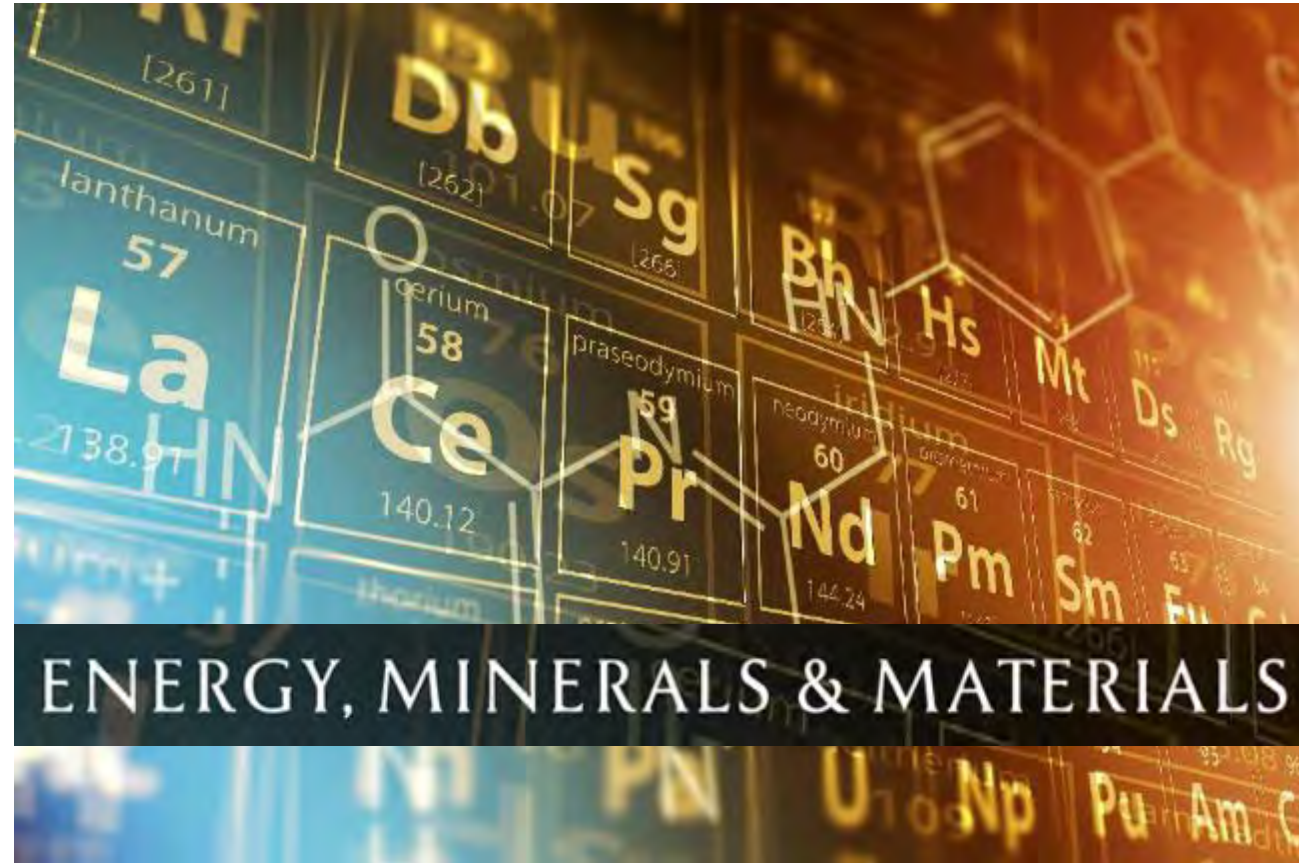


Transition Bumps



Michelle Michot Foss, Ph.D.

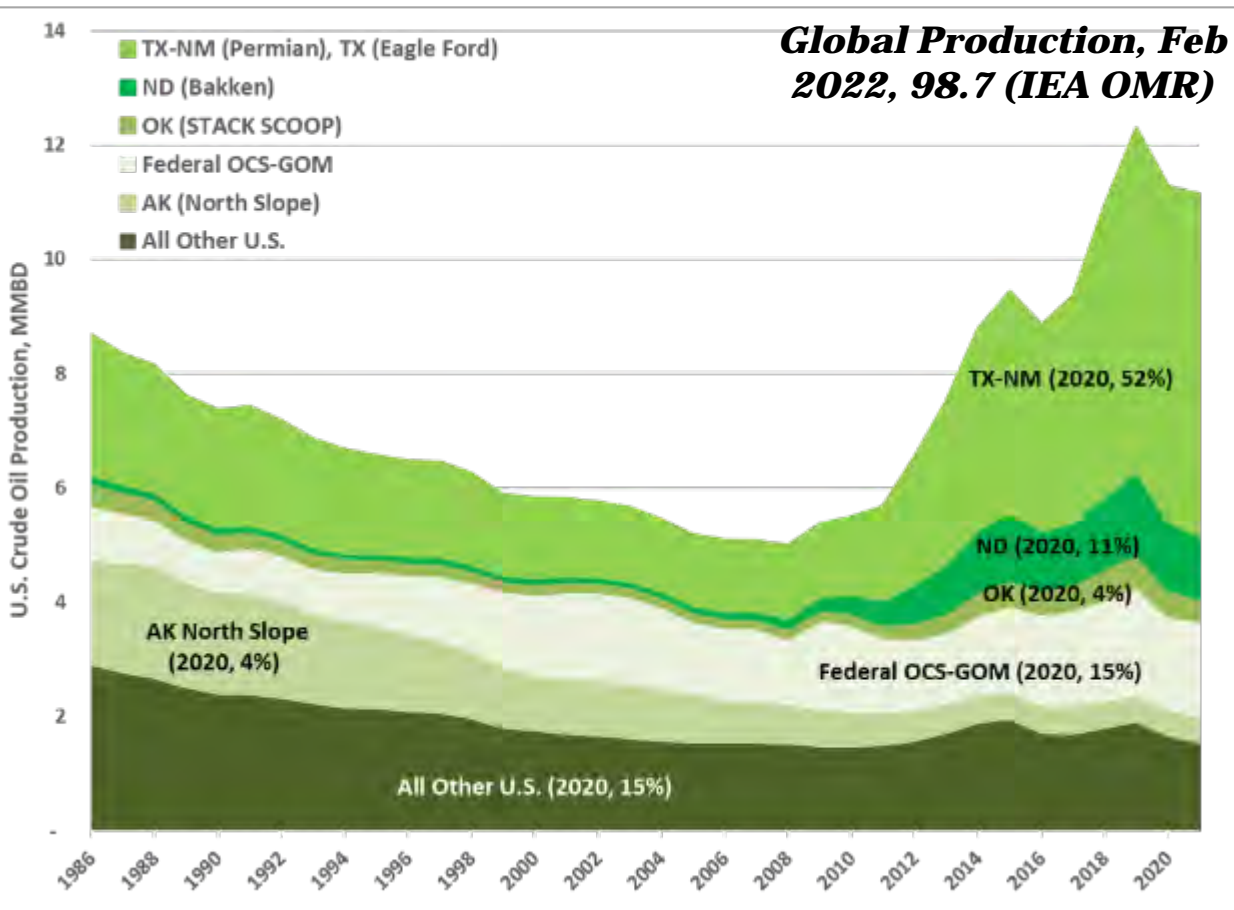
ASA-Houston Chapter Energy Valuation Conference, May 12, 2022

“The Revenge of the Old Economy”

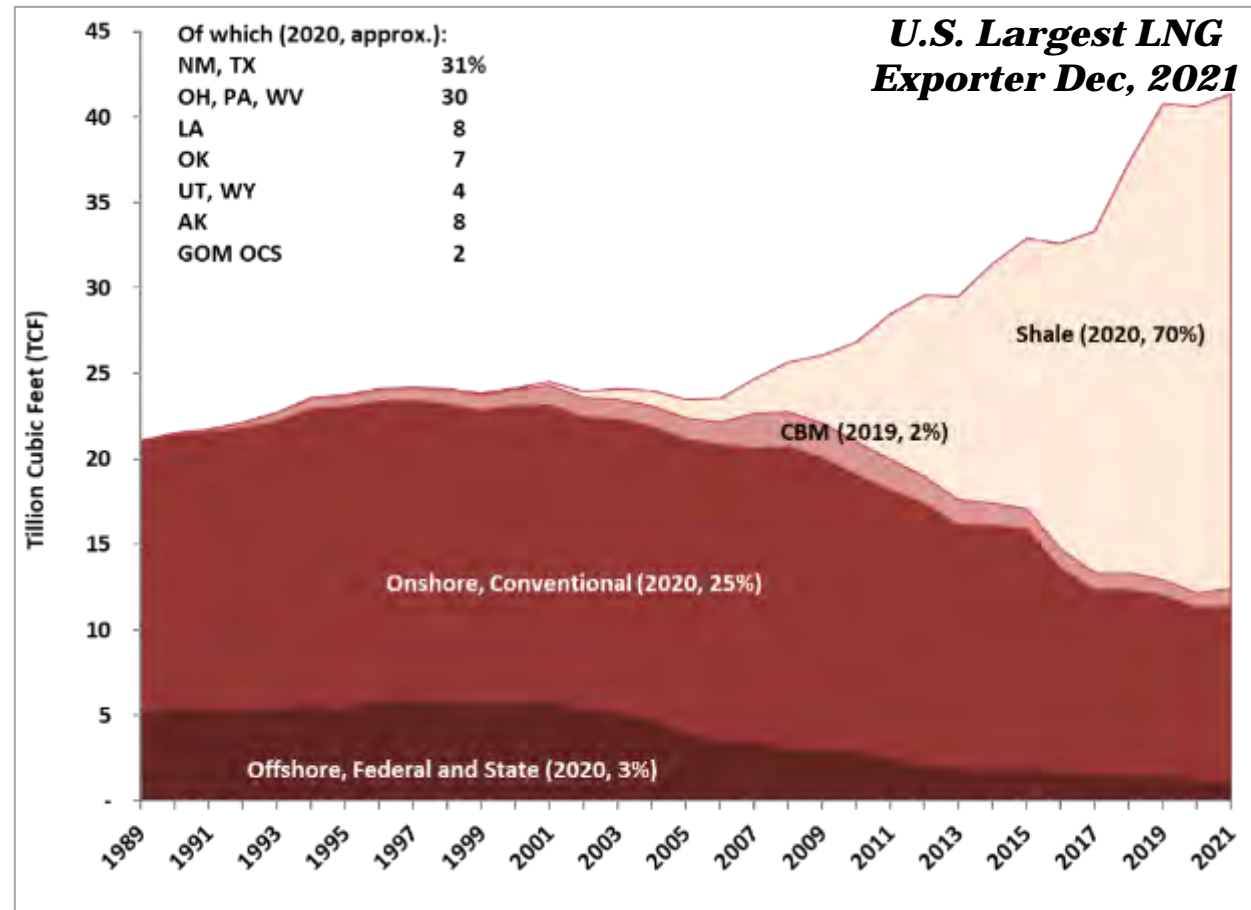
State of the Markets

U.S. supply abundance worth worrying about..

U.S. Crude Oil Production



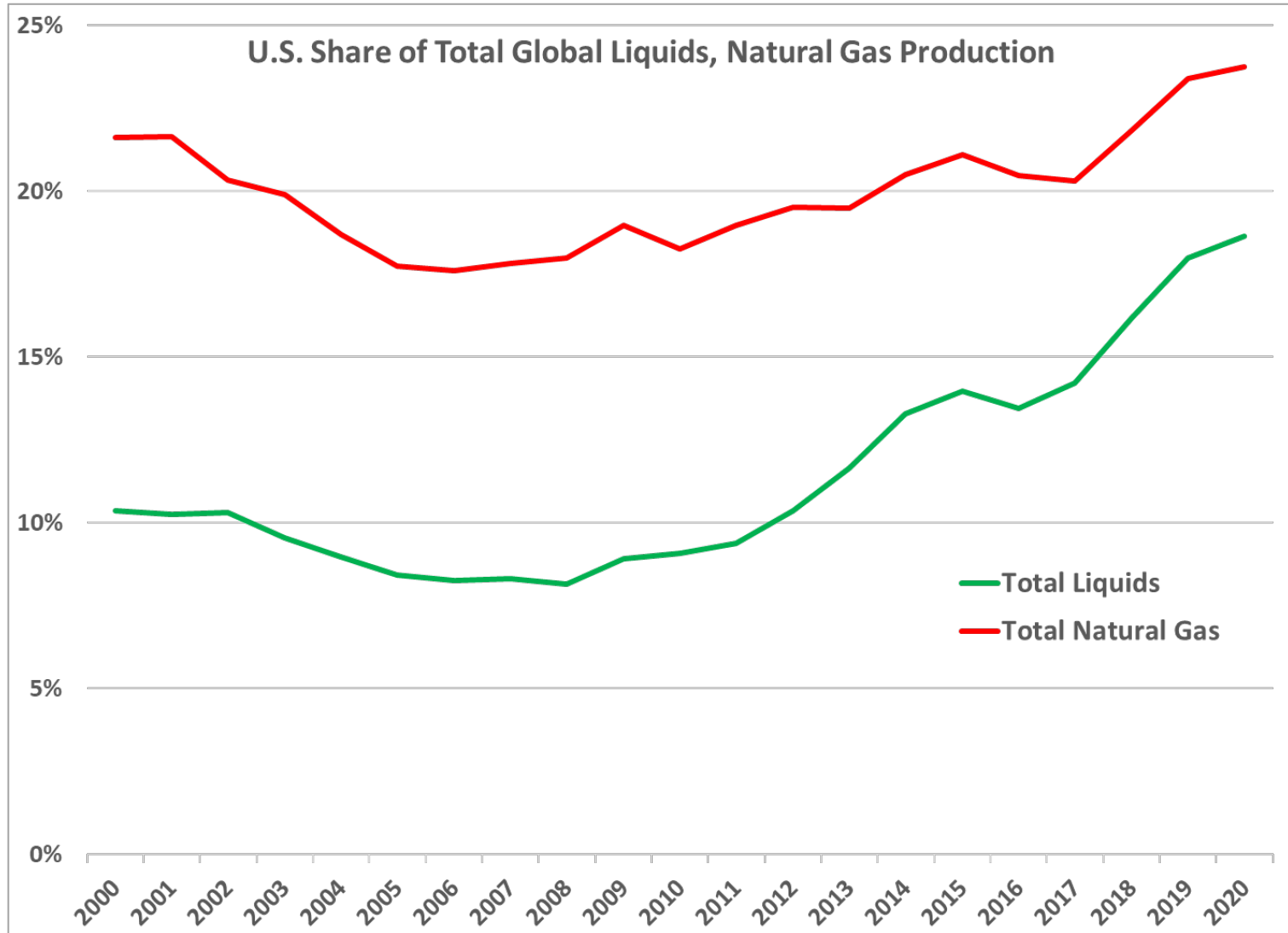
U.S. Natural Gas Production



...in so many, many ways.

