **here**)

Zero emissions leads to constant temperatures*. Temperature is a ratchet. It can go up, but cannot go down. Below from Matthews and Weaver 2010. Constant atmospheric CO2 composition requires a reduction of current emissions by ~70% (orange), yet temperatures still rise. Their models assumed instant zero in 2010



Coupled bio/climate models (but w/o permafrost melt) show zero CO2 emissions only yields constant temperatures… for centuries, even millennia (later work). Below is from Port *et al.* 2012



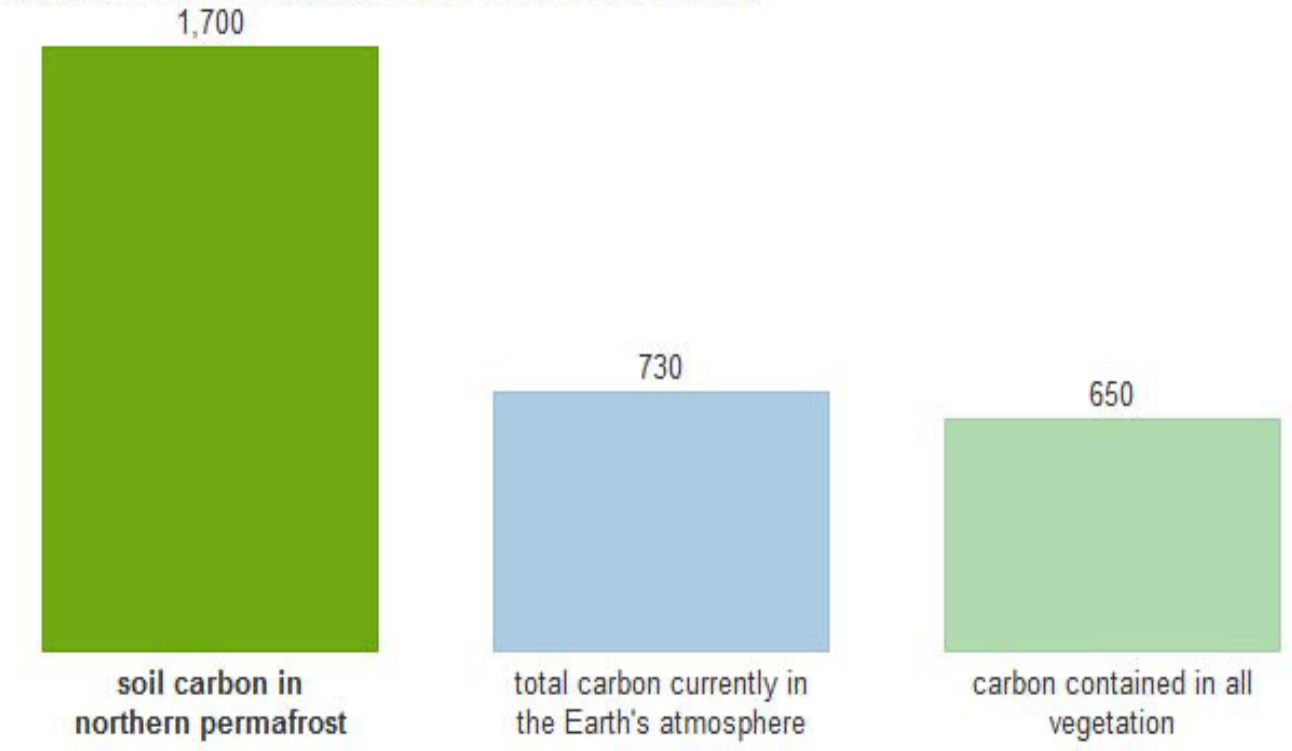
If we end not only CO2 emissions, but ALL Anthropogenic GHG's and their resulting aerosols, it's worse

- Because *e.g.* coal-generated sulfate pollution adds aerosols which reflect sunlight and cool climate, so ending fossil fuel burning aerosols will add an immediate WARMING.
- Zickfeld and Matthews (**2012**) show that, in this case, temperature immediately **rise** by several tenths C, then slowly go back down to the temperature at which the ending of all anthropogenic emissions ceased, but no lower.

Why is +1.25C Dangerous?

- …Because the Lawrence *et al.* 2008 studies of paleo data show that when the Arctic Ocean melts completely in summer, as it's close to doing now, the pulse of warmth extends as far as 1500 km southward across the Tundra. And further…
- …Because **Vaks *et al*. 2013** studied limestone cave formations throughout Siberia to discover that by **+1.5C**, in the previous inter-glacial, all of the Arctic permafrost is doomed to melt, releasing large stores of frozen carbon in the form of CO2 and methane over coming decades, centuries, and millennia
- We will not be able to stop those emissions, short of re-freezing the tundra, which would require **lowering** global temperatures, which, we just saw, won't happen.
- "Reducing emissions" as one hears in ostensibly climate-friendly advocacy, is complacency-inducing pablam! It is not enough – Re-freezing the polar ice caps is not possible without massive atmospheric CO2 removal and sequestration – which we don't know how to do (*e.g.* Bern2.5CC model on prev graph), or GeoEngineering.

There is more carbon in the Permafrost than in both the atmosphere and all Earth's vegetation combined. How much will be released to the atmosphere is poorly known at present



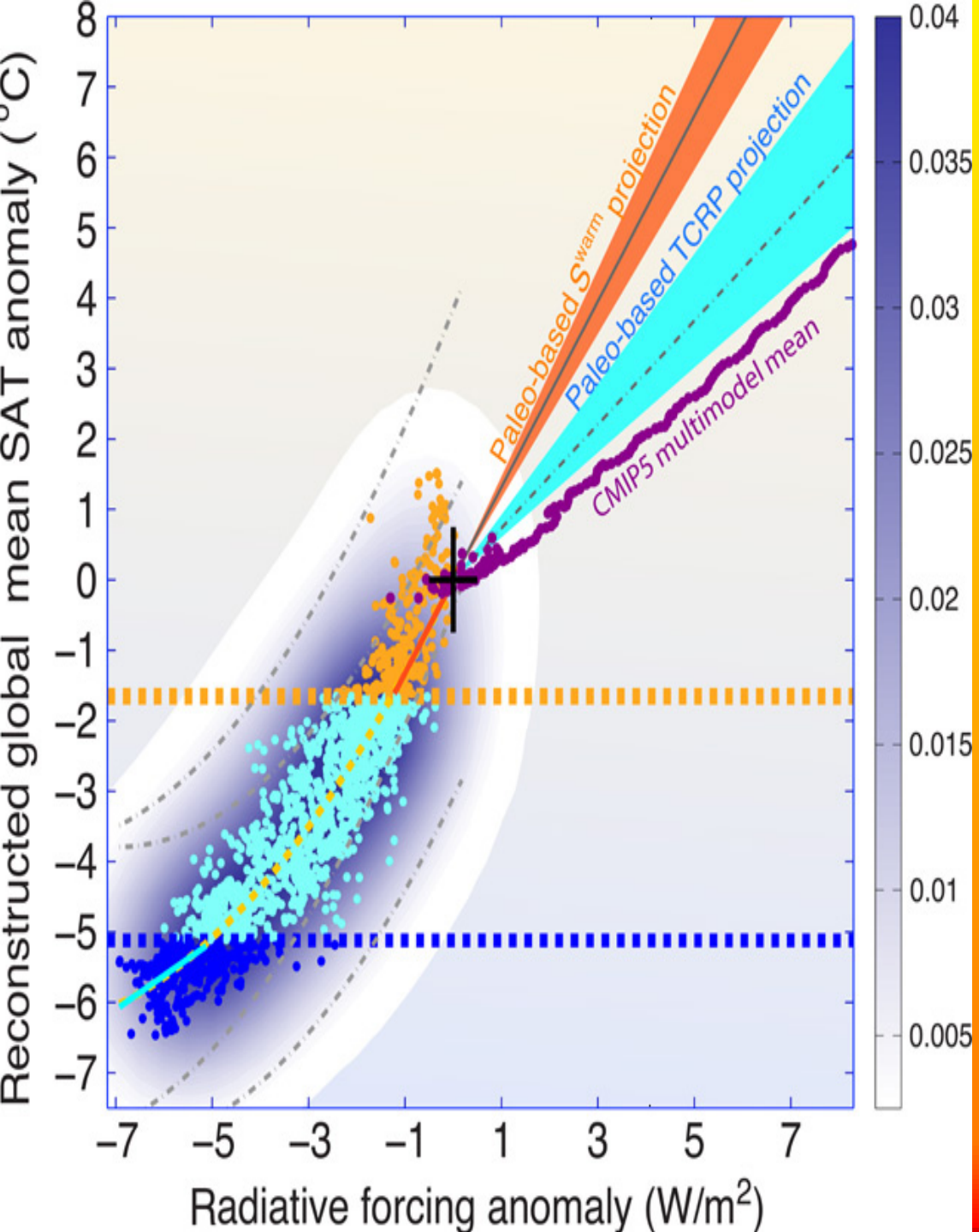
Methane craters are appearing in the Siberian Tundra. First seen in the Yamal ("Yamal", interestingly, means "End of the World" in the native dialect). However it would take a million of these to affect climate strongly

Since Presenting this Public Talk in summer '16, I've learned of MacDougall *et al.*'s work.

- Unfortunately, the earlier studies, based on non-ecology and 1-dimensional modelling, showing constant global temperatures if all human CO2 emissions cease, are too conservative.
- **MacDougall *et al.* 2012** instead find that the PCF (Permafrost Carbon Feedback) leads to self-reinforcing carbon emissions even after human emissions cease, for all climate sensitivities greater than 3.0C (and the best modern estimates are ECS =3C or higher, see *e.g.* HS12=**Hansen and Sato 2012**, well discussed **here**.
- But even ECS=3.0C is very likely conservative, since HS12 explicitly state they consider only the "fast feedbacks", yet slow feedbacks will add further to it, on longer time scales than a few centuries.
- Now, the latest work makes this situation much worse still…. (next slide)

Indeed, (Friedrich *et al.* 2016) find climate sensitivity itself is non-linear: ECS increases at higher temperatures

- ***i.e.*** climate does have positive feedbacks which amplify the warming direction non-linearly. They find that **ECS=3.22C** best fits for the average over the entire glacial and interglacial past million years, in agreement with Hansen and Sato 2012.
- But **ECS = 4.88C** during the high temperature regimes of this period, and is as low as ECS=1.78K for the glacial periods alone. **This shows strong ECS sensitivity to global temperature**.
- They take great pains to point out how using only the average ECS=~3C **will substantially underestimate** how hot climate will evolve in the future, given our current CO2 level of 404ppm, which is well above the 280ppm maximum during all other interglacial periods. Adding in “slow feedbacks” (Hansen et al. 2016) will make ECS even higher over long terms.



Friedrich *et al.* 2016 Fig 3. Dots are paleo data: a straight slanting trend would indicate ECS is the same at both low and high temperatures. Clearly, paleo data shows a strong curvature upwards. The orange band assumes **ECS=4.88C holds today** and for the future. But the curvature suggests ECS might be even higher still

Atmospheric CO2 for 300 years after ending all Anthropogenic CO2 and sulfates emissions (MacDougall *et al.* 2012). Unlike earlier models, this includes the Permafrost Carbon Feedback, hence higher ECS can lead to amplifying feedback of thawing carbon release. Friedrich *et al's* ECS=4.9C is above the black curve here; showing CO2 concentrations continuing to rise strongly, driving higher temperatures

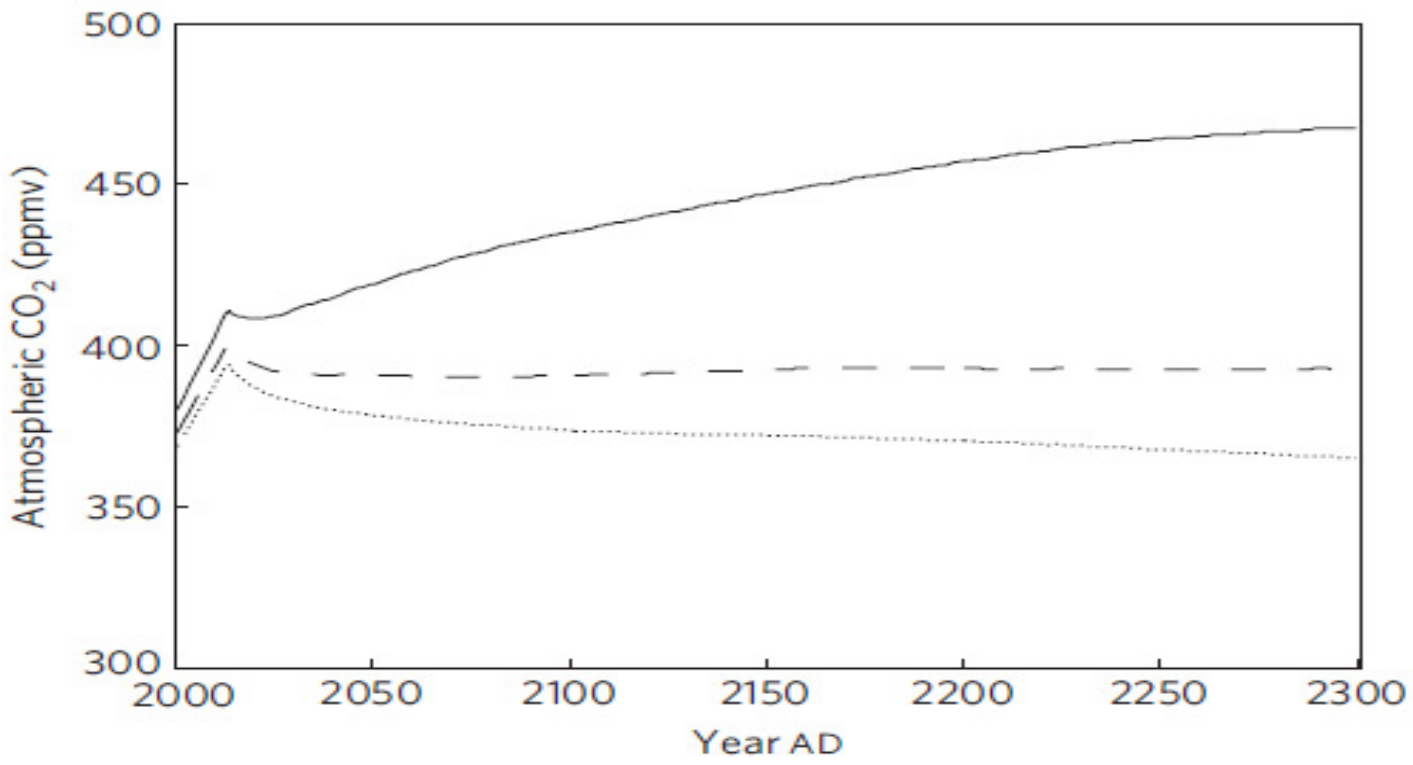
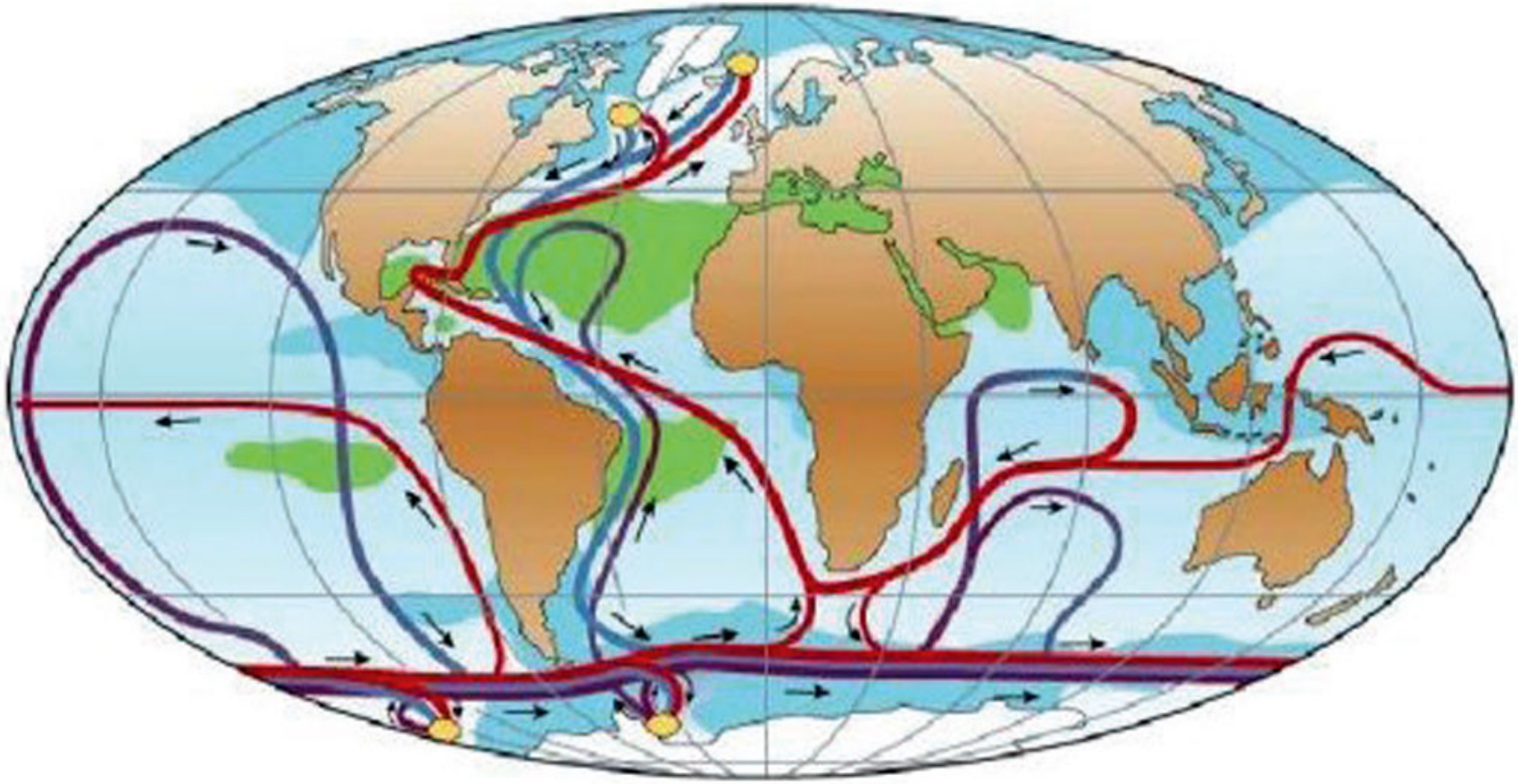


Figure 3 | Evolution of atmospheric CO_2 concentration in response to a cessation of anthropogenic CO_2 and sulphate emissions in the year 2013. The dotted line represents the response for a climate sensitivity (to a doubling of CO_2) of 2.0 °C, the dashed line a climate sensitivity of 3.0 °C and the solid line a climate sensitivity of 4.5 °C.

How Will This Affect the Globe?

- If Friedrich *et al.* and MacDougall *et al.* are correct, climate is already past this tipping point, and therefore it will be very difficult to halt temperature rises going forward, **even if we end all human-caused GHG's.** We can expect…
- Amplified glacial melt
- Shut down of the ocean thermohaline circulation, with dire consequences.
- And more….

Near +2C, paleo data shows that the global ocean circulation shuts down (Hansen *et al.* 2016), as it did during the prior interglacial. Note the two Deep Water Formation locations in the Northern Hemisphere are off Greenland.



(Rahmstorf, Nature 2002)

But Greenland is melting rapidly, and meltwater will cool the offshore surface waters (2nd and 4th rows). This physics is missing from the IPCC Models (top row). IPCC assumptions and climate model were both different than Hansen's, so global comparisons are made difficult – but the point here is that Greenland melt makes for large areas of North Atlantic cold surface waters

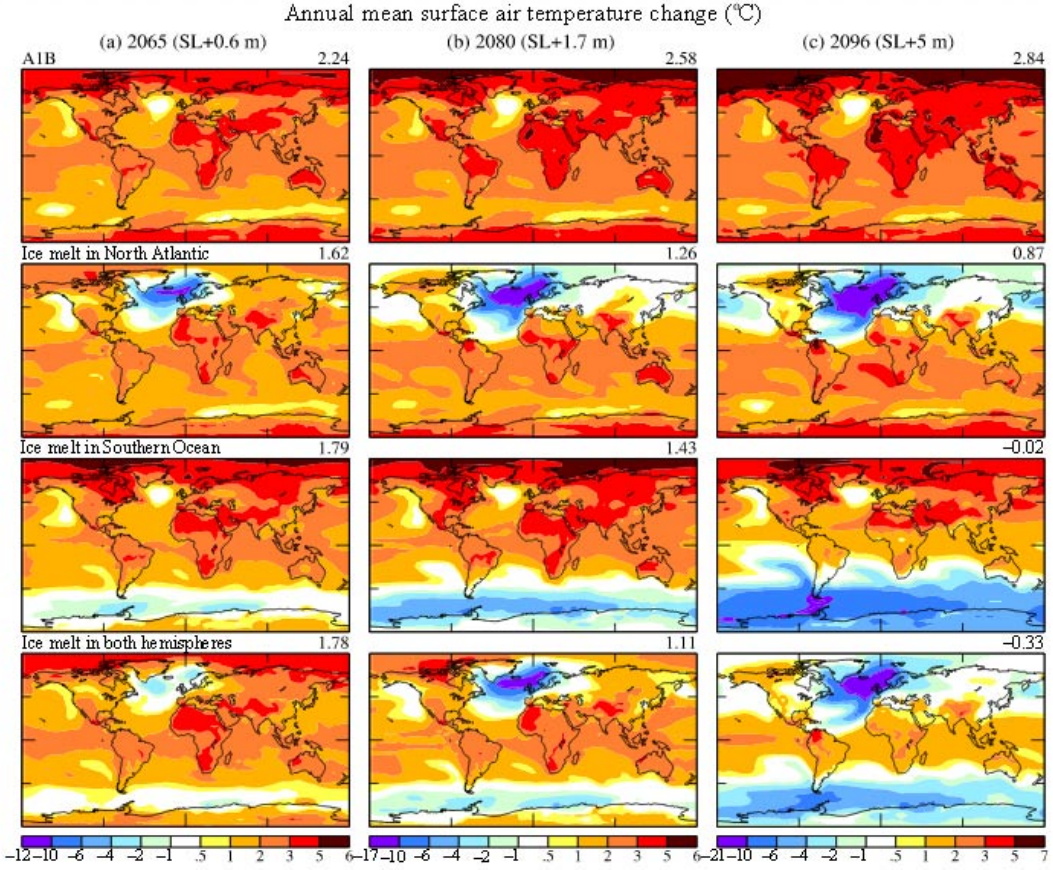


Figure 6. Surface air temperature (°C) relative to 1880–1920 in **(a)** 2065, **(b)** 2080, and **(c)** 2096. Top row is IPCC scenario A1B. Ice melt with 10-year doubling is added in other scenarios.

Rapid melting of Greenland is producing thousands of square miles of cold low-density surface fresh-water near Greenland, generating a larger thermal gradient relative to hotter equatorial waters as ocean circulation shuts down, and will drive SuperStorms. This happened during the last Interglacial, when these ~1000 ton boulders were tossed up onto the shores of the Bahamas, apparently by storms generating waves of enormous power…

Fig. 1. Two boulders (#1 and #2 of Hearty, 1997) on coastal ridge of North Eleuthera Island, Bahamas. Scale: person in both photos = 1.6 m. Estimated weight of largest boulder (#1, on left) is ~ 2300 tons.

Enormous boulders tossed onto an older Pleistocene landscape (Hearty, 1997; Hearty et al., 1998; Hearty and Neumann, 2001) provide a metric of powerful waves at the end of stage 5e. Giant displaced boulders (Fig. 1) were deposited in north Eleuthera, Bahamas near chevron ridges and runup deposits (Hearty, 1997).

… Waves capable of generating wash-back chevron deposits which are over 2 miles long and 50 feet high (Hansen 2016). Pause and try to imagine storms capable of such waves

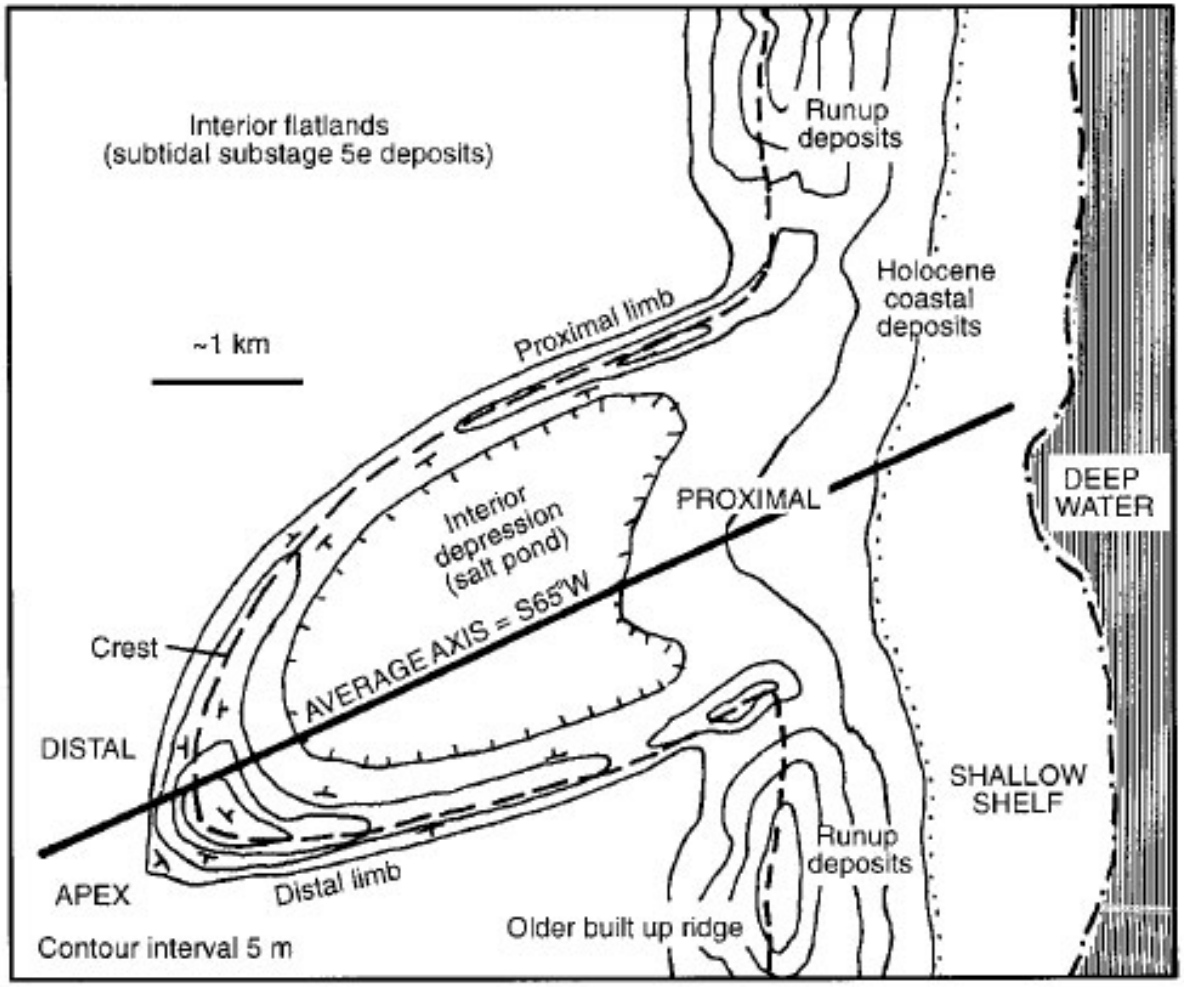
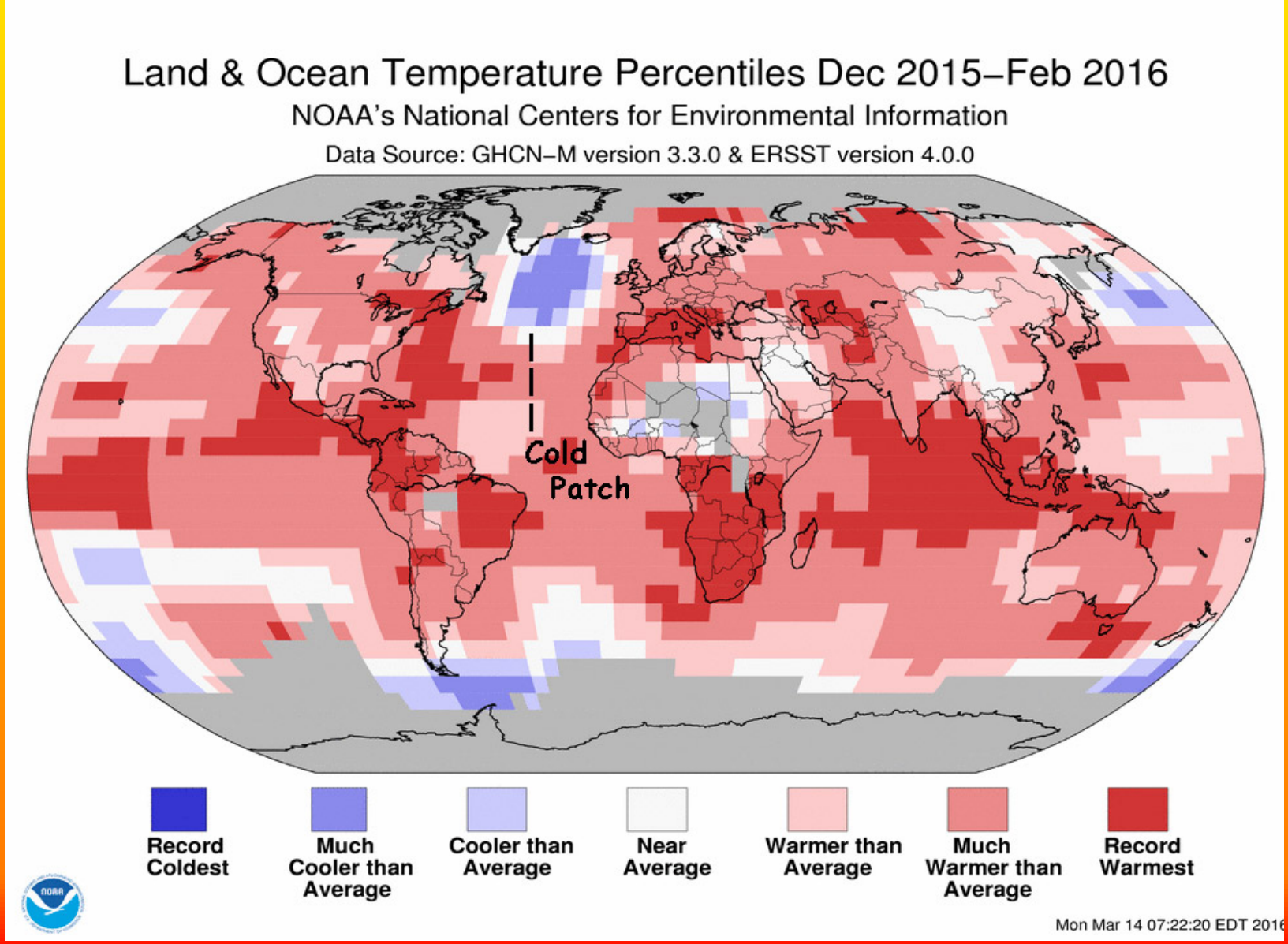
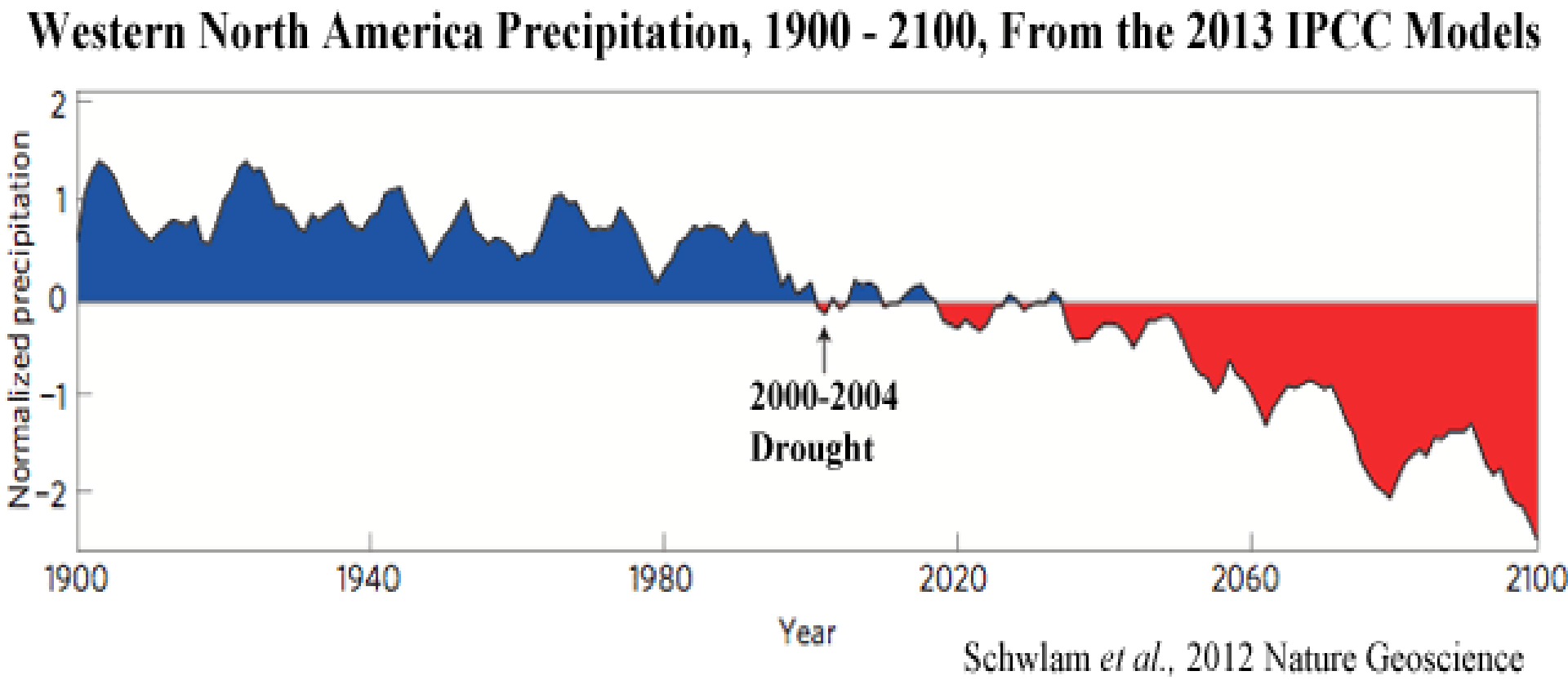


FIG. 1. Schematic map of chevron beach ridge.

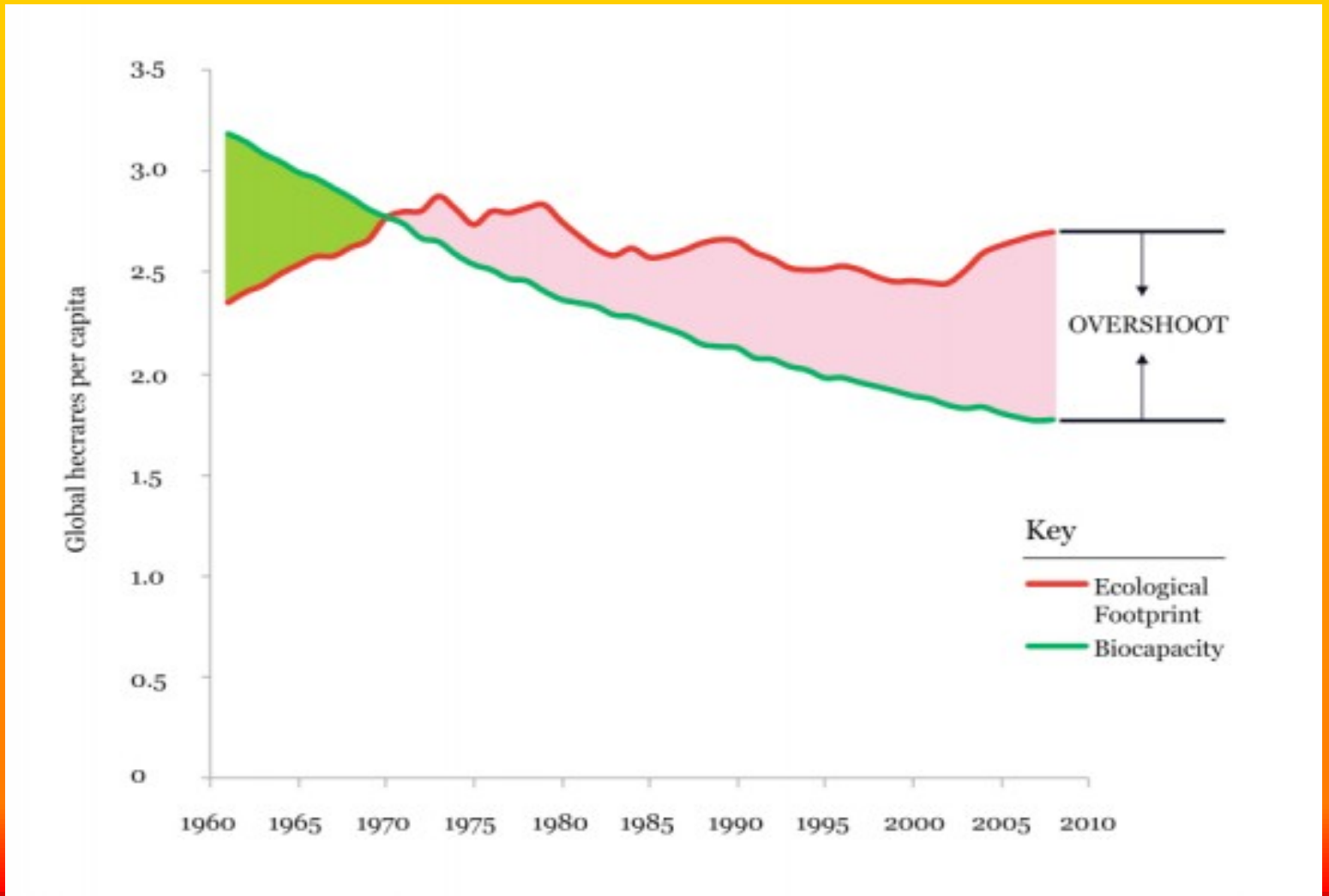
The process has already begun… See the cold water (blue) now forming off Greenland in current data



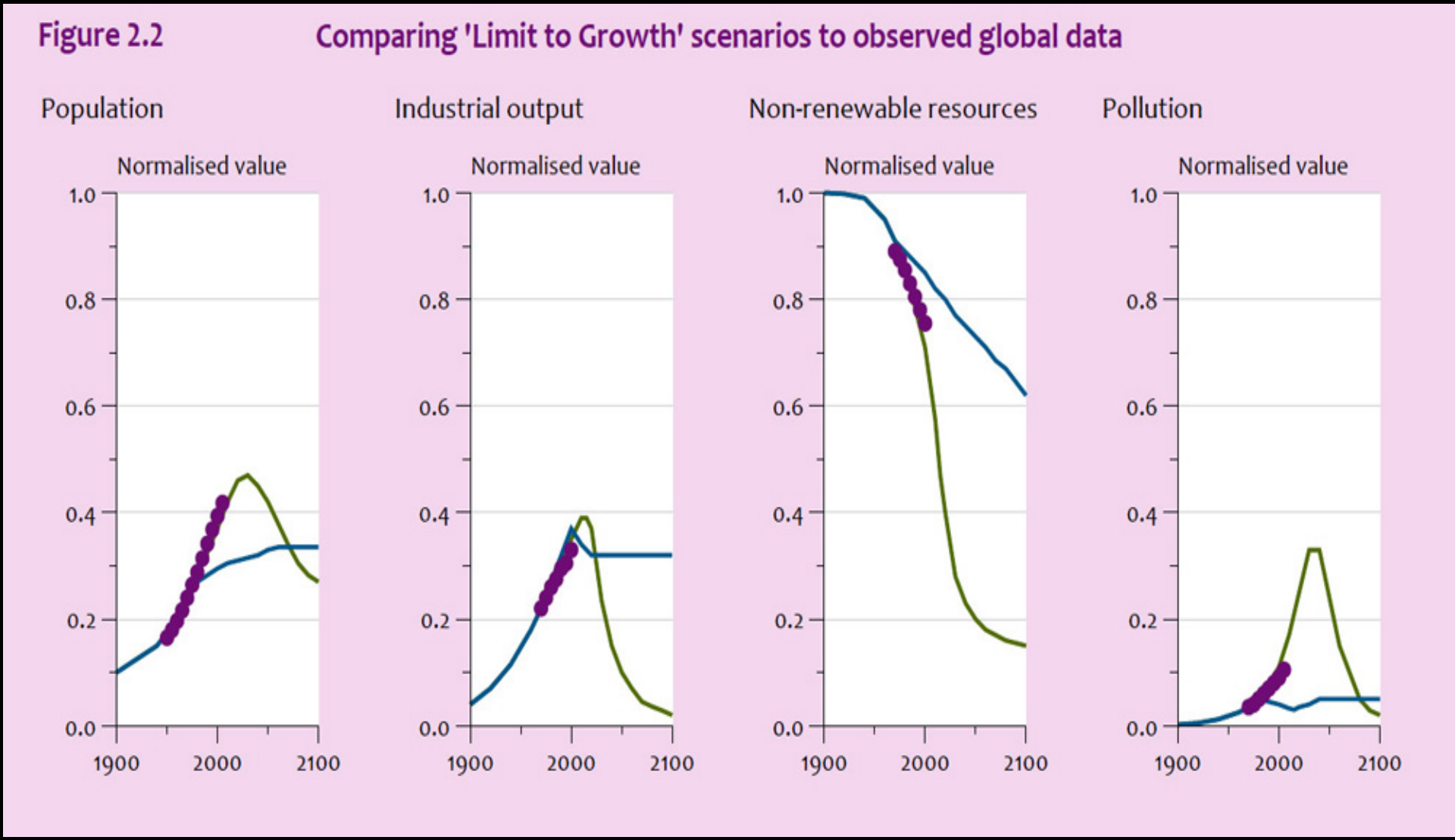
Meanwhile, back home… Even the overly optimistic IPCC AR5 models say – Droughts in the American West are just getting started



The Bio-capacity of Earth continues to decline from over-exploitation, while the demands of soaring populations have us rapidly eating through our "seed corn". We lost ground only slowly during the "Green Revolution" of GMO's and Monsanto, but now rapidly falling further behind in the 21st century



Our population, industrial output, non-renewable resources, and pollution are all on "Overshoot-and-Crash" trajectories (see next slide, from van Vuuren *et al.* 2009 a study for the Netherlands Government)



So; how drastic must policy actions be?