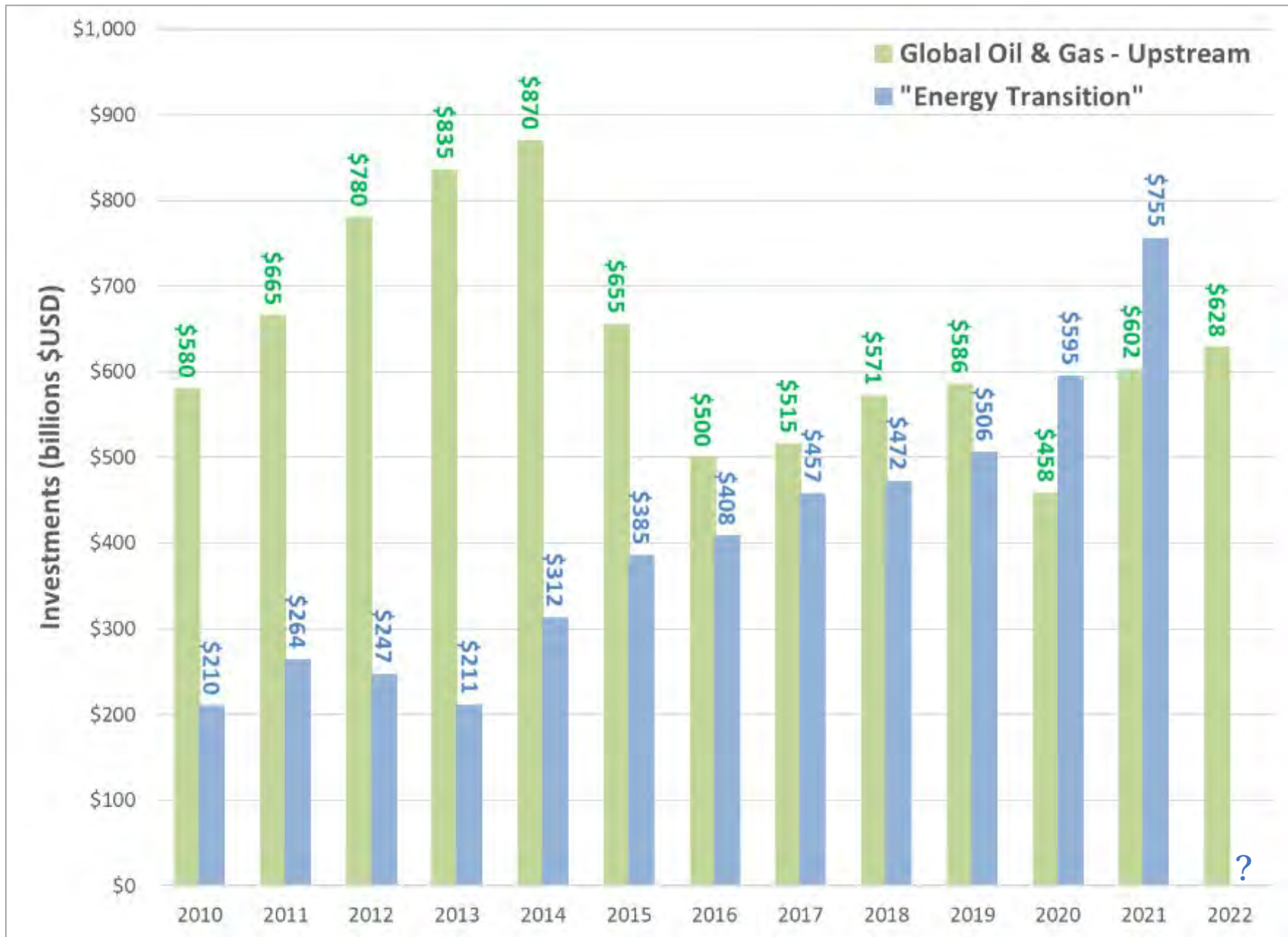


YOU'RE A PETROLEUM GEOLOGIST CHARLIE BROWN!

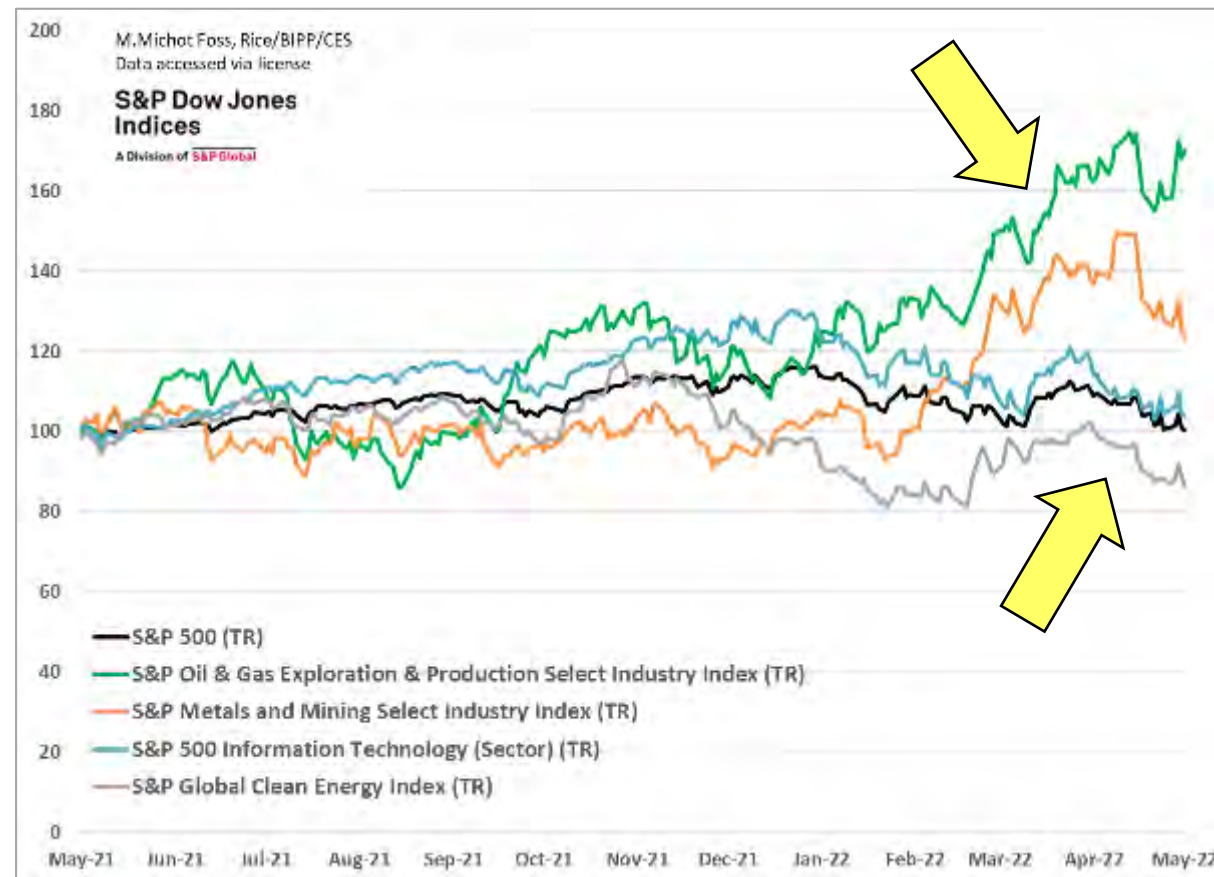
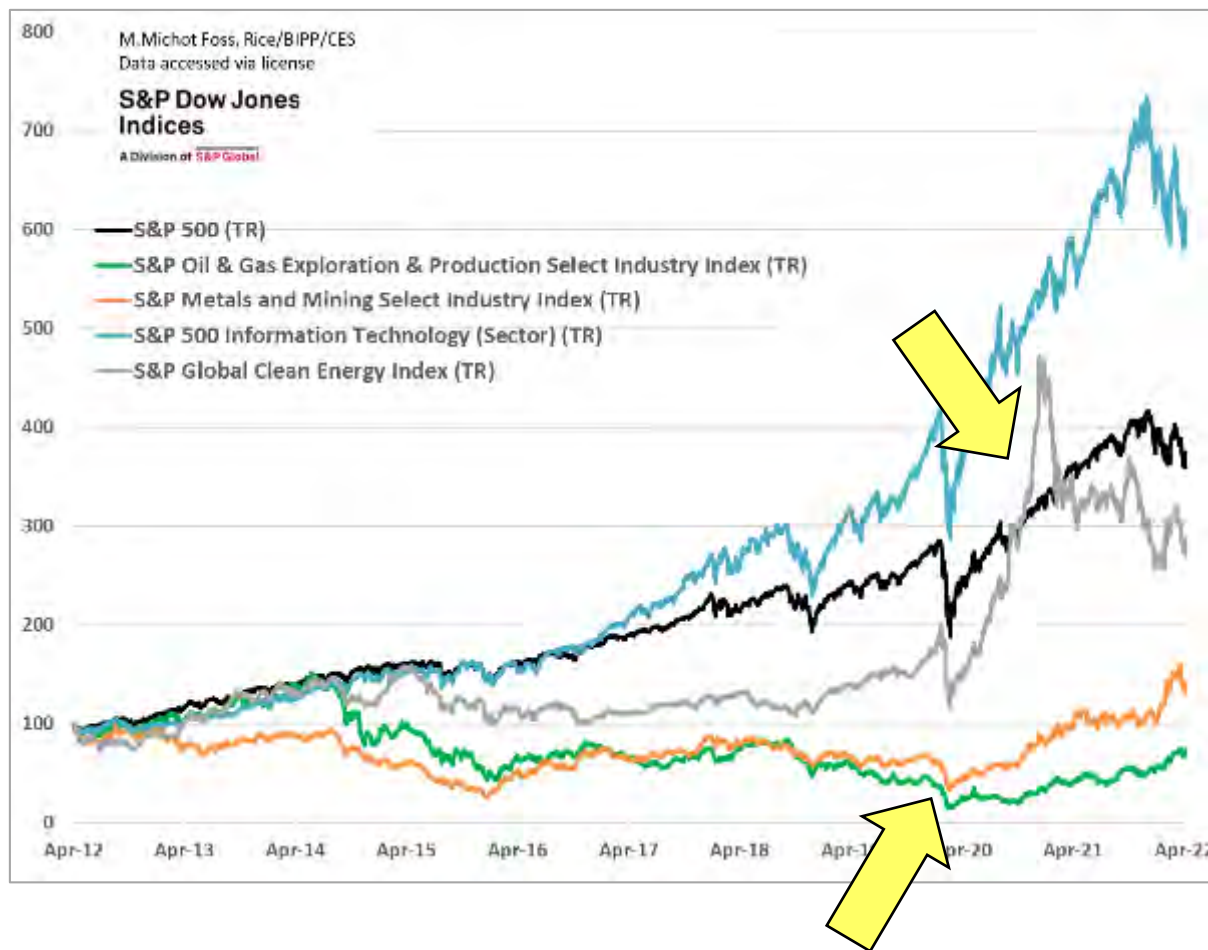


The lure of “green” investment...

Note: For 2021 about half of ET investment is wind, solar; more than one-third electrified transport. CCS was ~0.3% of ET investment.



...but what a difference a year makes.





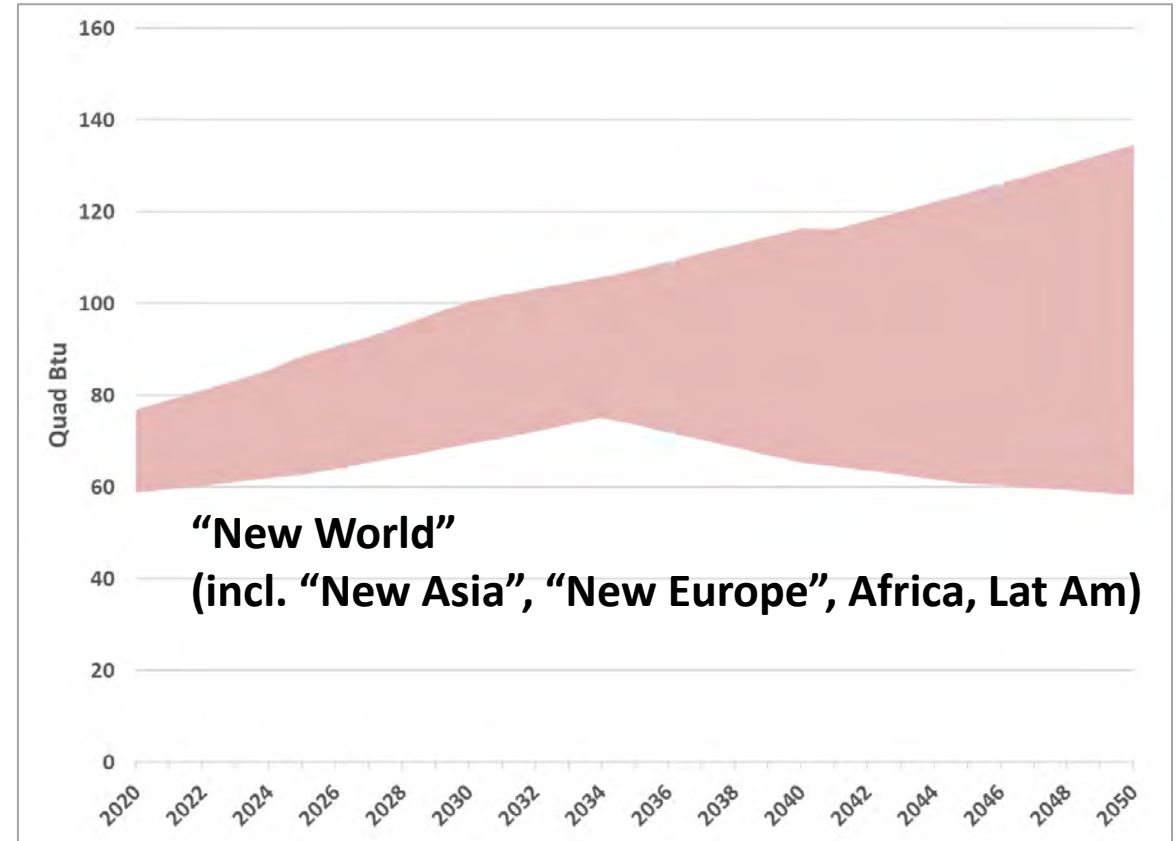
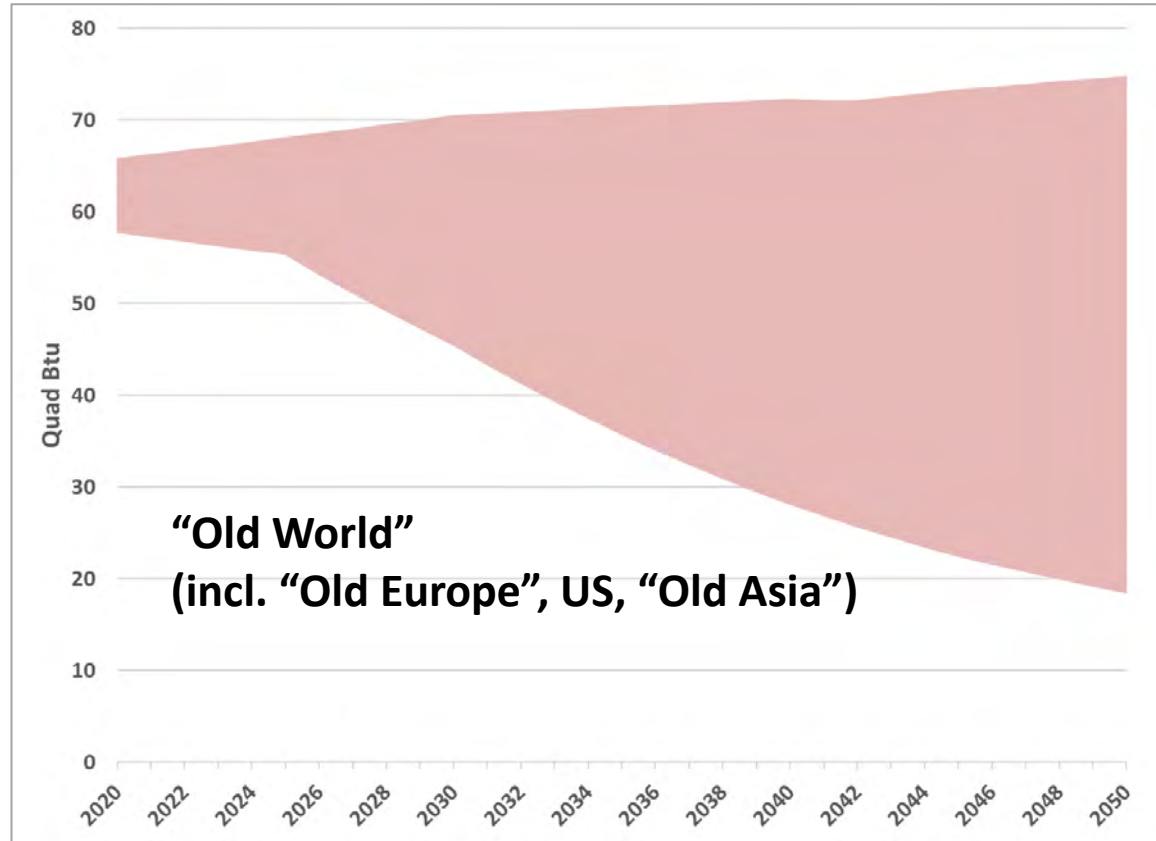
Qu'ils mangent de la brioche

<https://www.britannica.com/story/did-marie-antoinette-really-say-let-them-eat-cake>

State of the World

Who's paying – and for what?

Projected Natural Gas Consumption



© 2021

Monetizing Natural Gas in the New “New Deal” Economy

<https://link.springer.com/book/10.1007/978-3-030-59983-6>

Editors (view affiliations)

Michelle Michot Foss, Anna Mikulska, Gürcan Gülen

Pictures Worth \$‘000s of Words

“Old World”

The New York Times

Europe Fears That Rising Cost of Climate Action Is Stirring Anger

Memories of the Yellow Vest movement are prompting officials to ensure that spiking energy prices don't fuel inequality or populist discontent.



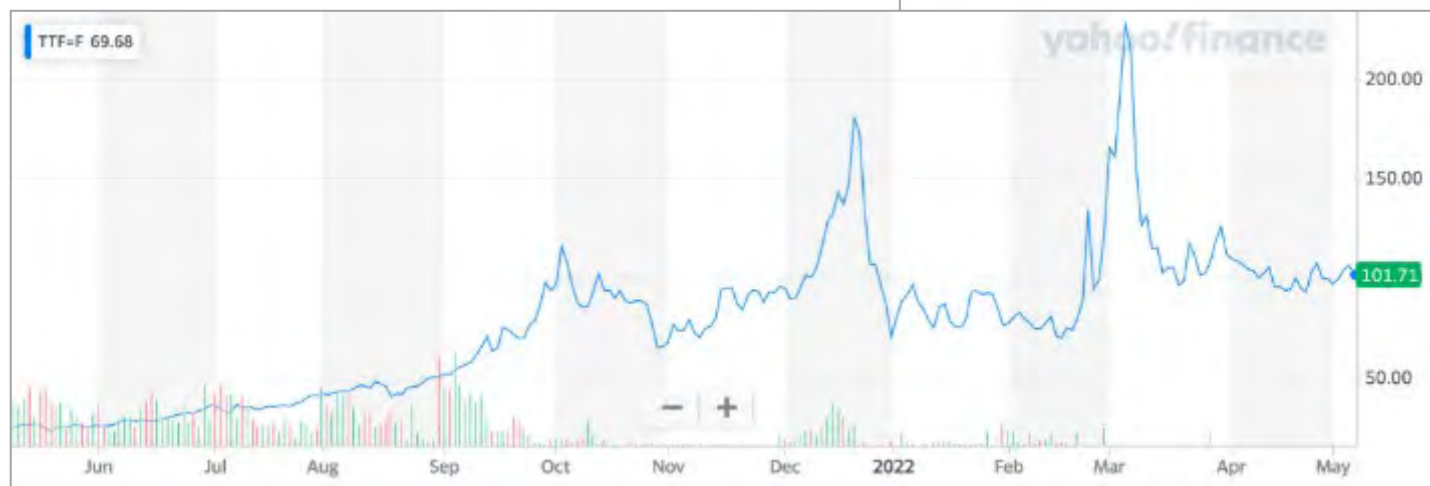
A protest in October in Madrid, Spain, against an increase in the price of electricity.

America to the Rescue (Again, and Again)

Liquefied U.S. Natural Gas Exports

Million Cubic Feet

400,000



— Liquefied U.S. Natural Gas Exports

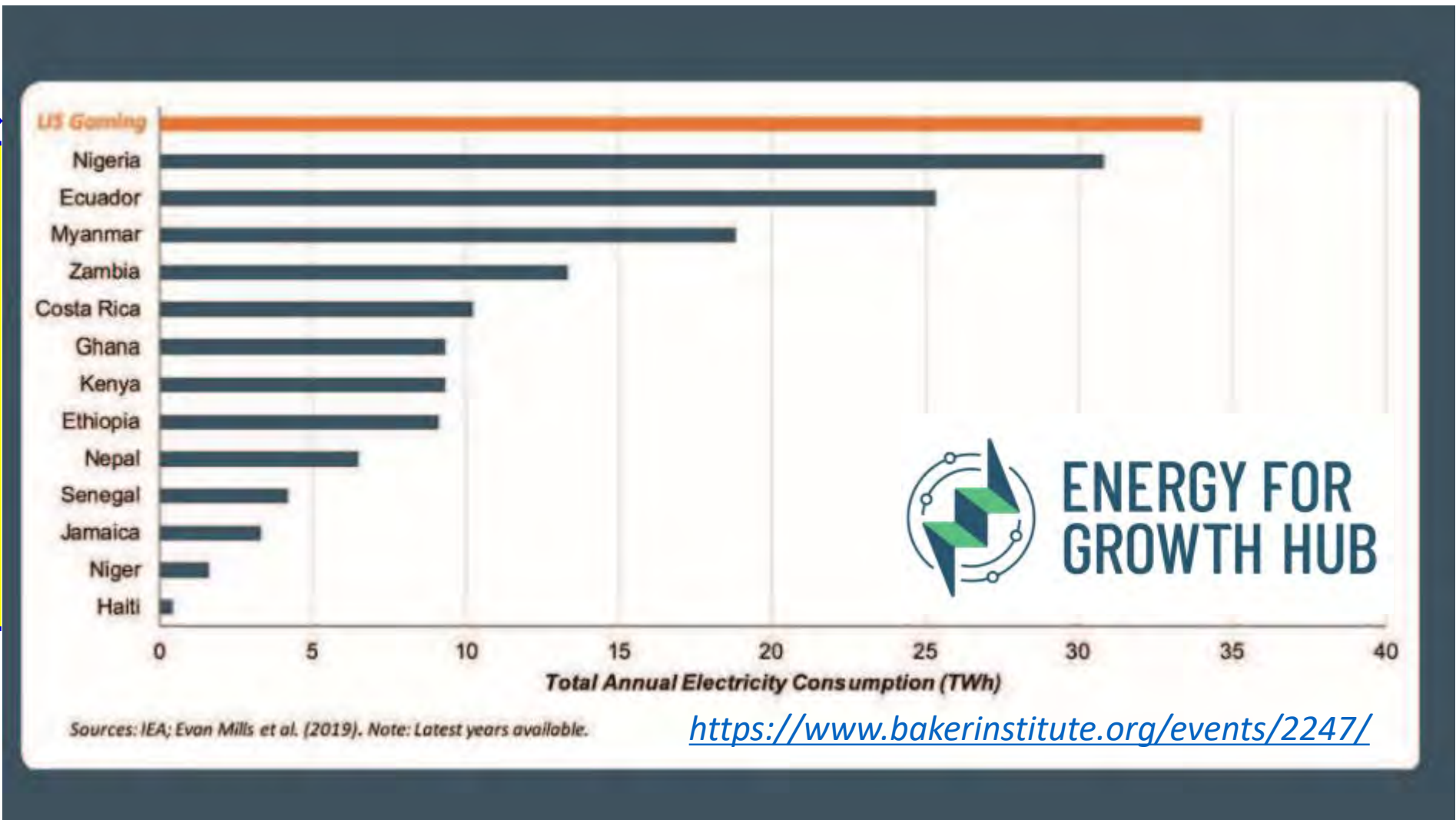


Source: U.S. Energy Information Administration

Getting “Perspective”

“Old World”

“New World”



Oh, the things that we do...

Extinction Rebellion visits the Royal Academy, October 2019...