Is our goal to merely slow the descent into chaos, or is it rather to truly halt climate change?

What is physically possible?

Enter – the insightful discoveries of cloud physicist Prof. Tim Garrett

My Introduction to Tim Garrett…

- I first heard of Garrett from proselytizer of near-term human extinction **Guy McPherson** in 2014 when he came out to join a public panel discussion, with me, in Santa Cruz on climate change and the future.
- McPherson implied Garrett supported the idea of human extinction because civilization was a "heat engine" and our own waste heat would cook us all.
- But that's just wrong; the waste heat of industrial civilization is less than 1% of the heat we TRAP via our CO2 (**Flanner 2009**). In fact, too many of McPherson's Near Term Human Extinction claims are from distorted or mis-interpreted science, obsolete science, or otherwise just **plain wrong**.
- So who WAS this Garrett fellow? McPherson urged me to look at his work and I promised I would. But this introduction didn't motivate me to get right on it. It took a few months before I got around to it.

When I finally began reading Garrett's papers…

- …I was surprised and impressed. He's not a advocate of the **Near Term Human Extinction** meme, and the "heat engine" reference was clearly misunderstood by McPherson (who is not a climate scientist).
- Garrett has nothing to say about human extinction, instead, has shown a close and simple relationship between the historical growth of civilization and its current required energy consumption rate, connected it to thermodynamic ideas in a logical way, derives a quantitative climate/economic model and identifies its key variables, which differ from those of traditional economic and IPCC modelling. He then shows such traditional models are missing key connections which impose strong constraints on our climate policy options.
- Let's explore these discoveries…

The Key: The Rate of Consumption of Energy is Proportional to the Accumulated Wealth of Civilization

- **Garrett 2012 (**and references therein) has developed a thermodynamic model of the relation between the global economy, energy use, and carbon emissions. The underlying thermodynamic approach has proven to have **wide application across dynamical systems .**
- His prediction and subsequent confirmation of a simple global relation between energy consumption rates and the accumulated Gross World Product (GDP summed all countries, summed over all time) and its theoretical link to Civilization as a thermodynamic system, is a unique and insightful new synthesis and has sobering implications.
- **Alas, his work has been misunderstood by many.**

It's an Elegant Thesis

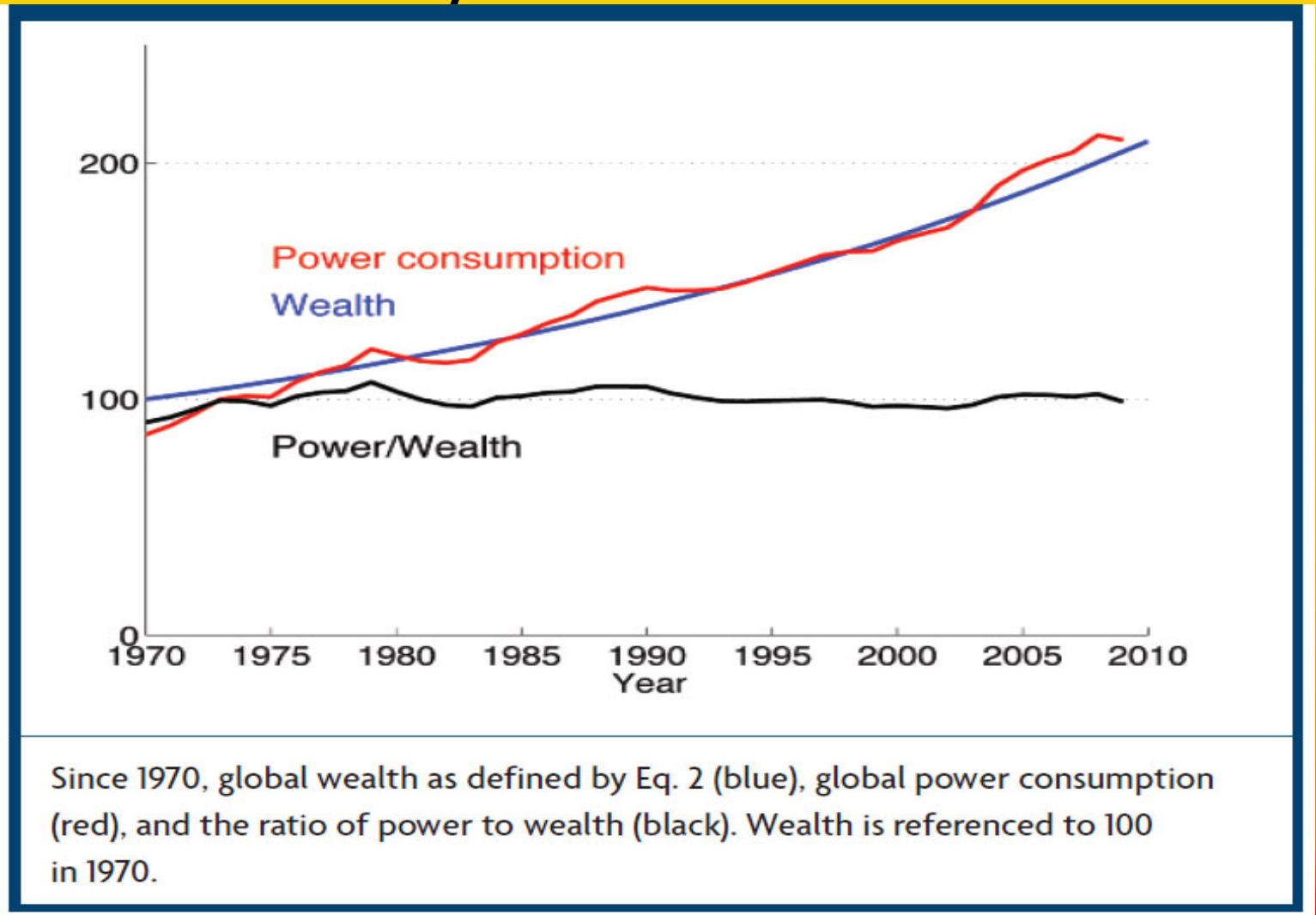
- The theoretical basis for the equations he derives which lead to this prediction is the science of **thermodynamics – the study of the flow of heat, entropy, and energy, and their relation to generating useful work**
- Maintaining Civilization requires a battle against the **2nd Law of Thermodynamics** (the decay of ordered (i.e. low entropy) energy into disordered (high entropy) energy. The ultimate in disordered energy is **heat** – the energy of random motion of atoms and molecules.

Energy must be taken from a low-entropy "ordered" state, and "disordered" in the act of getting useful work from that energy.

- Useful work meaning… make things, repair things, grow food, write a symphony … anything useful at all)
- Garrett's ***C****limate and* ***Th****ermodynamics* ***E****conomic* ***R****esponse* ***M****odel* (**CThERM**) a computational model which results from this, has been **successfully back-tested** against a history of past data, and shows high skill scores when compared to simple extrapolations of existing trends

- **The hypothesis is testable, and succeeds…**

Historical energy consumption rate (power) and total accumulated wealth, plotted on top of each other for clarity. Result? They're directly proportional; *i.e.* black curve is flat. (Recent new data extends this through 2014.) I will be calling this "The Garrett Relation". Now why should this hold…?



Since 1970, global wealth as defined by Eq. 2 (blue), global power consumption (red), and the ratio of power to wealth (black). Wealth is referenced to 100 in 1970.

Thermodynamic laws are only simple in a closed system. Energy consumption and economic growth are now seen to be elegantly simple as well, but only when seen in a GLOBAL (hence closed) system

- The great discovery moments in physics have come from the realization and appreciation of elegant symmetries obeyed in Nature.
- Should we be surprised that one product of Nature – humans and human enterprise – might also obey elegant simplicities when the artificial isolations focused on by many economists are removed? (In fairness, so many quantities of economic interest exist on smaller scales, and are not closed systems, and are therefore indeed very complex and hard to model)

The larger an economy, the more energy required merely to maintain its current state against the natural forces of decay

- Even the goods and services long gone in the distant past still enhanced our ability back then to grow into what we are today. Properly appreciated, the relevant "Wealth" is not merely present existing goods – it is **total** accumulated spending over all time. Why?
- **Wealth:** it's not in things themselves, which require perhaps physical maintenance (re-painting, repair, etc.), but rather it is the relationships which are enhanced between things and people which constitute the "wealth". Enhanced relationships, is the intent and value of that spending, and constitutes the real Wealth.

Wealth: It is in the Enhanced Networks of Relationships within Civilization

- Garrett uses the example of a road. Its value is in the efficiency with which it provides so many opportunities to expand countless relationships through its existence. Less tangibly, a symphony can inspire, energize, and promote enhanced relationships if it touches our core values and enhances our desire to live fully.
- Because these relationships are subtle, non-physical, and extend in countless directions not obvious at first, there is a quality of "emergence" to them, which enhances their value beyond the most obvious initial connections one might make
- Thus, the realization that the global rate of energy consumption should, by thermodynamic reasoning, be proportional not to current GWP (GWP = **G**ross **W**orld **P**roduct), but to the total ACCUMULATED GWP of the world over all time

Climate is global - The diffusion time for atmospheric CO2 is only a few weeks.

- The atmosphere's greenhouse gases are "well mixed". This is fundamentally important. All countries' CO2 becomes all other countries' CO2 very quickly.
- **Likewise, economies, too, are "well mixed" in the modern world** – the trade flow of wealth and materials between countries is rapid in comparison to the evolution time scale of the global economic system as a whole.

Therefore, studying one country in isolation, and ignoring the flows of material, energy, and money across its borders can lead to dramatically wrong conclusions.

- Similarly, The **2nd Law of Thermodynamics** will **appear** violated if one only looks at an increasingly ordered complex growing system and ignores the even larger amount of disorder imposed on the rest of the surrounding environment by the energy required to create that complexity.
- Not only does this approach greatly simplify studying the relation of economics to energy and climate, but in fact…We NEED to consider things globally in order to avoid making fundamental errors due to false or missing feedbacks between the hundreds of parts of traditional complex economic models, which are too often only **fitting functions without fundamental theory** to support them
- **But there's a deeper truth here…**

Jevon's Paradox

- **Implicit in the Garrett Relation is the observational confirmation of what I will call "Generalized Jevon's Paradox"**

- Most eco-friendly advocates and policy cheerleaders compose or cite "white papers" and speeches claiming that if we just increase energy efficiency, we'll make big strides in cutting CO2 emissions.

But this claim is naïve. It's like a novice chess player, who, upon taking your rook with his pawn, gives a satisfied look of triumph, only to find 4 moves later that his king is trapped. You MUST look several moves ahead to get the real picture.

The savings claim implicitly assumes that the "dollars" saved in efficiency <u>are never spent</u>. It assumes, essentially, that the wealth created by that savings, denominated by that money, is **<u>destroyed.</u>**

History shows quite the opposite

- **Instead, those savings will be used to GROW Civilization, both enabling and necessitating its accessing new energy sources.**
- And since there is 7.1 milliwatts of new ongoing power needed for every (2005 inflation-adjusted) dollar of goods and services ever produced, net CO2 savings do not happen, but in fact CO2 generation gets worse
- **This is an example of a wider meaning of "Jevon's Paradox**", first discussed by William Stanley Jevon in 1865, who observed that increasing the efficiency of steam engines' burning of coal made for a significant INCREASE, not decrease, in coal consumption.
- A more limited aspect of this phenomenon is commonly called **"Rebound", which is different.**

Those Who Dispute Jevon's Paradox; Look Closer…

- Narrowly interpreted ("rebound", e.g. coal steam engine to coal steam engine, say), yes - it does not necessarily apply, and indeed the **link here** includes links to advocates who believe that "green taxes", for example, do not display Jevon's Paradox. More recently, even in 2017 I've heard this misunderstanding made at the UCSC Climate Conference by David Austin (begin 10min into **this lecture**)
- **But here, they fail to realize that ANY economic activity requires energy. This is key to understanding how CO2 emissions relate to economic growth.**
- **In other words, even if the savings of coal in coal-fired steam engines did not stimulate making more steam engines burning more coal, the money saved would have gone SOMEWHERE in service of ourselves, and that SOMEWHERE would have needed energy to fuel it.**
- **To distinguish this globally understood form from Jevon's early formulation, and the "straw man" it has become for some policy people, I will call this…**
- **Generalized Jevon's Paradox**

Generalized Jevon's Paradox

- **Increasing energy efficiency (*i.e*. the ability of a given quantity of energy consumption to produce more economic wealth) will lead not to a lessening of energy consumption, but rather to an increase in energy consumption, as the savings from the increased efficiency can and will be spent in ANY area of life, expanding civilization and its therefore its energy needs (Garrett Relation).**
- **Historical evidence shows any spending, as reflected in Gross World Product, will require new consumption of additional energy to enable it.**

“Backfire”

- …is also a term one hears here, meant to imply higher efficiency leads to more, not less consumption.
- But in recognition of the painstaking (and painful) work and insights of Stanley Jevons, and also to distinguish this from all the other meanings for “backfire”, I will stick with **“Generalized Jevon’s Paradox”** and hope it catches on.
- Tim Garrett agrees, and likes the term

"Being able to falsify a result lies at the core of the scientific method. It must be possible to set up a test that could lead to a model being discarded" – Tim Garrett

- The above is from Garrett's article with the blunt title **"Macroeconomics is not a Science", examining the unphysical heuristic curve fitting that is common in macroeconomics**
- Integrating physics (thermodynamics) with civilization's economic aspects, on the other hand, does qualify in this regard…
- (from same article) **"Current global rates of energy consumption growth and GWP growth can be accurately predicted based on conditions observed in the 1950s, without appealing to any observations in the interim, with skill scores >90%."**

- For more detailed study of Garrett's work, see key papers linked near the top of this page of mine.

But Wait! You Say…

- “Money I save through efficiency might be spent in less energy-intensive ways. Maybe I’ll take the money saved and buy more vacation days, and on my vacation days I could go hiking or just reading.”
- But to the extent that you don’t spend or invest those savings dollars, they are not getting reflected in GWP (and integrated GWP means energy, as data show). And if they are spent (even to buy a bike or running shoes), then the 7.1 mW of power per 2005 dollar does apply.

More central to the argument: Even those running shoes are helping you to become a better, healthier, happier, more expansive person and thereby increasing your future energy needs

- In other words, the consideration above is already reflected in the historical data – the same data that confirms the **Garrett Relation**.

There is only one alternative

- – if wealth is actually destroyed or does not lead to further enhanced ability to exploit energy resources (*i.e.*, it was not productive wealth creation),
- In that case, it is a different form of “inflation”, a term explicitly in the CThERM model
- Recognize the more general nature of “inflation”, it extends beyond just nominal monetary inflation (Fed printing presses), but also to include destruction of wealth not paired with destruction of the money which denominates it.

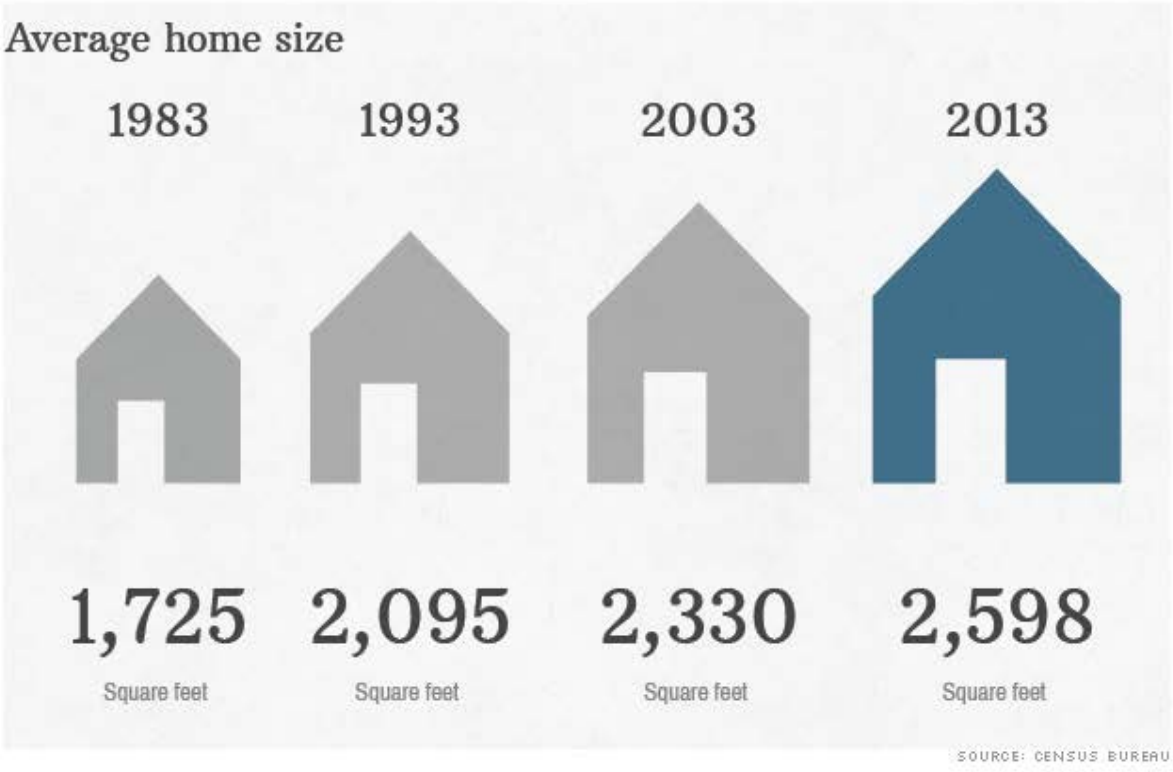
Efficiency Gains Lead to MORE Energy Consumption, not LESS

- This key fact (Garrett 2012) is simply missed, ignored, or distorted into a "straw man" by policy "white papers" and promotional publications and speeches.
- They ignore what humans actually DO with efficiency gains in energy production – we do not destroy those "dollars", we do not get happy with a static lifestyle that costs less. Instead, we strive to grow further, perhaps in new ways, and that means higher, not lower, energy consumption.
- This goes a long way in explaining the differences between reality-based analyses like Garrett's, and extrapolations focusing only on assumed declining carbonization, with no thought to what increased energy is required to accomplish that decarbonization, or how improved efficiencies will actually (*vs*. hoped for) affect economic activity.

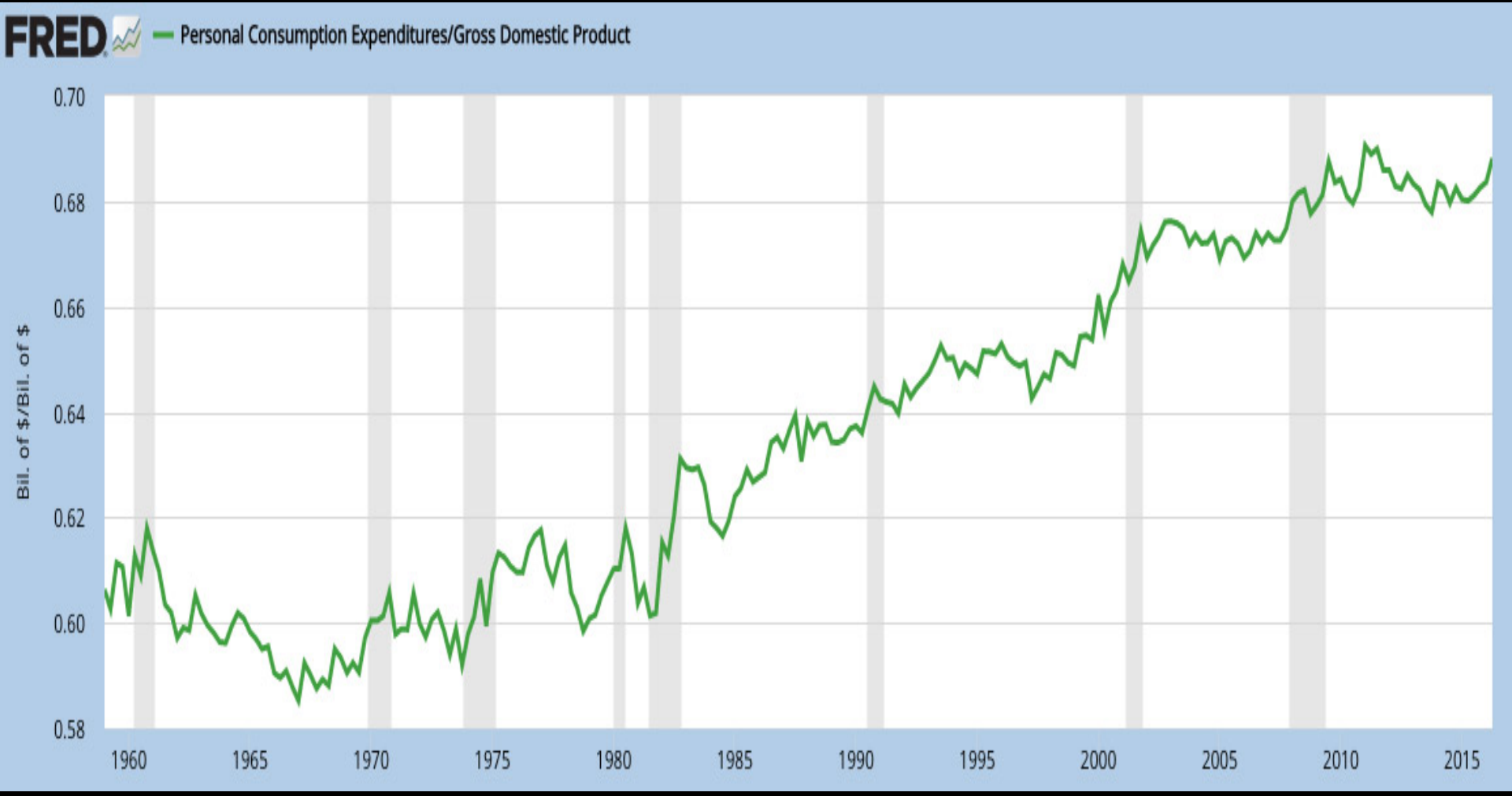
A Good Example of this Poor Grasp, from the Otherwise Laudable National Resources Defense Council

- …in an article linked **here**,
- They fundamentally miscast those who point out the existence of "rebound", as enemies of renewables (certainly not true), and then try to disprove rebound by cherry-picking individual countries such as Germany and the U.S. in isolation from the fact of global trade and **off-shoring of CO2-generating manufacturing**
- They compound their errors by attacking the notion of current GWP being proportional to energy consumption, failing to have read and digested that the relevant proportional quantity is instead GWP integrated over all time.
- And worst of all, they assume "rebound" narrowly refers to only the use of more of the same product that one has savings in, and ignore how the efficiency-created new wealth can rather be spent in any area of civilization
- Jevon's 1865 original formulation does not apply. Ignore it. Instead understand **Generalized Jevon's Paradox**

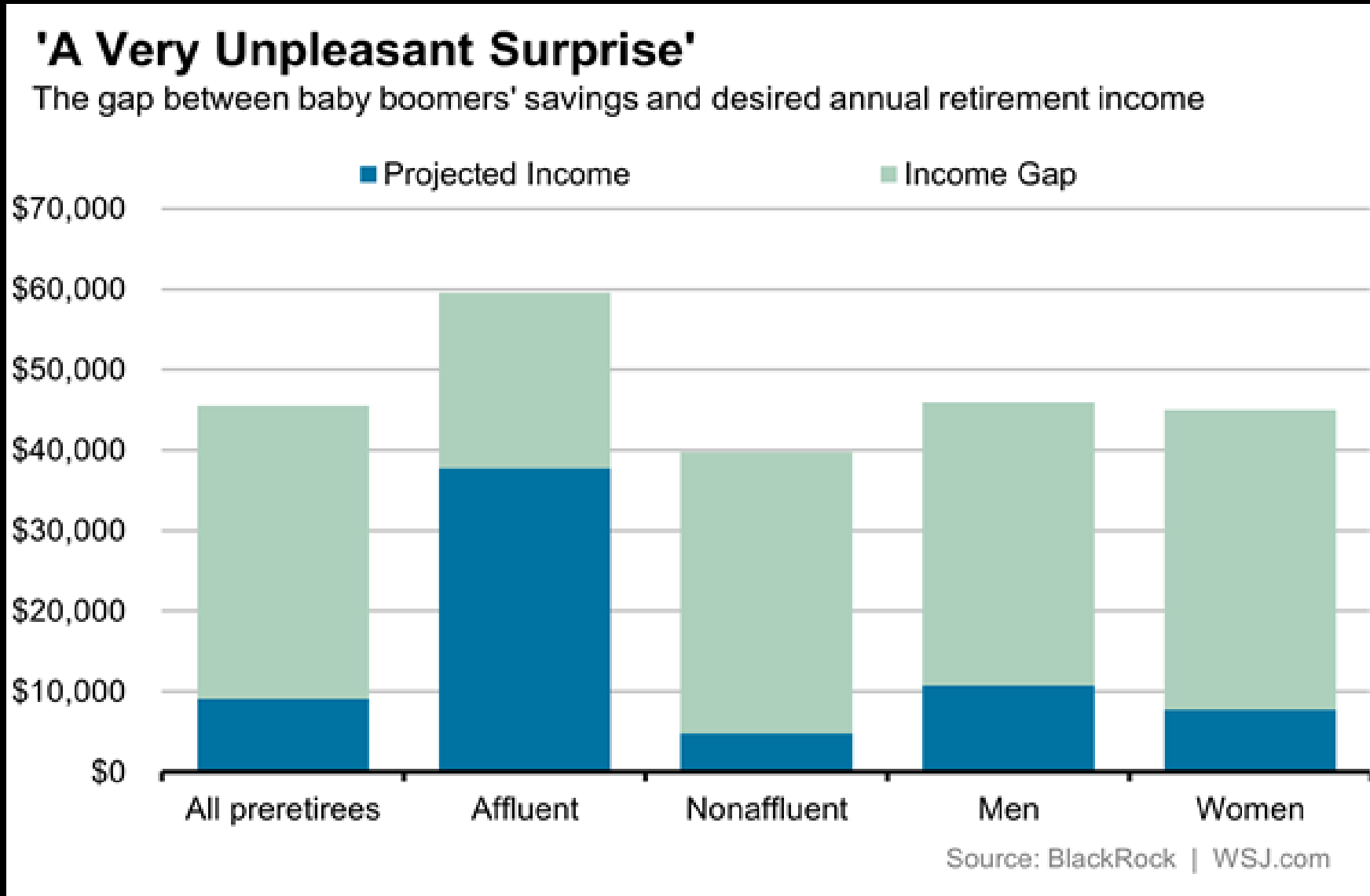
We Do Not Save our Efficiency Savings, We SPEND them; on Bigger Homes…



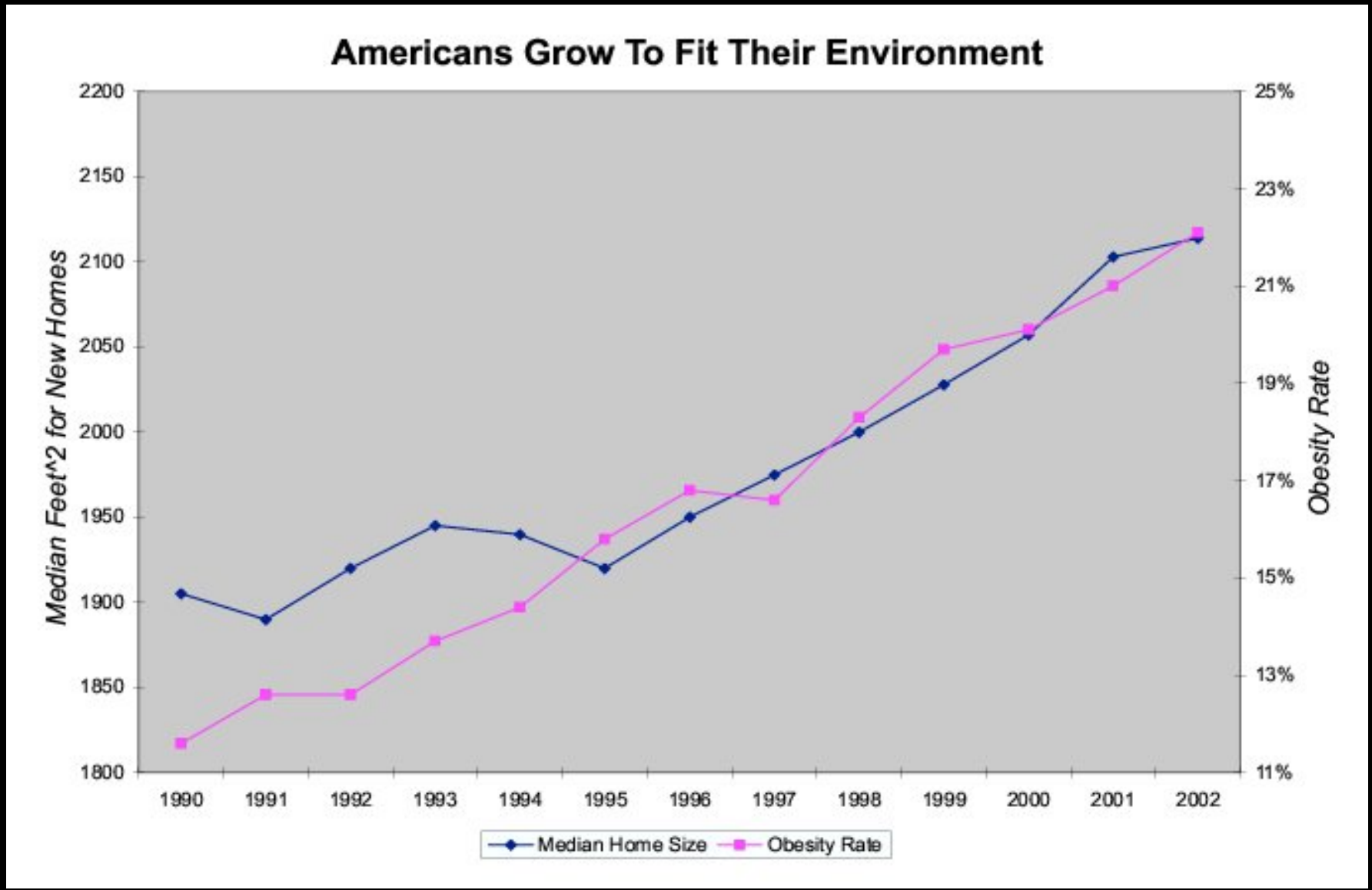
…on more consumption spending per $ of GDP



And We're NOT Saving. Even for our own Retirement

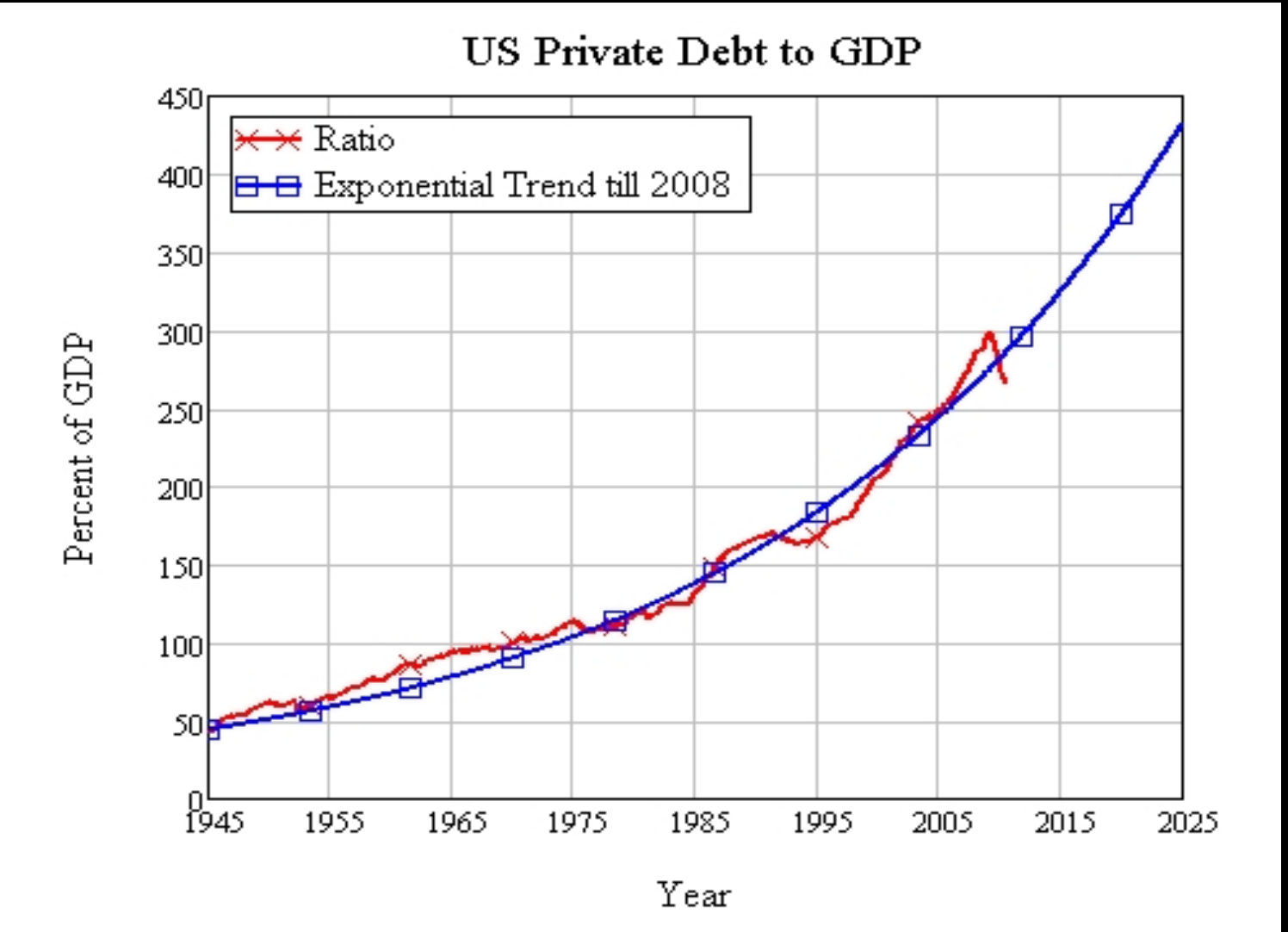


We're "Livin' Large"; making ourselves <u>obese</u> with our consumption



Yes – Livin' Large!

…Even if, to do it, we have to borrow from future generations, impoverishing them. Debt/GDP is Exponentially Increasing



Well, Rick - what if I just leave my energy efficiency savings in the bank and don't spend them?

- Even if you simply leave your savings in the bank, the bank uses those dollars as an asset base enabling lending out a multiple of those dollars (newly minted money out of thin air) to others who will spend them. So that's also a no-win. (We all live in a fractional reserve banking system-based world)
- Thus, if you're going to avoid expanding energy generation rates, you have to destroy the "dollars" saved through efficiency gains.

So, We have to Essentially BURN Our Piles of Efficiency-gained Cash??

I Wish it Were That Easy… No, it's Worse

- The cash only denominates Wealth, and if the wealth remains, the ability and reality it enables and requires - that of further growth in energy consumption - remains.
- Burning the cash only makes for "negative inflation" after it's burned. It doesn't help our dilemma – our necessary goal being to LOWER Civilization's Energy Consumption, Which Requires Shrinking Civilization Itself.
- We need to actually cripple civilization's ability to grow, or else voluntarily halt that growth by policy action or (impossibly hard?) universally embraced and continually summoned human will power

To avoid Generalized Jevon's Paradox, improved energy efficiency savings cannot be spent elsewhere. Even spending them on de-carbonizing will require energy, and will raise CO2 emissions in the present (but better spent on decarbonizing than on more consumption)

- **This last observation may help explain the next graph, which many of you will find surprising. As a set up, consider…**

Pop Quiz Question!

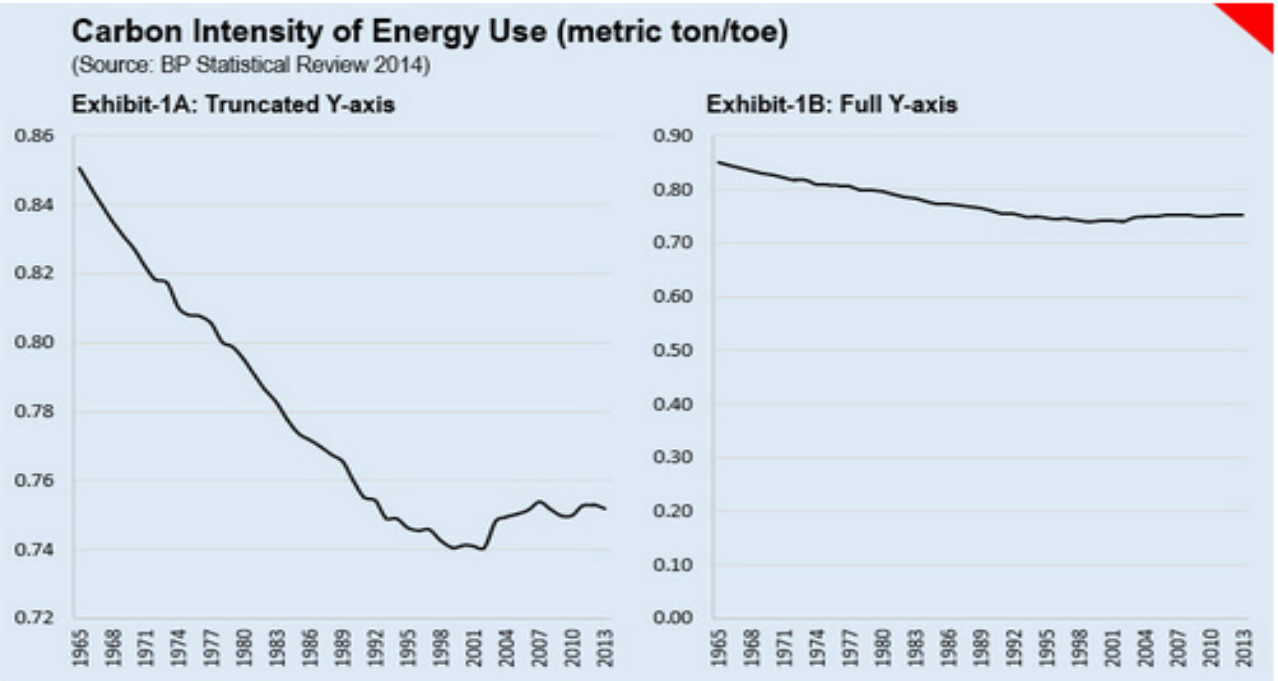
- You've heard of all the great strides we're making in Renewable Energy…
- Now, in the past ~decade, looking at total global energy consumption…

- **Has the fraction from Fossil Fuels…**
- A. gone down substantially?
- B. gone down a little
- C. gone up a little?
- D. gone up substantially?

We've All Heard the Cheerleading of Solar and Wind Power Taking Over the World

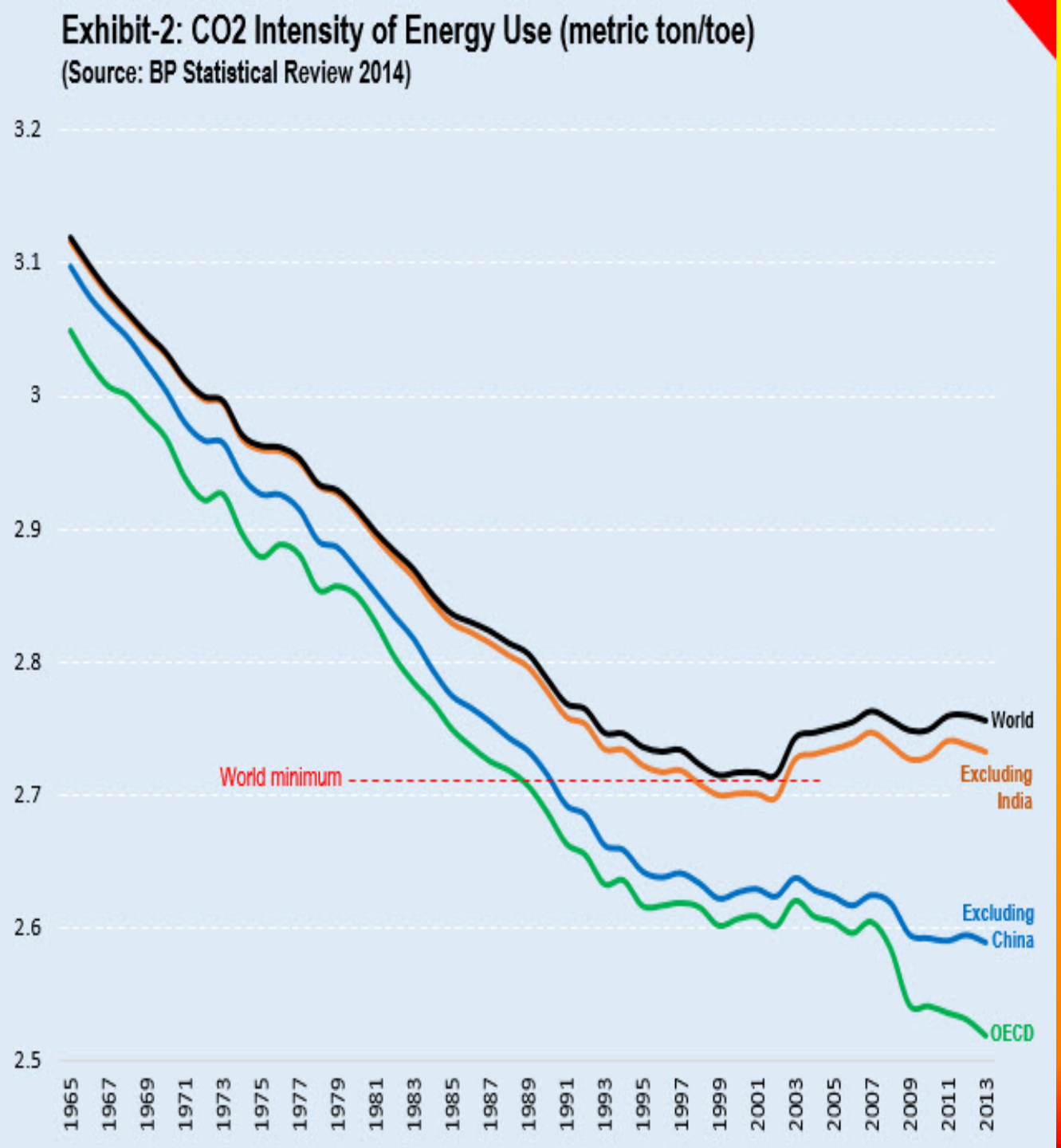
- I'm guessing you expect the carbon intensity of energy (**CI**) over time has been nicely dropping here in the 21st Century, after perhaps rising during the dirty 20th Century.
- Dropping in the 21st century… as solar and wind take the place of coal and oil, after the Industrial Age ramped up during the 20th Century.
- Is that your guess? Let's look at the actual data…

Global carbonization of energy dropped in the 20th century, but in the 21st it reversed, then halted, despite the rise of solar and wind power. Economic growth has been faster than the strides made in renewables.