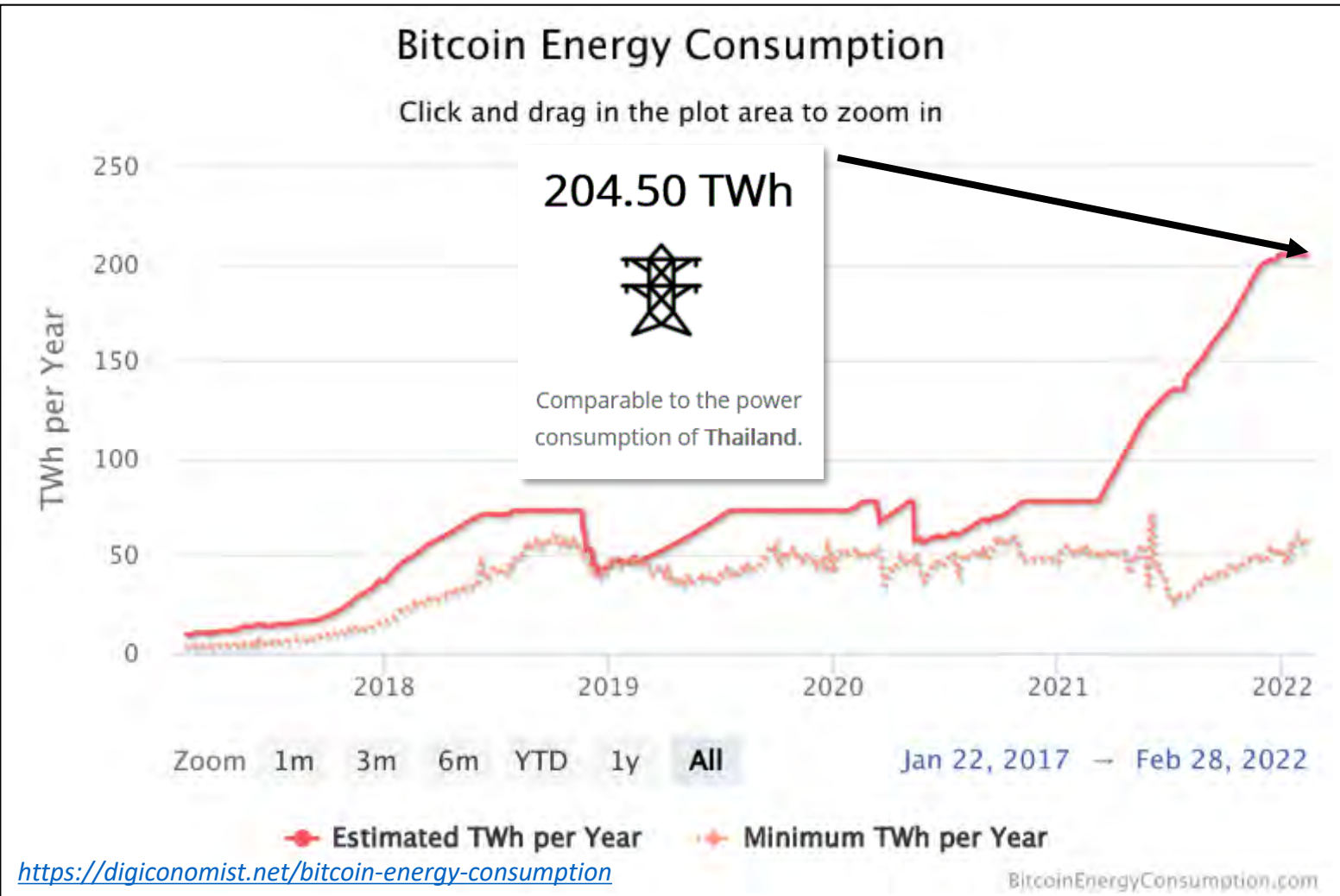
..meanwhile...



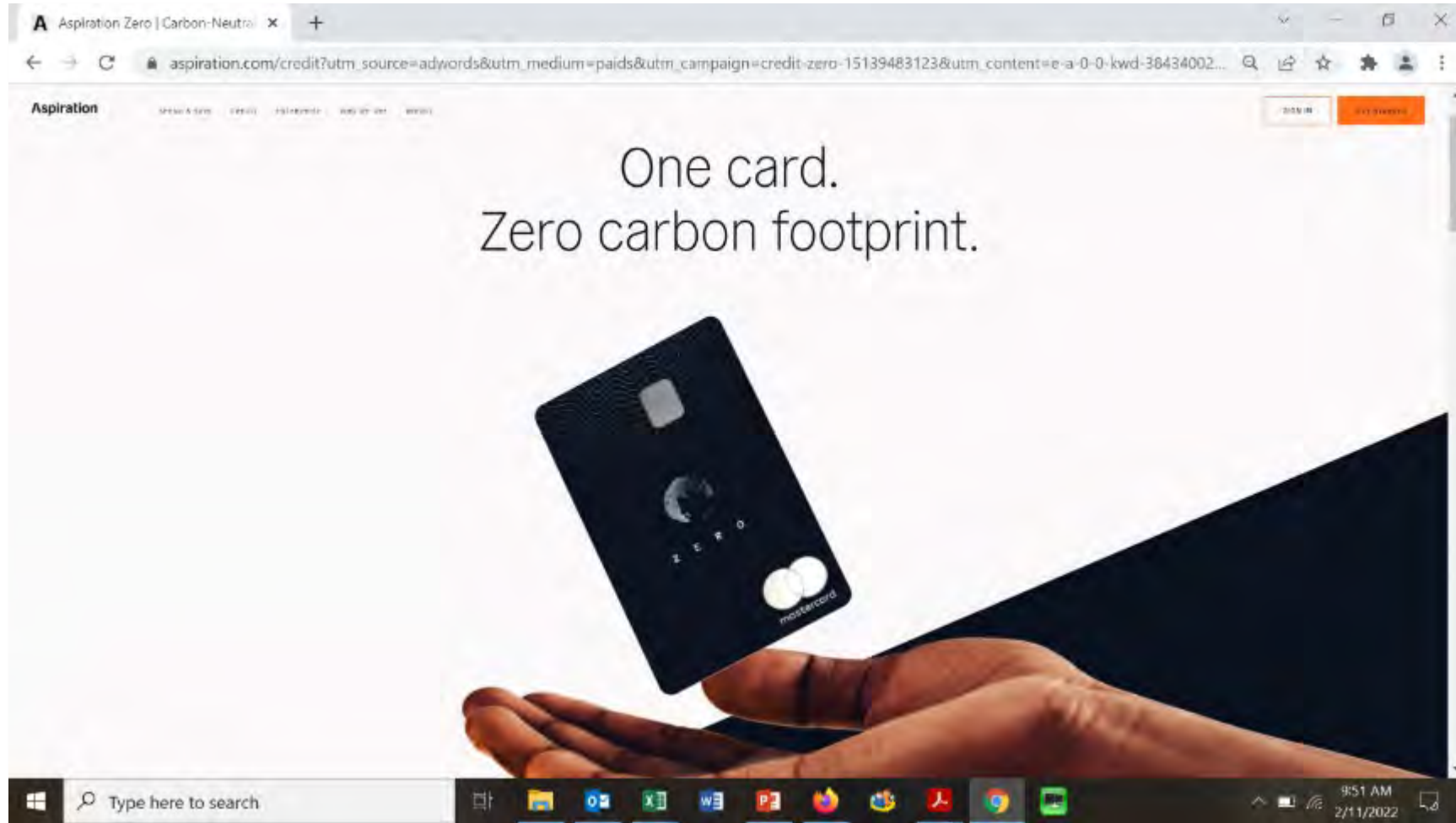
..and so much for them Apples.



...and then some.



Just plant a tree. Gazillions of trees.



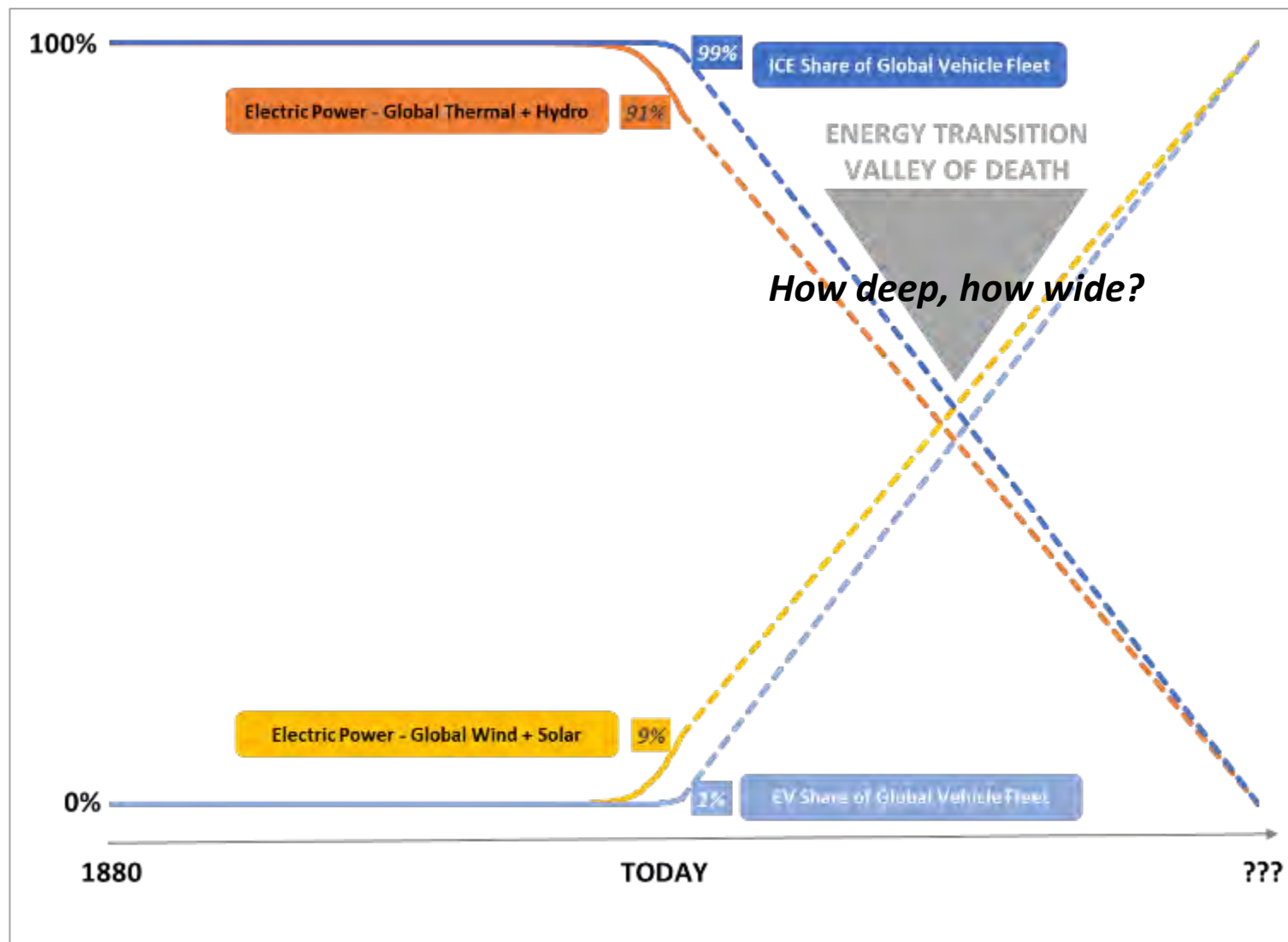
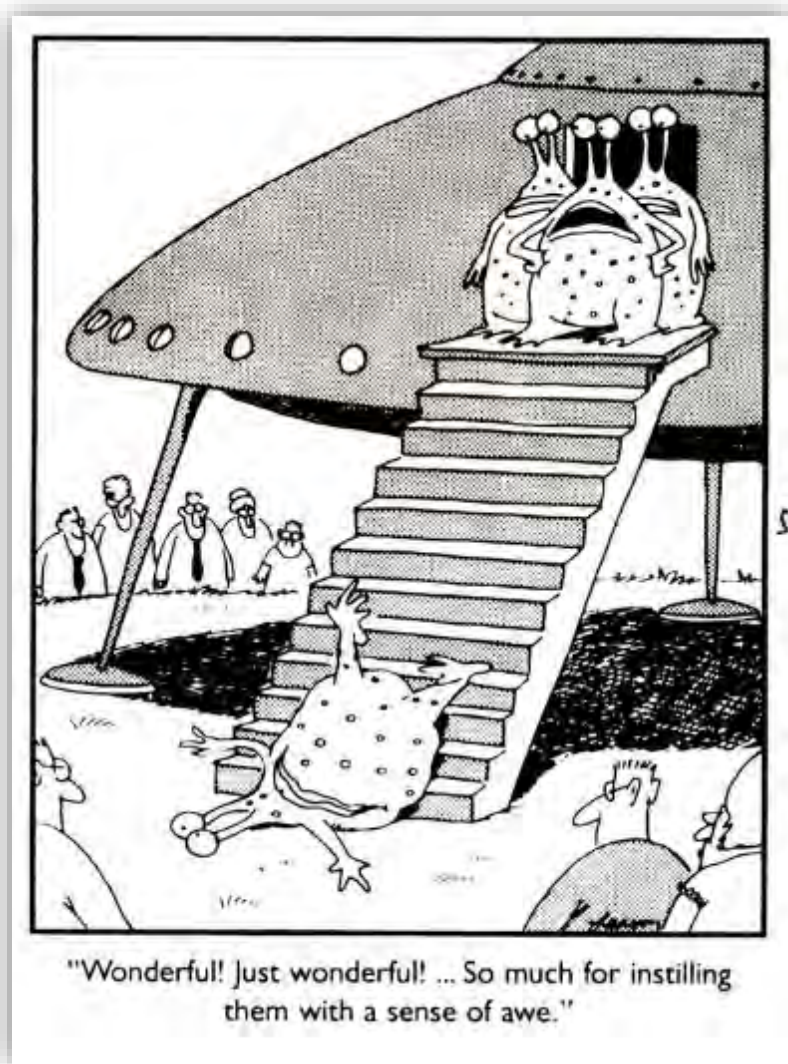
<https://www.aspiration.com/credit>

Fourth Law of Thermodynamics: If the probability of success is not almost one, then it is damn near zero.