A Closer Look

From here on, the numbers will show CO2 intensity instead of carbon intensity, because the original data from BP and the EIA report CO2 emissions. To convert CO2 to units of carbon (C), simply divide by 3.667. Carbon intensity and CO2 intensity are used interchangeably in the text – both are ratios that depict emissions generated versus energy produced. In the relevant literature, CO2 intensity is also reported as a ratio of CO2 emissions to GDP--which includes the effects of prices. In this note however, CO2 intensity is measured in physical units--metric tons of CO2 per tonne of oil equivalent (toe). Also, 1965 is the first year for the data published by BP.



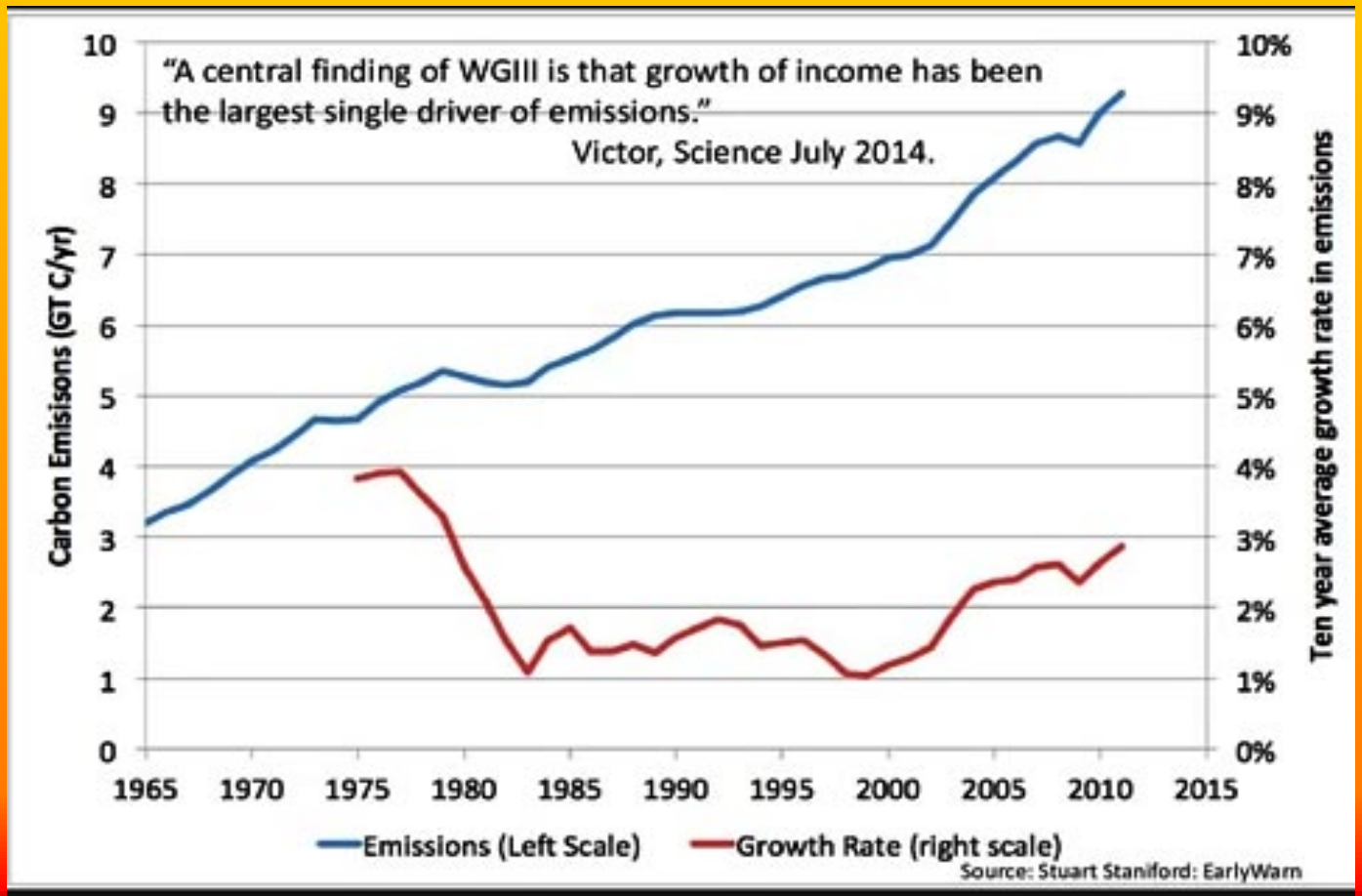
CO2 intensity per unit of energy generated. Strong growth from China (coal) halted decarbonization this century. Even the non-China world (blue) has slowed its de-carbonization, although it's still continuing. Developed world (OECD green) is doing better. The current (2016) global economic slow-down may see these curves resuming downward, is my guess. But *Climate cares ONLY about the black (world) curve!*

Note: The exponential fitted halving time of carbonization for 1965-2001, is **180 years**

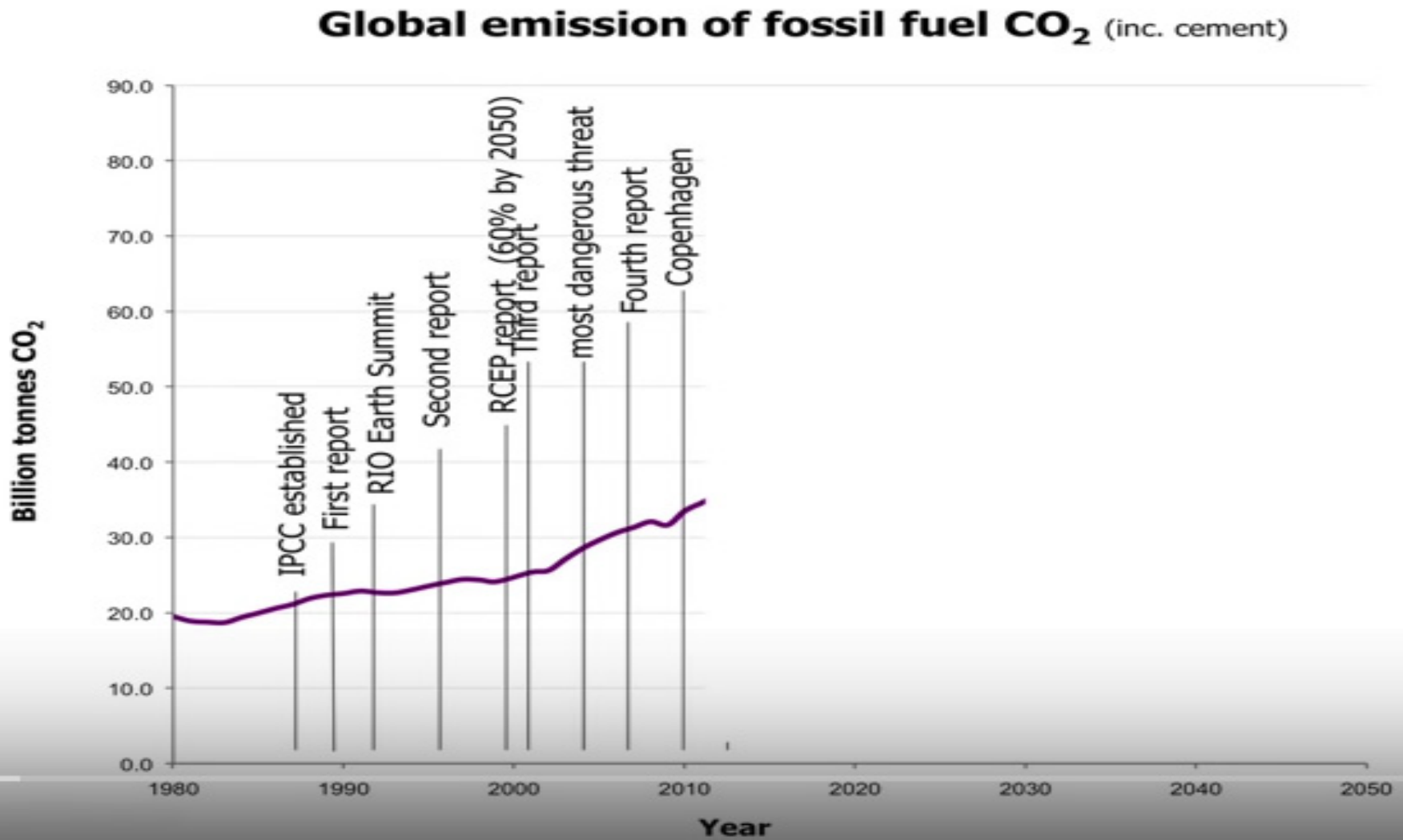
Well, OK. But we were decarbonizing for a while, Rick! We could do it again, no?

- We were indeed decarbonizing globally. Due to the world being economically dominated then by technologically advanced countries (U.S., Europe, Japan) and the adoption of nuclear power, hydro power, and slow moves away from coal to more efficient natural gas as well, to some extent.
- But for future reference, note that the smooth global carbonization curve from 1965 to its minimum in 2001, fit to a decaying exponential, produces a **halving of carbonization time scale of fully 180 years. That's a long time.**

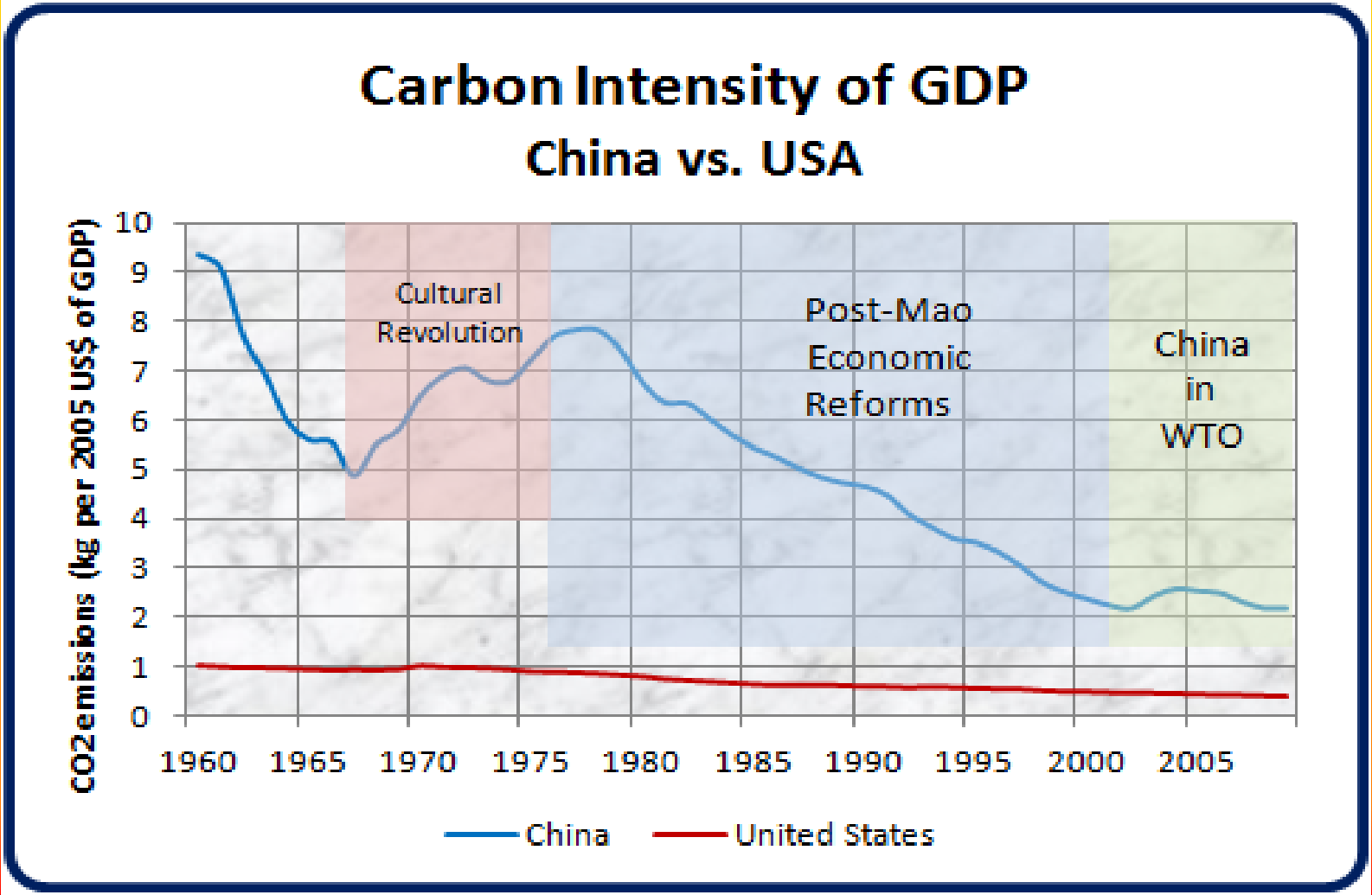
And the IPCC Working Group III (on the science) found that the single biggest determiner of the growth in GHG emissions – <u>is income growth</u>. Not surprisingly, the political/policy people who must sign off on what gets into the "Summary for Policy Makers" insured that this did NOT make it in.



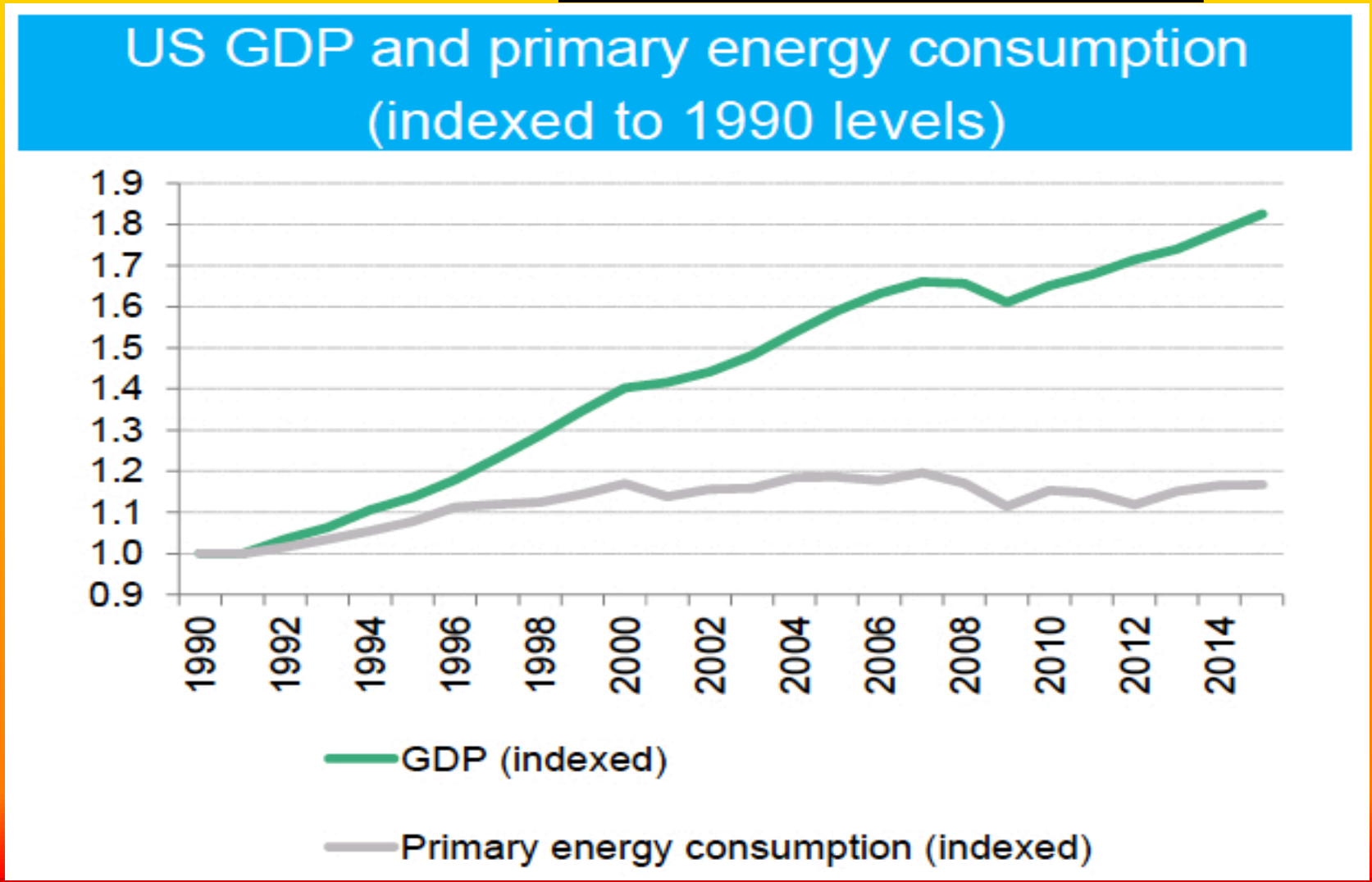
Total Policy Failure: CO2 Annual Emission RATES Are Rising Relentlessly, despite IPCC Climate Summits. But there's a reason – You can't have a growing economy w/o growing CO2 emissions today, and the Economic Elites (Gilens/Page 2014) INSIST on growth. Without growth, Wall Street plummets. Wall St. (who installs our politicians who then employ policy people) finds this absolutely UNACCEPTABLE. Many Greens do too, it seems



But Rick, look at how the carbon intensity of GDP has been falling in the U.S and even in China! For at least 60 years and probably before that as well!



And look, Rick, at how U.S. GDP still rises while primary energy consumption has Flattened. For fully 20 years!



Yes. Impressive. But it's a case of classic mis-direction ("look over here!" while the real action is over there). Consider…

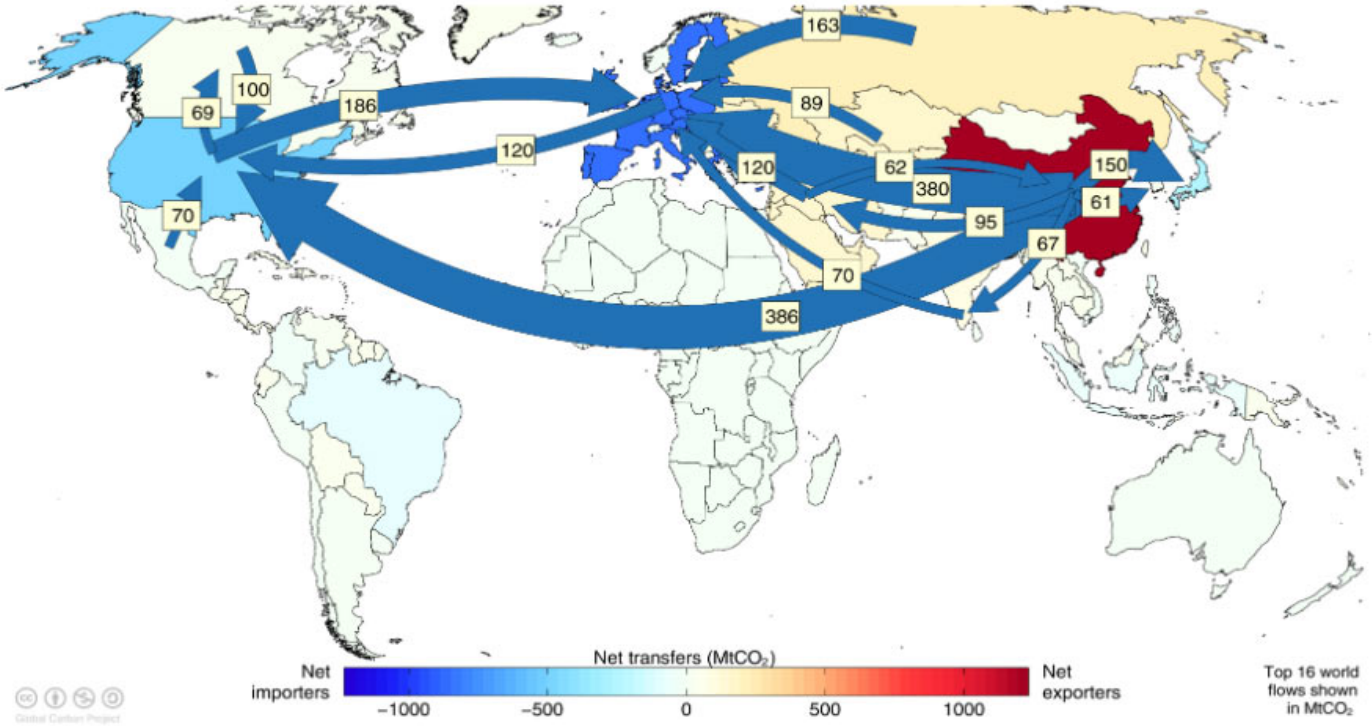
- **1.** These rich western countries have **outsourced their CO2 generating manufacturing to Asia**, whose carbon emissions are skyrocketing.
- **2.** These curves only show the carbon intensity of GDP. NOT of energy itself, which is the climate-relevant quantity to consider, and since…
- **3.** Global economic growth in GDP is far **faster** than these CO2/$GDP improvements, then **carbon emissions continue to grow**.

Strong CO2 Emissions in Asia, from manufacturing goods flowing to the U.S. and Europe. <u>We get the goods. They get the carbon guilt.</u> An inconvenient fact not highlighted by Policy People

GLOBAL CARBON PROJECT

Major flows from production to consumption

Flows from location of generation of emissions to location of consumption of goods and services



Values for 2011. EU is treated as one region. Units: $MtCO_2$

Source: Peters et al 2012

For decades, China's Central Planning has put them through Cycles of Overbuilding (think "Ghost Cities"), followed by a year or two of negative growth. The latest is happening in the past two years (2016). Excited declarations of "Peak Emissions" are premature. Look at the cycles! There is no question China is determined to economically grow much larger, requiring more energy, still mostly provided by coal and other fossil carbon for some time to come.

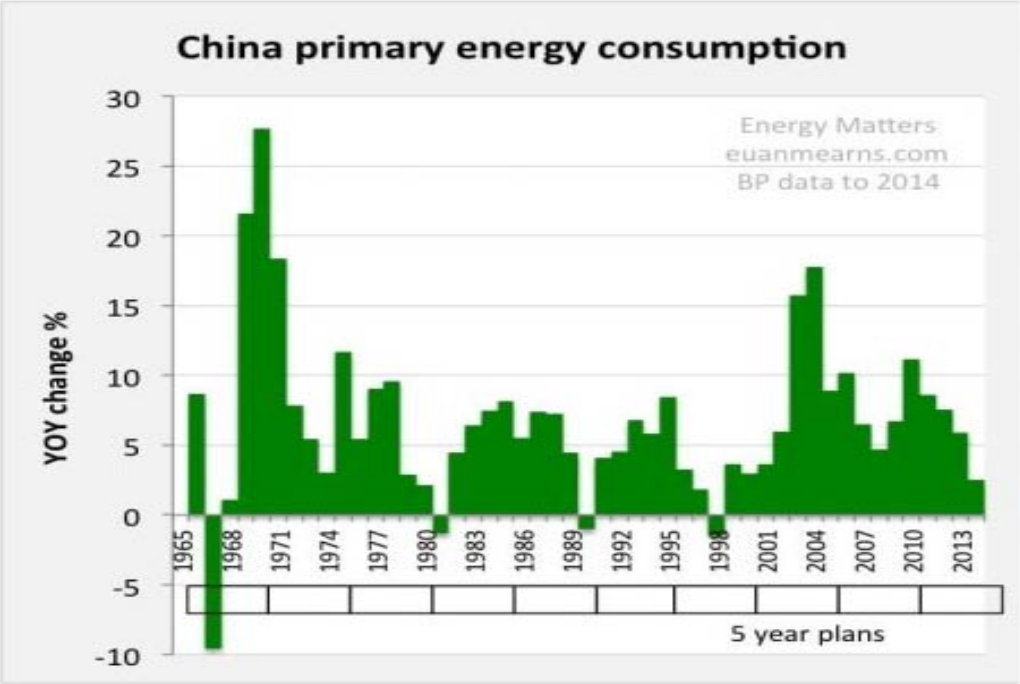
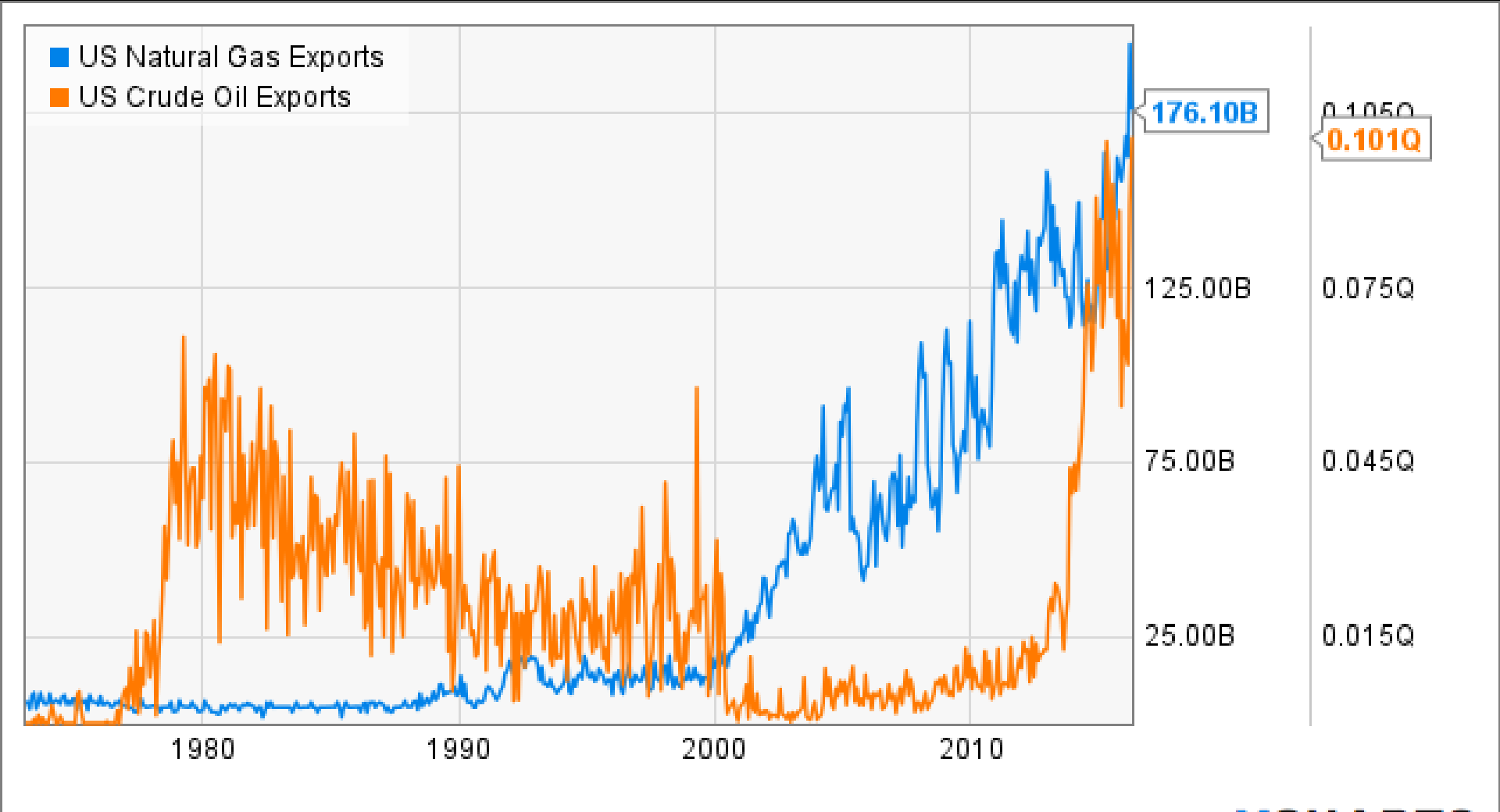
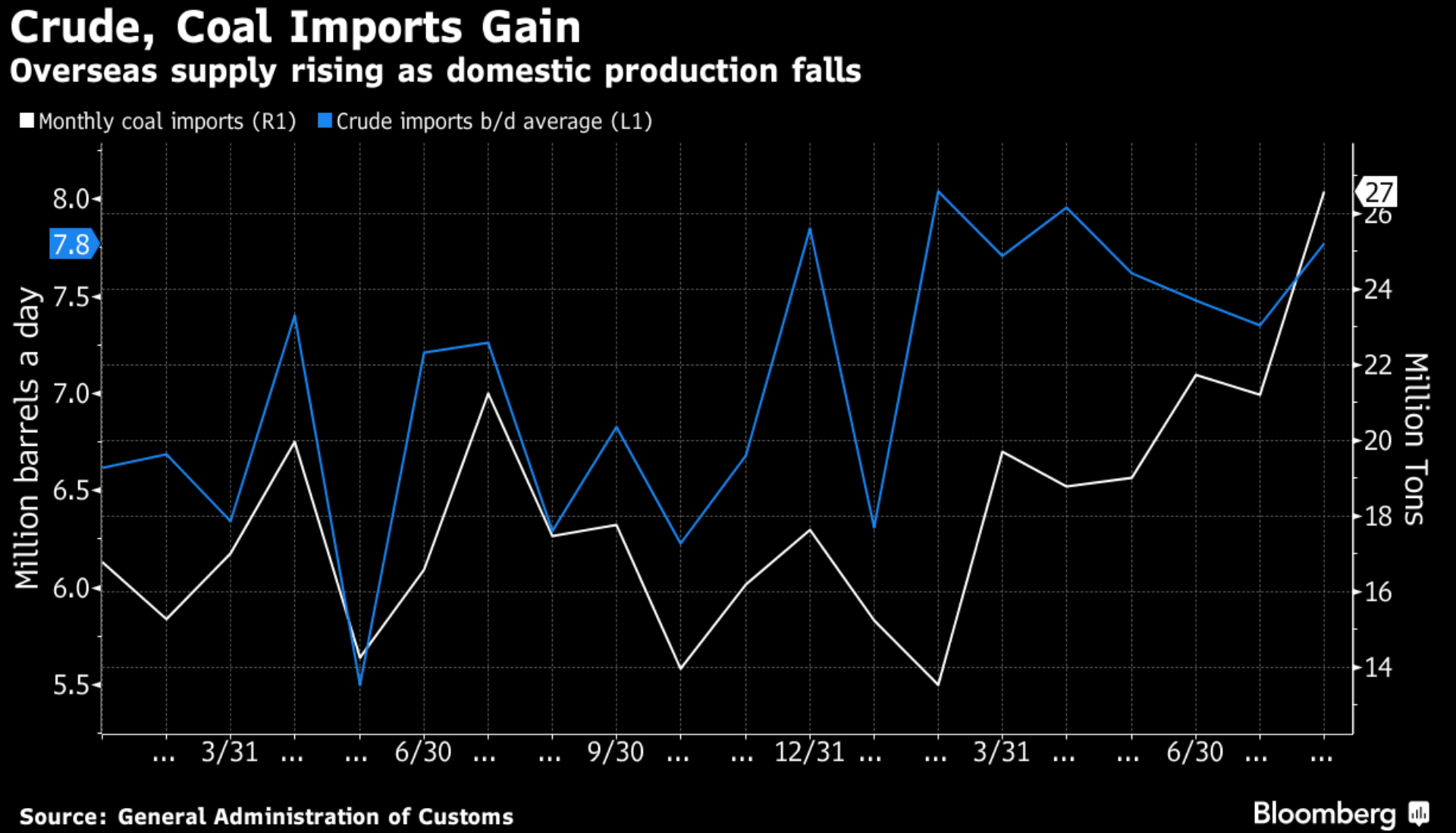


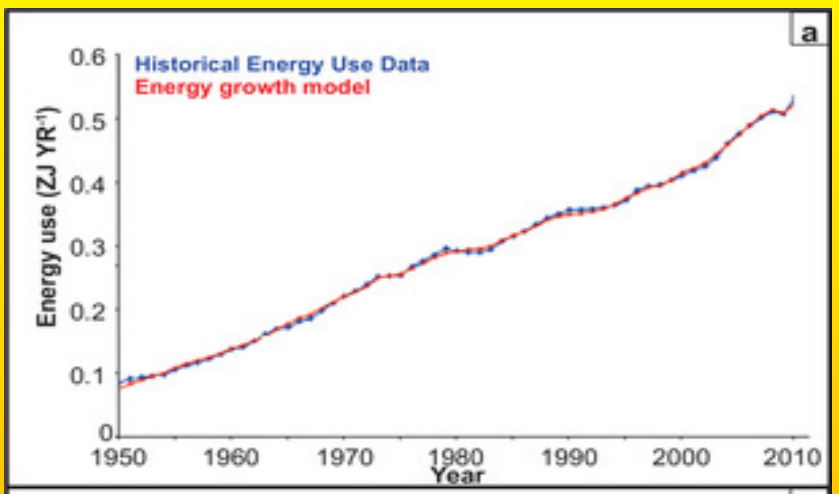
Figure 6 This chart plots the year on year (YOY) changes in China's energy consumption (Figure 2) and reveals this somewhat surprising and interesting pattern. There appears to be a quasi 9 year cycle with growth lows in 1967, 74, 81, 90, 98 and 2008. The recent slowdown in energy growth since 2010 is clear to see. It is tempting to speculate that this pattern is linked to the 5 year central planning cycle although it is not obviously so. If this pattern means anything, and it may not, then it may be 2017 before China's energy consumption accelerates again.

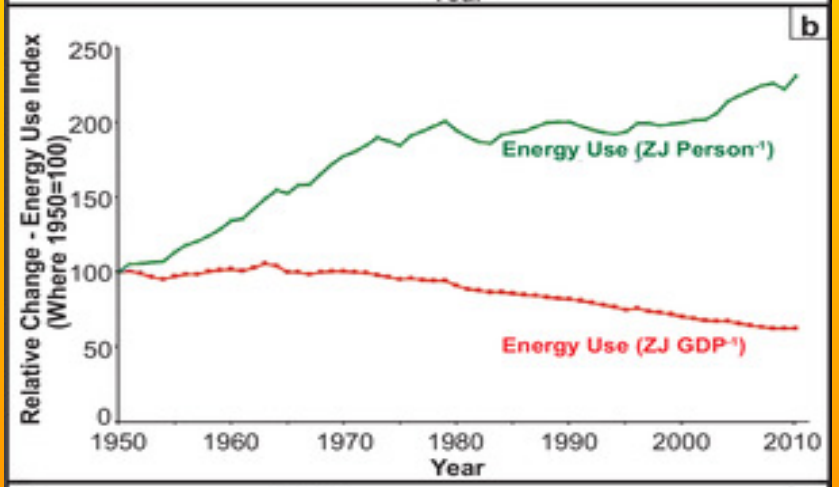
So, while we in the U.S. may not be burning quite as much… instead we're exporting our Oil and Gas to other countries, especially Asia, and THEY burn it. In the past decade, our exports of Nat Gas have quadrupled, and oil exports have gone up 1500%

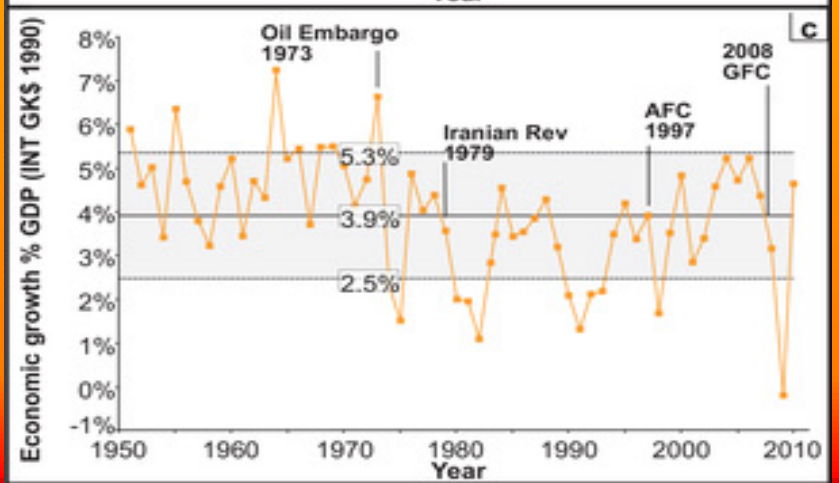


Chinese Imports of Coal and Crude Oil in 2015 and 2016; Rising





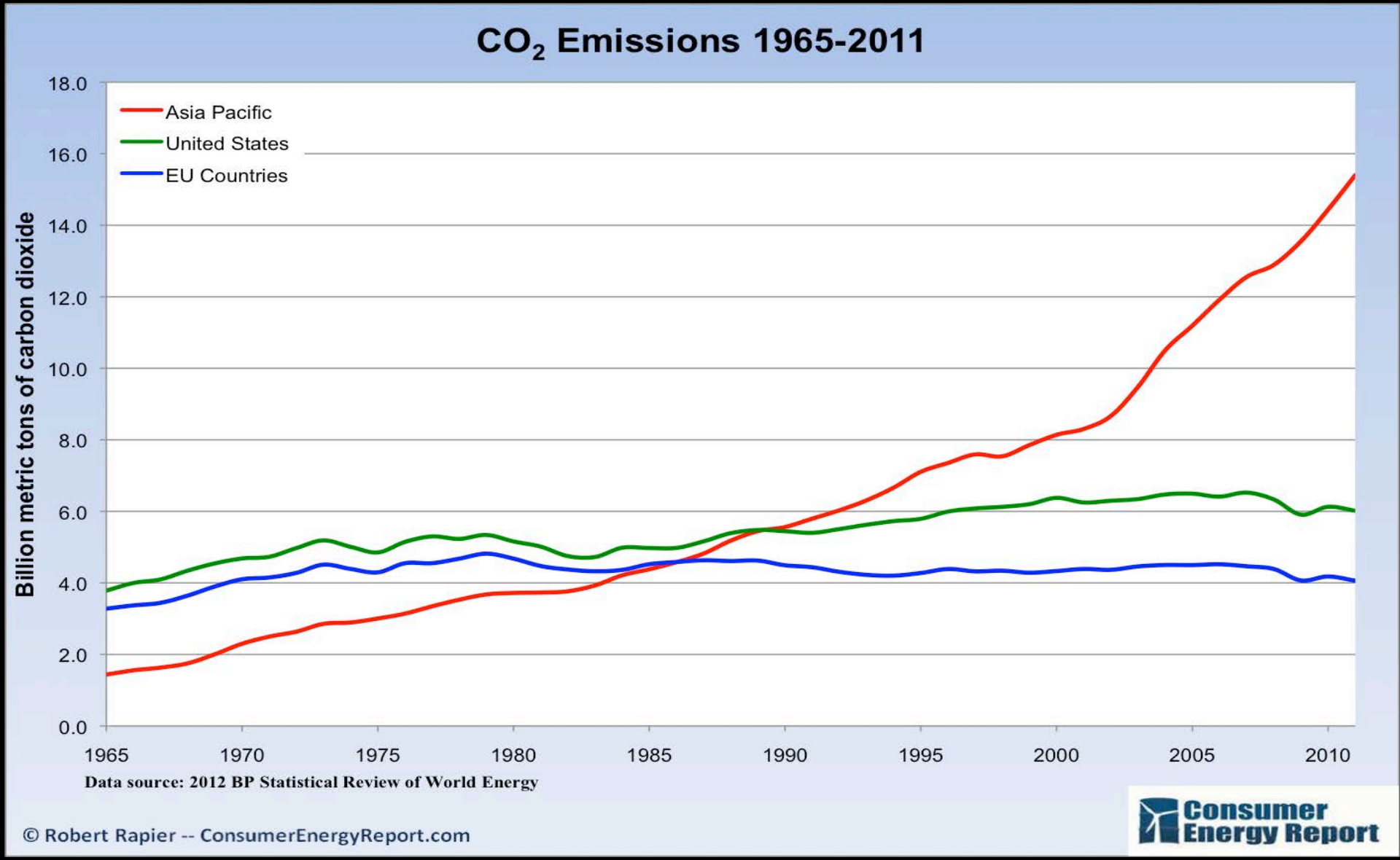




We have indeed gotten more efficient at producing new GDP with less energy (red curve, middle plot). But the energy use per person has continued to rise as more 3rd world people aspire to wealth (green), and the total energy consumption rate continues to rise in an accelerating way (top curve) (**Wagner *et al.* 2016**).