David R. Ellis

Reality Checks

The Energy Transition Valley of Death

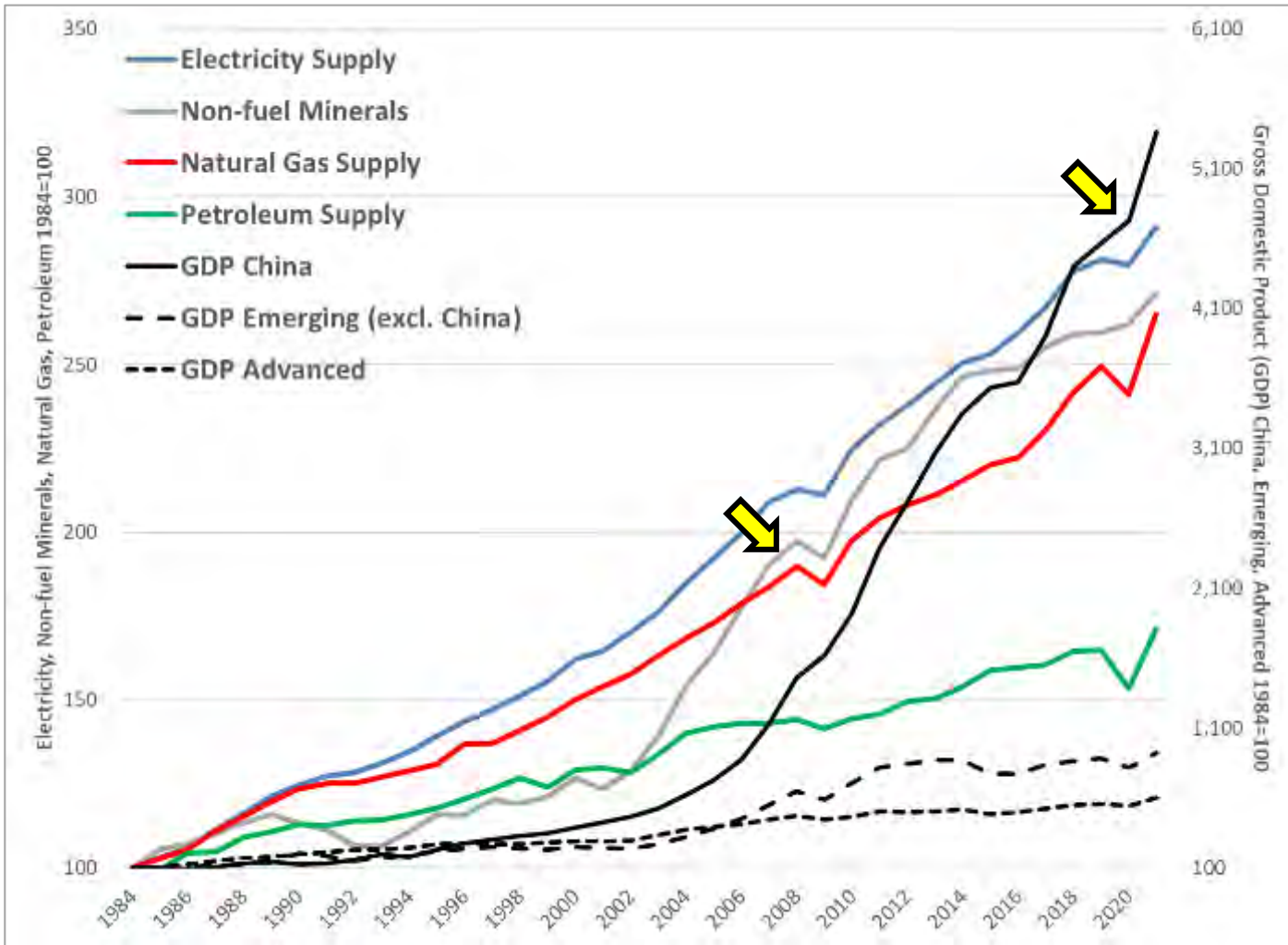


Challenges to Timing, Scale

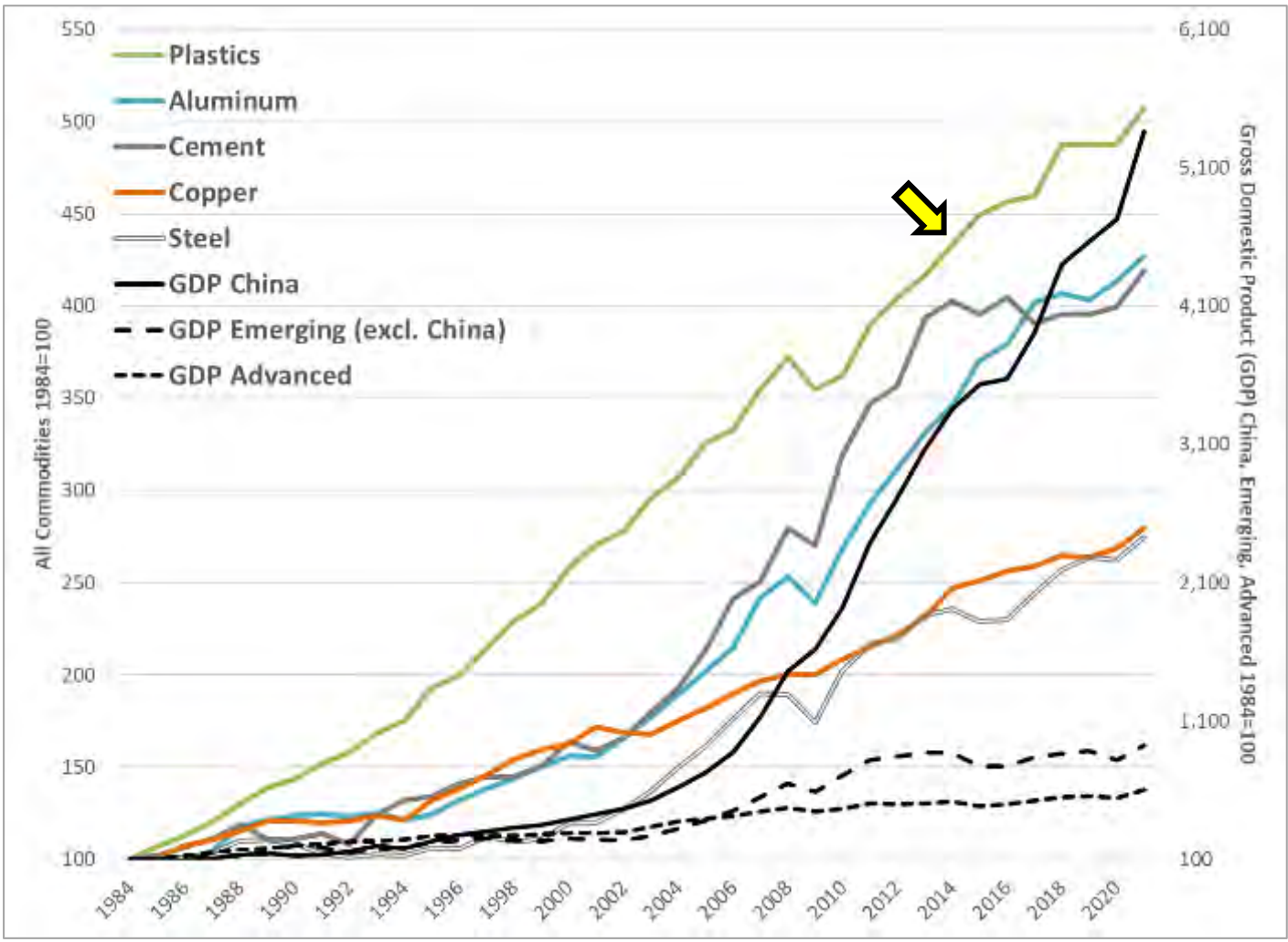
Breakthroughs and acceleration need solutions to or more clarity around:

- Fundamental physical, chemical laws
 - Periodic table – “constrained” palette
- Uncertainty about demand drivers
 - Technologies, components, applications, pace of adoption – closing the “willingness to pay” and “affordability” gaps – and underlying demographics
- Batteries and advanced solar are complicated and will cost more going forward
 - Uncertain demand drivers = great variation in designs and what the raw materials “market basket” could look like
 - “Economic geopolitics” – battery production and raw materials, energy and emissions intensity of battery production, logistics and associated costs, uncertain regulatory landscape for shipping, packaging, disposal, recycling (EPA), “hazmat” (PHMSA, EPA), what battery chemistry in the first place.....
- “Footprint” of “new energy” and fragmented regulatory oversight
- Political backlash - “socioeconomic politics/geopolitics” landscape vs “green” promises
 - Job creation, new investment, new businesses, ESG metrics.....
- What about the nuclear option???
- **The harsh bottom line of profitability and valuations for both “old” and “new” energy**
 - How to achieve both operational and financial sustainability?
 - “Pension politics” will dominate government budget debates and “green energy” spending commitments

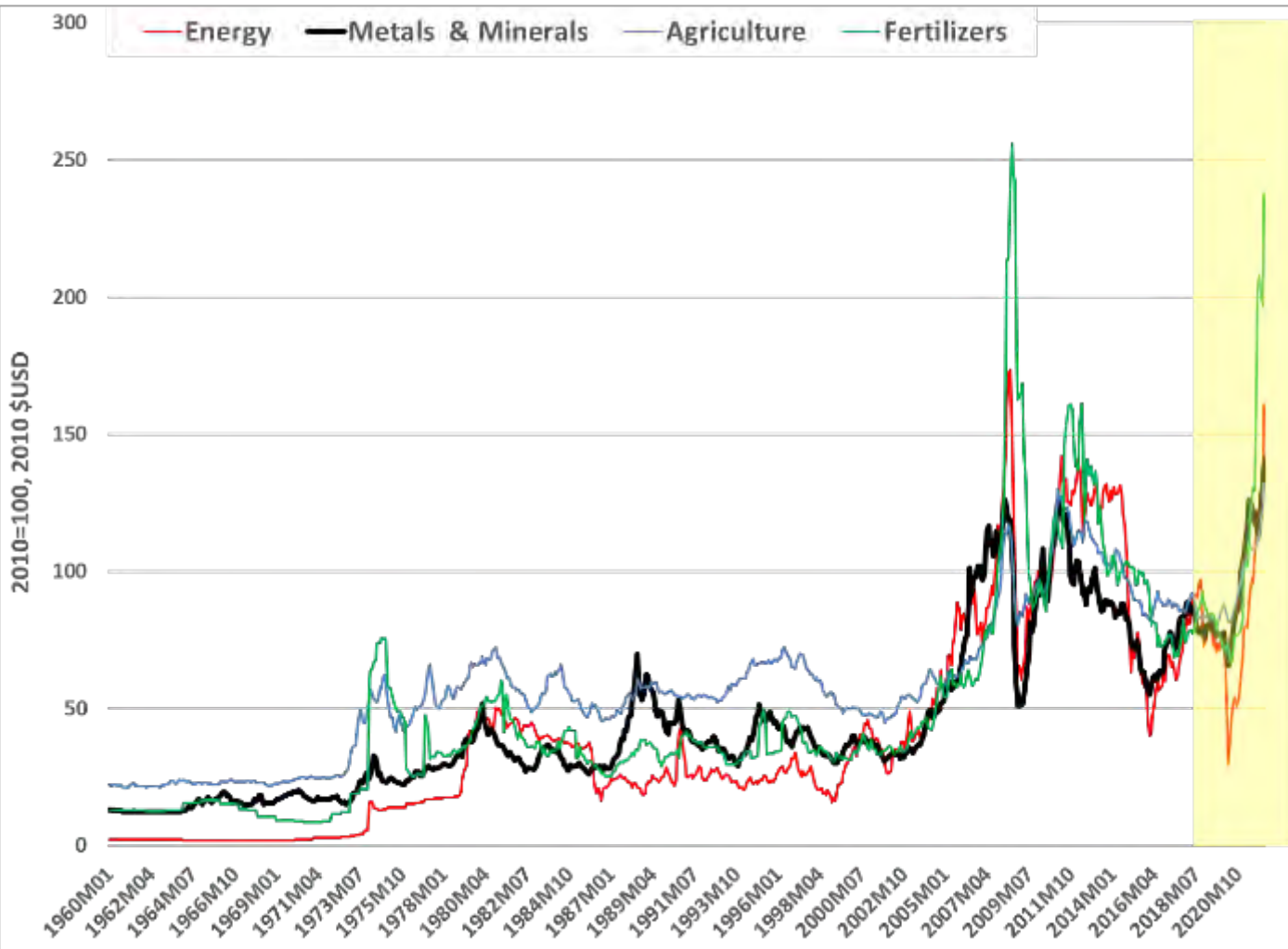
Where Things Stand, I



Where Things Stand, II



Where Things Stand, III



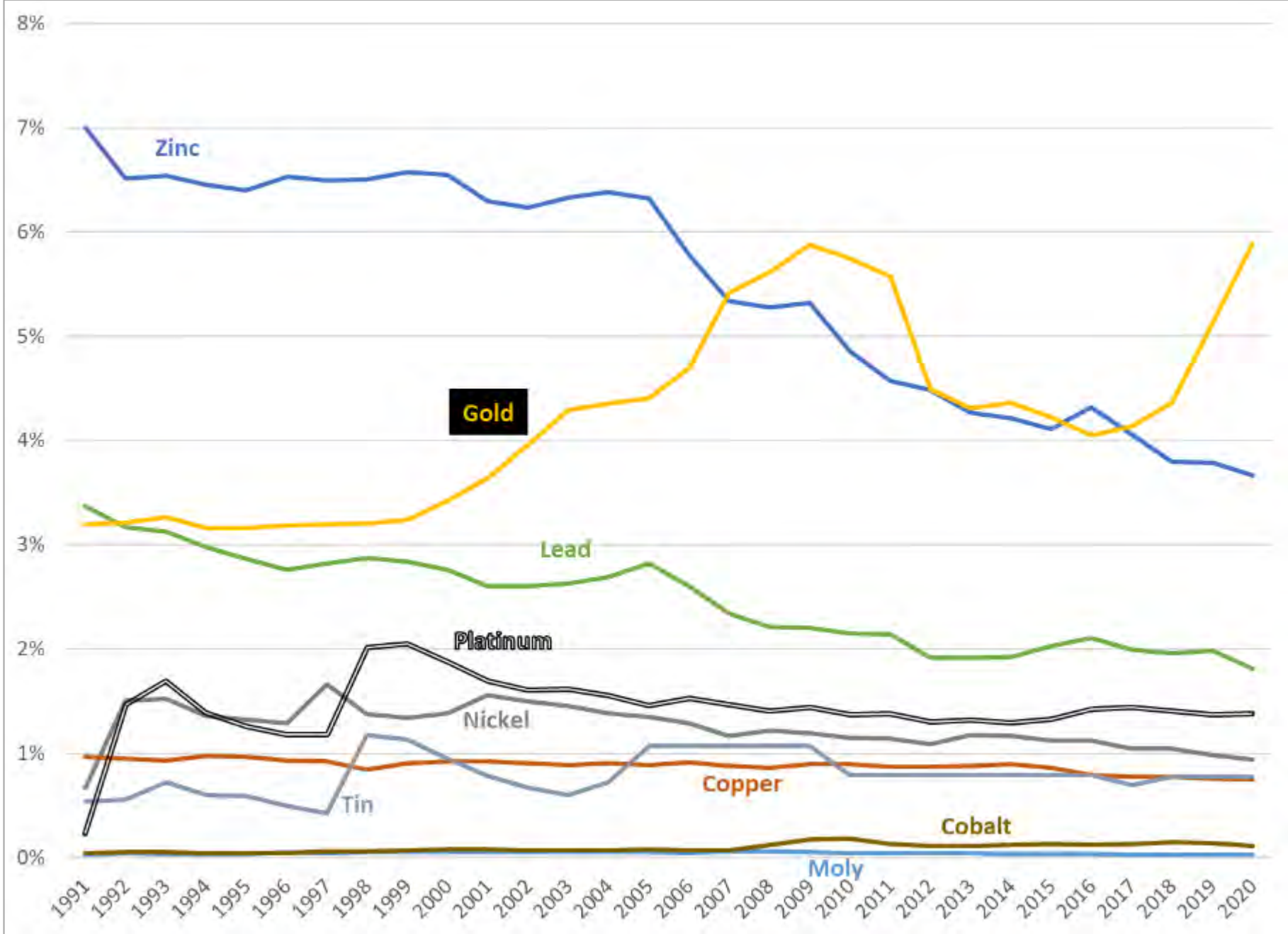
Not Much Running Room

Historical head grades from operational data.

“US Mining: Heightened Risks Of Regulatory Changes As Resource Nationalism Intensifies Globally”

Fitch Solutions / Mining / United States / Tue 12 Oct, 2021

<https://www.fitchsolutions.com/mining/us-mining-heightened-risks-regulatory-changes-resource-nationalism-intensifies-globally-12-10-2021>

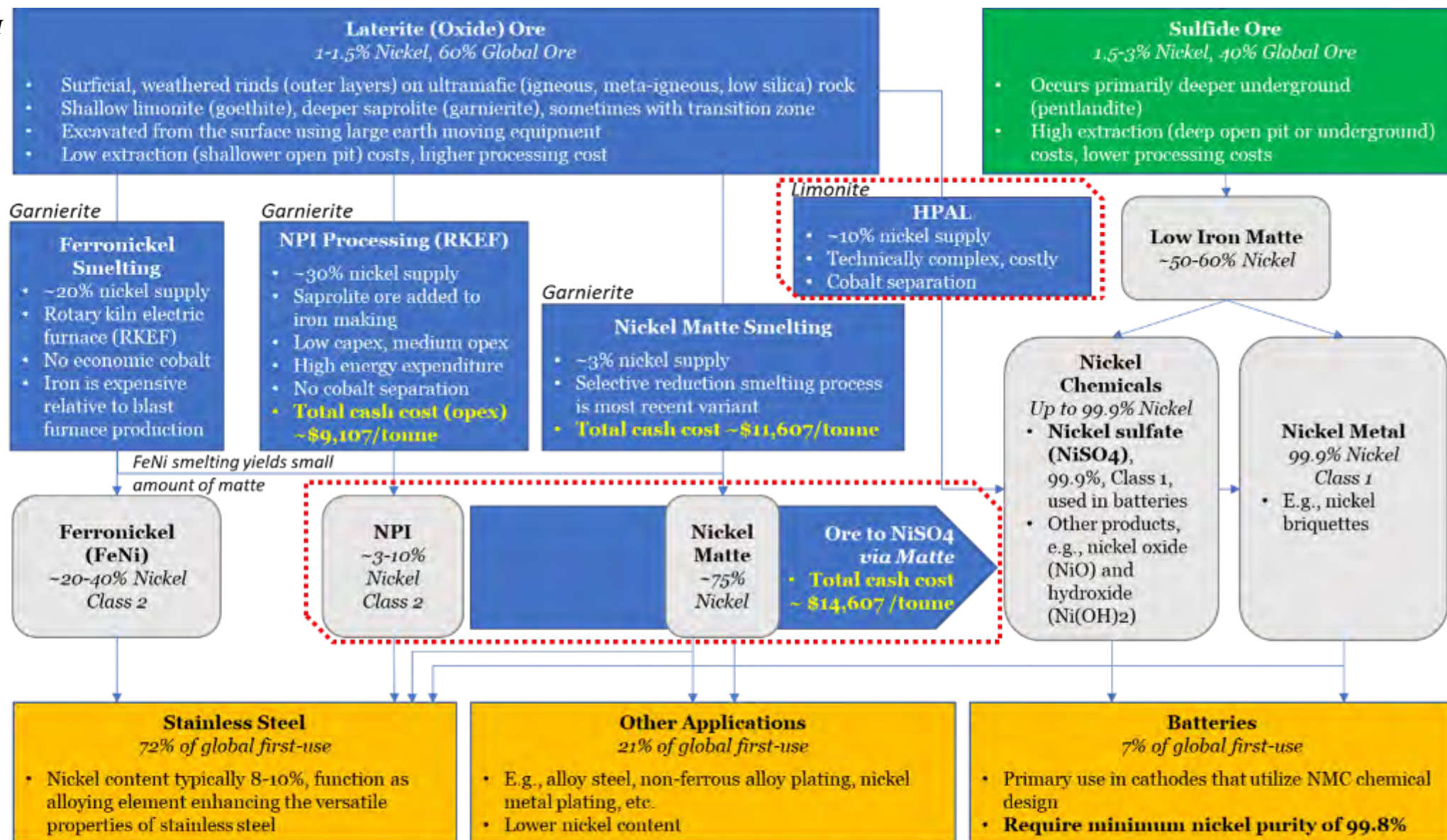


Author analysis based on SPG, accessed via license.

Generalized Nickel Processing Streams

Note that sulfide ores typically are crushed, ground, floated to achieve concentrate and flash smelted to matte.

Red-dashed boxes capture strategies to process low-grade lateritic ores to battery grade nickel.



Sources: Mineral nomenclature from USGS, see endnote 4. UBS Research, from <https://www.kitco.com/commentaries/2018-09-13/Nickel-Laterite-s-Integral-Role-in-the-Coming-Nickel-Boom-Part-2.html>. For ore treatment processes, please see Monhemius, A. J., 1987, Treatment of Laterite Ores of Nickel to Produce Ferronickel, Matte or Precipitate, Imperial College, London, January, https://www.researchgate.net/publication/291165654_Treatment_of_laterite_ores_of_nickel_to_produce_ferronickel_matte_or_precipitated_sulphide and Davenport, W. and Moats, M., 2014, Nickel and Cobalt Production, Treatise on Process Metallurgy: Industrial Processes, <https://mail.google.com/mail/u/0/?tab=rm#inbox/FMfcqzGllVqgdbQTprVMRmTWrpNSRjfp?projector=1&messagePartId=0.4>. For processing costs, please see Sappor, J., 2021, Commodity Monthly – Nickel April 2021, S&P Global Market Intelligence, April, accessed via license. For global first-use figures, please see Nickel Institute, 2021, About Nickel and Its Applications, <https://nickelinstitute.org/about-nickel-and-its-applications/>.

Spreadsheet Decarb: “Net Zero” Math Problems

Tangible: Energy + Materials



Assumption:
Materials from
the “blue”
barrel (BBL)
without
monetizing
fuels cuts.

Intangible: fungibility, storage, reliability,
security, performance, convenience...

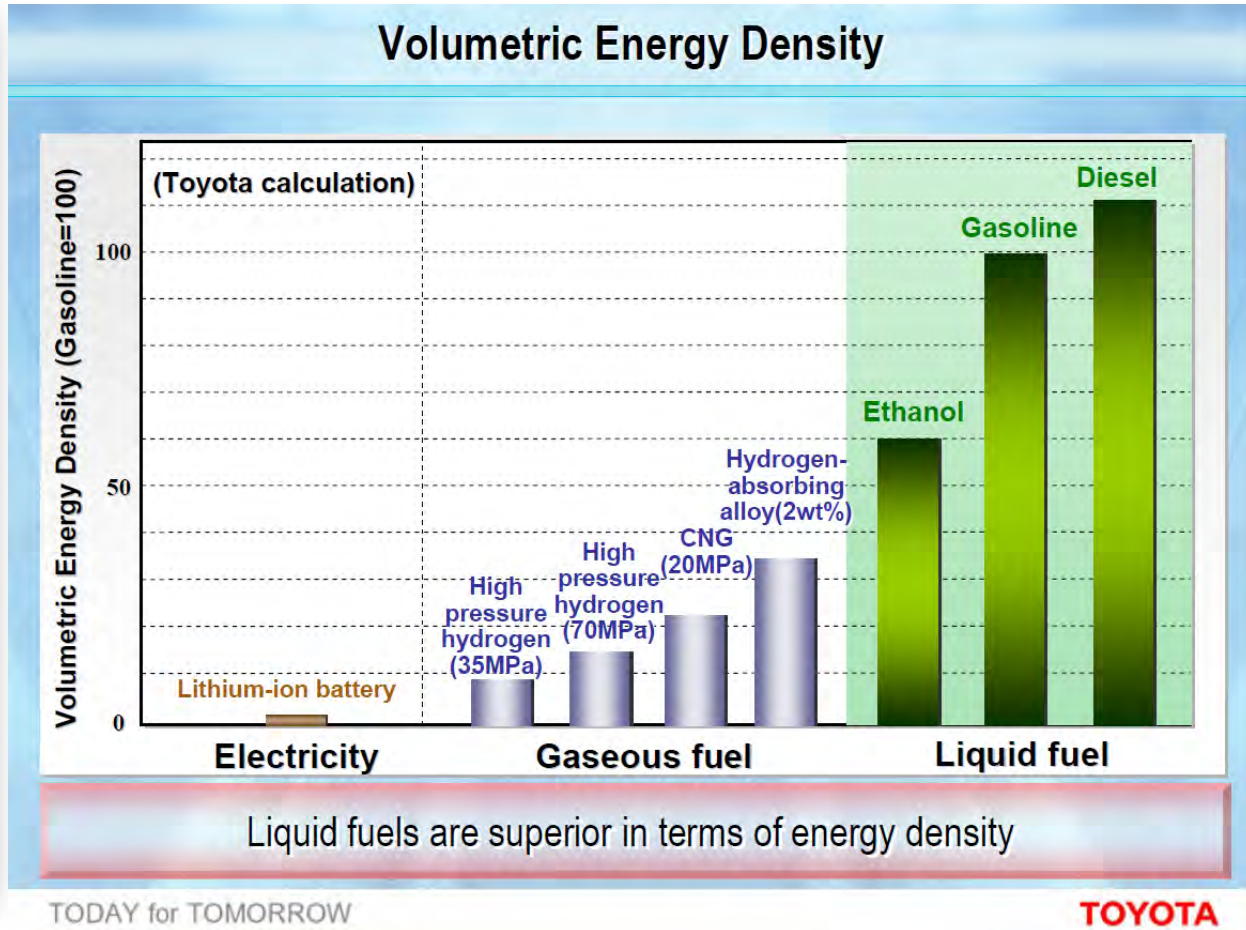
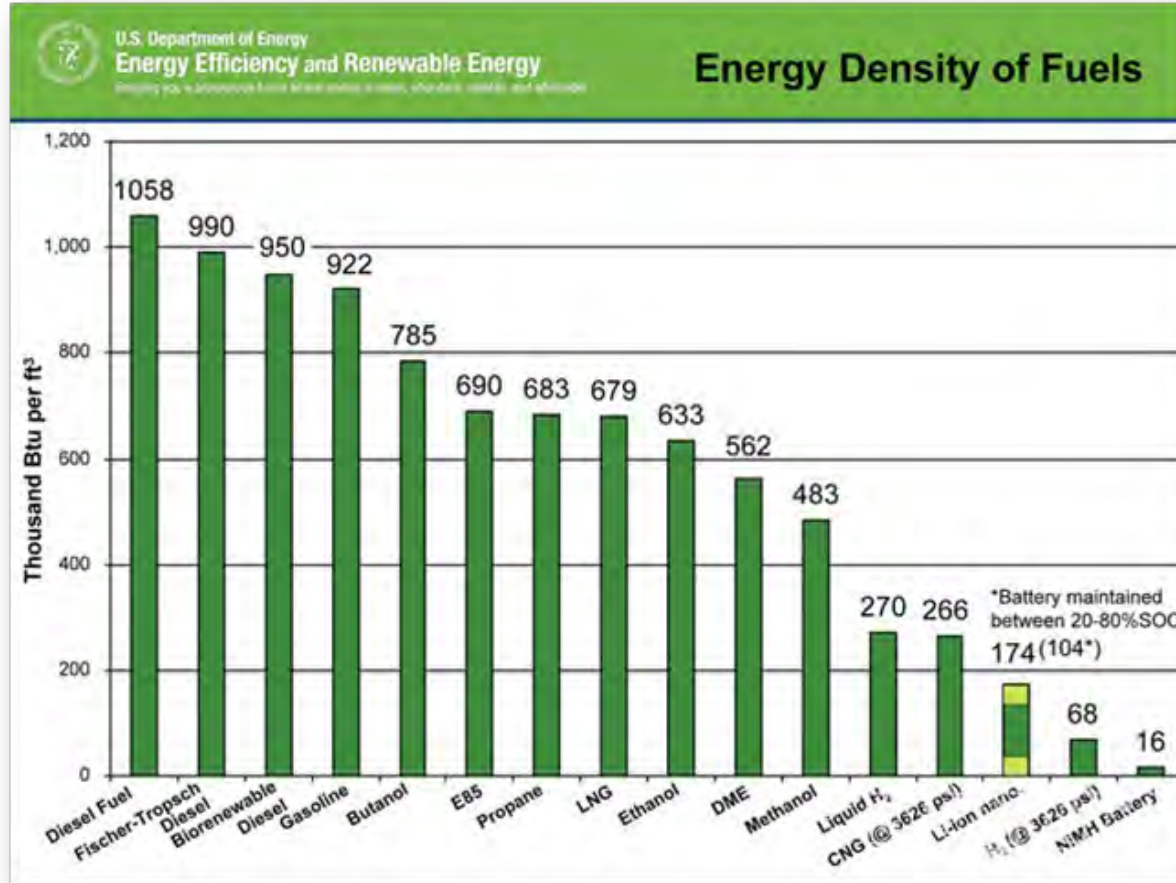
- Total global liquids consumption 2022 (expected):
~101 MMBOED
- Share of liquids for chemicals:
~11 MMBOED, ~12%