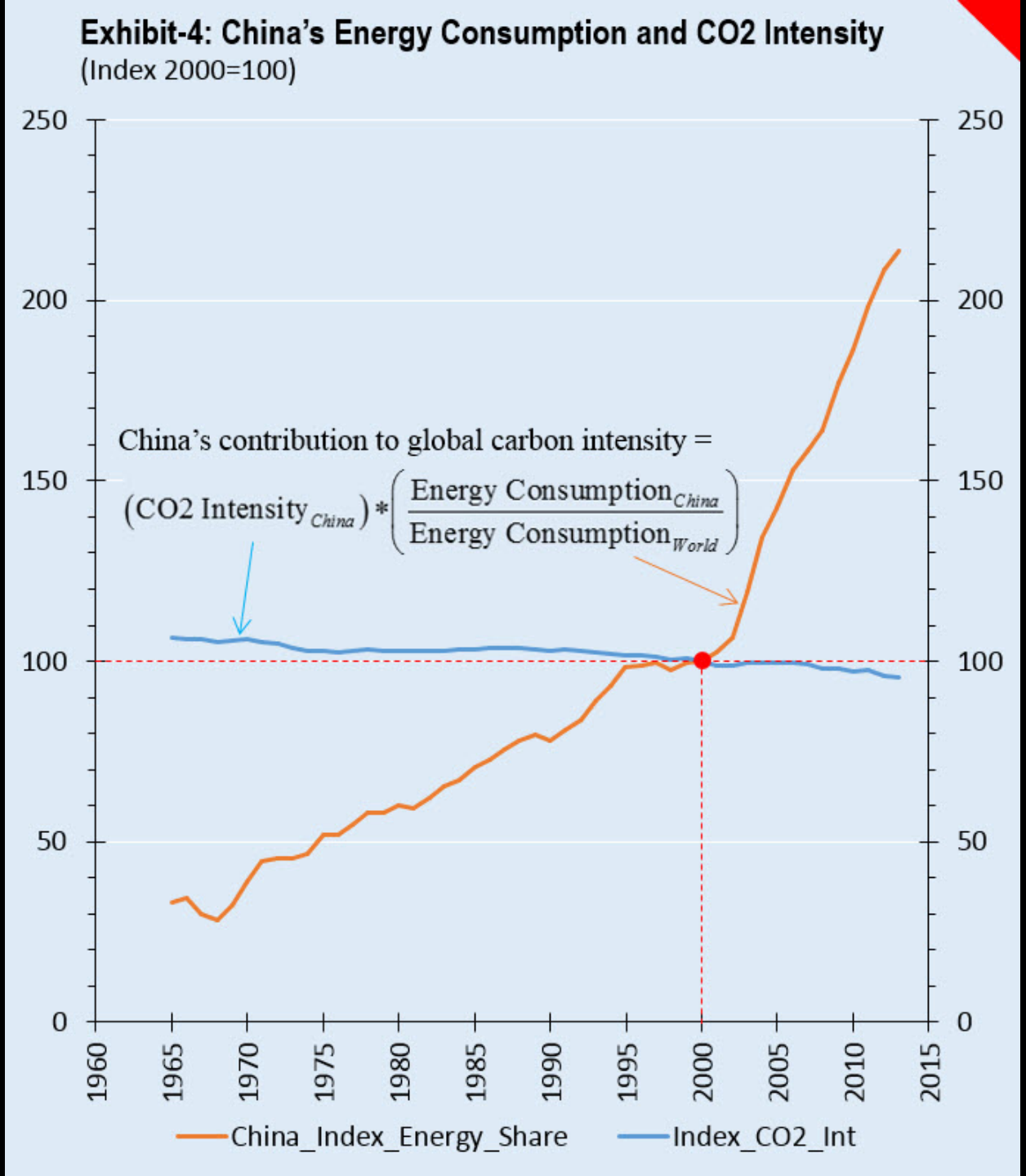
It's as if we're walking 3 mph backwards on a CO2 escalator running forwards at 10 mph.

U.S., Europe (green, blue) are exporting CO2 emissions-making to Asian manufacturers (red)



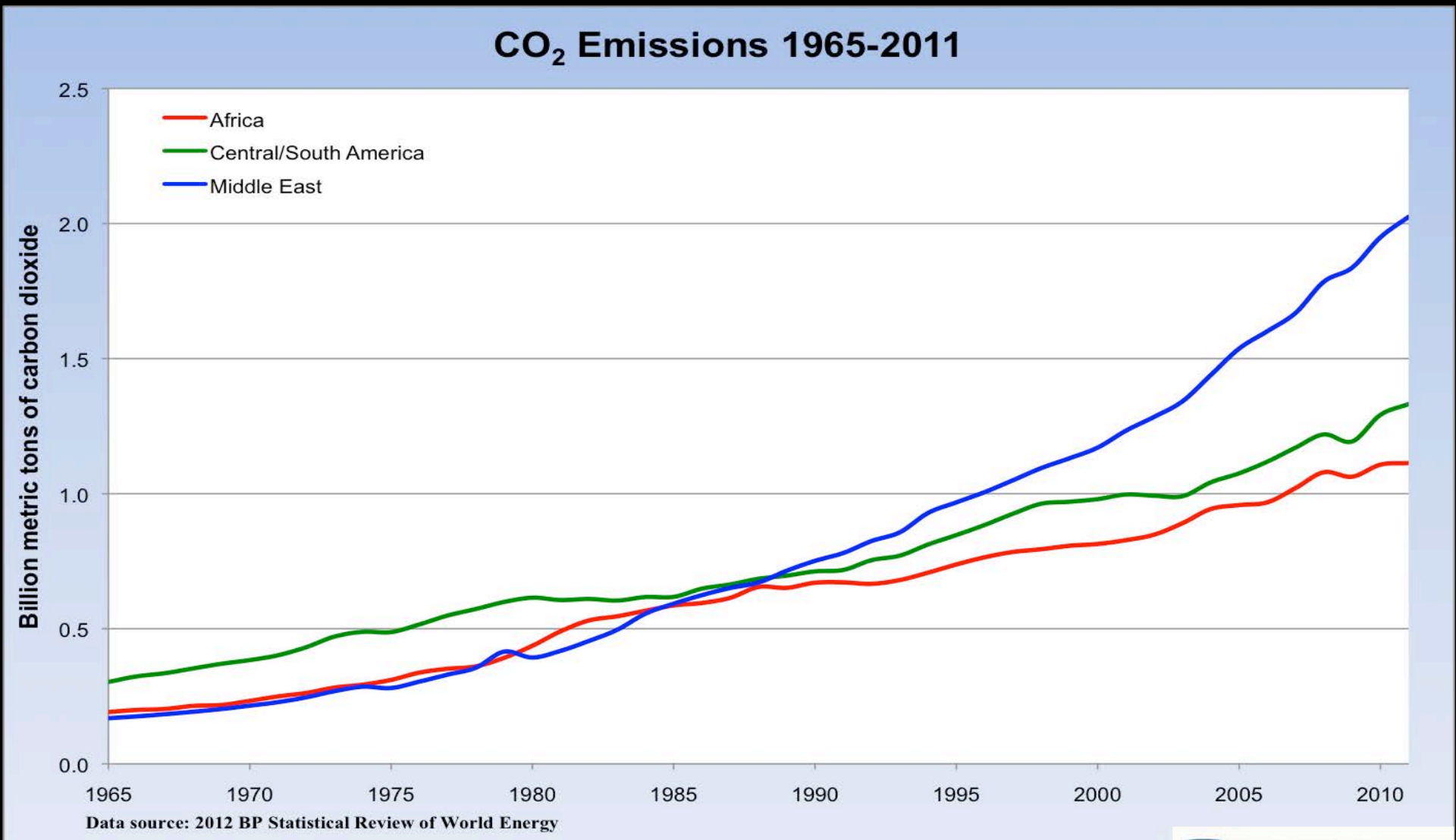
But we hear so much about China's leadership in "Going Renewable"!

- In terms of adding new generation capability, the percentage rise in renewables is indeed much higher than in fossil fuels
- **And it's very misleading!** A high percentage growth on a tiny number can (and is) still dwarfed by a much slower growth on a mammoth number.
- Climate cares ONLY about the total emission into the atmosphere, not these PR "optics"!



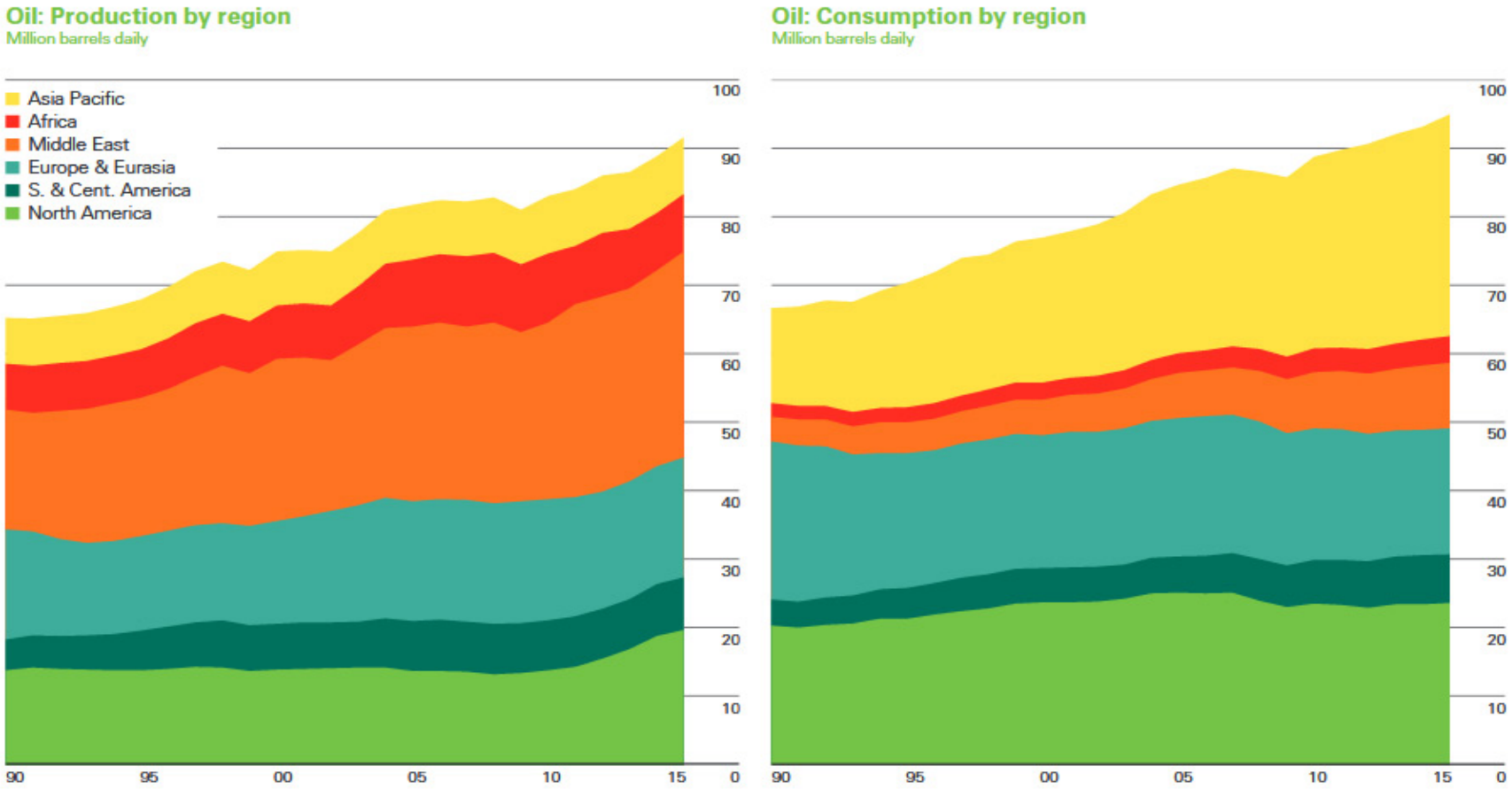
China is indeed de-carbonizing (slowly, blue curve), as a percentage of total energy. But that trend is overwhelmed by the sheer acceleration of their new energy consumption, so CO2 emissions continue to rise

Africa, Central and South America, and the Middle East are also continuing to accelerate their CO2 emissions



Consumer Energy Report

Global oil consumption continues to rise, right into 2016 (last data available), led by Asia, while Europe, North America flat.



World oil production growth in 2015 significantly exceeded the growth in oil consumption for a second consecutive year. Production grew by 2.8 million b/d, led by increases in the Middle East (+1.5 million b/d) and North America (+0.9 million b/d). Global oil consumption increased by 1.9 million b/d, nearly double the 10-year average, with above-average growth driven by OECD countries. The Asia Pacific region accounted for 74% of global growth, with China once again contributing the largest national increment to global oil consumption growth (+770,000 b/d).

China's consumption of oil and coal are controversial

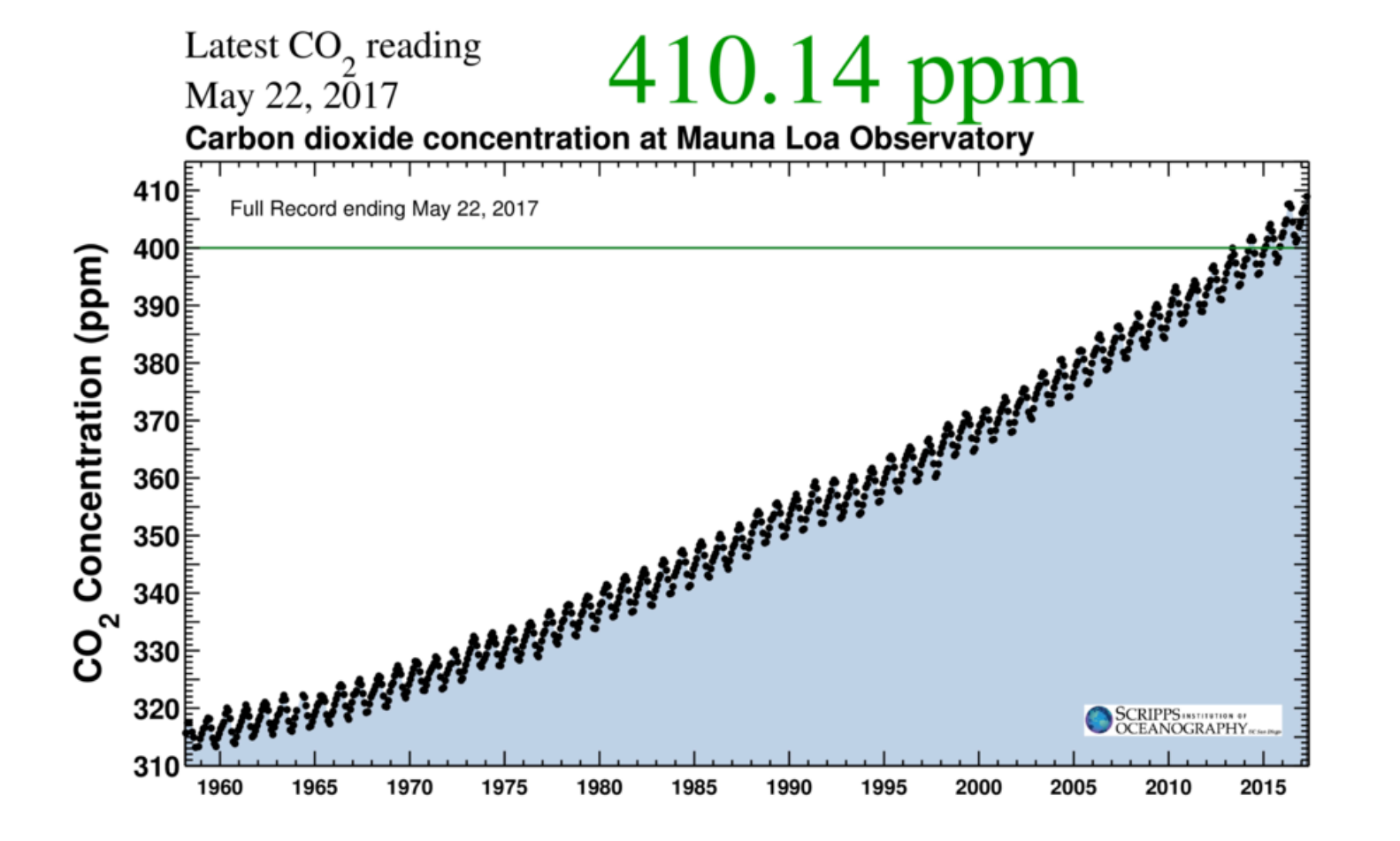
- Greenpeace contends the BP Statistical Review over-reports their consumption, but their evidence relies on China government's own figures
- Are such figures reliable? The **NY Times investigative people** find just the opposite – that China has significantly under-reported their consumption. Given China's commitment to international agreements, one can see their motivation, just as they have **under-reported their over-fishing since 2000** (by 1200%!)
- Unfortunately, the under-reporting gives cover for glossy cheerleading claims of "peak emissions" having arrived (!), and serve the interests of complacency in our predicament.
- Let's instead rely on Nature herself to tell us the truth…

For Climate, there is only ONE Curve that Matters…

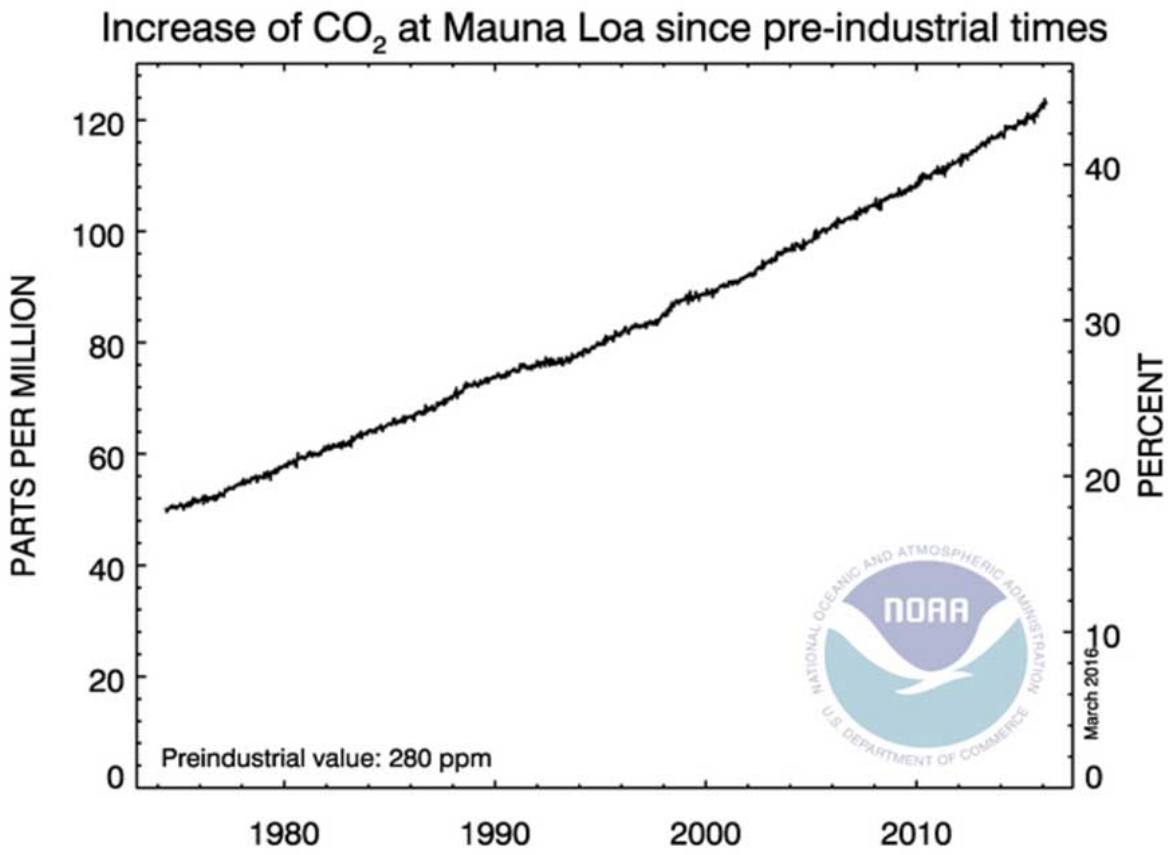
- – and that is the **Keeling Curve**: the concentration of atmospheric CO2. THAT is the curve that primarily determines global climate.
- From those rosy Western nations curves, and the warm glow from listening to cherry-picking policy cheerleaders, you probably expect to see at least a slight easing in the accelerating rate of our atmospheric CO2 rise, given that China and the U.S. emit most of the world's CO2, right?
- **But, no. (next slide)** It's relevant that China has been caught significantly under-reporting also their CO2 emissions (**source**).

- **Nature, however, does NOT under-report. She does NOT LIE. And her report is contained in the Keeling Curve: CO2 Concentration in the Atmosphere (next slide)**

CO2 remains on an exponential rising curve. Now over 410 parts per million (ppm). The RATE of INCREASE has hit new records the past 3 years, of 3 ppm/year. This does NOT indicate global emissions have levelled. Governments can lie, but Mother Nature does not. We've been increasing energy efficiency for over a CENTURY. Let's not be delusional – Increasing energy efficiency leads to RISING energy consumption, not FALLING. We SPEND our energy savings.

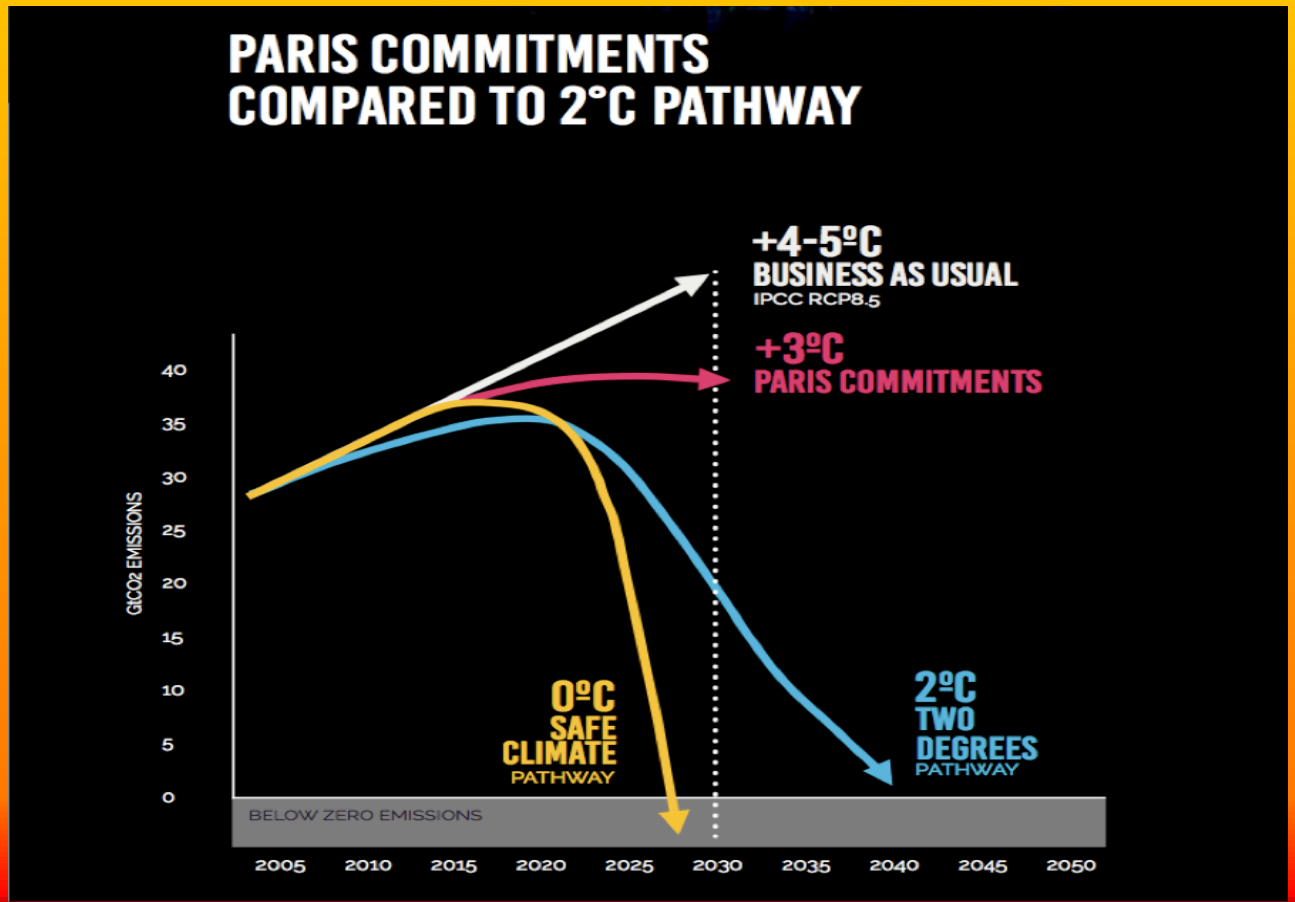


The same, seasonally adjusted, as of February 2016. We have a new record in the ACCELERATION rate of rising atmospheric CO2 concentration (New Scientist 2016), despite claims of China perhaps beginning an era of declining CO2 emissions (except, again, they've been caught under-reporting)



Atmospheric increase of CO_2 over 280 ppm in weekly averages of CO_2 observed at Mauna Loa.

The Garrett Relation makes the +2C pathway essentially impossible. Also, the pathways are actually much more severe than shown here, given the missing PCF (Permafrost Carbon Feedback) (MacDougall et al 2012), the higher ECS than assumed below (Friedrich et al. 2016), and the skyrocketing baseline global temperatures of 2014-2016. The +0 C "safe climate" pathway is particularly obviously wrong, since we saw earlier that even without the PCF, temperatures continue to rise until ALL CO2 emissions stop. Temperatures are for 2100.



Before Getting Too Encouraged by China's Promises…

- They have a growing middle class and rising wages and are themselves under increasing pressure to outsource their own CO2-intensive manufacturing to yet cheaper-wage countries
- Especially to **Vietnam**, and to Thailand and Cambodia and more primitive countries with higher carbon intensities
- Expect to continue to chase the carbon pollution sources until there are no more lower-wage countries with standards of living to bring up to Western standards
- These decisions are clearly dictated by economics, not concern for the future environment

Power Plant Retirements: US *vs.* China. Energy Expert Vaclav Smil Observes…

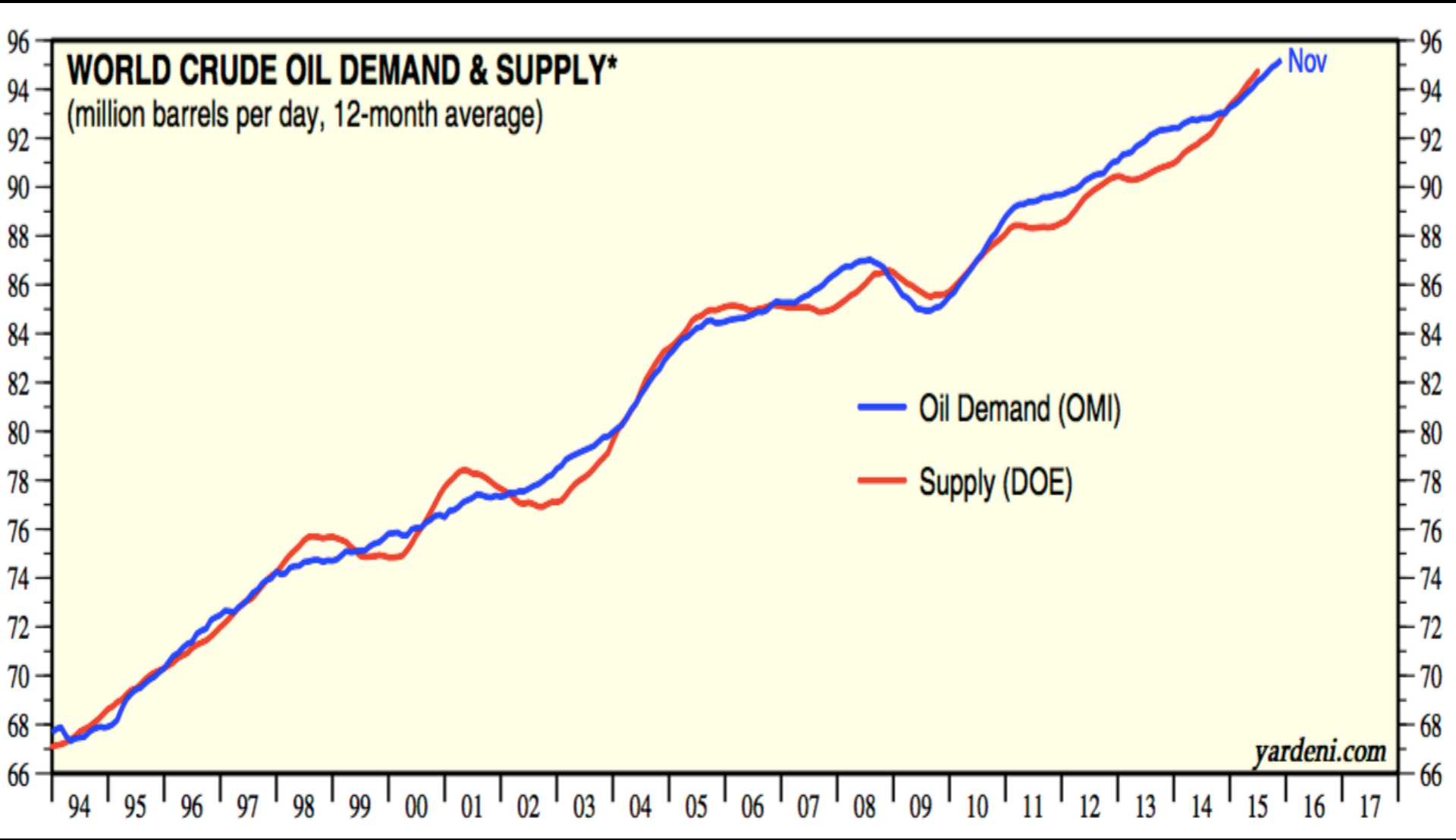
- …that the favorable growth in renewables in the U.S. and Europe is significantly due to the fact that most of **our** power plants date from the go-go 1950-1970 era. They are old and expensive and due for retirement, to be replaced by natural gas power and renewables.
- **But China's vast and growing coal-fired power plants are brand new**, and China's determination for strong growth and global influence will make it very unlikely they'll de-commission perfectly working new power plants just for environmental reasons – not if it means hindering their growth.

Again: Energy Consumption is Proportional to Integrated Gross World Product Added Over All Time

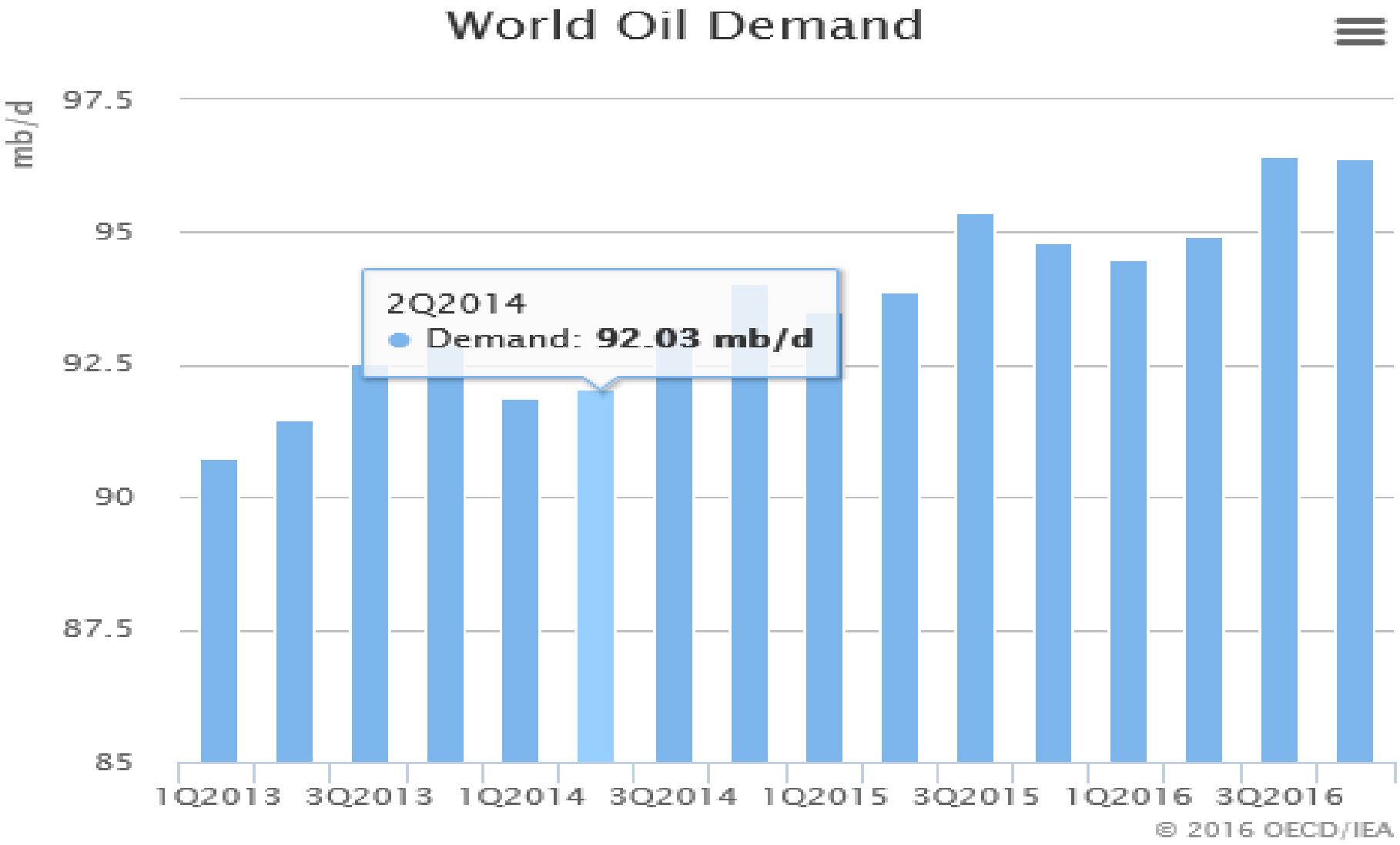
- The rest are details of who off-shores what aspect of energy consumption for whose increasing wealth.
- ***Climate is global, and so is Civilization's networks.***
- **You're not getting the true picture of our challenge if you limit your focus to a single country's GDP rate and CO2 emissions.**
- CO2 emissions can only be reduced in a rapid (*i.e.* meaningful) way by reducing or elimination of GLOBAL economic growth (but then, how to finance the massive transformation of the world's energy infrastructure?)
- That, in a nutshell, is **The Great Catch 22**
- **Well, you may say, we can hope that fossil fuel consumption is at least slowing somewhat in this Renewables Era.**

- **Is it? Is Oil consumption decreasing in this era of rising renewables?**

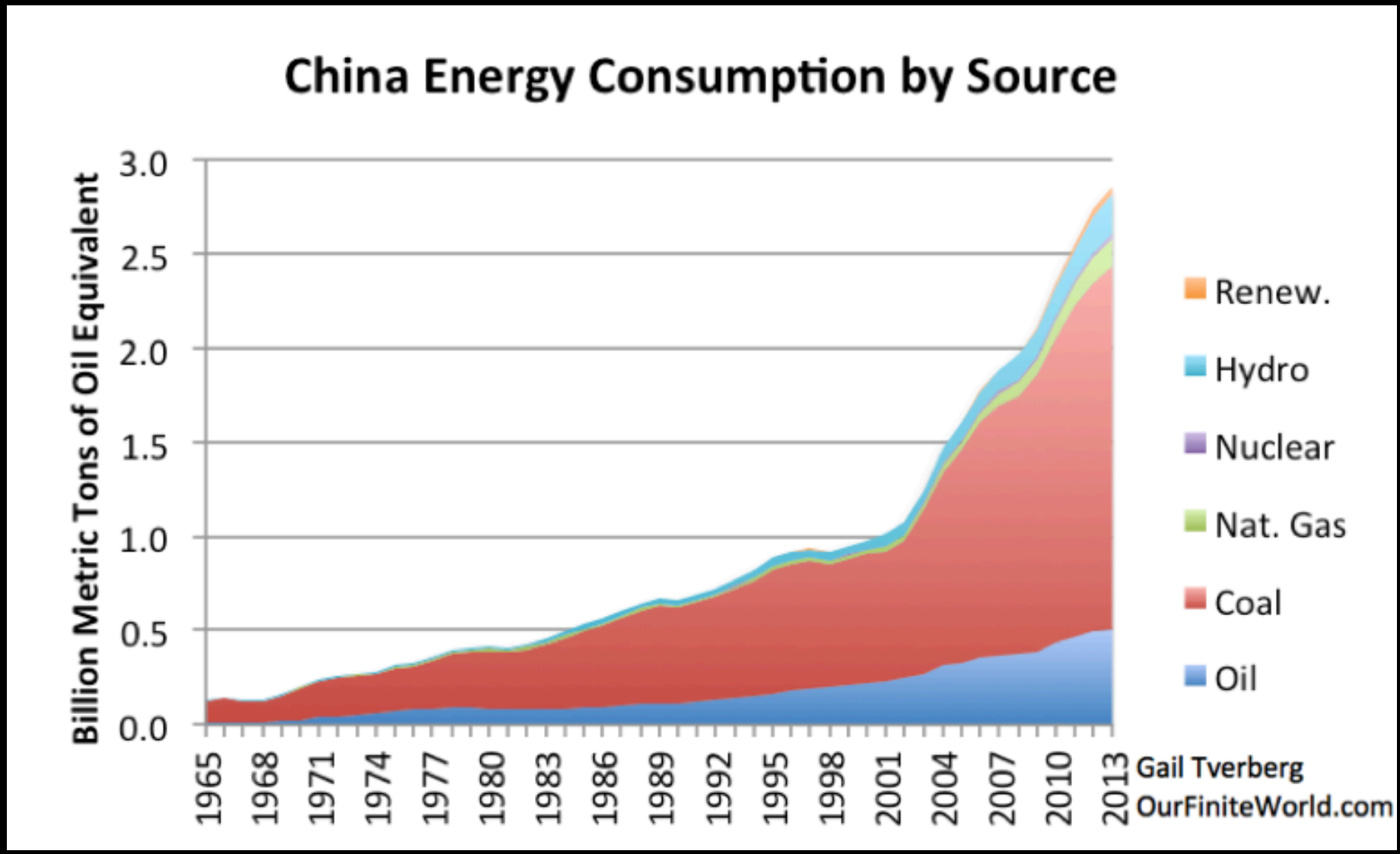
Past 22 Years, Oil Supply and Demand Rising 1.52%/year on Average, with Just Little dips during the '01 and '08 "Great Recession". This is a rising RATE of demand curve, meaning CO2 emissions will be exponential, as indeed we saw



Last 3 years: Continuing net rise quarter-by-quarter even during the global economic slowdown of the past 2 years. Millions of barrels PER DAY



China – Energy consumption per year rising rapidly through 2013, nearly all is carbon energy.



With all the rhetoric about the end of coal and dirty oil, and the failure to approve the Keystone XL Pipeline, that the Alberta tar sands would be in decline… yet they are planning on adding yet more capacity this year and even double that in 2017. No plans yet for 2018 added capacity, but "the end of an era" doesn't fit…. At least not yet. Any more than in 2003 or 2005. Global energy needs continue upward, as global economic growth demands

Now let's look at the implications of this Thermodynamic Relationship between Civilization's Wealth and Energy

- Garrett has run forward in time the global atmospheric CO2 concentration given the **Garrett Relation**, and two **sets** of assumptions;
- **Set #1:** Assume the 21st century growth rate of Global Wealth and global carbonization both continue to remain constant. Wealth growth at 2.2%/year, and also that the decarbonization rate=0 (as is the trend so far in the 21st century)
- This could be called the **"Business as Usual",** scenario…

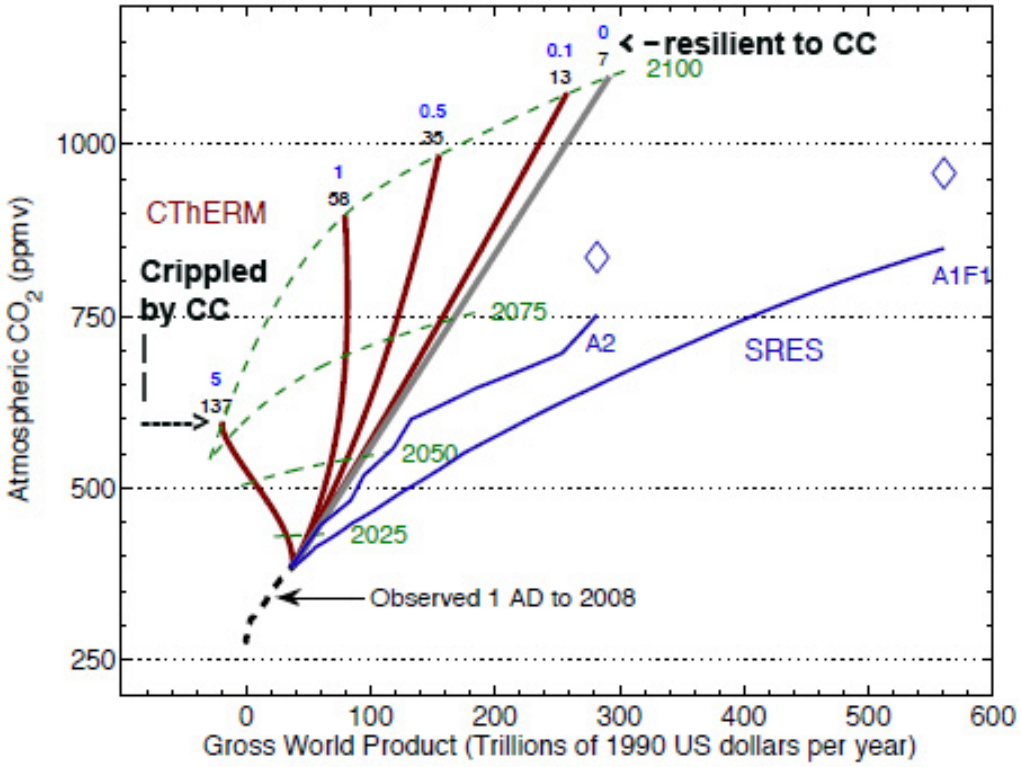


Fig. 6. As for Fig. 5, except for CThERM trajectories calculated out to 2100, with the model initialized with conditions in 2008 and assuming that $d\beta/dt = 0$ and $dc/dt = 0$ for a range of values of inverse resilience $1/\rho$ (blue numbers expressed in % yr^{-1} change in the decay coefficient γ per CO_2 doubling). Small numbers in black correspond to the calculated inflationary pressure $i = \gamma/\beta$ (Eq. 25) in year 2100. Green dashed lines represent the modeled year. Shown for comparison are the IPCC SRES A1F1 and A2 scenarios based on the CThERM linear sink model for CO_2. CO_2 concentrations for these scenarios using the Bern carbon cycle model are shown by blue diamonds. Historical data from 1 AD to 2008 is added for reference (see Appendix C).

Garrett's CThERM model runs *vs*. range of assumed resilience of civilization to Climate Change: On this graph, de-carbonization continues its 21st century historical trend – i.e. no decarbonizing.

Even when civilization is assumed most crippled by climate change (lowest red curve), with staggering ~137%/yr inflation rates by 2100, with GWP growth falling below zero (civilization in collapse), still atmospheric CO2 rises 50% above current levels by 2100 and still rising.

New research by Motesharrei *et al.* 2016 adds insight

- In the summary linked above is this quote from the paper: ***"…all societal collapses over the past 5,000 years have involved both 'the stretching of resources due to the strain placed on the ecological carrying capacity' and 'the economic stratification of society into Elites [rich] and Masses (or 'Commoners') [poor].' This 'Elite' population restricts the flow of resources accessible to the 'masses', accumulating a surplus for themselves that is high enough to strain natural resources. Eventually this situation will inevitably result in the destruction of society."***

Motesharei *et al.* Continue…

- ***"Elite power", the report suggests, "will buffer 'detrimental effects of the environmental collapse until much later than for the Commoners,' allowing the privileged to 'continue business as usual despite the impending catastrophe.'"***(it is disconcerting to read this, given **Gilens and Page 2014**)
- ***"'Science will surely save us', the nay-sayers may say. But technology, argues Motesharrei, has only damned us further…"*** (by way of Generalized Jevon's Paradox, I will add)

From Garrett 2012

"There are no plausible, thermodynamically supported solutions that avoid inflation rates less than 100% per year, and lead to stabilized atmospheric CO2 concentrations within this century" (assuming decarbonization rates of ~0 in the 21st century, as has so far been the case)

- Inflation, realize, can either happen through excess printing of money, or through the progressive destruction of the wealth which that money denominates (or a combination of both). **100%/year - this is "runaway inflation", and the decline of civilization**
- In other words: civilization must contract (something it has never done), **rapidly**. Rapid decarbonization can certainly help, but given the current crossing of tipping points, the implications here as well as explained by Prof Kevin Anderson – civilization must dramatically drop its total energy use, immediately, to have any hope of returning to a stable climate.

Collapse!? But can't we just Decarbonize our Power Sources Instead?

- Decarbonization is a two-edged sword. Higher CO2 levels mean a more climate-crippled civilization, which is, perversely, **good** in that it lowers civilization's growth rate and hence CO2 emissions growth rate
- Alleviating this crippling by steady decarbonizing enables faster civilization growth rates and hence MORE CO2 emissions from the power sources not yet decarbonized – ***Jevon's Revenge***!
- **What is needed in order to stabilize, let alone reduce, atmospheric CO2 concentrations is an optimum combination of BOTH Civilization collapse AND extremely steep rates of decarbonization.**
- This point is appreciated by the U.K.'s Tyndall Climate Centre director and climatologist Prof. Kevin Anderson as well, which we will see.

Garrett Scenarios #2: The CO2 concentration trends on the next slide assume we replace carbon energy with non-carbon energy at a rate such that the CO2 emission rate per unit of power drops exponentially with a halving time of $t_{1/2}$=50 years

- Recall late 20th century carbonization showed an exponential halving time $\mathbf{t_{1/2}}$ which was much slower: 180 years)
- With the 50 yr assumption, let's follow the trajectory of CO2 in our atmosphere *vs.* growth in total wealth in the next slide's graph.
- Time is not one of the axes - Instead, time evolves generally upward <u>along</u> each of the curves, time ticks are the green dotted lines

The CThERM DeCarb Case: Same resilience curves as earlier slide, now including steep de-carbonization with halving time $t_{1/2}$ = 50 years. All are significantly worse (red) than the IPCC eco-friendly scenarios (blue). CO2 levels never drop for any CThERM scenario here. Economic growth is far less, and CO2 far worse, than the simple IPCC scenarios which assume adjustable relevant parameters but in unrealistic isolation from each other (see following slides)

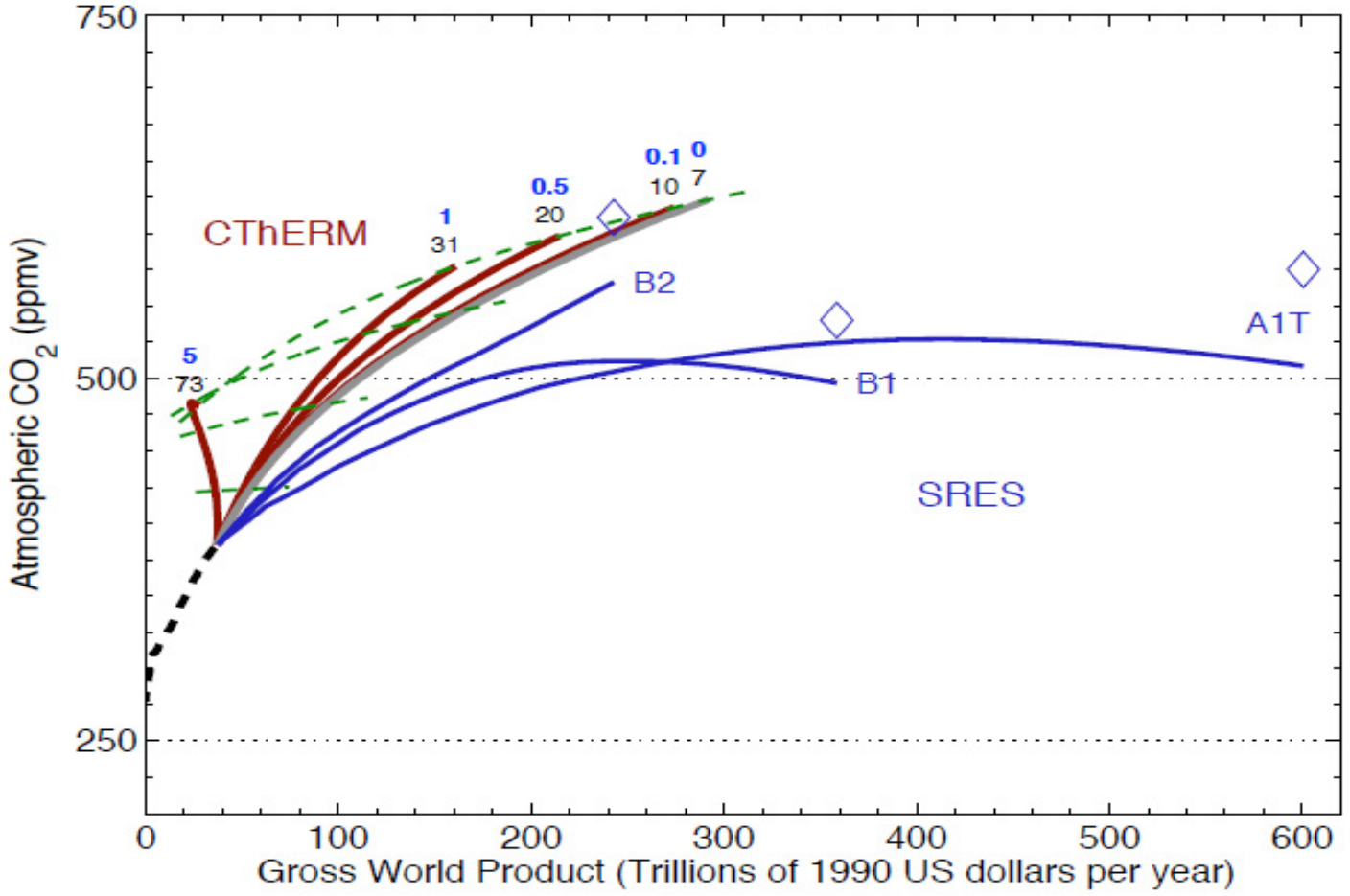
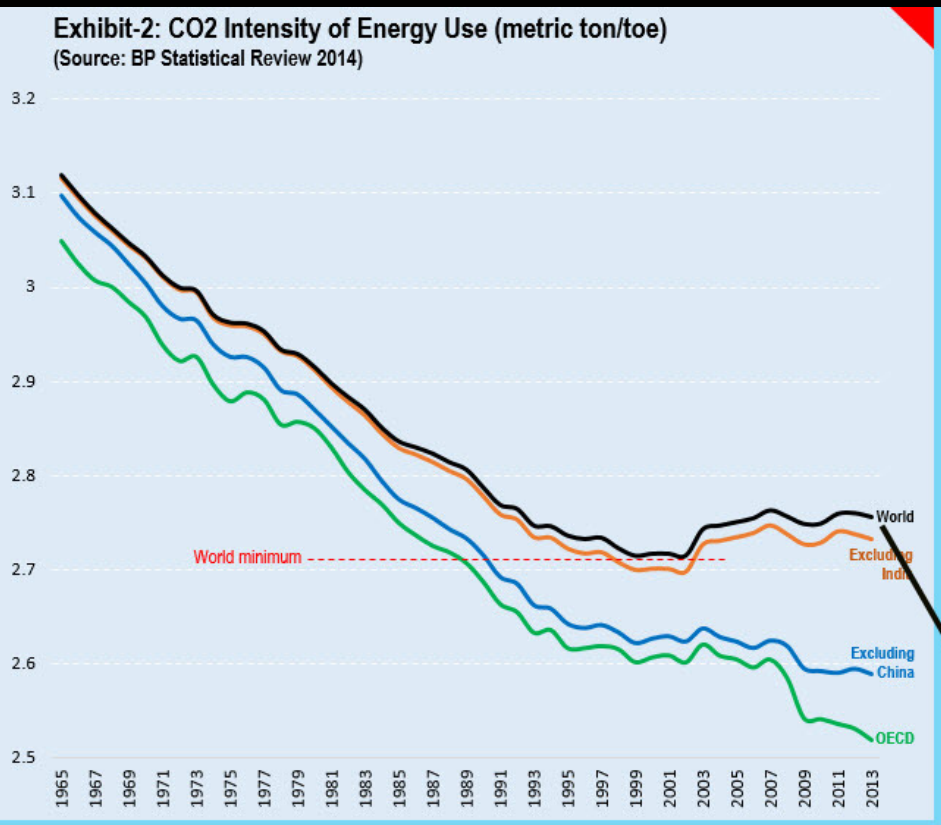


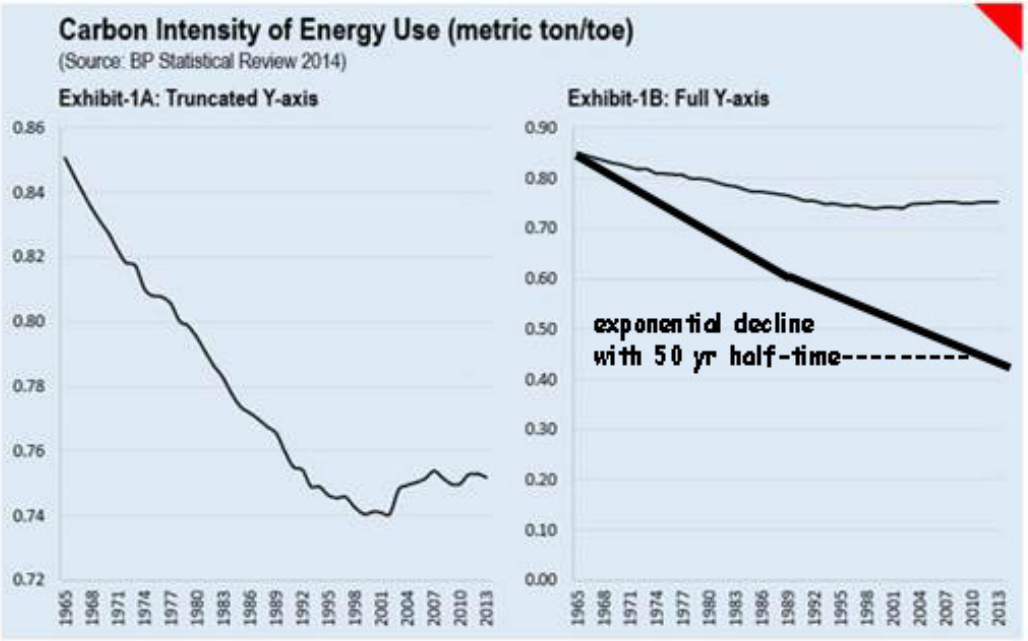
Fig. 7. As for Fig. 6 except that it is assumed that the value of carbonization c has an assumed halving time of 50 years. For comparison, the IPCC SRES trajectories that are considered are the A1T, B1 and B2 scenarios.



trend of linear approximation to exponential halving time of 50 years

Garrett's assumption of an exponential halving time of 50 years is quite steep by historical standards

If we'd committed to a steep $t_{1/2}$= 50yrs decarbonization back in 1965 (right side, heavy line), *vs.* what desires + energy actually permitted us to do (thin curve=historical actual data)



A Closer Look

From here on, the numbers will show CO2 intensity instead of carbon intensity, because the original data from BP and the EIA report CO2 emissions. To convert CO2 to units of carbon (C), simply divide by 3.667. Carbon intensity and CO2 intensity are used interchangeably in the text – both are ratios that depict emissions generated versus energy produced. In the relevant literature, CO2 intensity is also reported as a ratio of CO2 emissions to GDP--which includes the effects of prices. In this note however, CO2 intensity is measured in physical units--metric tons of CO2 per tonne of oil equivalent (toe). Also, 1965 is the first year for the data published by BP.

Let's Emphasize the Conclusion of Garrett's Scenarios #2 Slide…

- Even if we decarbonize at a much more rapid rate than ever in the past, such that the carbon intensity of energy drops in half every 50 years…
- Even if climate change cripples civilization such that the growth rate in Global Wealth is cut in ~half by 2100, with rising inflation rates reaching over 70% per year by 2100… (today's is 2-3%)
- **…STILL, atmospheric CO2 levels climb, and are as high as 485 ppm by year 2100.** 485 ppm is high enough to trigger the tipping points for complete thaw of all permafrost, and also **Hansen's (2016) dire scenarios**, if they haven't already been triggered.

Worse, there are at least two reasons why his atmospheric CO2 curves are likely too optimistic

- **1.** They don't include explicitly the cost of transforming our energy systems from high EROI energy-dense fossil fuels, to dilute and low EROI renewables – and it would require complex and uncertain assumptions to even try to include this in his explicitly global model
- **2.** His atmospheric CO2 model, for computational efficiency, is a simple parameterized source+sink model which, while it works well in hindcasts up till present concentrations, it neglects the effect of the inevitable higher future temperatures on crippling of the ability of plants, oceans, and soil to uptake CO2 in non-linear ways.

Coral Reefs are Dying. Most of the Great Barrier Reef is now bleached and dying. Didn't hear? Thank your corporate news – they make a concerted effort to scrub unpleasant climate change from their news

As ocean phytoplankton and other aragonite species perish…

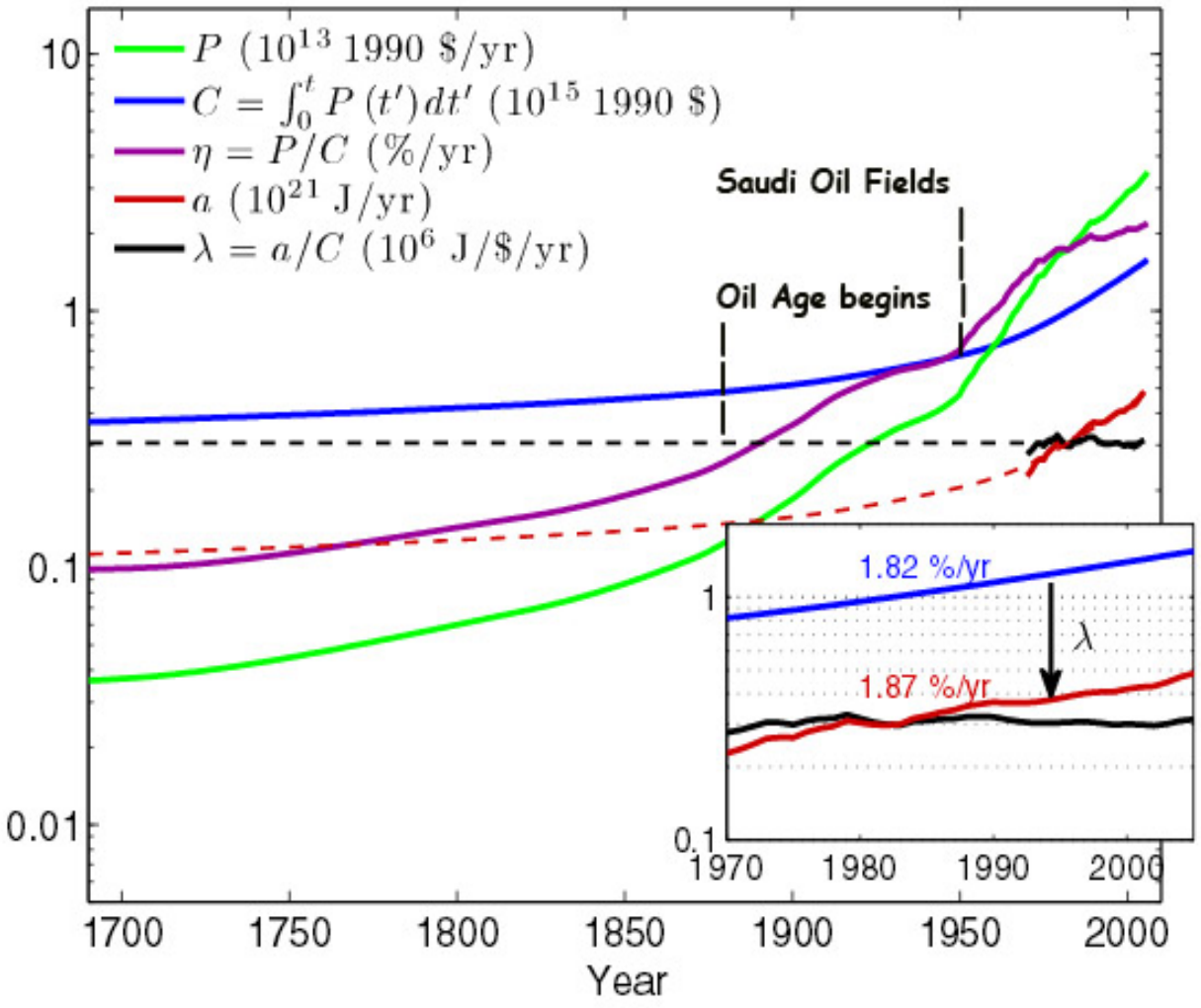
- …in warming, acidifying oceans, they will not be able to chemically fix dissolved CO2 into stable calcium carbonate. And soil microbes will suffer in the droughts and heat waves to come, crippling land plants and soil further.
- Whereas currently, with temperatures still only just now having risen to +1C globally, rising CO2 has been a fertilizer for plants and increasing their carbon uptake. This will change soon.

While Increasing the Construction of Renewable Power Plants Will be Expensive at First…

- Their ongoing upkeep will be smaller than that for conventional power. Solar is “free”; as free as the wind.
- If this results in increasing energy efficiency, and with the large amount of solar energy falling on the planet, it may be that we will eventually see another surge in the the Global Return on Wealth; the global Wealth growth rate, such as we saw in the late 19th century from the discovery of oil, and again in the 1950’s with the discovery of the vast and easily drilled oil fields of Saudi Arabia and the rest of the Middle East (next slide)
- If so, this will require an increase in all energy use, including the remaining carbon energy. (**Jevon’s Revenge**).
- In this case, Garrett’s simulations will underestimate atmosphere CO2 levels again – they assumed Global Return on Wealth will no longer rise but instead stay constant at 2.2%/year

The Purple Curve Shows the Rate of Growth of Global Wealth = the "feedback efficiency" of Wealth in its ability to grow more Wealth. It has never declined, and is now at 2.2%/year. Inset box shows the Garrett Relation (black curve flat)

Fig. 3 Estimates of gross world product P in market exchange rate, 1990 US dollars and economic value C, defined by $P = dC/dt$. Also shown are recent global primary energy consumption a, the ratio $\lambda = a/C$, and the feedback efficiency $\eta = P/C$. *Dashed lines* correspond to extrapolations based on assuming $\lambda = 9.7$ mW per 1990 US dollar



How are the IPCC and CThERM Models Different?

- The IPCC's SRES models split off the evolution of **population**, global average **standard of living**, and **energy efficiency** (*i.e.* energy expenditure's useful return to civilization) as separate drivers which they specify arbitrarily and independently of each other (see IPCC **sec. 5 here**).
- **But the actual data shows that population and standard of living growth rates are only constrained by our access to new energy and our ability to raise energy efficiency , and so are actually dependent variables, not independent variables.**

Power Consumption historically has been Limited ONLY by Available Energy Reserves and Energy Efficiency

- In other words, population growth and standards of living growth can both be predicted knowing **only** the available energy reserves and the efficiency of energy in growing Civilization's wealth
- As proof, Garrett (2015) has shown that the **CThERM** model reproduces observed economic growth rates accurate to 0.1% over the 1950-2014 period, (which is where data is available) despite significant changes in trends during this time . The IPCC SRES model only reproduces this with a particular "worst case" assumed carbon scenario (Raupach *et al.* 2007).

Indeed - Stevenson and Pielke(2015) show…

- … that the IPCC scenarios implicitly include much rosier assumptions of "spontaneous decarbonization" and growth than any historical analysis can support
- "Spontaneous" – meaning, occurring without any impetus from policy changes
- See next slide

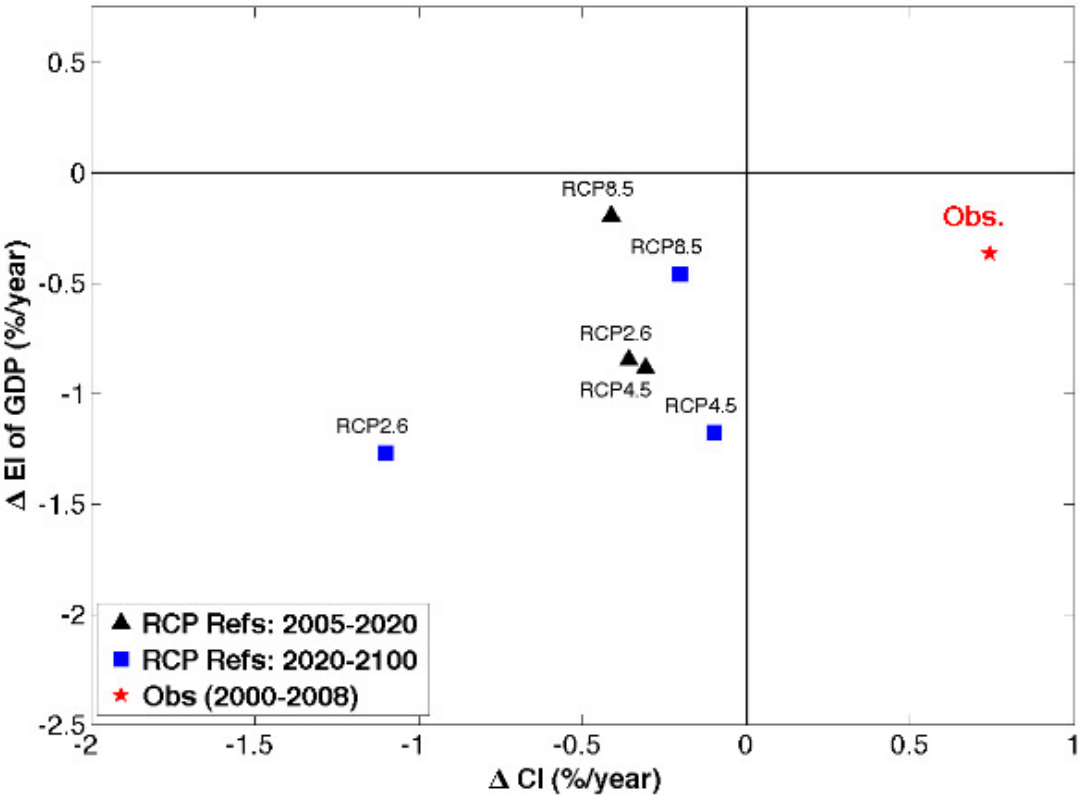


Figure 1: Rates of decarbonization in three of the RCP baseline scenarios for which data is available as compared with the observed rate. This figure is modeled after Figure 2 from [1].

From Stevenson & Pielke (2015)

All RCP scenarios, even the most dire RCP 8.5, assume declining carbon energy intensity (CI) over time. Observations (red) show in fact carbonization lately is RISING, not falling. These scenarios are the implicit baseline assumptions, without government enforced policy to motivate further improvements. The point is, IPCC RCP scenarios are unrealistic. Garrett's presumed 50 yr halving time for CI (carbon intensity of energy) corresponds on this x-axis to -1.39%/yr; stronger even than any IPCC scenario

Let's Pause and Consider How Global Wealth Rises in the Most Crippled DeCarb Case

- You might be thinking "*Well, OK, global wealth rising at half its current rate…. While it's not enough to save us, but still, it doesn't really sound SO bad.*"
- But the global wealth rise rate since the Industrial Revolution has never declined. Global wealth rise rate has ALWAYS risen, and at worst, it has plateaued for a time (as it has right now, at 2.2%/yr), before new energy resources were discovered and exploited and growth rates could rise once again.
- **The current 2.2%/year real rate of return (to civilization Wealth, and) on energy invested is higher than it has EVER been.**
- **With the new energy resources of solar and wind and perhaps tidal… will we respond with even higher energy growth rates into the future as we have in the past?**

But if, on the other hand…

- …we somehow transform human nature and reverse our growth before it is too late…
- We're going to have to prepare for a very different world. To halt climate change will require severe negative growth combined with severe decarbonization, for starters.
- It will also require a technology to remove existing atmospheric CO2, chemically stabilize it, and rapidly and permanently sequester vast amounts of it somehow. By all estimates, a phenomenally expensive undertaking, if possible at all.
- Expense means (by Garrett Relation) Energy consumption…. Which means CO2 emissions until accomplished. This is the **Double Bind**

But What of all the Talk About our Carbon Budgets and That we Still Have Time…

- …before we've used up that budget keeping us below +2C temperatures?
- Anyone still talking this way is recycling obsolete information. Scientists acknowledge the IPCC AR5 and earlier CMIP models were missing many key climate feedbacks, and also, in hindsight, the much steeper than assumed rise in global temperatures since 2013.

Look at the tone and couched response to the direct questions…

- …about how carbon budgets should be changed to start including the missing feedbacks.
- Indeed, spinning it at our rosiest best, we're expected to use up the actual carbon budget for **+1.5C by 2020, and for +2C by 2032. (Wagner *et al.* 2016) and (pdf of original research paper), and this fails to include the substantially larger climate sensitivity ECS shown by Fredrich *et al.* 2016 (earlier in this presentation).**
- The physics inertia of our civilization's path means that **these temperatures are unavoidable**. Why "rosiest"? Since these links were written, global temperatures have dramatically risen 0.4C in just 2 years, ending 17 years of slower growth

What is the Fundamental Driver?

- Here are my thoughts, not necessarily Garrett's, although recently his reading of this PowerPoint Presentation finds him in agreement.
- For the vast majority of human genetic history, it was an advantage to evolve a biological drive to fight for our place in a vast wilderness of dangers and competitors for our needed resources – ***Grow, or Die.***
- When we became more efficient, we became better at carving away that wilderness. This is reflected in the CThERM model, implicitly

Now in the 21st Century, unconquered Nature is mostly gone

- …and we've taken nearly all arable land for our use, stripped the oceans, commandeered over 1/3 of the entire primary productivity of the planet to ourselves… and sanity requires that growth must end.
- **But….we still have the same genetic inheritance and urges – to grow, to expand, to exploit energy and resources. Especially, as we saw in K40b, those with the most challenged mental fitness and capacity (the Conservatives) most loudly voice this unquestioned mindset**

But Wait, Isn't there a Point Where Even Energy Gluttons are Satiated?

- The "larger" your life, the larger your energy needs, it's a thermodynamic law.
- Still, it's conceivable that the tendency to consume more energy for oneself might not rise as fast as one's individual wealth, beyond a certain high level.
- But post-diction experiments run by Garrett (2015) so far show no evidence of this.
- Indeed, most of the world is anything BUT "satiated". They are adamantly determined to spend whatever energy they can lay hands on to increase their wealth to AT LEAST the level of those Americans. Half the world's population lives on just $2.50 per day wages.
- So if there is such a point, it would appear to be too high to help with our emergency now

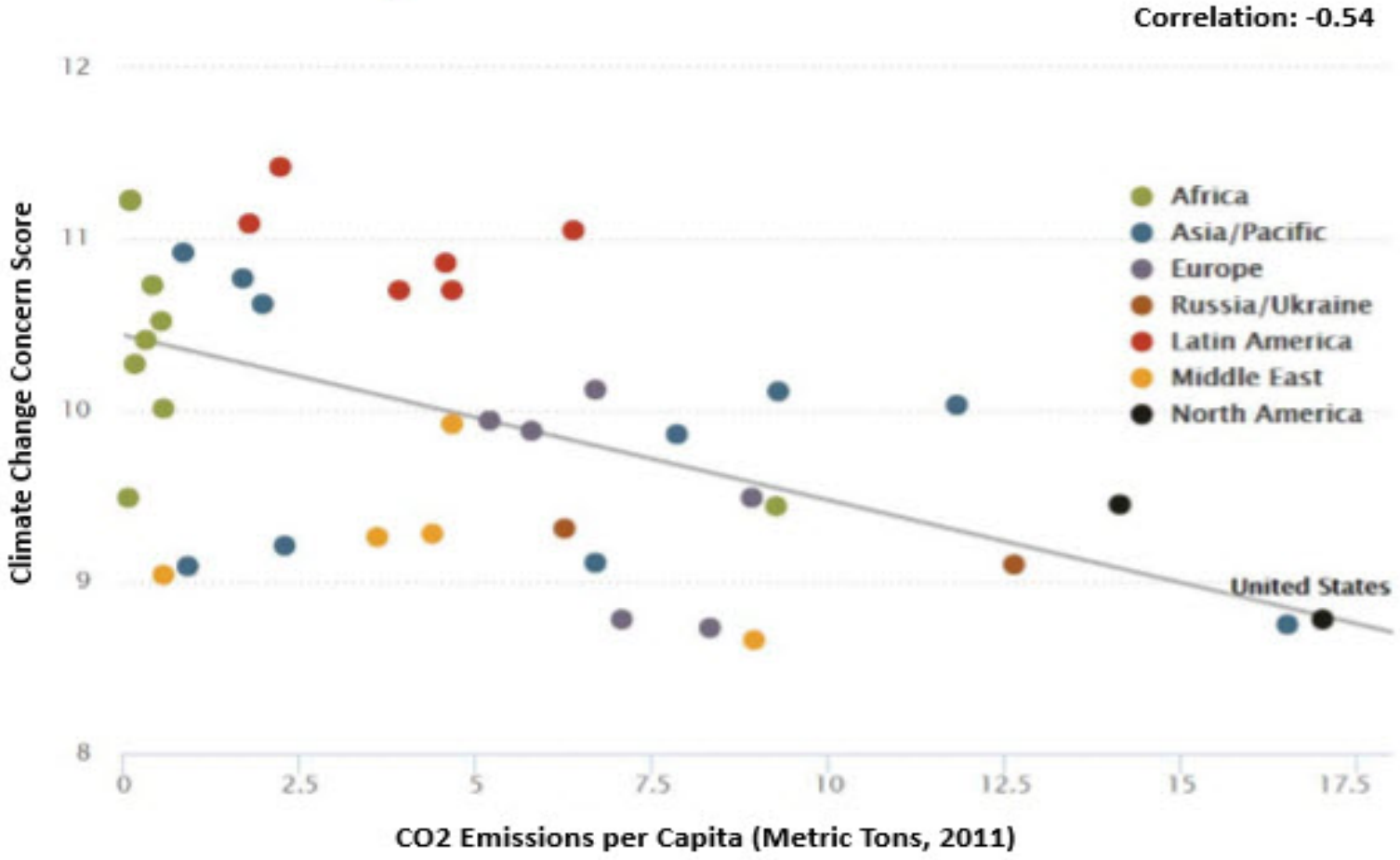
Since Climate is the Most Efficiently Global of all Problems

- …due to the rapid dilution of CO2 from its source, it means that there is no realistic incentive for voluntary individual action to reduce one's carbon footprint.
- Even the most Draconian local or individual carbon footprint cuts will have negligible impact on climate – yours or any one else's.
- Even if a billion of the highest CO2 emitting population somehow, inspired, voluntarily cut their carbon footprint by ½ (if that's possible), still it will only reduce CO2 emissions globally by 13%, when in fact they need to rapidly be cut to zero.

Worse: The Highest Per Capita Carbon Emitting Countries are the Most in Denial (Stokes *et al.* 2015)

Exhibit 11: Carbon Emissions: The More You Produce the More in Denial You Are

...now that's wishful thinking!



Source: Pew Research Centre Report: "Global Concern about Climate Change, Broad Support for Limiting Emissions" by Stokes, Wike, and Carle (Nov. 2015)

Our Forebrain - Cause for Hope?

- The only bit of hope I see, is that as part of our evolutionary survival mechanisms, Nature also evolved in us a forebrain – capable of reason, of identifying principles, of applying them, and forecasting the future to enable better planning.
- It's our forebrain *vs.* our "reptilian brain". For most of our history, they both mostly led to the same goals - Domination. Now… they are in conflict, and our survival and well-being requires that our forebrain assume agency. Will we allow it do so, in time? Can it, at all?
- Can such deep fundamental change in human behavior happen, such that we would voluntarily inflict a substantial negative growth of civilization, affecting the inflation term in CThERM and while still decarbonizing and allowing atmospheric CO2 to not rise beyond ~500ppm?

Nolthenius' First Law: *"People Learn the Hard Way"*

- Review my **Chapter 0**
- I know from experience and that of others, that it usually takes long-standing pain to motivate a person to change. And even then, it takes real work, real commitment to overcome ingrained patterns of thought and achieve emotional maturity.
- How can we expect this of the entire global population of individuals?

- **A few do learn. But they are a tiny minority – the far tail of the bell curve. Despite what economic growth is doing to this planet, most of the Earth is peopled by those desperate for MORE, not LESS. And not a single leader will dare talk of limiting population, or reversing growth in Wealth – they feel they can't and still remain in power.**
- And worse, our global political/economic power systems are designed to reward short-term returns, not nurture long term planetary health (review the importance of **Gilens and Page 2014**).

Improving energy efficiency requires accelerating CO2 emission growth…

- …because for now, doing ANYthing, including improving energy efficiency, requires carbon-generating energy to accomplish.
- Further, **energy consumption is determined by the size of Civilization, which is determined by all <u>past</u> growth.**
- **<u>Since the past cannot be changed, energy consumption rates</u>** <u>cannot be changed except very slowly</u>.
- Energy consumption rates cannot be reduced without an on-going significant contraction of the world economy and a declining population
- In other words - **A purposeful, engineered Global Economic Depression that lasts many decades or longer**
- **Consider the math…**

Merely Halting the Further Rise of CO2 Emission RATES is a Herculean Task

- In 2016, total primary energy consumption is 17 trillion watts (TW), growing at about 1.5% per year (down from 2% for most of the 21st Century).
- That's 255 GW of additional power needed per year, or 700 MW of additional power per day.
- To keep CO2 emission rates constant, this 700 MW per day must be carbon-free power…

Considering Solar Photovoltaics as the Carbon-Free Power Source…

- …700 MW per day is equivalent to 3.5 gigawatts of "boiler plate" rating capacity per day (given the standard 20% capacity factor between peak ("boiler plate rating") output and actual average continuous PV output)

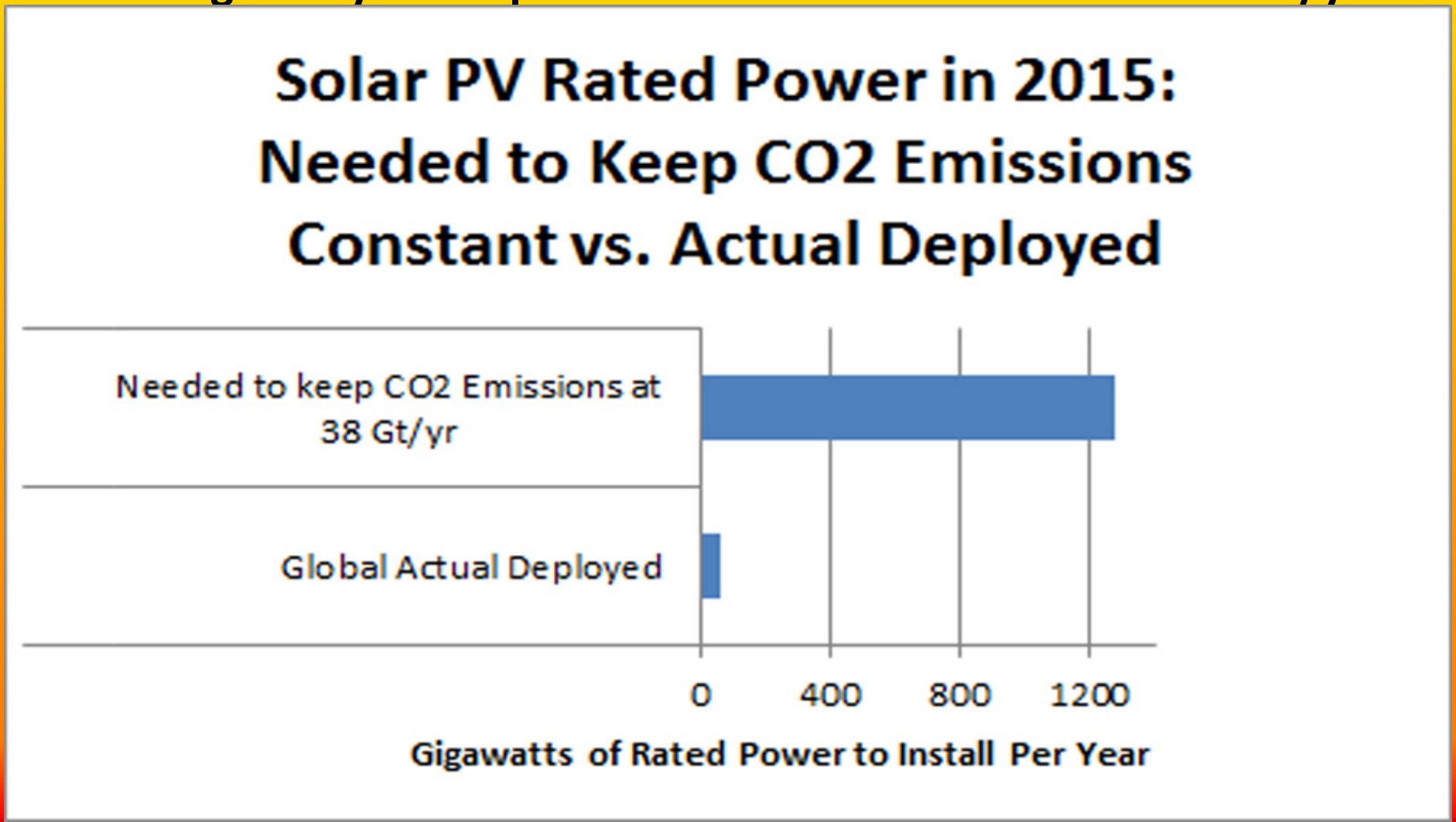
- **=1,277 GW (rated) additional solar PV power to deploy every year**
- **= 4,100 square miles of solar PV active panel area, every year. Or,**
- **=11.23 square miles of solar panels every day**

- **That's merely to halt further rise in CO2 emission rates, *i.e.* keeping them constant at 38 billion tons per year**

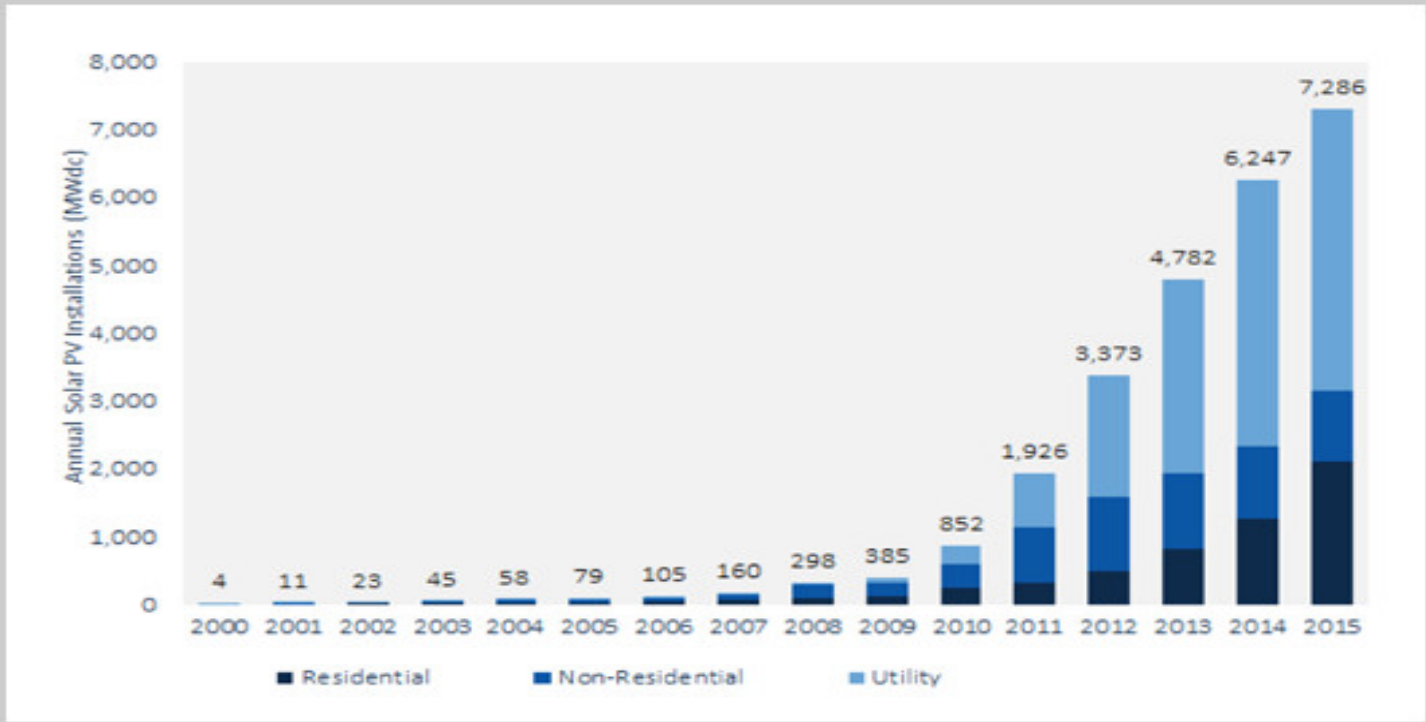
To put 700 Megawatts per day of new carbon-free power into a Nuclear Power Plant Context…

- The **Diablo Canyon Nuclear Power Plant** (the entire generating facility takes up only 12 acres), produces the equivalent of 2,055 MW of continuous power averaged over the year.
- **Diablo Canyon's 12 acres produces the equivalent of 33 square miles of modern solar PV panel area (or roughly 55 square miles of utility-scale solar power plant facility area).**
- **This is the problem of trying to power this vast civilization using only incoming energy, rather than the accumulated fossil energy of millions of years of captured solar energy**

For comparison, the U.S. installed 7.3 GW of solar in all of 2015. And 59 GW globally. Twice that for total renewables (but the total then includes substantial biofuels which are at best only carbon neutral, and far inferior to solar/wind). That rate is less than 10% of what's needed globally to keep CO2 emission rates constant at 38 Gt/year



That's based on 1.5% global wealth growth rates and therefore global energy consumption growth rates. Below, note that for the past 5 years, solar deployment has risen only linearly, not exponentially, in the U.S. Most of the gain is in utility-scale projects). First Solar, Inc. is the top builder of such projects



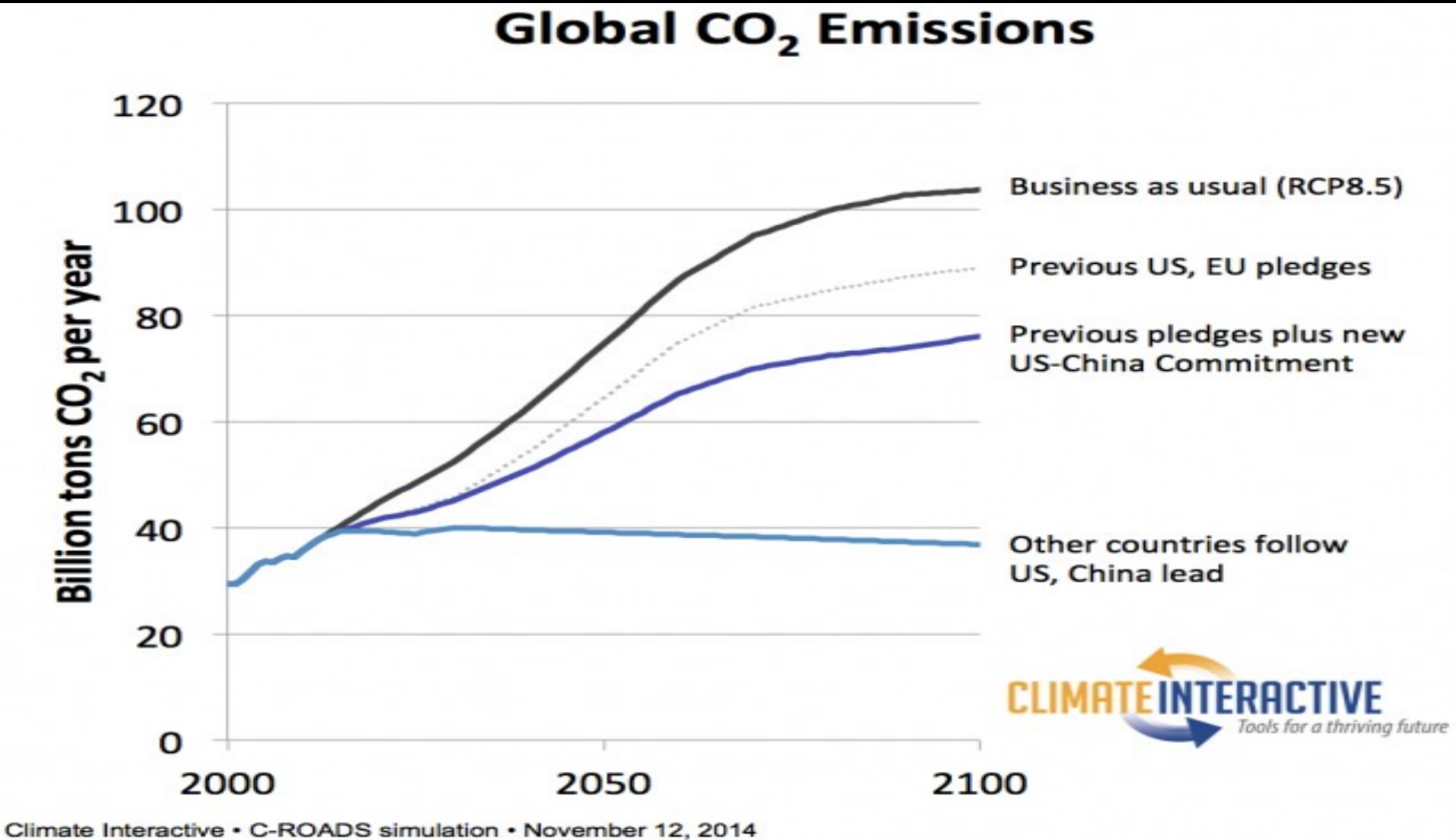
So. 700 MW of carbon-free Power Per Day. Would the Resulting Constant CO2 Emission Rates Mean Constant Atmospheric CO2 Levels?