- IEA 2050 “net zero”
 - 2050 total liquids demand (incl. biofuels and other):
36 MMBOED
 - Of which industry non-combusted use (chemicals):
23 MMBOED – 65%
 - Total oil demand:
24 MMBOED (implied upstream output)
 - Of which industry:
18 MMBOED – 76%

- **Current contribution** to chemicals/plastics from bio sources: **~1%**
- **Current contribution** from plastics recycling: **~9-20%** (depending upon polymer)

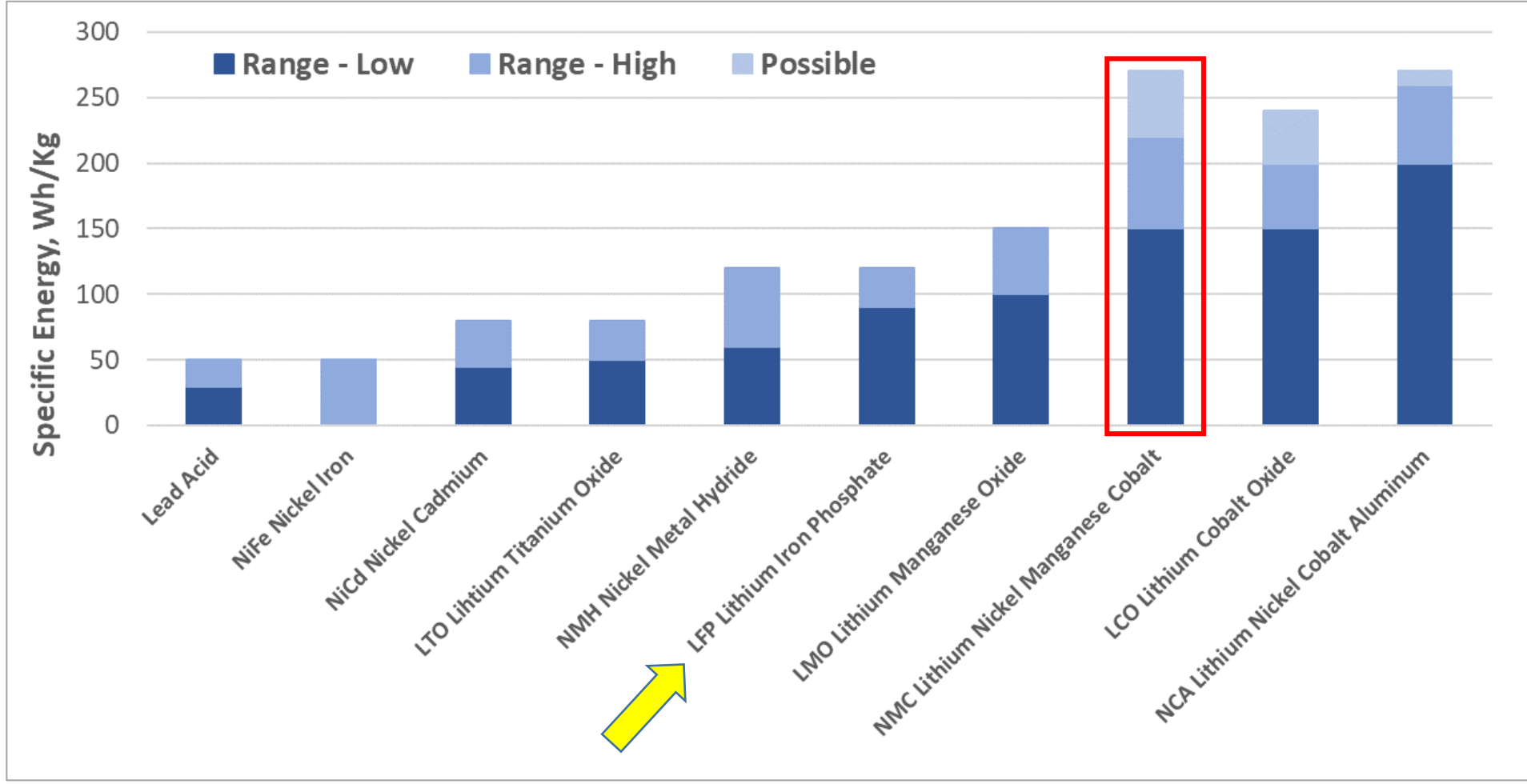
Why greater materials intensity?? Shifting energy paradigms means a battle with energy density.

Two views, same difference.....



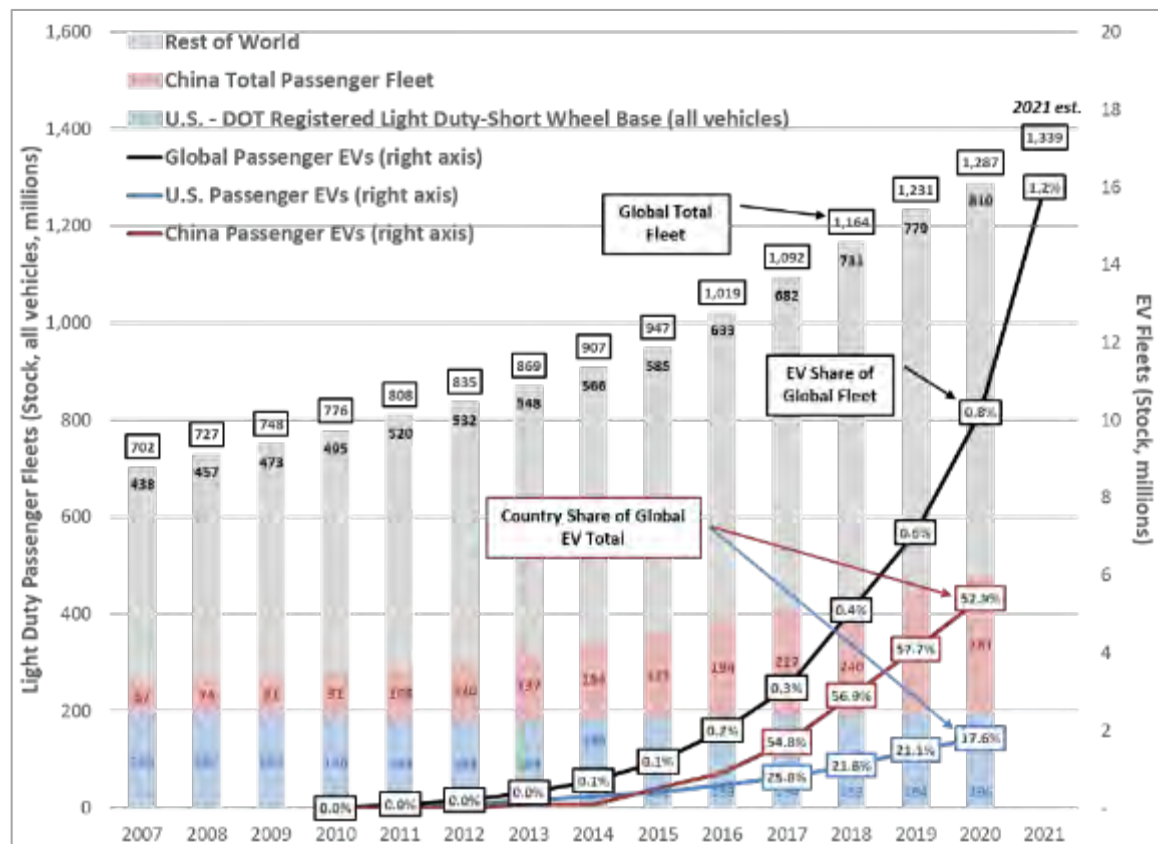
Commercial Battery Chemistries

**Gasoline =
~12,500 Wh/Kg**

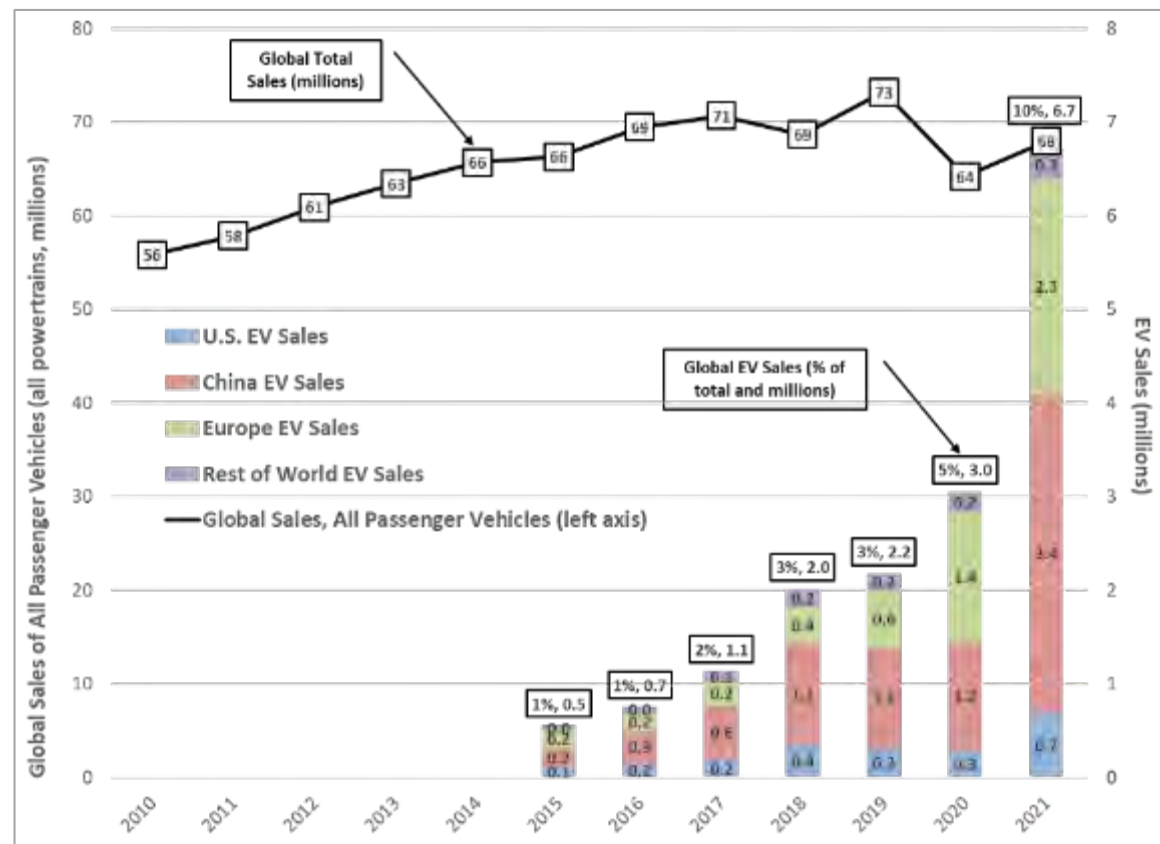


Only A Billion, More or Less, to Go

Global Passenger Vehicle Fleet



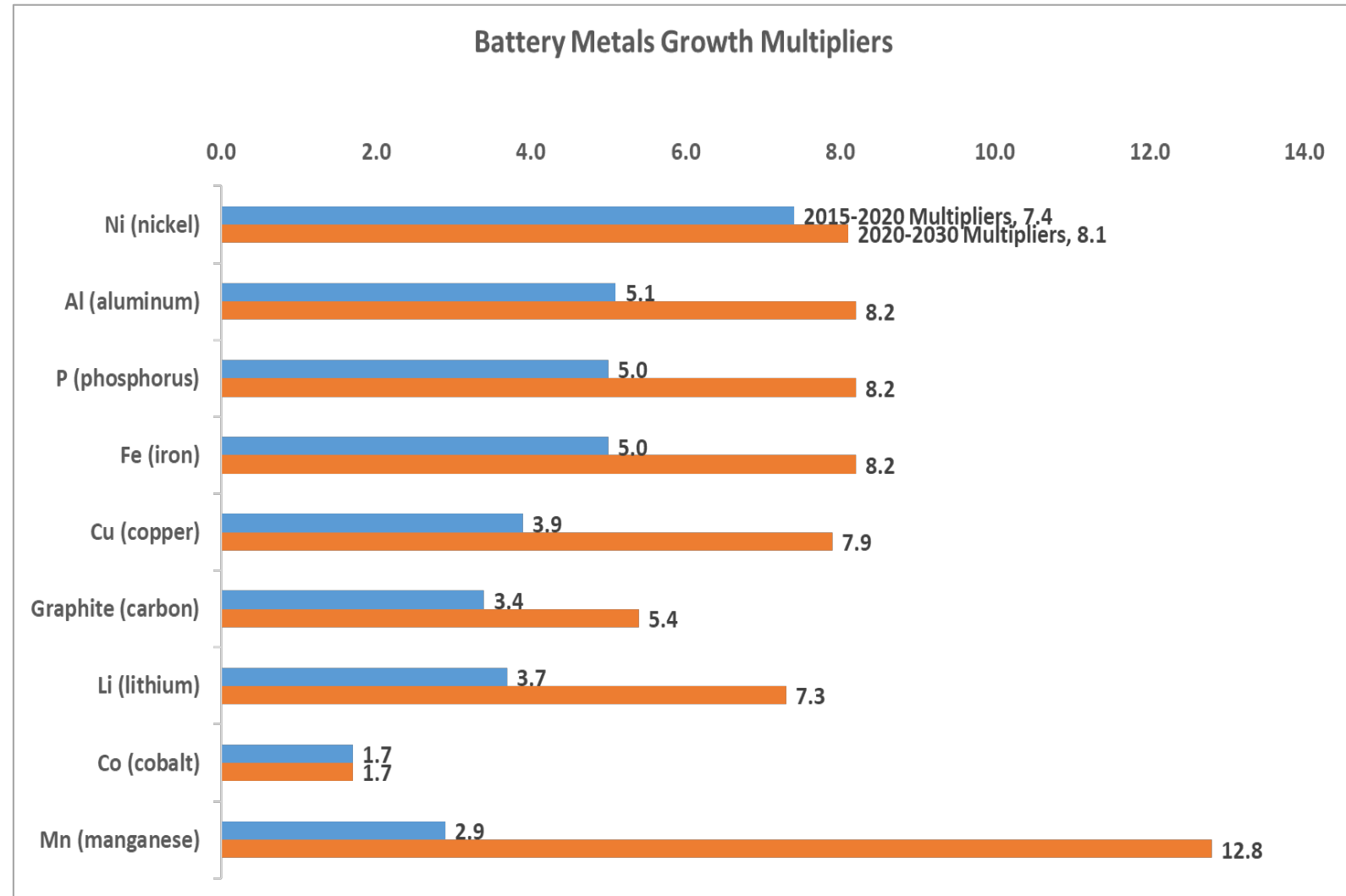
Global Passenger Vehicle Sales



EV “Call” on Metals, Materials

Plastics, the fastest growing material, makes up ~50% of content of traditional vehicles and will comprise more of EVs for weight and safety.