- ***No.*** **This is a common but wrong assumption by the non-mathematical public!**
- Instead it would mean that atmospheric CO2 would continue to rise, but now linearly (as an upward sloping line at the same slope as when you finally construct the equivalent of 11 square miles of solar panels every day), rather than exponentially (a curve of accelerating upward curvature.)
- Except, even that's very likely too optimistic, since at today's high temperatures, we can't halt growing methane emissions and carbon release from the permafrost melt, so likely the CO2 rise rate would still be exponential (albeit with less acceleration than at present)

If you Want Constant Atmospheric CO2 Levels (at today's 410 ppm)…

- The new work of Vaks *et al.* 2013, Friedrich *et al.* 2016 and MacDougall *et al.* 2012 say – It's already too late; the permafrost carbon feedback has begun.
- **Only a complete halt of human GHG emissions, combined with GeoEngineering CO2 back out of the atmosphere at massive rates, combined with re-freezing the Arctic could accomplish the goal.**
- **That will be hard. Especially considering we're doing essentially nothing but token grandstanding at present.**

The Wildly Celebrated US/China Emissions Pledges… do very little. Even if the entire world joins (bottom curve), CO2 emissions per year at best stay flat so that atmospheric CO2 continues to climb, and global temperatures would continue to climb, past +4C. And this graph includes no melting Arctic permafrost or new, higher ECS.



Head of the Tyndall Climate Centre in the U.K Prof. Kevin Anderson Points Out

- Global power generation in 2015 was 105,000,000 Gigawatt-hrs
- Nuclear power provides 2.5% of that
- Merely to get nuclear to provide ¼ of our power means we need to build 4,000 new large nuclear power plants in the next 30 years. Instead, we have scheduled 70 (or less).
- His bottom line is, whether it's wind, solar, CCS (carbon capture and sequestration from fossil fuel plants), or whatever the new technology trumpeted **– "you cannot build them fast enough** to prevent us from blowing through our carbon budget" designed to hold temperature rise to ~+3C. Not without drop-**everything**-and-decarbonize-like-your-life-depended on it.
- This **lecture presentation** reinforces the conclusions of Garrett, and highlights the myopic unreality within so many policy reports delivered to climate policy negotiators
- And this is without the additional constraints discovered by Garrett, and the new ECS physics, and the **Permafrost Carbon Feedback**.

Kevin Anderson…

- …relays the universal reaction he's gotten privately from the policy ministers when he points out how our path, and proposed paths for increasing renewable energy and lowering CO2 emissions, are hopelessly too small to avoid +2C, and that we're on the path to +4C long before the end of this century, and then hotter.
- He further relays *that "+4C is universally among scientists declared to be incompatible with an organized society"…*
- The reaction he got – *"I can't say that sort of thing in Copenhagen"* – this from the U.S. Secretary of State (2008 Copenhagen climate summit)
- Sources **here**, and **here**, **here , here**, **and here**

Anderson Continues…

- …Political scientists advised him that he and other climate science academics should be very careful to whom he spoke about these realities.
- A friend and senior policy maker advised him *"you can't say these things to policy makers"*
- The (U.K.) chief scientists who advise policy makers agreed *"I can't say these things to the policy ministers!"*
- Anderson explains that the pressure being brought to bear on climate science academics in the U.K. **has resulted in most giving rosy views in public and in print**, on what the policy ideas being brought up will do for the future.

Yet when Anderson talks with these same scientists in <u>private,</u> they admit – *"I know it's not true"*

- I'm thinking of a white paper I read recently trumpeting a "Pathway to our Renewables Future" – and it clearly simply took renewables % of total energy today, and french-curved them up to what was desired, with no appreciation of the effect of Generalized Jevon's Paradox on actual energy consumption when efficiencies happen.

An Exasperated Kevin Anderson …

- "We're all trying to spin the message to make it acceptable to the next tier up" (64 min into this talk)
- The tiers being… the climate scientists, to the climate science/policy intermediaries, to the policy advisors, to the chiefs in government, and then to the international negotiation team at climate talks.
- And with unreality rising with each tier passed
- We're all playing "The Emperor's New Clothes", with those few courageous scientists who speak out, like Garrett, and like Anderson (Anderson and Peters 2016), pointing out the insanity of it all.

Post-Paris: A Post-Mortem

- The Paris Climate Summit (COP21), was an utter failure, despite all the back-slapping congratulations for the press
- No policy machinery was created or agreed to
- No enforcement mechanisms
- No time deadlines for any positive climate actions, just an agreement to meet again in 5 years.
- Instead, the countries agreed to "try" to limit global temperature rise to +2C, and perhaps even +1.5C
- But in fact, we're almost at +1.5C today, and +2C is impossible to avoid, knowing what we know in 2016, and most certainly impossible without shock-and-awe Draconian cutbacks to energy use and near instant decarbonization. We're not even trying; instead just posturing. Remember – **temperatures do not go down, they only go up.**
- Prof. James Hansen **called** the Paris COP21 results **"a fraud".** And I agree.

Dr. James Hansen Makes an Analogy

for the Paris results, given the utter failures of the prior COP's

- *"It's like an obese person proclaiming his goal of losing 40 lb… and failing, and instead gaining 10 lb over the next 2 years. And then making a public proclamation of his new goal – to lose 50 lb! And then celebrating the proclamation with a large pizza and a gallon of ice cream."*
- Myself, I hear endless promises from government policy people, using hyperbolic prose. I've heard them for decades. Paris is just the latest.

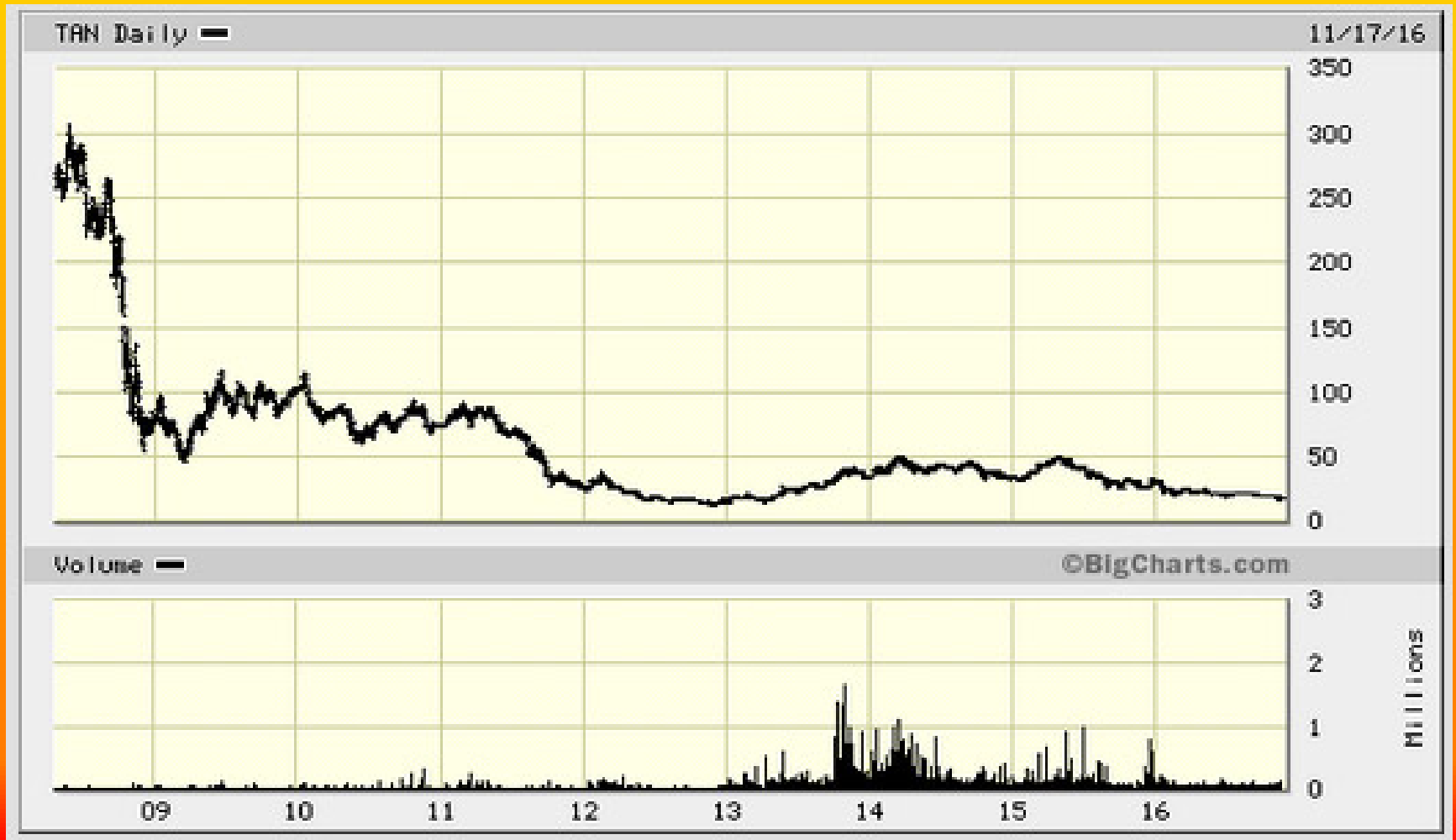
But Solar is taking over the World, right? Except, you need healthy Solar companies to accomplish this. Here's First Solar, Inc.'s 10 yr stock chart. Not healthy.

Growth rates slowing from exponential to linear, materials costs rising…

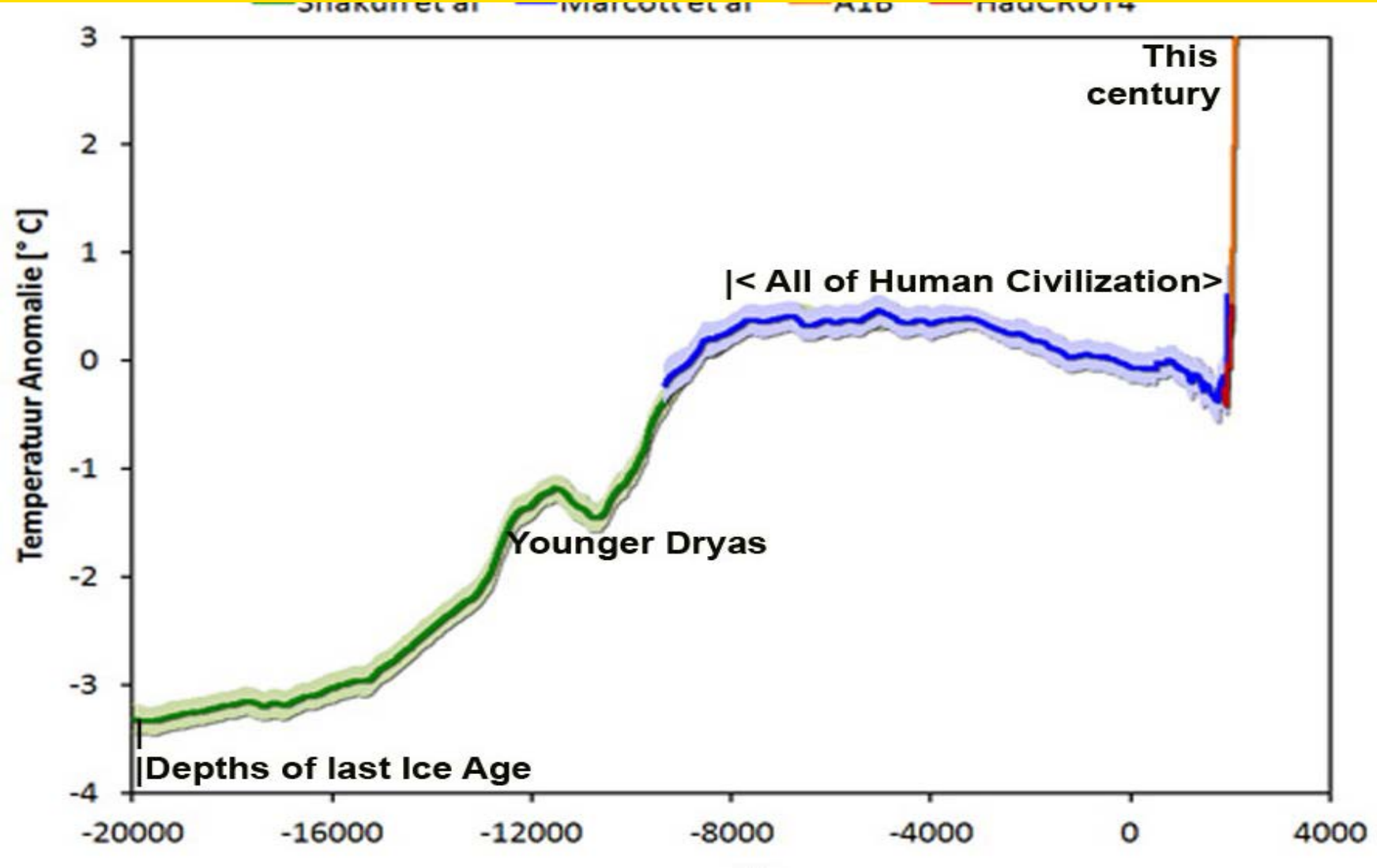
- Profit margins squeezed to zero and below, as oil prices and fracked natural gas prices plummet, adding more competition for renewables
- Government subsidies are required, still, for renewables to stay in business, and are uncertain even long before the Trump Empire took over
- The largest solar company was Sun Edison, now bankrupt.
- **Chinese solar companies have similar charts**
- **There's a "cognitive disconnect" going on**

"But, Rick – the Chinese, at least, must be doing GREAT, what with their commitment to clean up their air and all the good buzz we're hearing." **No. Their solar companies: all suffering**. Here's last 3 yrs for their top rated panel maker – **JK Solar, Inc.**

It’s not just Utility-scale solar, it’s all solar companies; Here’s the Guggenheim Solar ETF chart for the past 8 years

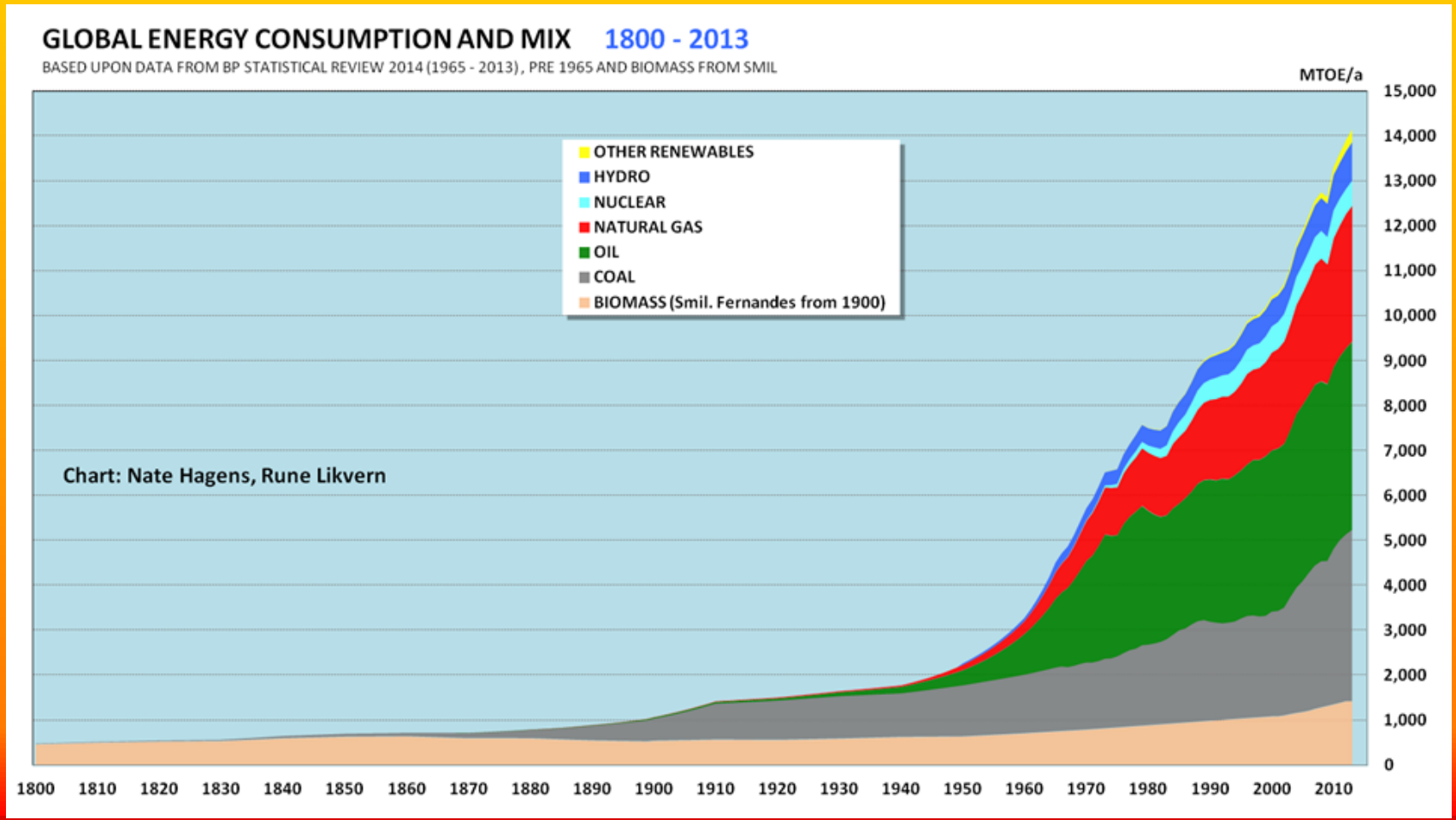


Garrett's work explains WHY it is so difficult to turn this temperature trend…



…around to something better

Global energy consumption skyrocketed with the discovery and exploitation of ~50 Million years of accumulated concentrated solar energy (fossil carbon) … The tiny blip of yellow is non-hydro renewables. They are not replacing, but rather in ADDITION TO steeply rising fossil fuels underneath. (Hydro and Nuclear have not grown for decades)



Prof. Joseph Tainter, on Parallels with the Fall of the Roman Empire: The key insight = Plundering ACCUMULATED Wealth *vs.* ONGOING GENERATED Wealth

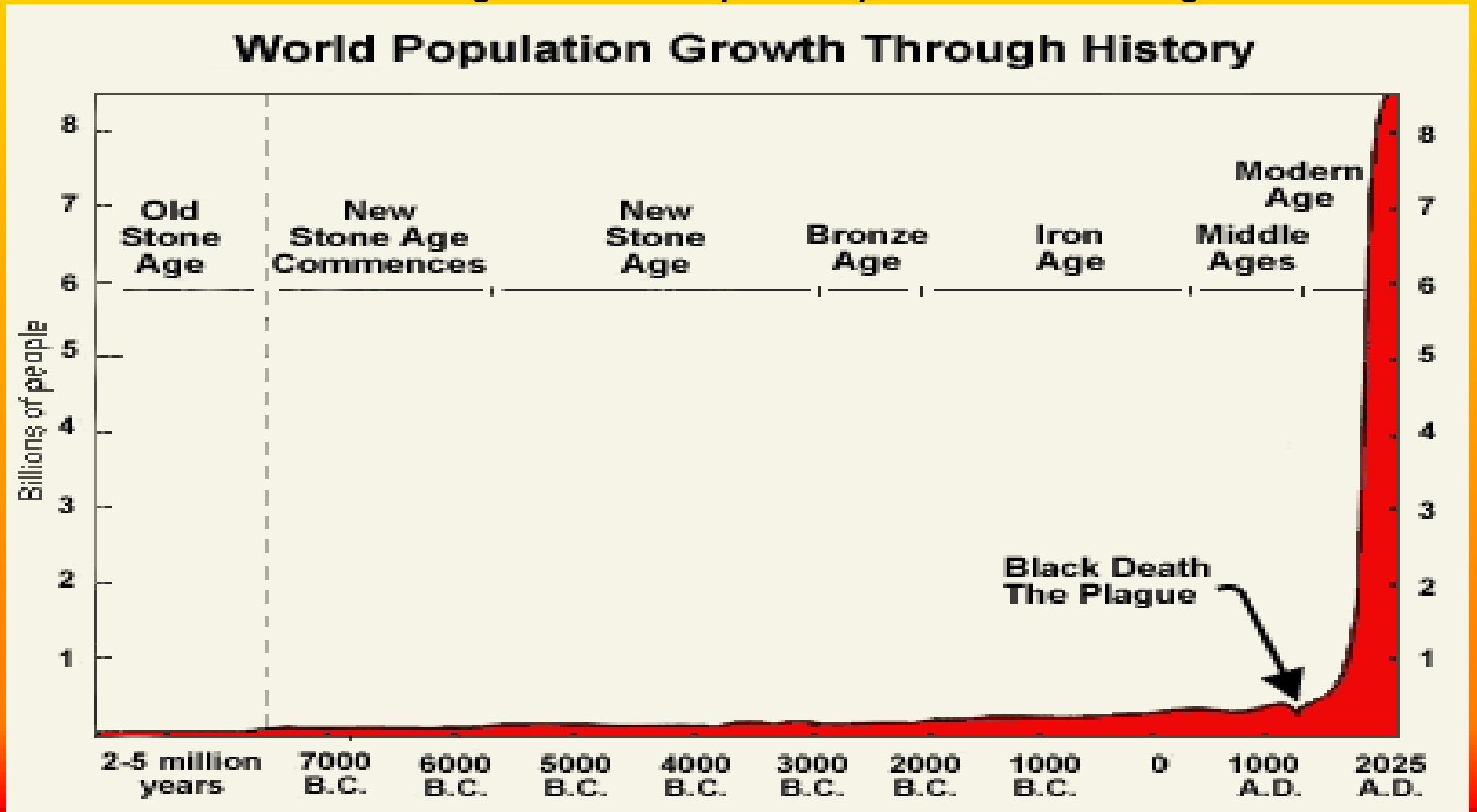
- Rome grew by conquering neighbors and then plundering the **accumulated** wealth of those neighbors. Rome could keep growing because its larger needs could be met by absorbing not merely the on-going currently generated wealth, but rather the much larger **accumulated** wealth of those it conquered.
- **When Rome ran out of rich neighbors, it could not sustain itself with merely the currently generated new wealth of its existing slaves and the sun (via agriculture), and it collapsed.**
- (especially **33 min into this talk**)

We are in the same situation.

- We have multiplied our civilization by over an order of magnitude by plundering the **accumulated** energy of the Carboniferous Era – ~50 million years of accumulated solar energy, spent at a speed-of-light pace limited only by our ingenuity and the incredible economic efficiency of Capitalism.
- We are faced with having grown vastly by using an energy source which, in fact, is a poison to our future, and face the necessity of having to shift support of our vast current civilization to only the **ongoing arriving solar energy**, not the easily mined millions of years of accumulated solar energy **crystallized into fossil fuels.**

Here's finally a bullish stock chart… KOL, the Exchange Traded Fund covering Coal mining corporations. More than doubling in 2016. Coal still runs most of the world's power plants

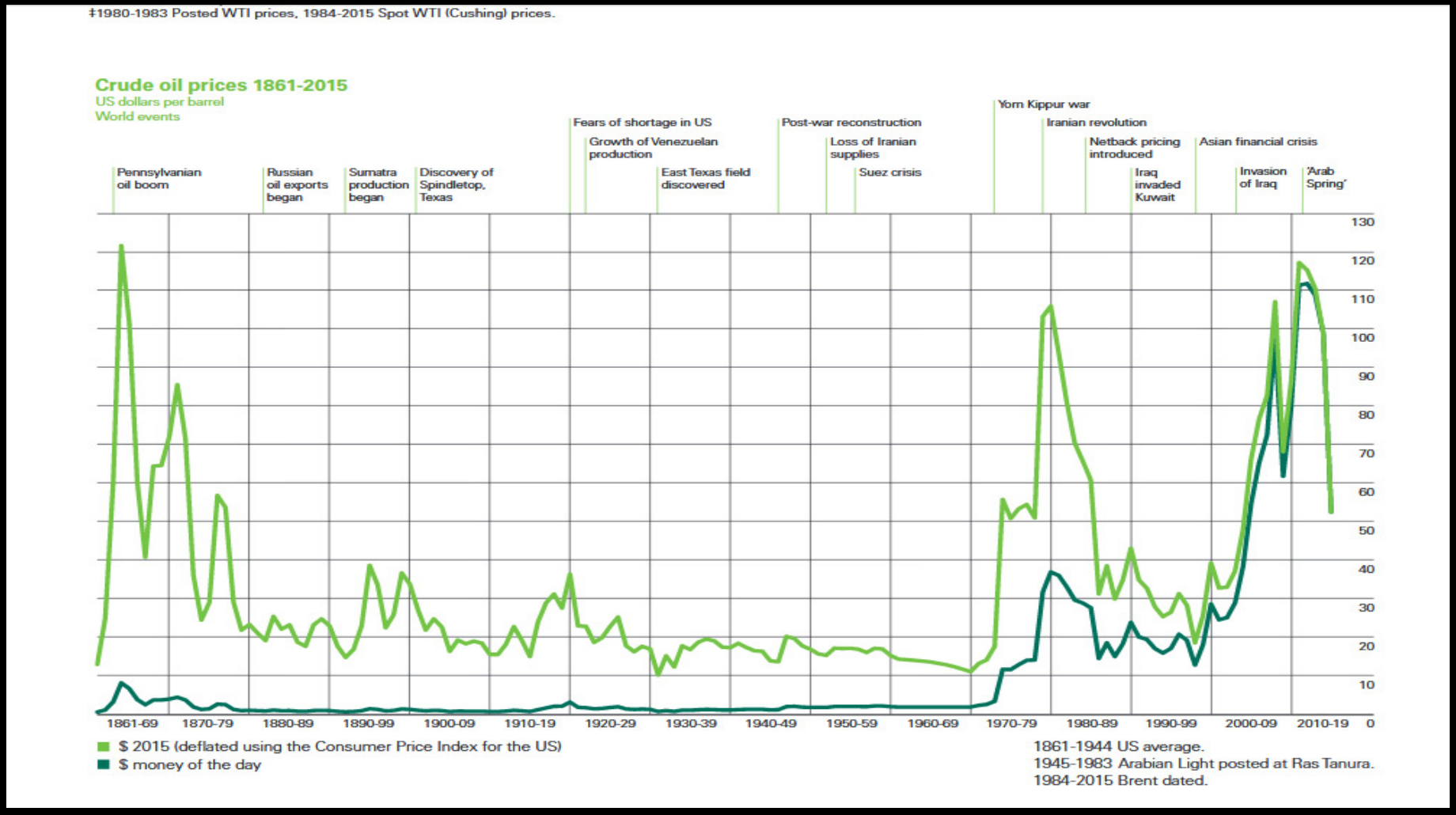
Fossil Carbon allowed us to multiply ourselves and our Civilization. Now; we're saddled with supporting that bloated Civilization. That population is IN PLACE. That Wealth is IN PLACE. That infrastructure is IN PLACE, all needing constant feeding of more energy just to maintain it. Short of Apocalypse, that is a FACT of our lives. We've dug a very deep hole: our energy needs. That incredibly energy-dense manna from heaven – fossil carbon – is killing our planet. Yet we're more than addicted to it. It is IN PLACE as our energy source, and we can't get off of it fast enough to avoid the planetary disaster it is causing.



How Robust is the Garrett Relation?

- Even though oil prices have gone through huge spikes; in the ‘70’s Arab Oil Embargo, again during the Gulf War, and just before the “Great Recession” of ’09, with large drops in oil prices in between – still the constancy of (time-integrated inflation-adjusted GWP)/(Energy consumption rate) - **the Garrett Relation - continues to hold.**
- Even though the rate of growth on global growth rates have slowed markedly in the past 20 years – still, **the Garrett Relation continues to hold.**
- Even with the largest and most populous nation on Earth – China – instituting 35 years of **1-child-per-family**, **still the Garrett relation has held.**
- These are impressive confirmations. Yet we can ponder…
- **…What kind of shock would it take for this relation to be broken?**

Oil Price Swings (inflation-adjusted) throughout history. Note the huge swings during the past 50 years.



Would a Giant Asteroid Impact do the Job?

- In that case, global wealth would be cut to a small fraction of today all at once, and so would our energy consumption rate.
- Yet, time-integrated GWP would not change immediately since it includes all past GWP as well – and the past cannot be changed
- There would have to be quite a few years before that integral dropped low enough to again match lower energy consumption rates. So does this reveal a flaw in the model?

No. The CThERM model includes a key term – **inflation.**

- Remember that the **Garrett Relation** applies only for inflation-adjusted wealth. A massive destruction of wealth would leave the existing nominal dollars of integrated GWP paired with far less actual wealth to denominate– *i.e.* the monetary number assigned to each unit of remaining wealth not destroyed by the asteroid would be far higher: in other words - **Inflation**
- Thus, it appears to be a very robust relation, which ultimately is based in Nature…
- **Nature created both physics, and human nature.** The integration of thermodynamics with actual human nature, as revealed by data encompassing most of the accumulation of all world Wealth, perhaps therefore makes these results less surprising.

Let's Clarify the Notion of Inflation

- Garrett, and others as well, note that there are two ways inflation can manifest. If inflation is the trend in the ratio of money supply/Wealth, one can see rising inflation either because the amount of money in circulation is rising too fast relative to Wealth, OR there is **less Wealth** out there for the existing amount of money.
- Printing press money not justified by an increase in Wealth, is one form of inflation which gets a lot of attention and well appreciated.
- But destruction of Wealth, if money supply remains constant, is another form of inflation.
- Given both poles of inflation, it's hard to argue with the Garrett Relation.

Destruction of Wealth from climate change; for example…

- Flooding of ports with rising sea level, forcing continual re-siting and re-construction
- Enhanced cracking of asphalt with rising temperatures
- Crop loss, higher food costs from top soil loss due to dying soil microbes in the new climate, inducing new “dust bowls”
- Lost work hours from rising disease and health costs
- Lower productivity due to reduced mental powers due to rising CO2
- Higher military costs due to resource wars
- Etc.

Said Another Way…

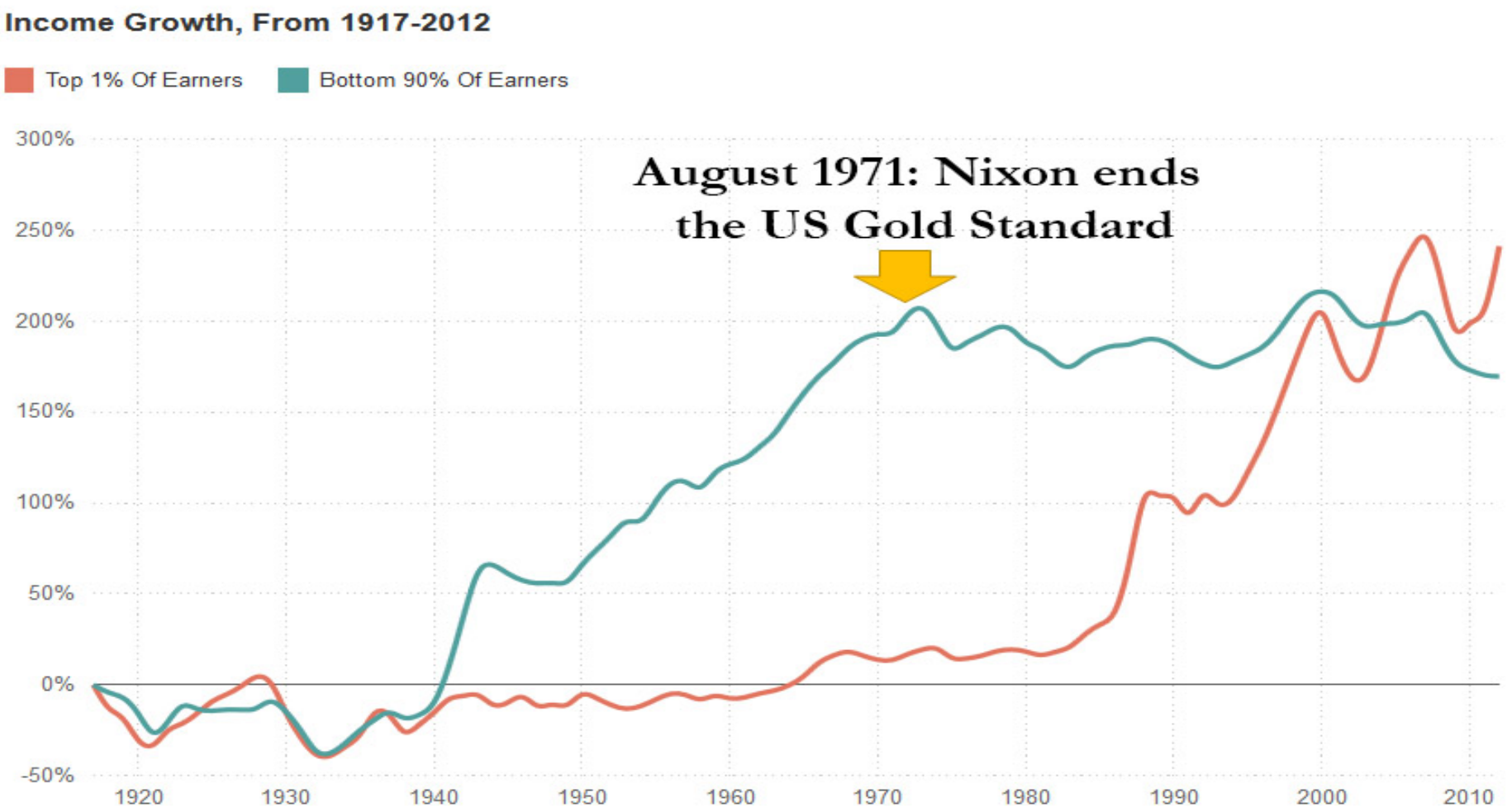
- The **CThERM** model includes inflation, and after cataclysms, we see that governments and central banks in the past have tried to force savings to be invested by penalizing savings via massive monetary inflation.
- Examples: Germany post WWI, Argentina in the 1970's, some African social/political cataclysms… but a notable exception being after the start of the U.S. Great Depression, when the Fed tightened credit in 1931, '33, and '37 – alas, a decision the current Federal Reserve has vowed never **ever** again to repeat

Currency Wars Are Underway Today

- The fact that growth rates of “only” 2.2%/year are not accelerating upward as Wall Street demands, are motivating central banks to fire up all-out currency wars in Japan, the U.S., Europe, Russia, China… to **devalue their currency** through massive printing press money, and “nuclear option” talk of negative interest rates as the ultimate weapon to pry-bar savings out of people’s pockets and into Wall Street markets, where the Economic Elites’ and their computer algorithms of ever increasing complexity are ready to extract the wealth of citizen stockholders.

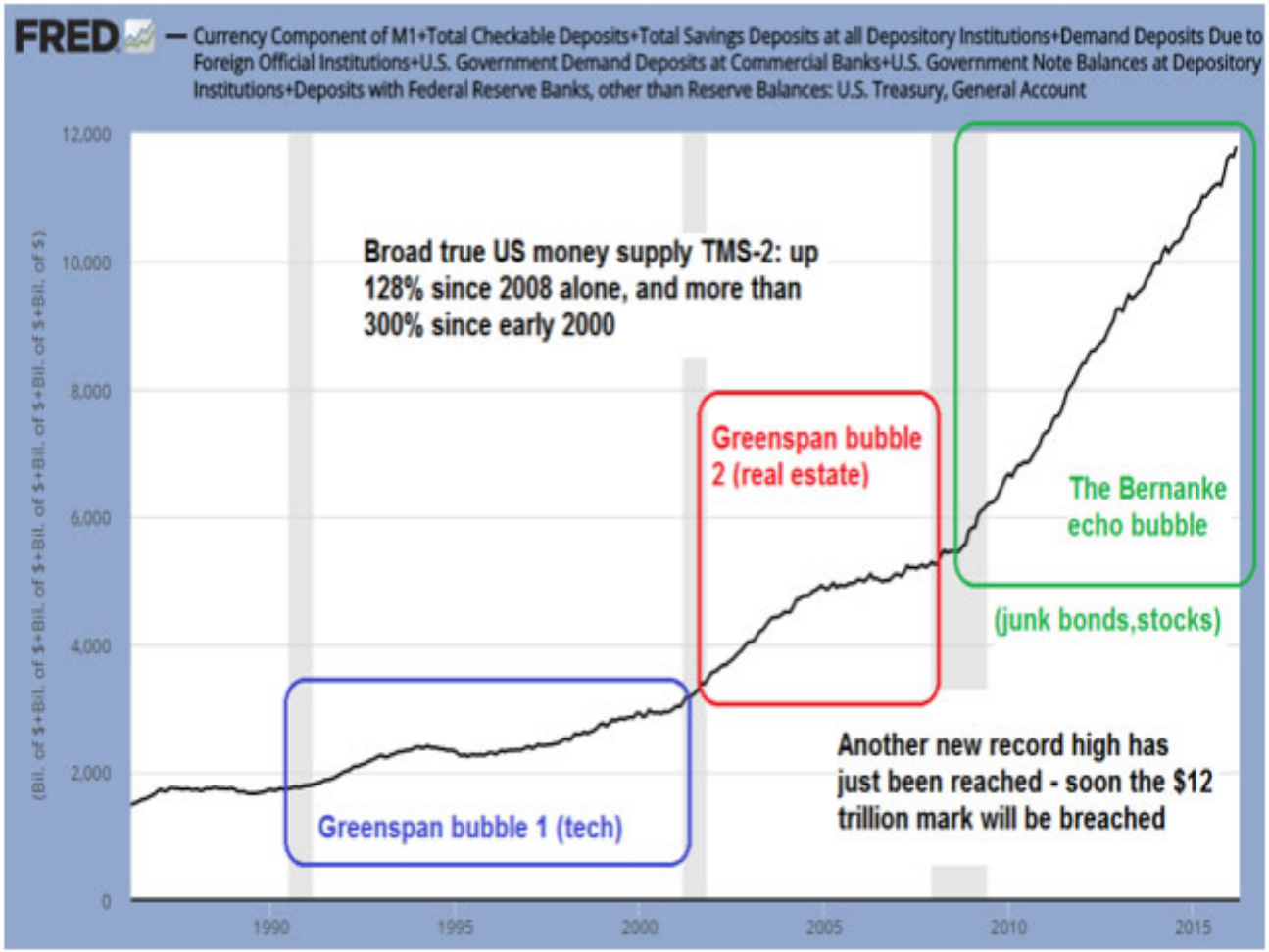
Monetary inflation leads to price inflation. So far in this post "Great Recession" world, this is mostly confined to asset price inflation: houses, stock prices, art and collectables…, since the average consumer is tapped out

Monetary inflation worldwide was unleashed when governments ceased backing their currencies with gold (which cannot be inflated) and began rampant money printing. This forces depreciating money into risk assets, which are the first repository of new money, There, sophisticated algorithms of the Economic Elites on Wall Street can extract even more of the wealth placed there by average global citizens.



Global Economic growth is 2% per year, but money supply inflation is 8% per year in the U.S this decade, 13% in the Eurozone, and even higher in Asia.

- Generalized inflation has the effect of lowering the efficiency of the economy and thus lowering the rate of return on energy investment (see Garrett). It is impressive that the world has yet been able to maintain a 2.2% return on energy investment, despite this drag.
- Global Central Banks are openly desperate to cause monetary inflation. The reason is that rising prices will spur consumers to buy now rather than save their increasingly devalued dollars for the future, and a higher velocity of money spurs GDP, making the economy look good.
- It speaks to our unshakable addiction to at least the illusion of growth …

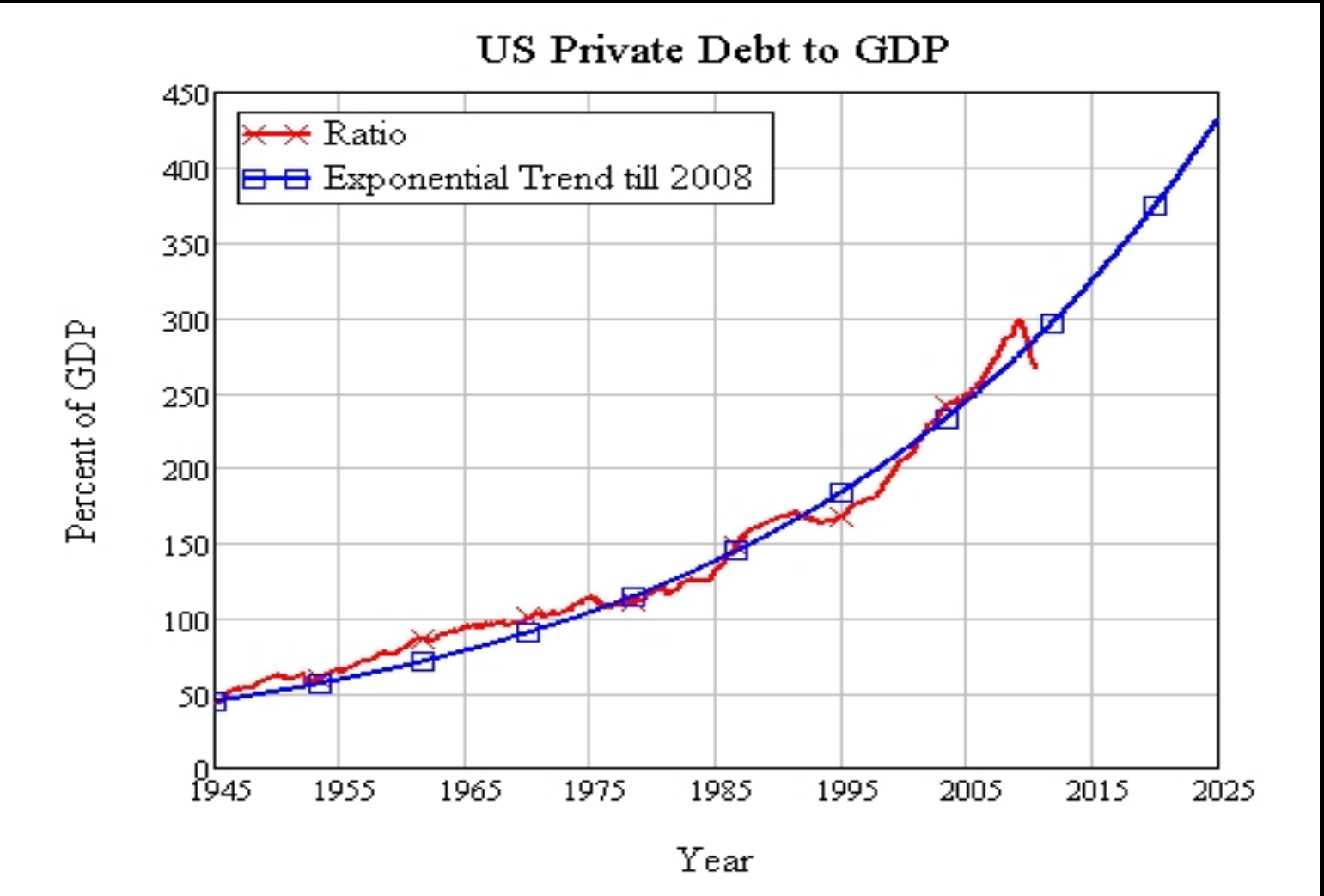


US money supply TMS-2 and the associated asset price booms since the late 1980s.

Currently, the true money supply is growing at 8% y/y in the US and 13.3% y/y in the eurozone. This remains historically a very high level, even though US money supply growth is well down from its 2009 and 2011 peaks:

Last 30 years: The U.S. Federal Reserve is absolutely determined to raise economic growth rates, even if it requires massive printing-press money creation and enforced low interest rates, (even negative rates, in a growing number of countries). They are penalizing saving, and FORCING us to take money out of savings accounts and put them into risky "growth" assets. "Growth", even artificially induced, requires energy consumption

So we go even deeper into debt, which is borrowing from the future generations (they aren't here to protest). In the U.S., Private Debt has exponentially crossed 350% of GDP in 2017



Same is true in China. Debt rocketing even faster than their GDP. In 20 years their debt has gone up 3x faster than GDP, and is today 300% of their GDP. This trend will end badly.

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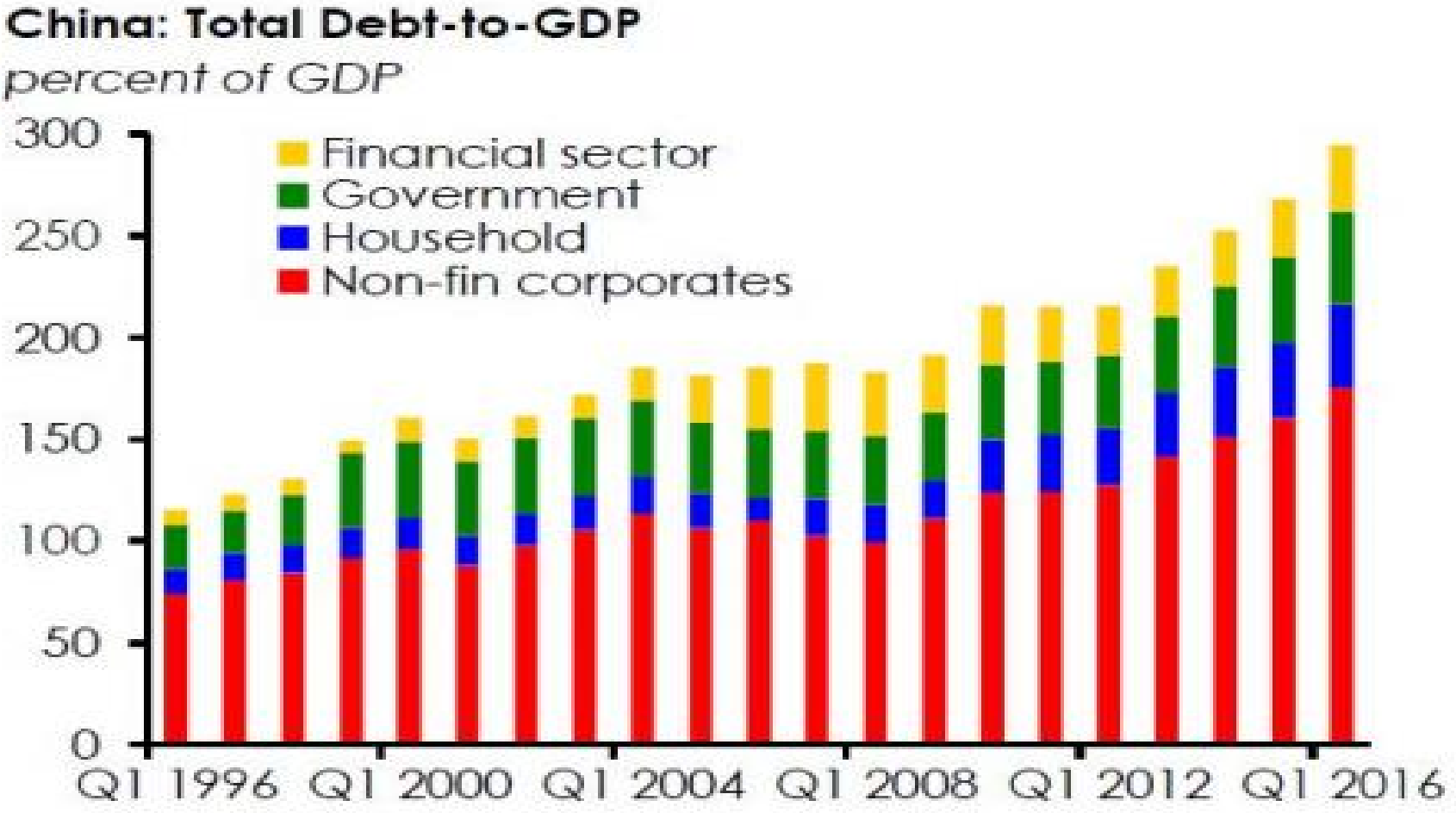


Source: PBOC, BIS, IMF, IIF.

The Accelerating Rising Global Debt Speaks to Human Nature's Prime Directive

- **Grow!** Grow faster than your neighbor and out-compete him for accolades, for choice mating opportunities, for the "good life"
- We will grow even if it is financed by borrowing from (even bankrupting) future generations. The average American couple has saved only $5,000 for their retirement (**source**). Taxpayers, *via* Fed printing press money, will make up the difference, charging future generations for the borrow.
- Here is why the **Garrett Relation** holds. History shows we are constrained in our growth **only** by our ability to access and exploit new energy reserves.
- We do not replace fossil fuels, we add new reserves and new opportunities **on top of** fossil fuels, until fossil fuels are exhausted or out-competed even by the poorest of people inheriting hand-me-down diesel engines and gasoline cars.

A Misunderstanding by Some

- Garrett used the old-fashioned word “heat engine” in a sentence meant to convey a thermodynamic relationship in his early papers.
- But “heat engine” was interpreted by some out there to mean that what we have to fear from Civilization is direct thermodynamic HEAT as a by-product of industrial production
- This is not what he meant, and it is a false statement
- This was worked out some time ago, and can be found, for example, in **Flanner (2009). Heat production by global civilization is only ~1% of the heat that we TRAP via the greenhouse effect from the CO2 civilization produces.**
- **It’s the CO2, not the waste heat, we need to worry about**

The CThERM Model's Key Parameters

- Future projections require assuming …
- **1. How fast can we create efficiencies in energy consumption to do useful work?**
- Remember, this raises CO2 emissions by raising the growth of Civilization, including remaining carbonized energy consumption

2. How fast can we decarbonize our energy? (decarbonize: lower emitted kilograms of CO2 per Joule of energy expended)

- Decarbonization is explicitly included by a free parameter; the decarbonization rate **c**
- Garrett parameterizes it as a simple exponential decline. Other assumptions, such as the classic “S” curve, are possible.
- The resulting atmospheric CO2 curves are not that sensitive to different reasonable functional forms
- Briefly consider carbon capture from fossil fuel plants…

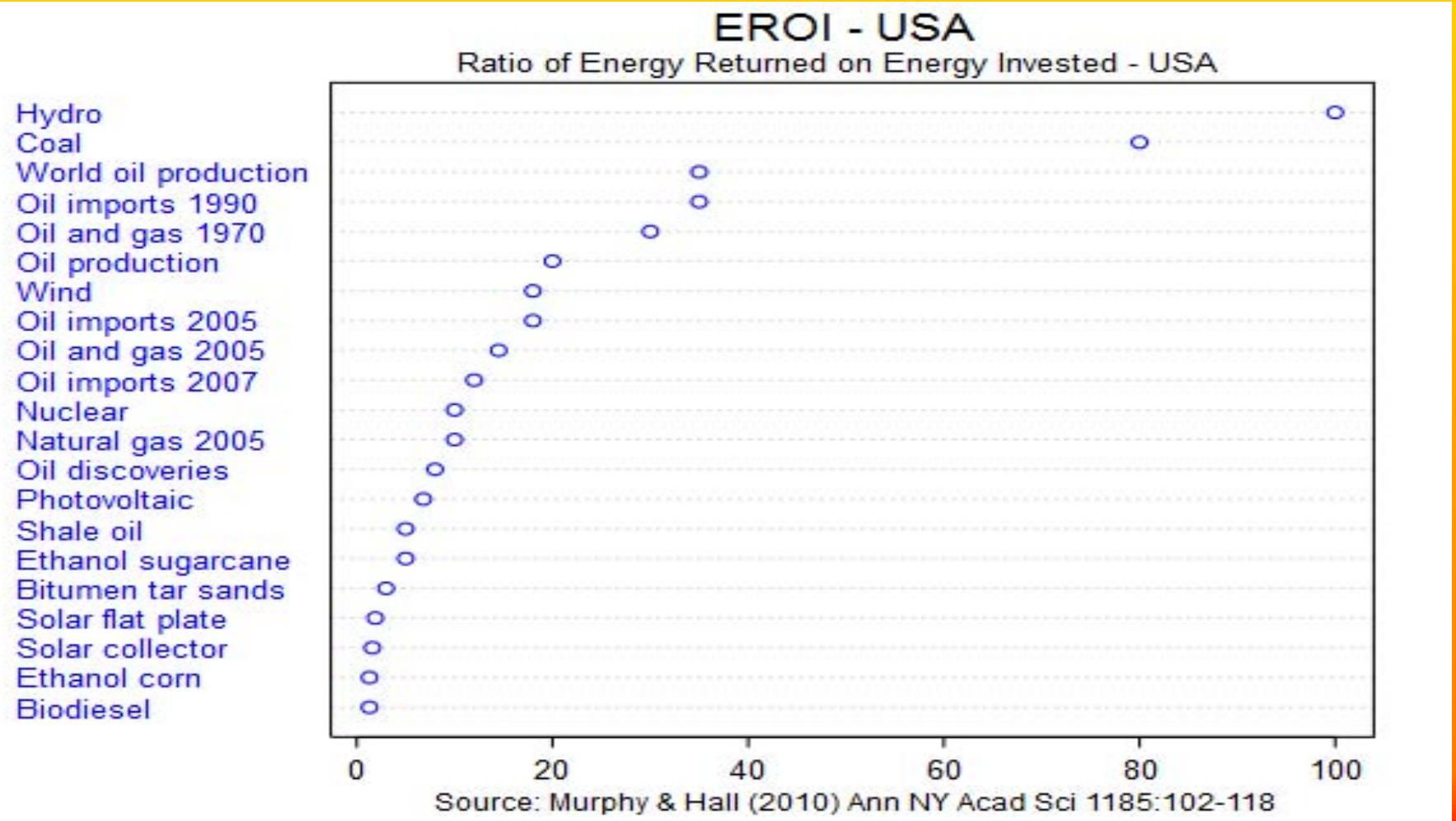
Carbon Capture from Carbon Burning is Costly in both $ and Energy

- The cost and energy input is comparable or greater than the energy gotten from the fossil fuels themselves, raising the cost of the plants prohibitively; http://sciencepolicy.colorado.edu/admin/publication_files/2015.32.pdf by 40-60%, whether natural gas or coal (Samuela Bassi, energy analyst).
- Professor Vaclav Smil calculates that even to capture and store just 20% of today's CO2 emissions *"would need a capacity 70 percent larger than the petroleum flow handled by the global crude oil industry"* (**source**). In other words, massive energy investment is required for this new infrastructure, producing more CO2 along the way.
- He, along with climatologist Dr. Kevin Anderson, and Tim Garrett, is among a handful of realists who are puncturing the complacency encouraged by the governments and corporations and policy people they employ, of the largest carbon polluting countries on Earth.

Carbon Capture and Storage (CCS) has been studied / engineered for decades

- But as of late ‘15 less than two dozen facilities exist worldwide. It’s too expensive. **And only one commercial power station in the world uses CCS to sequester its emissions** - a dam in Canada – and even that is economically viable only because the CO2 is sent to nearby oil wells to enhance oil production(!)
- CCS lowers substantially the **EROI = Energy Return on Energy Invested, which is high for fossil fuels**

EROI: Note that coal has the 2nd highest EROI, with Oil and Natural Gas next. Murphy and Hall (2010) found Solar PV only 1/7th of the EROI of Fossil Fuels on Average (but rising as prices drop). Wind is high. Biofuels are the Worst.



Another Confirmation of the Theory: The Garrett Relation + thermodynamics show that net EROI should be the inverse of the Inflation term

- **EROI = 1/Inflation (but note that for significant double-digit inflation or larger, this simple relation breaks down)**
- This is another test and confirmation of the **Garrett Relation**: data today (**Murphy and Hall 2010**) show that our high-carbon energy mix has an EROI of about 37 and indeed our inflation term then was about 1/37 or 2.7%.
- At the solar PV EROI (**Murphy and Hall 2010**) of about 7, that means an inflation rate of about 14%, very steep by historical standards, but that's with 2010 data. Better today, no doubt.
- If so, this means that decarbonizing our Global Economy will be a significant drag on global growth: The inflation term will be larger.

"Well, that's discouragingly expensive in CO2 emissions. But can't we Just Do It anyway, and still have a better future?"

- Better than not doing it – yes. But CO2 is a tough molecule. It doesn't go away. As Anderson emphasized, many studies show that ultimate equilibrium temperature depends only on the cumulative CO2 emissions. You can't fix later what you emit today.
- If CO2 is emitted, it raises global temperatures. **Permanently. (absent artificial atmospheric CO2 scrubbers)**
- **Doesn't matter if it's emitted today, or in 20 years.**
- **It's cumulative emissions that determine final temperatures. Recall that temperatures rise until carbon (human and permafrost, and natural) emissions cease, and then remain constant thereafter, for thousands of years.**
- **For climate, you can't afford to emit it in the first place.**

Suppose somehow, impossibly, we rapidly transform to a ~Zero Carbon global energy system

- In such a new world, we have a landscape covered with solar PV panels and giant wind turbines, enough even to perhaps power atmospheric CO2 capture and induce lowering global temperatures.
- **After all, Humans have only commandeered 36% of Earth's primary productivity. There's another 64% to be pried from the hands of Earth's other species.**
- But if the ruling urge remains "**Growth**", we must consume ever larger amounts of raw materials as well. We must grow food even more efficiently (lower the cost per calorie) to enable our further domination of the planet
- Bulldozing wild places and fellow creatures, to perhaps only end up in a **"Blade Runner"** future.

Blade Runner World - Inspiring? Is this where we want to go?

Today's constant 'mere' 2% GDP growth, as Wall Street constantly bemoans, is still exponential growth

- It leads to a doubling of Civilization, and more than doubling the consumption rate of food and raw materials every 36 years.
- Even if you pave the rest of Planet Earth with solar panels… **Earth IS finite. Growth WILL end.**
- **Despite SciFi and bizarre claims, other planets are hopelessly unsuitable to support Earth-based life except for brief, vastly expensive flag-saluting visits**
- Our **ONLY** choice is this: Do we learn that lesson BEFORE we doom the last square mile of unspoiled Earth, or AFTER?
- If AFTER, **what end will WE meet**?

To transform the World's energy system is an expensive (and therefore energy consumptive) enterprise

- It's not good enough to just draw some french curves, ignore the ramifications, and then say "Voil'a! Our Pathway to a Renewable Future!"
- To SAVE CO2 from entering the atmosphere we have to engage massive CO2-emitting energy today in the manufacture and deployment of new technology, above/beyond the energy needed to produce the other Wealth we crave; new grid systems, new transmission lines, and new industries to service this new infrastructure

From Energy Expert Dr. Vaclav Smil…. …*"Turning around the world's fossil fuel based energy system is a truly gargantuan task" (source)*

- *"That system now has an annual throughput of more than 7 billion metric tons of hard coal and lignite, about 4 billion metric tons of crude oil, and more than 3 trillion cubic meters of natural gas. This adds up to 14 trillion watts of power. And its infrastructure—coal mines, oil and gas fields, refineries, pipelines, trains, trucks, tankers, filling stations, power plants, transformers, transmission and distribution lines, and hundreds of millions of gasoline, kerosene, diesel, and fuel oil engines—constitutes the costliest and most extensive set of installations, networks, and machines that the world has ever built, one that has taken generations and tens of trillions of dollars to put in place."*
- *"It is impossible to displace this supersystem in a decade or two—or five, for that matter. Replacing it with an equally extensive and reliable alternative based on renewable energy flows is a task that will require decades of expensive commitment. It is the work of generations of engineers."*
- *(RN: I very much want to believe that Human ingenuity and commitment may allow at least a little more optimism than this, but with each new scientific paper, and election, I feel less optimism.)*

Dr. Kevin Anderson in an interview following the Paris COP21 Conference

- *"In true Orwellian style, the political and economic dogma that has come to pervade all facets of society must not be questioned. For many years, green-growth oratory has quashed any voice with the audacity to suggest that the carbon budgets associated with 2 °C cannot be reconciled with the mantra of economic growth."*

Anderson Continues: *"I was in Paris, and there was a real sense of unease among many scientists present…*

- ***"…The almost euphoric atmosphere that accompanied the circulation of the various drafts could not be squared with their content.*** *Desperate to maintain order, a club of senior figures and influential handlers briefed against those who dared to say so—just look at some of the Twitter discussions!"*
- *"It is pantomime season and the world has just gambled its future on the appearance in a puff of smoke of a carbon-sucking fairy godmother.* ***The Paris agreement is a road map to a better future? Oh no it's not."***

Even Some Scientists Are Part of this Problem

- Prof. Kevin Anderson (former engineer) points out that too many scientists have no appreciation of engineering and how hard and how long it will take to transform the world to new technological solutions.
- As example, listen to a recent **interview of Mann here**, and contrast that with Kevin Anderson **here**.
- I too have some early years working in engineering; in aerospace and thermal design and analysis, and can applaud Professor Anderson for noting this key point which is so rarely acknowledged.
- I have also seen that the most aggressive promoters and unwavering devotees of the "engineers/scientists will save us" mantra are non-scientists/non-engineers. They have trouble distinguishing between big-picture solid work, and narrow-minded out-of-global-context venture capital oriented promotionals, and out-right hype.

Another Interview in Paris, with Stanford's Mark Jacobson and Tyndall Centre's Kevin Anderson together

- Delucchi and Jacobson's policy publication showing how the world could go 100% renewable, was a big hit among the negotiators and eco-friendlies generally.
- Jacobson summarizes in this **Youtube interview**, with Anderson part of the interview as well. There's certainly no question there is enough solar energy hitting the Earth to power all civilization via its various forms: wind, solar PV, waves… But what will it take, and how long, to GET there, and what will be left of the natural world if we do?

A telling moment in this video…

- Notice Anderson interjecting that rising renewables need to REPLACE, not just be an ADDITION to, carbon energy sources, and that in fact renewables now are simply globally being used on top of fossil fuels (*i.e.* the unabatted prime directive to engage any and all energy sources in service of economic growth, continues)…. **Jacobson's response was: silence**.
- Since Jacobson is now a hit among the policy people, this was a very **important opportunity to reinforce this critical truth pointed out by Kevin Anderson, and Jacobson did not take it**.
- **Silence**, is how the World is reacting to these disturbing physics: the physics of the material world, and of human civilization.

Renewables (thin yellow sliver at top) are not replacing, but rather in ADDITION TO steeply rising fossil fuels underneath. (Hydro and Nuclear have not grown for decades)

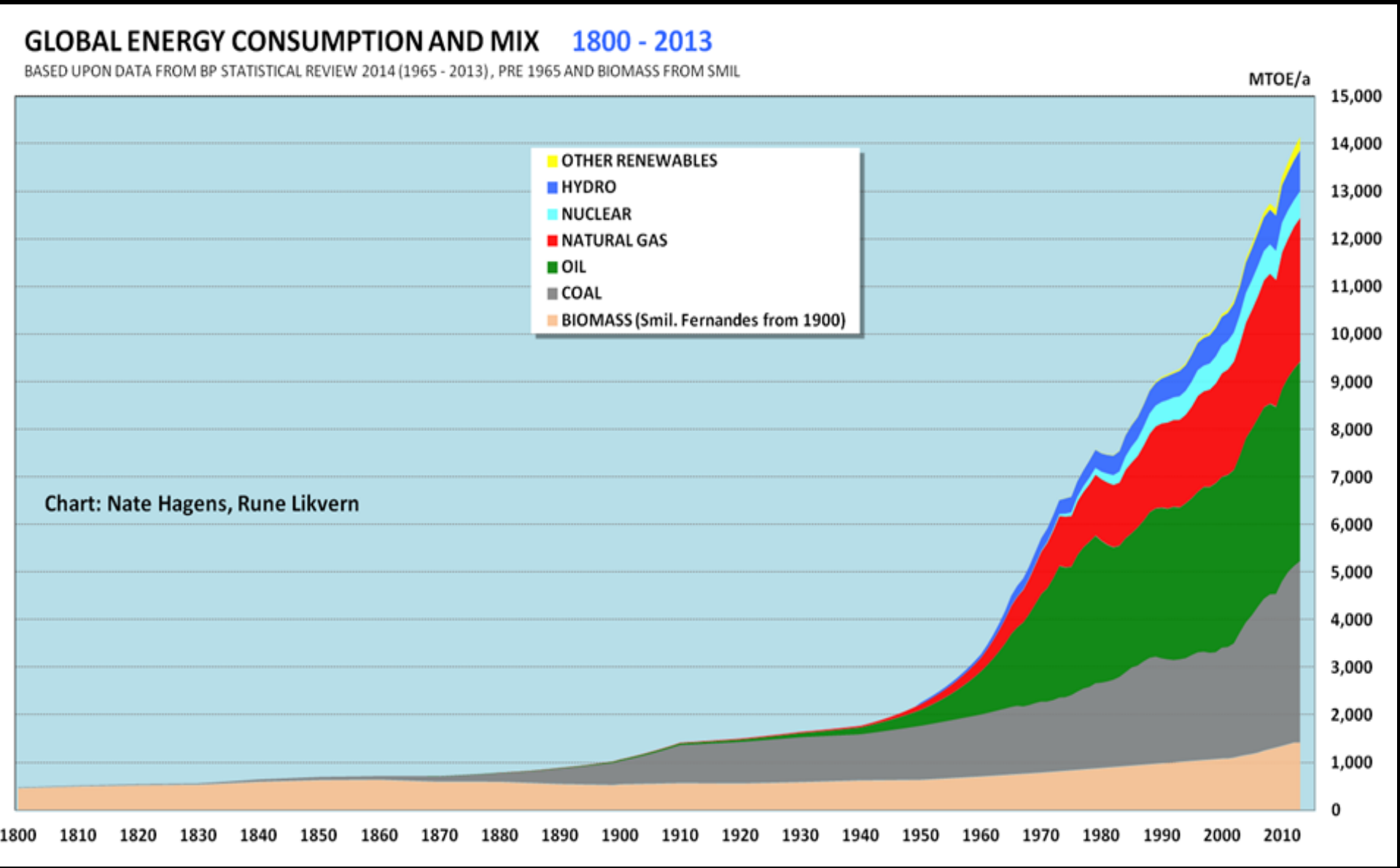
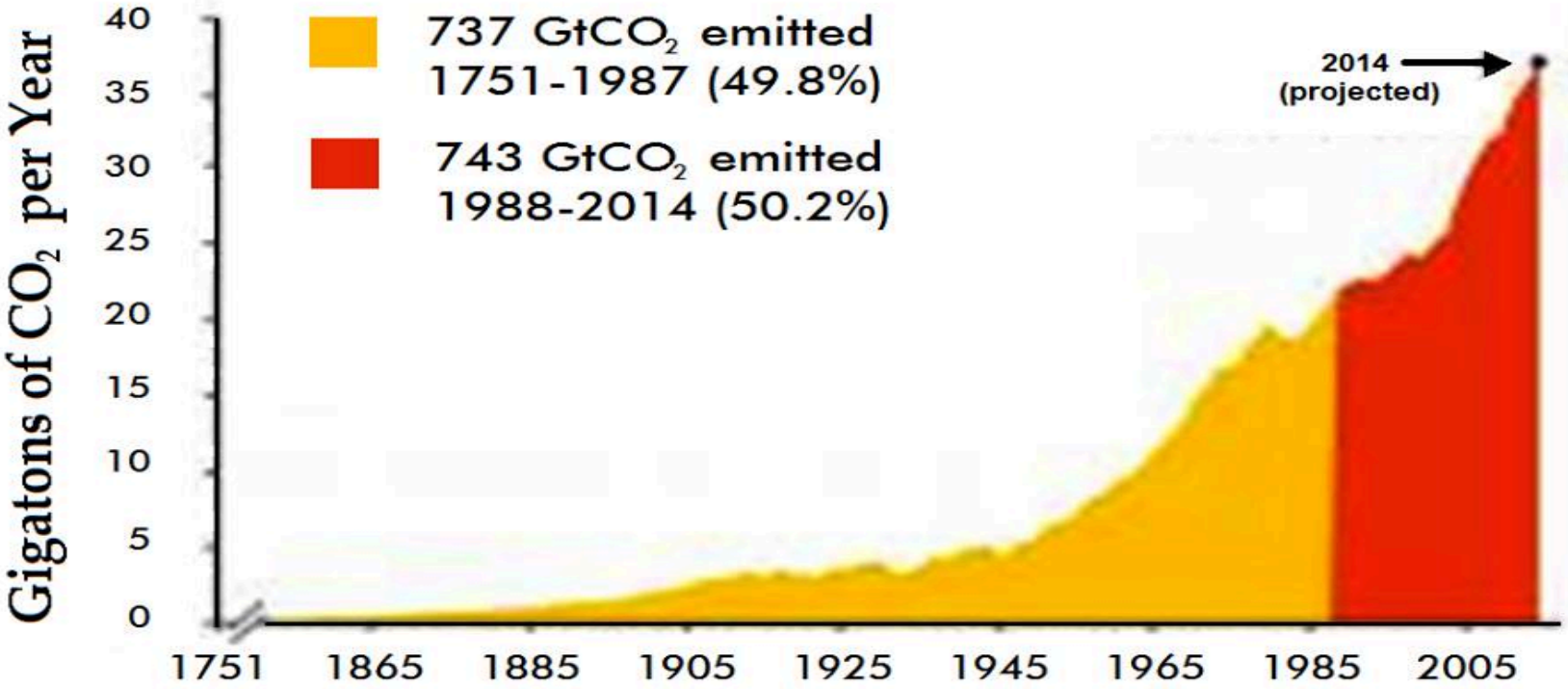


FIGURE 1: Half of Industrial Carbon Emissions Have Been Released Since 1988



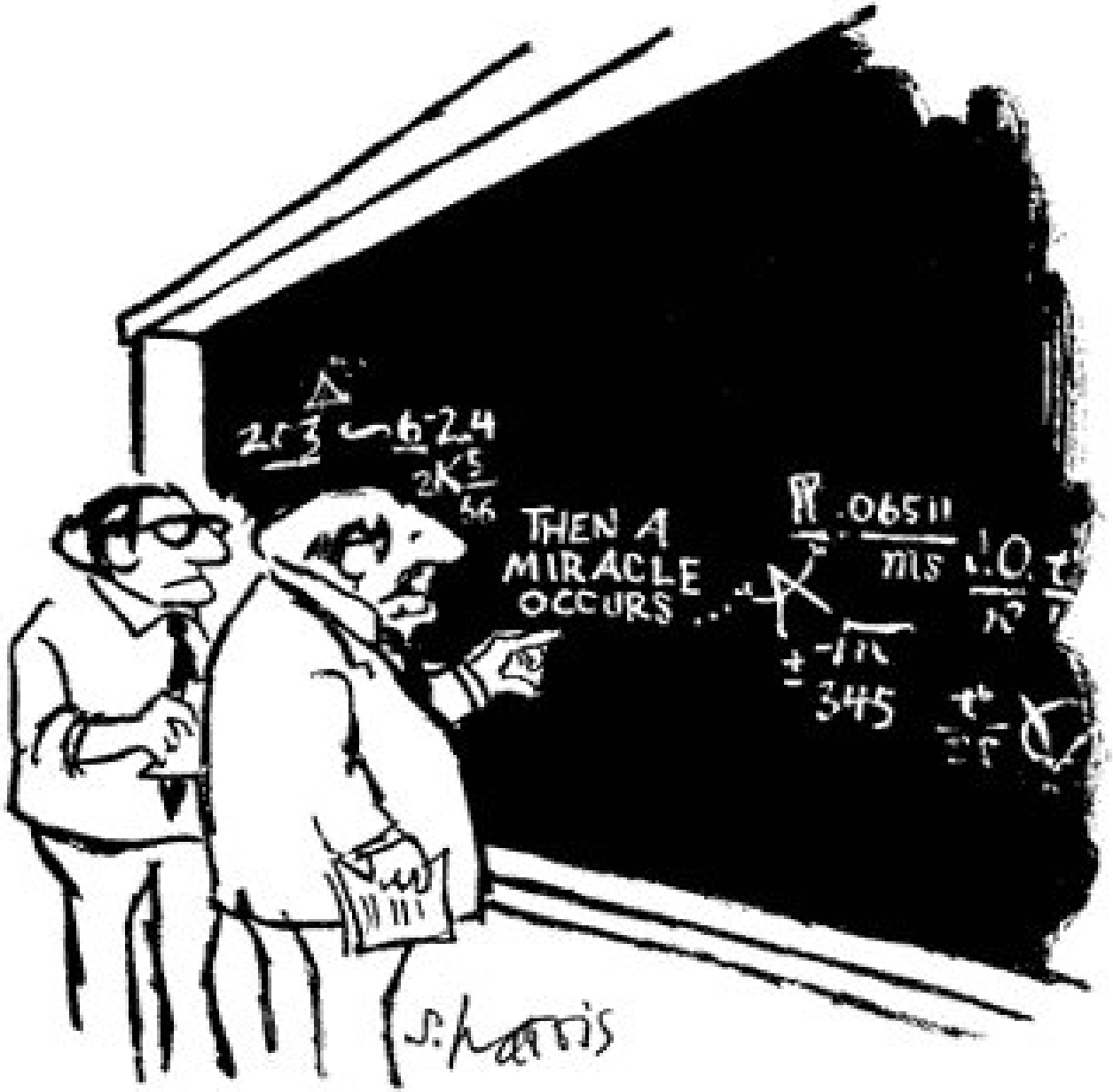
Although the Industrial Revolution began more than 250 years ago, more than half of all industrial carbon emissions have been released since 1988 - after major fossil fuel companies knew about the harm their products were causing.

SOURCES: LE GUERE ET AL 2014, BODEN, MARLAND, AND ANDRES 2013

* UNION OF CONCERNED SCIENTISTS, www.ucsusa.org/DecadesofDeception

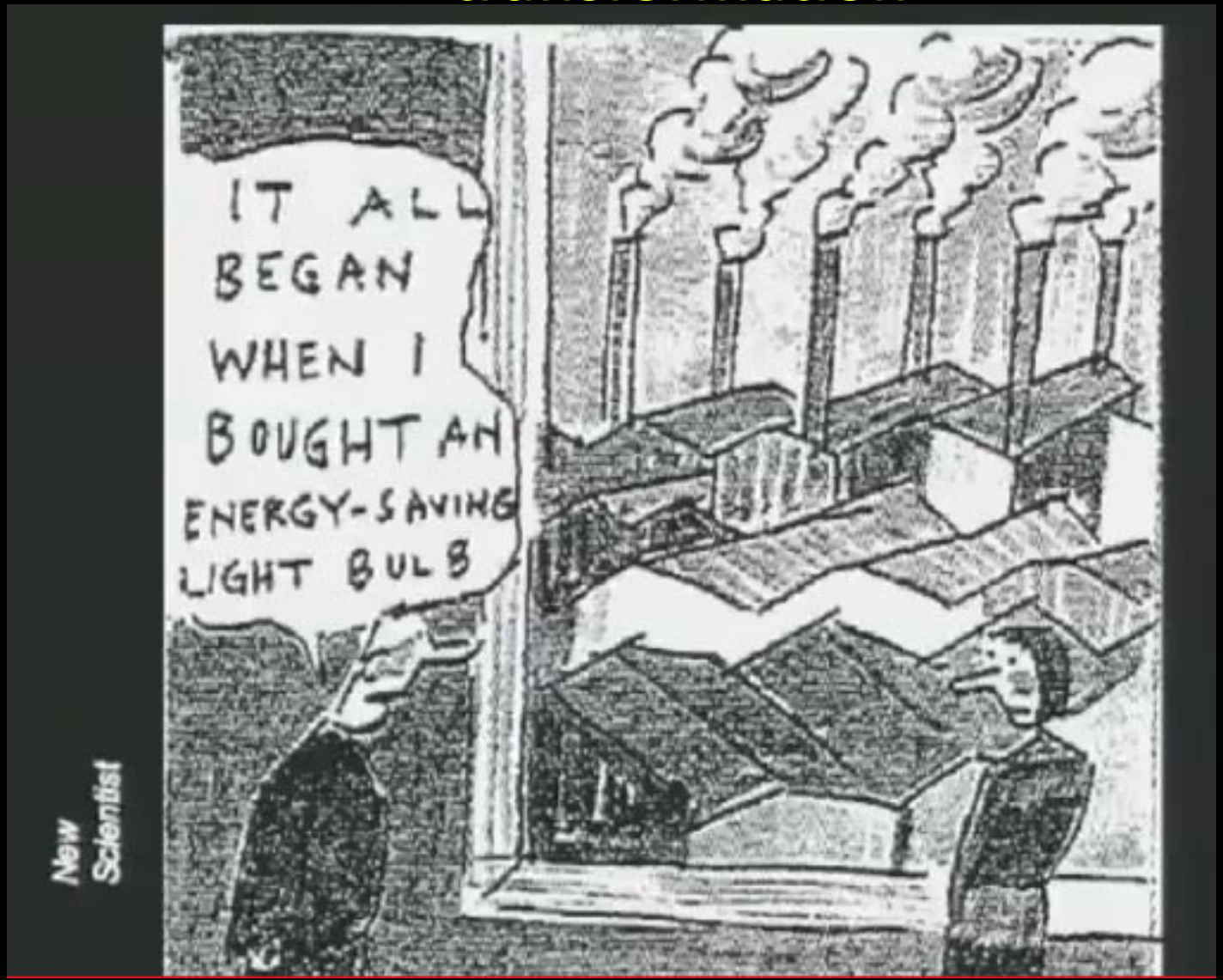
Quote from a CBS News Story "Fight Against Global Warming Runs into Cold Hard Reality"

- *" 'For 1.5 degrees we would have to start retiring things like crazy and we wouldn't be able to build anything new,' says University of California, Irvine, scientist Steven Davis. 'Two degrees is starting to look equally bleak.'*
- *"That hasn't quite sunk in amid the fanfare surrounding the Paris Agreement, which entered into force with record pace"*
- **…this is a refreshingly honest piece from CBS – which is mainstream media news**



"I think you should be more explicit here in step two."

Jevon's Revenge: Prepare to pay the FULL costs when you embark on energy efficiency for your global transformation



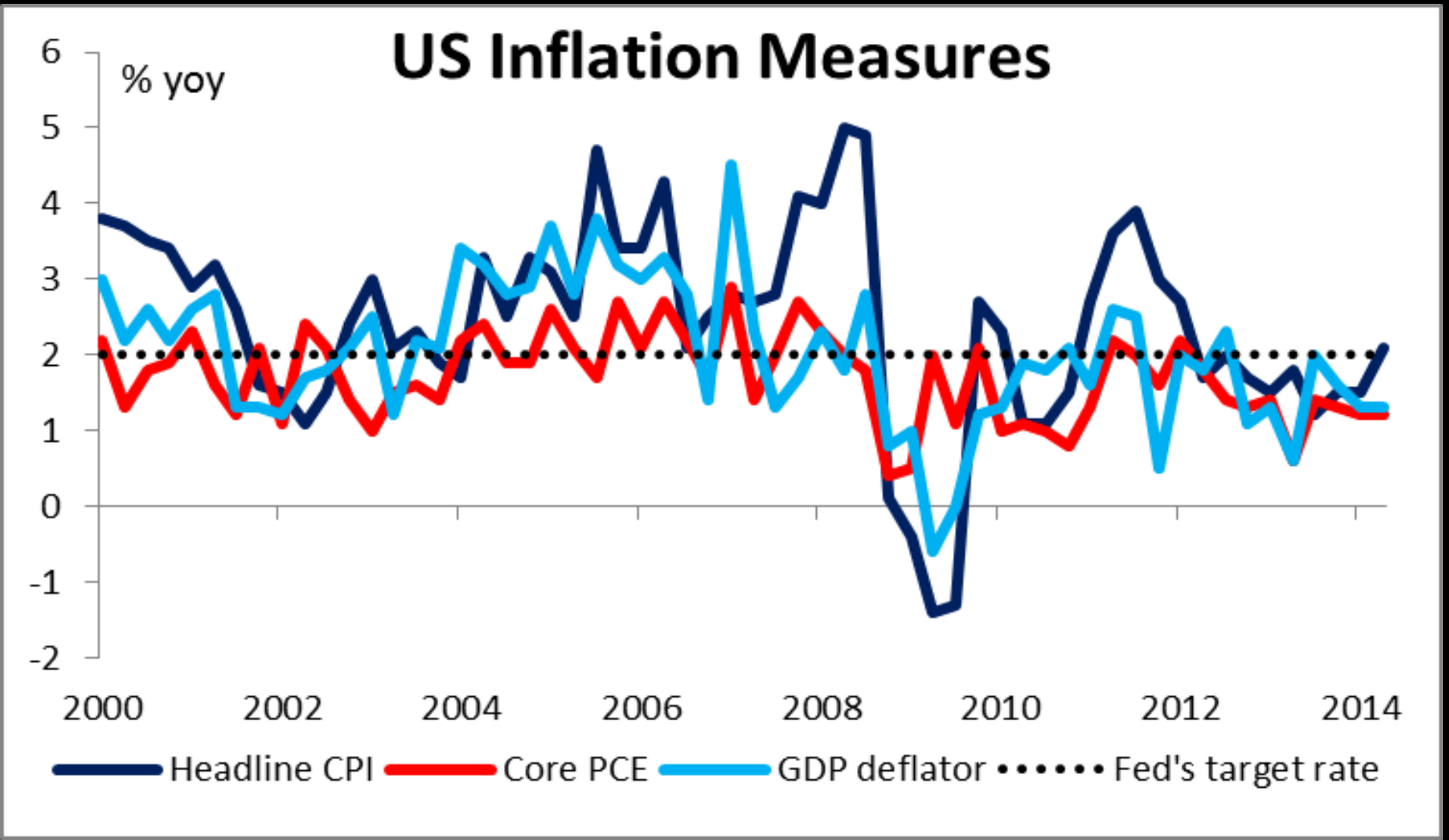
Can We Find Weaknesses in This Thermodynamic Reasoning?

- **1. The Garrett Relation graph only goes back to 1970, when careful global energy statistics began. Fatal flaw?**
- Total accumulated wealth surely extends vastly further back than 1970, no?
- **True**, it goes back through the history of civilization.
- Data since 1970 is the most accurate, data from earlier in the century less so, and going back centuries further, less still, but decent estimates have been published and included by Garrett
- **And most important, the majority of all of the accumulated wealth since the beginning, has happened just in our lifetimes; since 1970. That graph does capture the creation of the majority of total Civilization Wealth**
- Since total Wealth is an integral over all Civilization, the inaccuracies of the much smaller pre-1970 past have only a minor effect and don't challenge the evidential truth of the Garrett Relation

2. Inflation is a Messy Concept: Is the GDP Deflator an Accurate Measure of True Inflation?

- I'll call **True Inflation** the thermodynamic-consistent quantity which corrects nominal prices year-on-year.
- The treatment of inflation leaves some uncertainty. The constancy of the Garrett Relation requires past GDP figures to be inflation-adjusted. GDP figures have been corrected for inflation by the **GDP Deflator**, which is calculated by governments from the prices of a basket of goods and services which varies year by year. Its stated attempt is to correct nominal GDP to real GDP, which we hope it does.
- **On the one hand, Garrett made post-dictions using the CThERM model and got results which matched observations quite well, strongly suggesting that up till now, the official GDP deflator measure captures the large majority of Garrett's deeper meaning of inflation = True Inflation.**
- **But on the other hand…**

For the U.S., the GDP Deflator follows the Consumer Price Index (CPI), with perhaps only a slight bias low of less than 1%



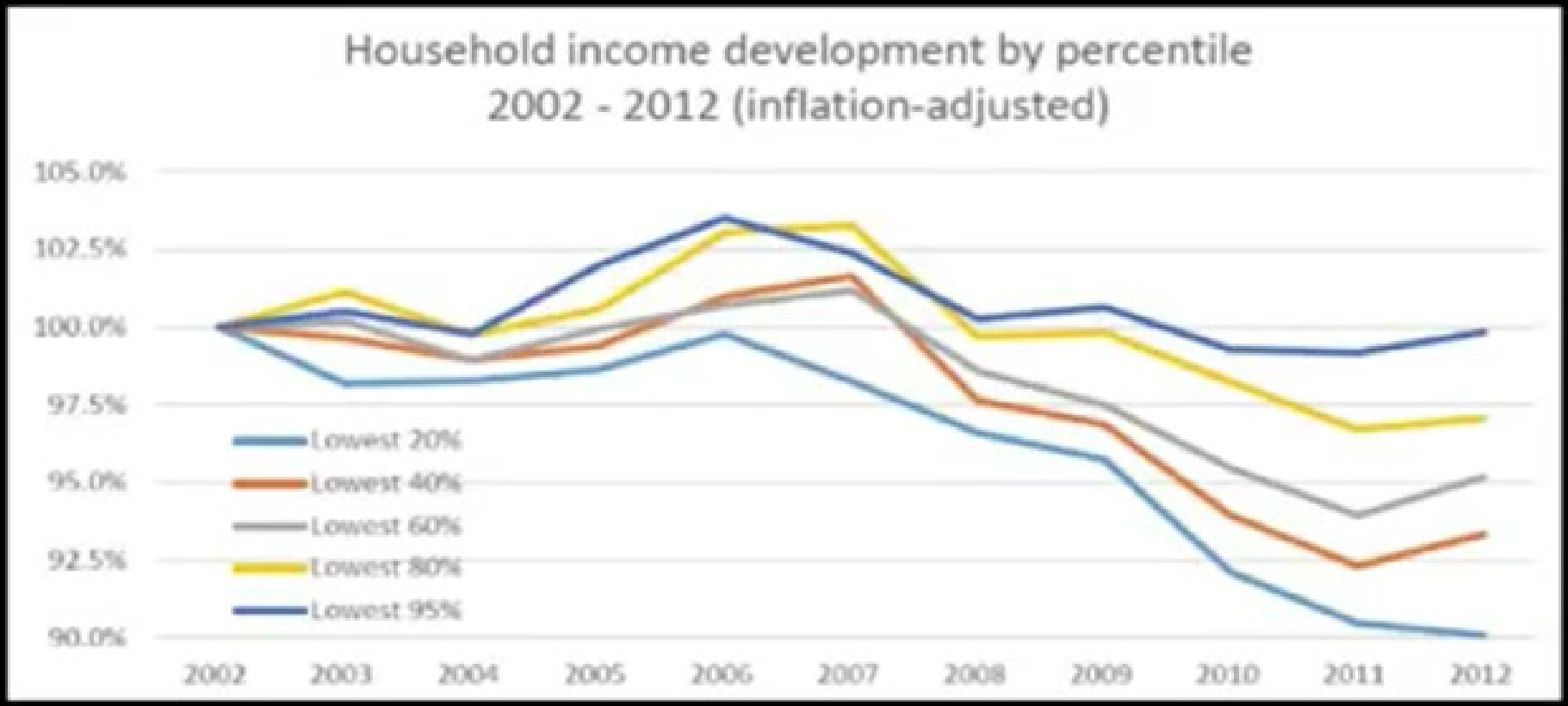
…And the CPI is officially stated to be designed to follow the actual prices paid by consumers each year

- But is this an inherently biased measure of inflation? If inflation is interpreted as a correction to insure constant standard of living (as some do), then if prices rise faster than incomes (as has happened for decades; next slide), then consumers will be forced to continually migrate down scale in their purchases.
- …down, from T-bone steak to chuck steak, and then to ground round, and then to chicken, and then canned chicken, and finally to beans.
- Hence, the CPI should be consistently beneath the true apples-to-apples constant-basket inflation rate

Income Growth Never Came Back after the '01 Recession.

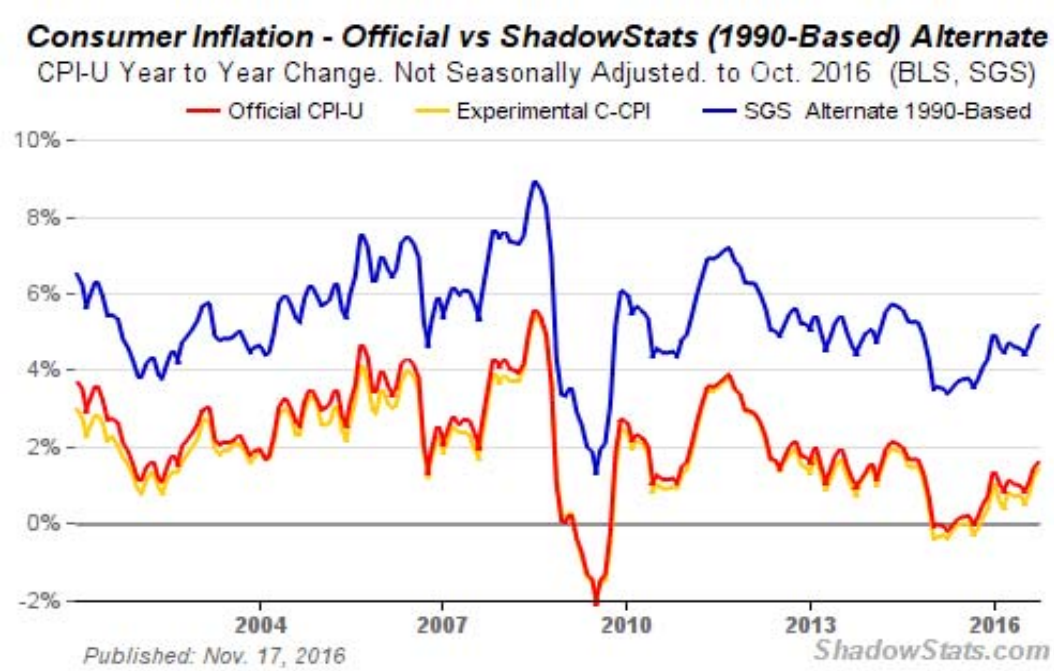
For most people growth is already over...

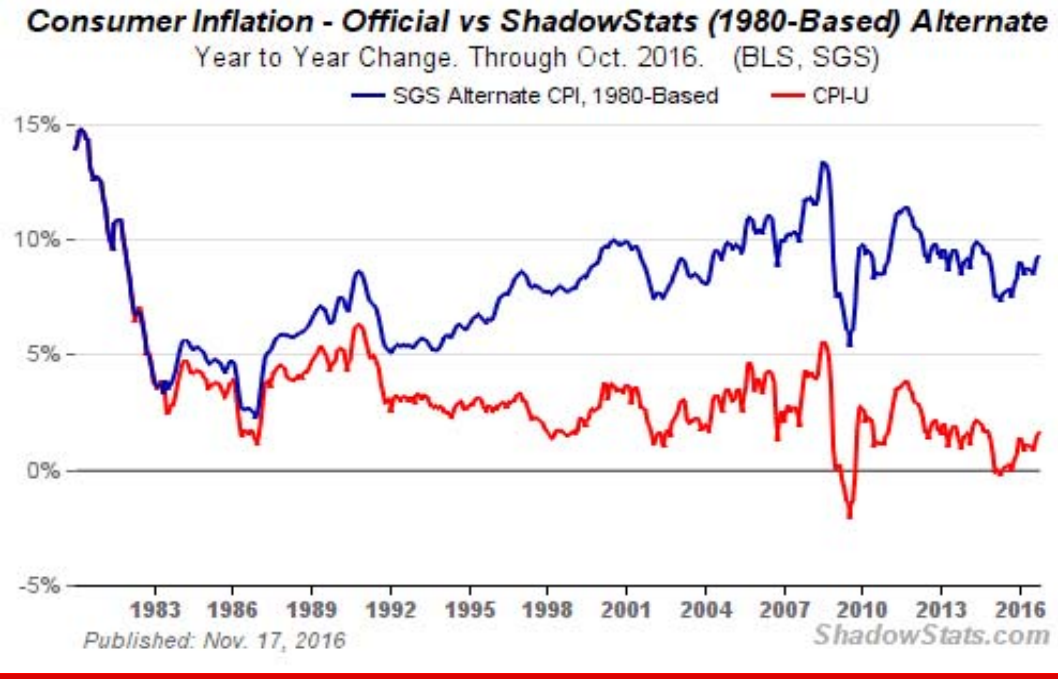
"lowest 95%" means top 5% of income earners (top curve)



Income development 2002-2012, U.S. census data (www.census.gov), graphic IIER

The average wage earner has actually LOST earnings over the past 42 years, while the top 5% have taken a far larger fraction of the total





ShadowStats makes an attempt to remove the bias mentioned, and finds the U.S. consumer inflation rate is consistently about 3% to 4% per year higher than published CPI since the early 1990's

There is also an inherent financial conflict of interest motivating governments to underestimate official inflation figures

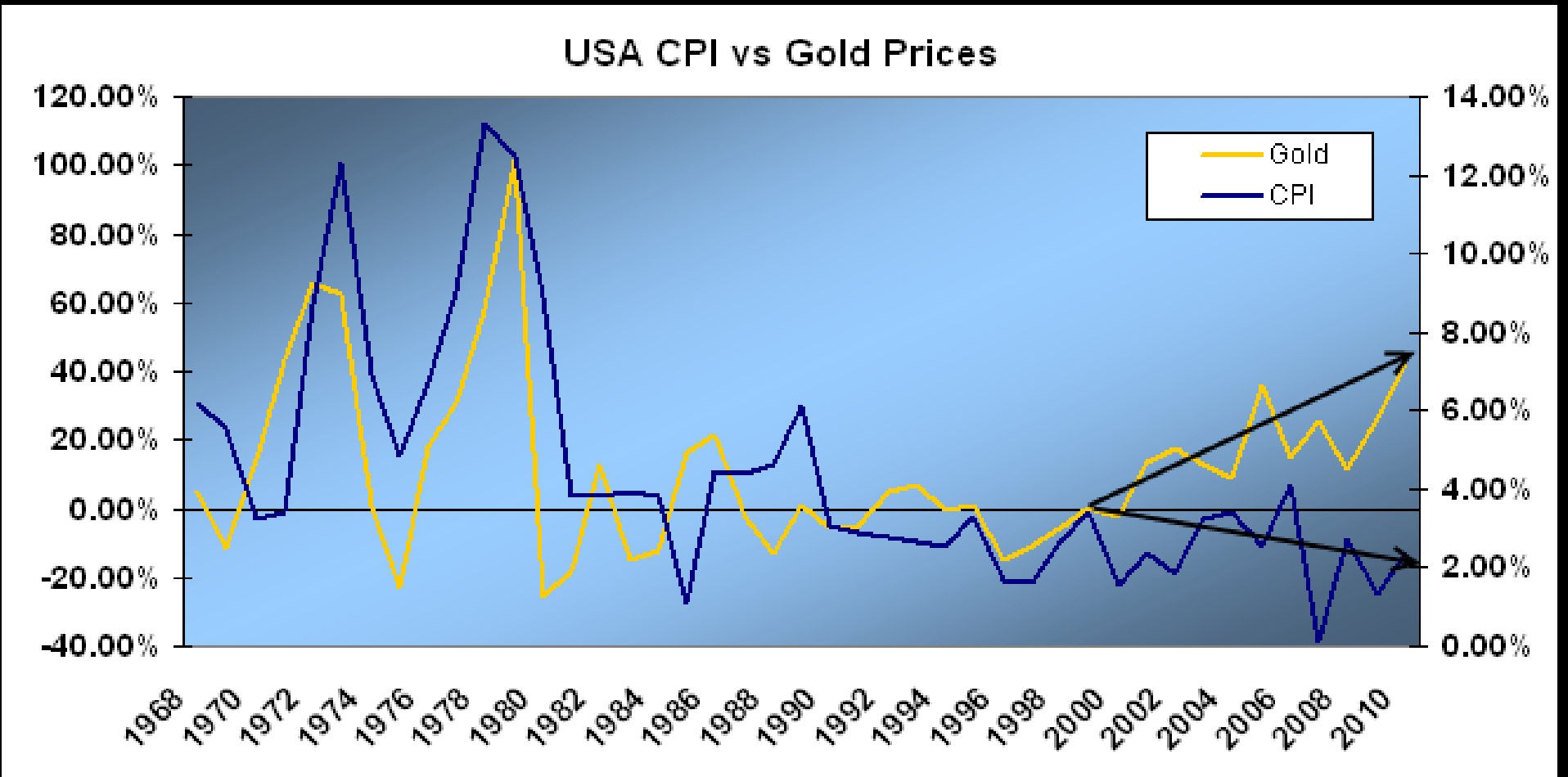
- Why? Because ~50 trillion dollars of U.S. government liabilities (*e.g.* social security, medicare…) are indexed to CPI-derived inflation. Lowering official inflation lowers government costs.
- By underestimating inflation, this makes a major improvement in the government's balance sheet, keeps international bond rating agencies from de-rating U.S. debt, and generally keeps the Debt Supercycle game going a while longer.
- And Europe and many other countries have followed the lead of the U.S. in doing similar accounting**.**
- **This will therefore have a significant effect on inflation corrections to Gross World Product.**

ShadowStats Goal

- …Is to measure inflation so as to correct to a constant **standard of living**. Their web site states…
- *"The **ShadowStats Alternative CPI-U Measures** are attempts at adjusting reported CPI-U inflation for the impact of methodological change of recent decades designed to move the concept of the CPI away from being a measure of the cost of living needed to maintain a constant standard of living. There are two measures, where the first is based on reporting methodologies in place as of 1980, and the second is based on reporting methodologies in place as of 1990."*

- **OK, but it's not at all clear that this is true thermodynamic-consistent inflation with regard to Wealth. My suspicion is that it is not.**
- Is there some other way to measure inflation? Gold, after the artificial fix to $35/oz ended in the 1970's, tracked the CPI fairly well into the 1990's. The accumulated gold mined can't be inflated like Central Bank printed money, is the rationale (next slide)

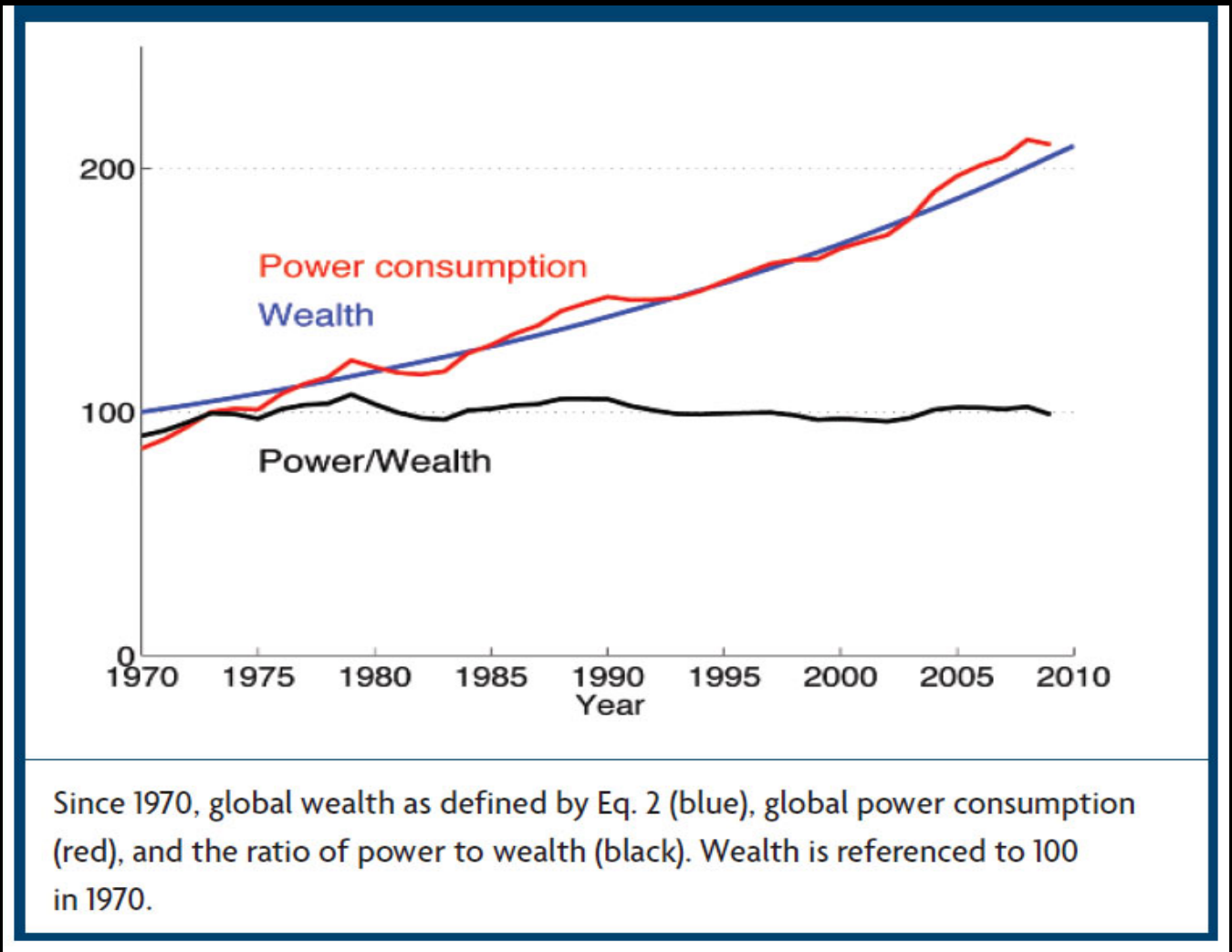
The price of gold followed (U.S.) CPI well, until the late 1990's, when gold outpaced the CPI, just as ShadowStats arguments would predict. But is this the measure of True Inflation, or merely the money-supply aspect of inflation, not capturing the full measure of Wealth change?



Not Clear How to Reconcile…

- … that an (apparently?) underestimated official **GDP deflator which changed in the 1990's** is yet giving the theoretically predicted constancy of the ratio of inflation-adjusted time-integrated GWP to energy consumption rate from 1970 on.
- However, if the GDP deflator **is** truly an underestimate of proper inflation for the **Garrett Relation**, it means that the global energy consumption rate is rising FASTER than inflation-adjusted time-integrated Gross World Product.
- If so I'm tempted to wonder if this is reflecting something akin to the **2nd Law of Thermodynamics**; (2nd Law of Thermodynamics: there is an inherent degradation of energy in any thermodynamic process, such that entropy in a closed system ALWAYS rises over time…)
- **In the context of Civilization, if the GDP Deflator is indeed biased, it indicates that energy consumption rates must ALWAYS rise at least as fast, or faster, than inflation-adjusted time-integrated GWP**

On the other hand – If the ShadowStats measure of inflation were "true inflation", there should be a clear trend change beginning in the 1990's when the moving-basket measure of CPI was introduced - and there is no trend change, as you see below. This argues the GDP Deflator is in fact ~accurately measuring "true inflation"



Since 1970, global wealth as defined by Eq. 2 (blue), global power consumption (red), and the ratio of power to wealth (black). Wealth is referenced to 100 in 1970.

On yet another hand …

- **GDP measures are <u>also</u> underestimated**, it has been observed, by failure to account for *e.g.* "black market" transactions which are also likely to be growing. This might compensate for any low-biased GDP Deflator via the ShadowStats argument and so once again remove any bias.
- And too, there are entirely valid reasons for using a changing basket of goods and services in estimating inflation.
- Updating the last graph with the latest data, and including the ShadowStats version (assuming it applies globally) will be done soon.

Setting aside cynicism about government motivations

- More work should be done (by economists) on clarifying inflation-adjustment to GDP figures, but taking the GDP Deflator as a good faith best-work estimate of true generalized inflation, as it is supposed to do and seems to do…
- …then indeed we find impressive confirmation with thermodynamic theory and I am, on balance, inclined to accept that the GDP Deflator does indeed measure true inflation.
- Check mark noted, and hope for further work here.

3. Will the Garrett Relation Still Hold in a World Dominated by Western Standards of Living?

- Garrett has shown that energy exploitation has only been limited by opportunity, not by human will power'd restraint.
- I strongly expect this will stay true as long as we have billions of people living well below the standard of living of Western Europe and the U.S.
- But what if, at a certain high standard of living – say that reached by a well-to-do state like California – increasing Wealth increasingly led to less energy-intensive leisure time? There are only so many hours in a day and so many days in a life.
- Can the world make it to such a place before it is terminally crippled? The evidence strongly suggests **No**, since crippling is already becoming significant and accelerating, and yet the Western lifestyle is enjoyed by only 20% or less of World population. There are too many poor but hard-working people seeking to RAISE their energy consumption.

Increasing energy efficiency, with unreconstructed human nature, is a dangerous combination

- …it will **hurt**, not help our future. as history shows it leads to even stronger growth in a world already far past sustainability.
- What is first required is a deep transformation of the global psyche, a radical pervasive personal growth which is strong enough to overcome the motivations of envy of others' riches, of material wealth as the measure of virtue, instead embracing the value of unspoiled Nature, and seeing other species as fellow travelers on this planet and not fodder for our advantage.
- That transformation of humanity appears very remote as I write these words.

Dr. Nate Hagens argues such human transformation is not possible – we are slaves to our inherited hormonally driven compulsion for relative status, and for out-competing the neighbors

- And yet, I don't feel such overwhelming compulsions, and I know of others (a few) who also (largely) don't
- Are we genetic freaks? Or is the power to mature in this way still within us all?
- I highly recommend spending an hour to listen to this insightful and excellent **2016 talk by Hagens on our predicament**

Transformation would include purposeful policy-enforced population control

- It is the single most powerful cause of growth; tightly correlated with energy consumption.
- Up till now, population growth has been limited only by our ability to exploit energy resources.
- Unwanted pregnancies in much of the world have high infant mortality if energy (wealth) cannot sustain them, so I'm skeptical that greater education and access to birth control globally will change adult population growth except in a minor way. In other words...
- Children are a joy; if we can personally afford them, we have them, on average; it's how Nature designed us).

It's a Conflict: <u>With</u> Human Nature *vs.* <u>Against</u> Human Nature

- <u>The "solutions" one hears in the media are **Easy to commit to;** because we **love** them:</u>
- **1.** Increasing energy efficiency? We LOVE doing this! It's an intriguing challenge to science and engineering, and gets us more wealth
- **2.** Recycling, bicycling instead of driving, etc? Most LOVE doing this, or at least the idea of it! – we feel empowered, we feel healthier and indeed are healthier.
- **3.** Creating techno-fixes like better-adapted crops and conserving or re-cycling water? We LOVE doing this! It's an invigorating scientific challenge, and gets us more water and more wealth.

Creating Denser, "Better(?)" Cities

- We **love** doing this; social interaction is easier, and cities are where the jobs are.
- But, **Bettancourt *et al.* (2007)** show that *"as population grows, major innovation cycles (for transforming cities) must be generated at a continually accelerating rate to sustain growth and avoid stagnation or collapse"*
- In other words, growth here must not only be exponential, but super-exponential.
- Is this sustainably healthy? Of course not.
- **All of these things we love - these INCREASE Energy's efficiency in ENHANCING Civilization growth, and hence…**
- **They raise** energy consumption rates

Instead, the REAL solutions include actions AGAINST human nature, so very few want to even talk about them…

* Enforced population control, globally.
* Voluntarily ending global economic growth
* Ending carbon emissions even before we can fully replace with renewables, and therefore severe belt-tightening in life styles
* Putting civilization's growth sanely and gracefully (if that is possible) into reverse
* Giving up on raising 7.5 billion standards of living globally to that of the West. We're too big already, it's too late.


GROWTH
1886-2007

The Actions which Reverse Growth are HARD to commit to, precisely because we do NOT love them

- These run AGAINST the innate programming of humans. I see stiff resistance to even admitting the possibility of truth to these - so myopically are people focused on the local and the short-term, and which ignore global reality.
- That includes many who are politically "Green". They try to sell decarbonizing solutions by telling us that we can have our economic growth and decarbonize too. No – not when we're pushing our carbon-emissions off on Asia while they make all the great stuff that we count as Economic Growth.
- COULD Asia also go Green? Technically, Yes, but not without severely hampering their growth, because they'd have to de-commission perfectly working new coal and fossil fuel power before end-of-life. They cannot decarbonize fast enough to prevent climate disaster, as early slides here showed.

Are we genetically programmed for the Rat Race?

- **If so, only crippling confrontation with resulting pain might make the average person reconsider it all – Nolthenius' First Law: "People Learn the Hard Way"**
- Such levels of pain may happen for enough people to change our systems, but only when it is FAR too late to do anything about climate tipping points; chaos will be inevitable, or already begun.
- So far I see no evidence of any such transformation in human nature, except perhaps in small pockets of people who are already rich enough to afford such personal evolution. The low-hanging fruit. The 3-sigma tail of the distribution curve, for human transformation. The evolution of the rest may be very hard and slow.
- **Wild speculating now… hey - what about CRISPR technology, applied to human genetic alteration on an advanced, industrial scale?**

Sure!...Churning out millions of "GMO" genetically re-programmed replacement humans, without our flawed urges!

Or would that turn out Apocalyptically bad?

Forgetting the last slide…. The Message is <u>not</u> "We're Doomed! - Accept your Demise!"

- The message to those involved in trying to save the future, is not to give up, but to **<u>UP the ANTE!</u>**
- The task is FAR beyond the happy-talk I hear even from too many climate activists who are supposed to be the good guys in this tragic drama.
- Realize the concerted interests of the stake-holders and those they control to have you believing we're already on our way so just be patient and optimistic and don't panic and, above all, **<u>don't agitate for any fundamental change of the political/economic global system</u>**.
- And on the Green side, the vested interests in insuring your votes for their Green ideas is by **making sure you believe there's no REAL sacrifice necessary; it's "Win/Win" for all**

If You're Not Morally Outraged, You're Not Paying Attention

- We have created a field of endeavor, where the prime directive is to understand the actual truth of things, apart from our feelings. To grasp the unchanging laws that govern the World. To abstract principles from our experience, apply them, project the future, and enable rational planning.
- We call this field – **Science.** And those who do it - **Scientists.**
- They have done there work very well, including in Earth climate.
- But we don't like what they're telling us, so we throw rocks at them.
- We threaten them, and their families (just ask Michael Mann and Phil Jones)
- Tar their academic record for whistle-blowing agenda-driven Oil-company sponsored lies postured as truth in certain college classrooms
- De-fund their hard efforts to create the technology and new scientists that must inform the consequences and guide our actions
- And even those who seek **real** solutions – we ignore them, call them "negative"
- *"If I were a scientist, I'd be incredibly pissed every day of my life!"* – Leonardo DiCaprio, listening to Michael Mann's experiences, during DiCaprio's interviewing him in **"Before the Flood"**
- **We insist only on happy-stories**

After realizing this…

- … I am no longer scratching my head over Professor Kevin Anderson's conversations with, and **depressing accounts** of, policy people's agenda-driven heads-in-sand on these key considerations outlined here.
- The incentive systems motivate too many policy professionals' resistance to confronting and communicating clearly the facts described here - It makes them look like they're failing at their jobs.

So What Do We Do?

That's a big question, and I will save for a later talk, but for starters…

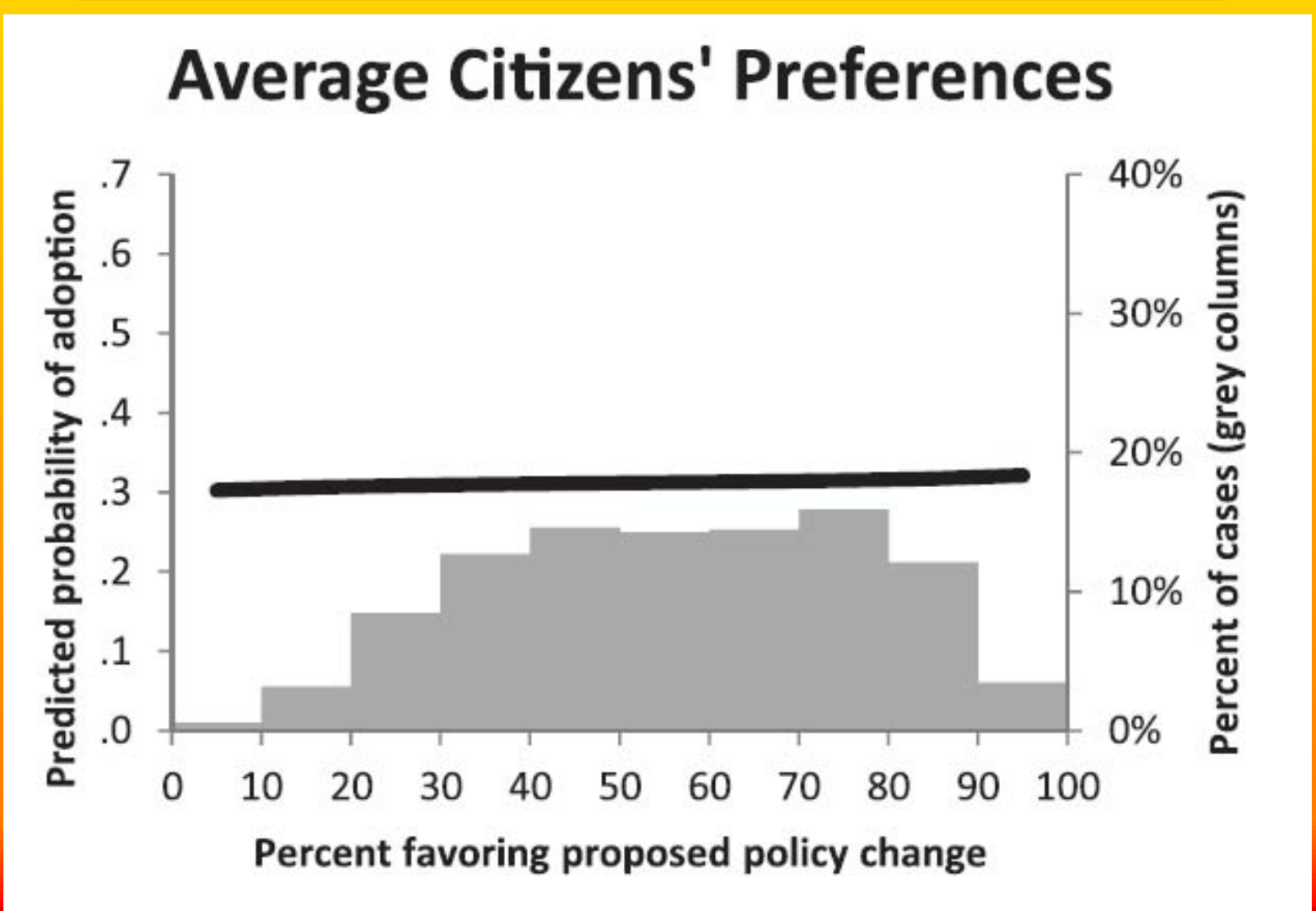
Strong evidence shows that politely asking Washington DC for better policy has gone, and will continue to go, <u>nowhere</u>

- This was true even before the 2016 election's horrific results.
- Why do I say this?

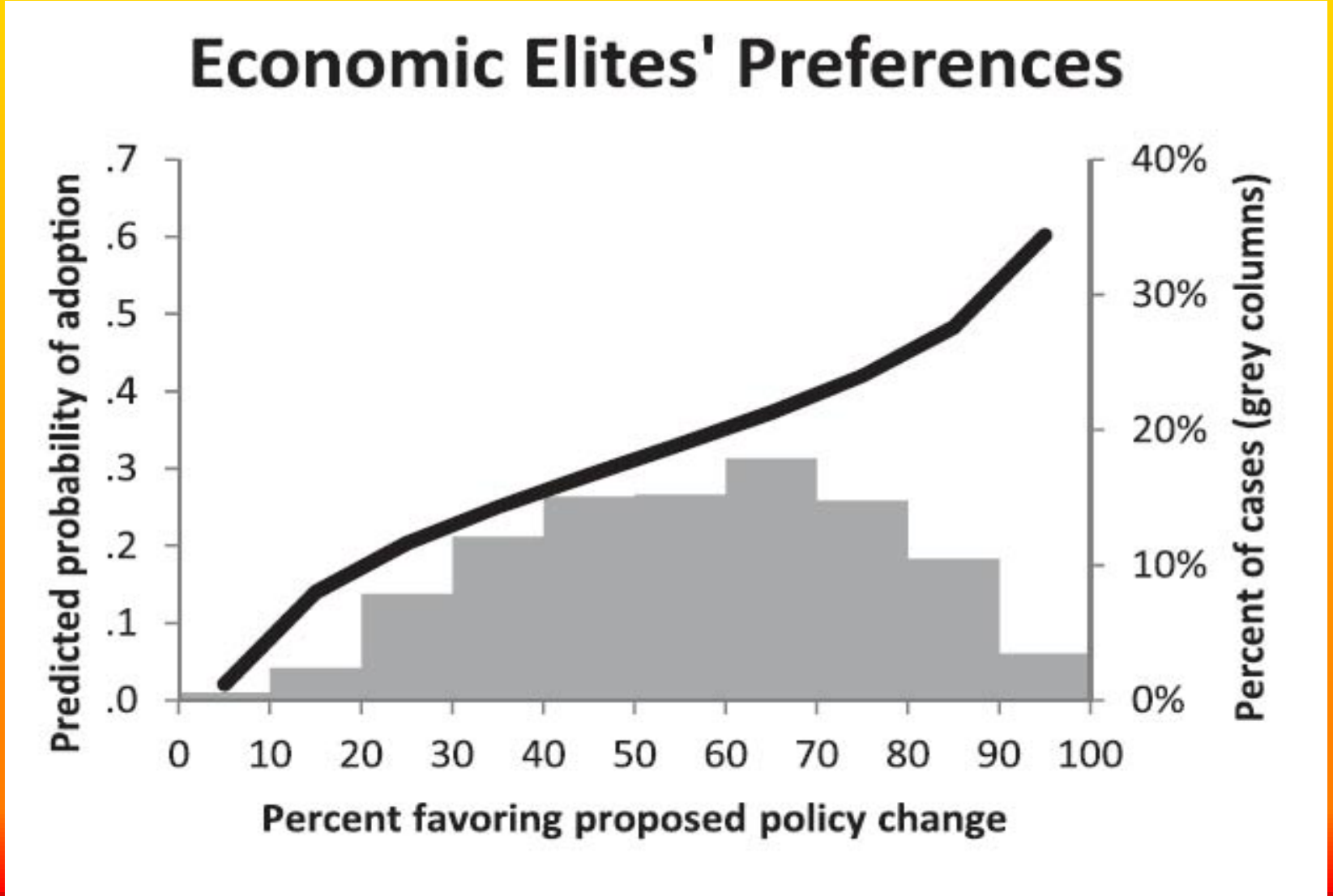
Gilens and Page (2014) wrote the most important paper in Political Science, and it gets almost no attention in the mass media

- They studied the prior 20 years of Congressional legislative bills both passed and not passed, categorized by measures of key aspects and correlated with the wishes of 4 groups – average voters, mass-based (i.e. average voter-based) lobbies (*e.g.* the Sierra Club), business lobbies, and finally the Economic Elites and their lobbies

They find there is ZERO Correlation between <u>what legislation is passed</u>, and <u>what the average citizen wants</u>



But there is near perfect correlation between legislation passed and the wants of the Economic Elites and their Lobbies.



Psychopaths in Corporate CEO Boardrooms

- So who are the Economic Elites and their corporate lobbies? Can we trust them?
- **This study** (**Brooks *et al.* 2016**, to be published in ***The European Journal of Psychology***) finds ~ 21% of Corporate CEO's fit the diagnosis for **psychopaths.**
- **This is the same fraction as found in hardened prisons.**
- **In the general population, the rate is only 1%, says the same study.**
- Lead author and forensic psychologist Nathan Brooks notes: *"For psychopaths, it [corporate success] is a game and they don't mind if they violate morals. It is about getting where they want in the company and having dominance over others."*

My Summary Thoughts, for now, on the Work of Garrett and the Thermodynamics of Civilization

- I'm convinced Garrett has identified a key constraint between energy and civilization and that the **Garrett Relation** and his projections for the future are on target…
- But, only in the case of **an "unforced" human system**. "Unforced" meaning, without global and even repressively enforced government policy to curb human nature and take the hard path.
- Unlike the laws of physics of inanimate objects, the laws of human nature can be bent in practice. It is physically **possible** for us to live much simpler, lower energy lives. We just refuse to **go** there.

How Do I See the Future Unfolding?

- I see continued and reasonably successful efforts in improving energy efficiency, which will expand civilization and hence energy consumption rates. This has been our history and it will continue for at least a while longer, probably a couple of decades at minimum.
- I see continued rising standards of living in the 3rd World, and hence energy consumption rates, at least until **climate chaos** begins.
- I see a resumption in global decarbonization, perhaps even to the rate of 50% reduction per 50 years, as Garrett thinks is very unlikely. Tentatively, I don't agree. My impression from recent advances is that it's do-able, if we have the global political will (but, political will is so far looking to remain unlikely)

We'll Need:

- Crippling Tax-and-Dividend legislation, with trade sanctions against countries not instituting the same
- A lottery to see which couples get to have a single child
- Much work on how to gracefully de-growth
- Massive investment in air-capture of CO2 and sequestration, beyond emergency all-hands-on-deck retirement of fossil fuel power. May be prohibitively energy-intensive however. This is not yet clear.
- Geo-Engineering as stop-gap: continual high-altitude aerosol dispersion seems the best cost/risk/benefit, subject to further study on ozone damage
- **<u>What to Do</u> will need to be a separate Public Lecture**
- **Otherwise…**

"Yes, the planet got destroyed. But for a beautiful moment in time we created a lot of value for shareholders."

(A lot of value for shareholders. Except shareholders of solar power companies)