- Projections of global total EV stock by 2030 range from 145 million (IEA) to 169 million (BNEF).
- Current Chinese control of battery manufacturing is 80-90% of world capacity.
- Current capacity contributes ~ 1 billion tCO₂.
- Projects under development will ~double global capacity but considered still insufficient to support EV production.



“Spreadsheet Decarb” Math Problems: Electric Power

U.S. Electric Power (net generation)

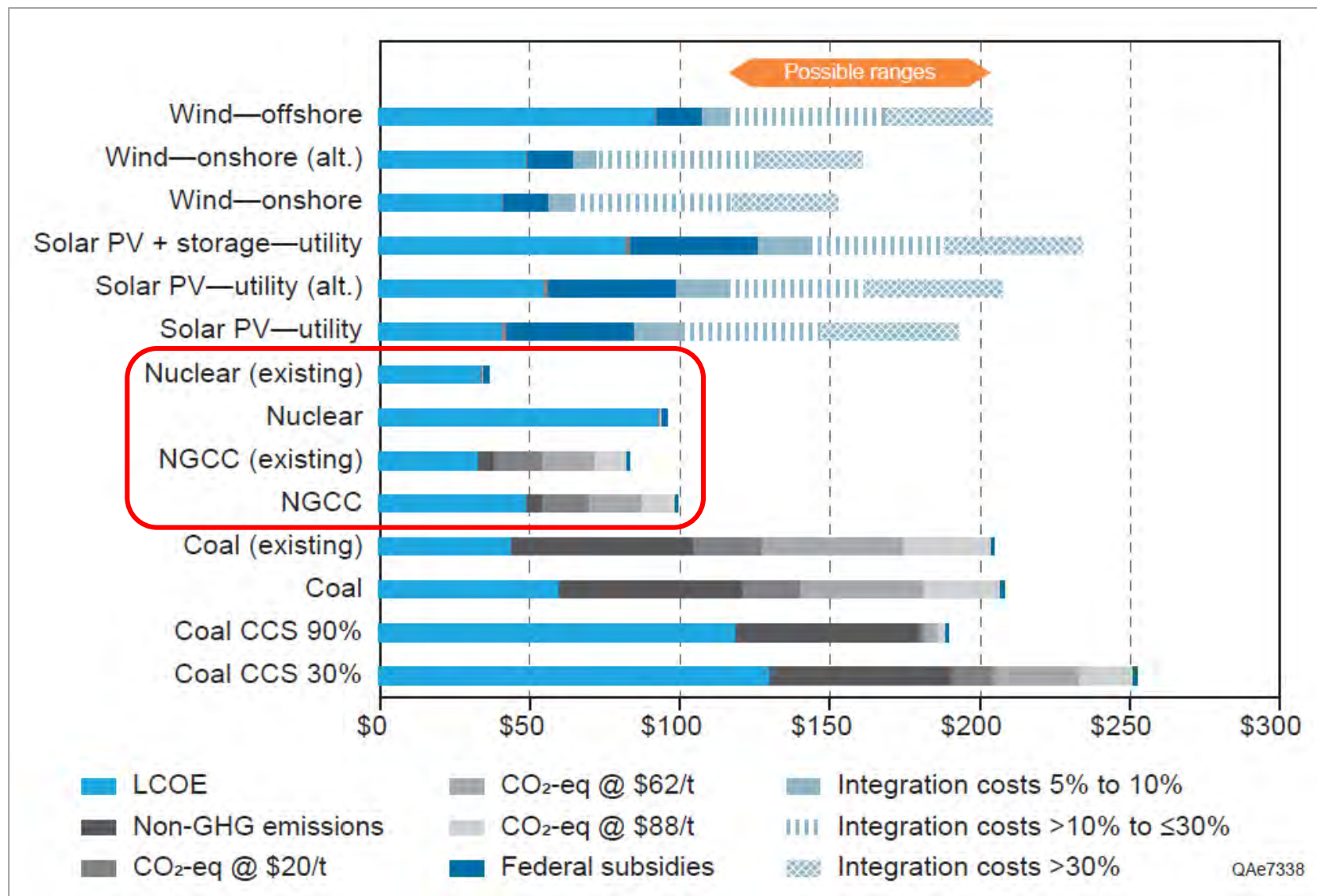
Type	Number	2020, %	vs 2019	‘000 Mwh per Loc.	‘000 Mwh per Unit	Net Gen to Rated Capacity
Nuclear	94 reactors, 55 locations	20	--	14,361	8,403	784%
Natural Gas	6,075 generators, ~1,800 locations (~1.7mm active wells)	39	↑+1%	906	267	294%
Coal	599 generators	19	↓-4%	3,170	1,291	330%
Hydro	4,009 dams	7	--			
Utility scale wind	~78,000 turbines of which ~ 25% in Texas , 1,422 sites	8	↑+1%	238	4	285%
Utility scale solar	Unknown number of panels, 4,599 sites	2	--	19		184%

To reach 50% of current total U.S. net gen:

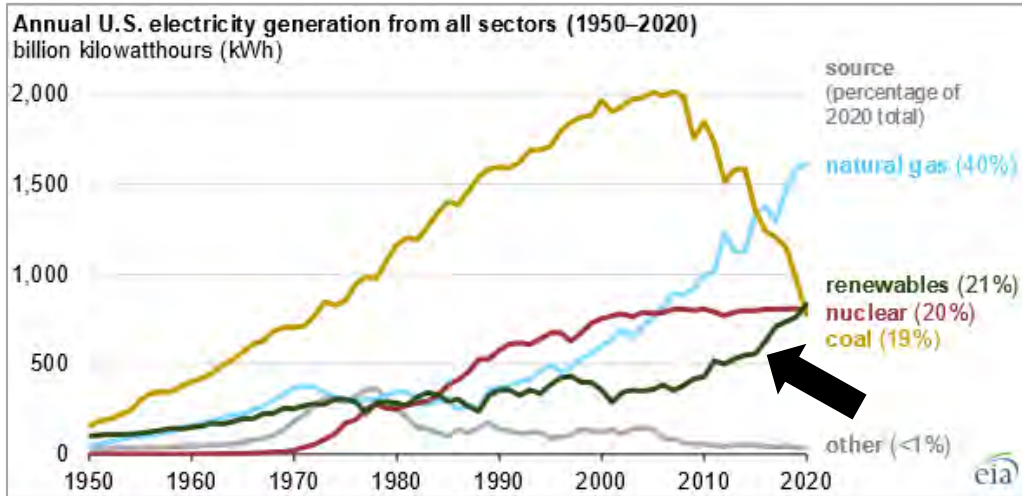
Wind – ~462,000 turbines@ ~8,400 sites, Solar - ~103,000 locations

LCOE with Externalities, Integration Costs, Subsidies

“Representative U.S. LCOE with air emissions, system-integration costs, and federal direct and tax subsidies (\$/MWh). Excludes negative externalities associated with water, land, and ecological impacts; positive externalities; nonfederal subsidies; and federal subsidies other than direct and tax expenditures. These comparisons should not be extrapolated to any project in any location. Base LCOEs are only valid for “average” U.S. locations where it is feasible to build any of these plants. State-level subsidies differ. The LCOE is a high-level policy-discussion tool. Developers do not use LCOE for investment decisions. It is not recommended for the market-IRP. CCS = carbon capture and sequestration; CO₂-eq = CO₂ equivalents; GHG = greenhouse gas; NGCC = natural gas combined cycle.”



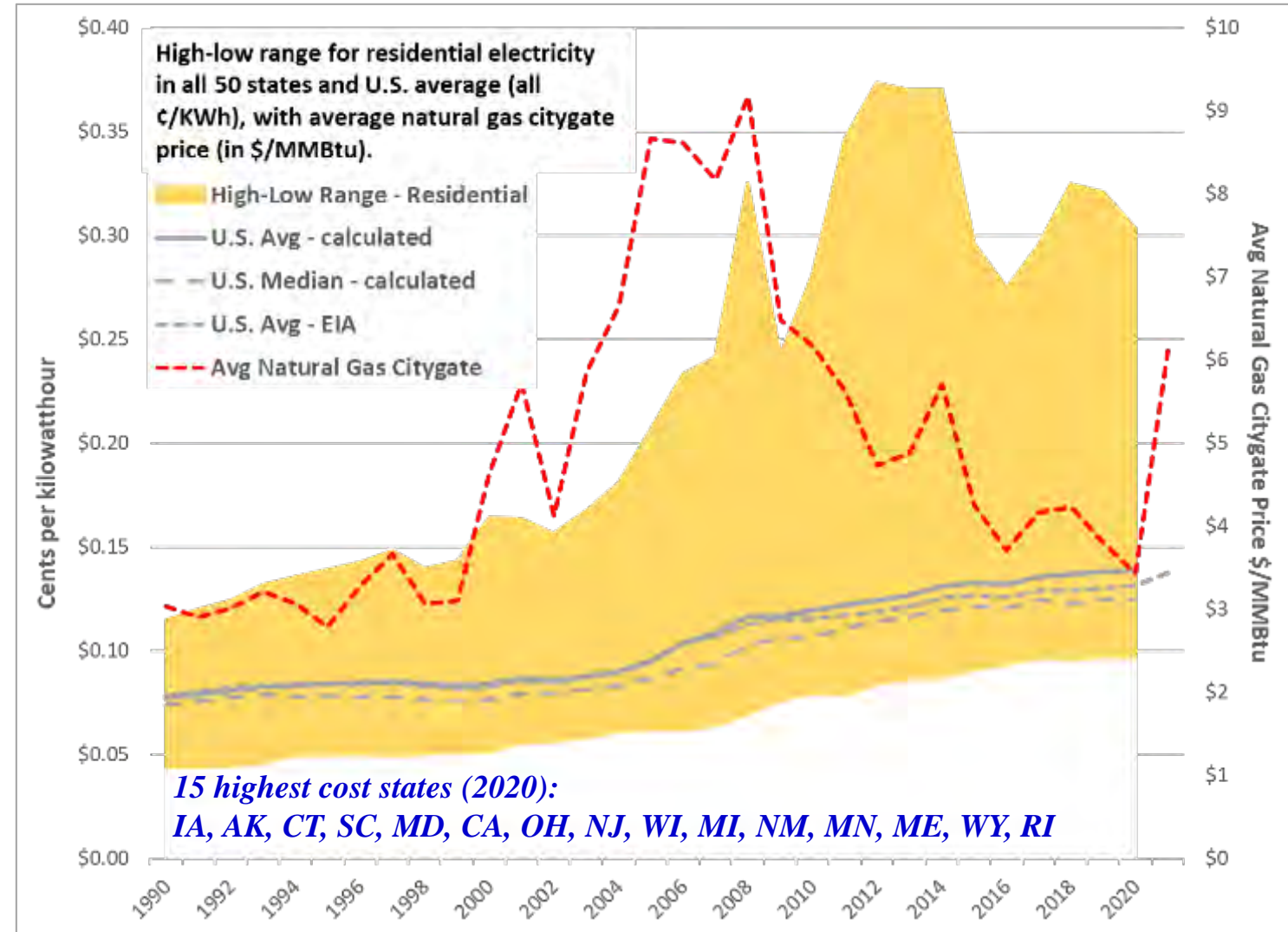
Who's paying – and for what?



“Other reasons commonly cited for higher retail electricity prices are the increased investment in transmission and distribution infrastructure, **rising requirements to generate electricity from renewable energy sources**, and utility investment in demand-side efficiency.”

<https://www.eia.gov/todayinenergy/detail.php?id=20372>

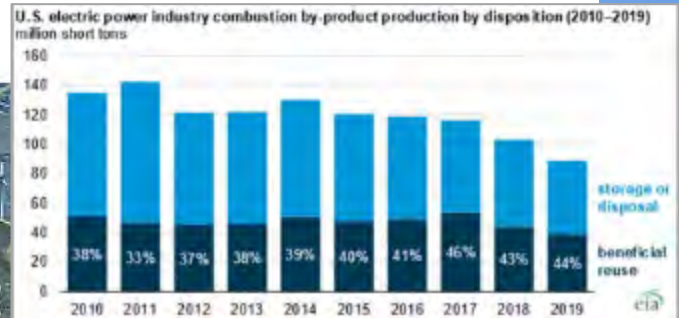
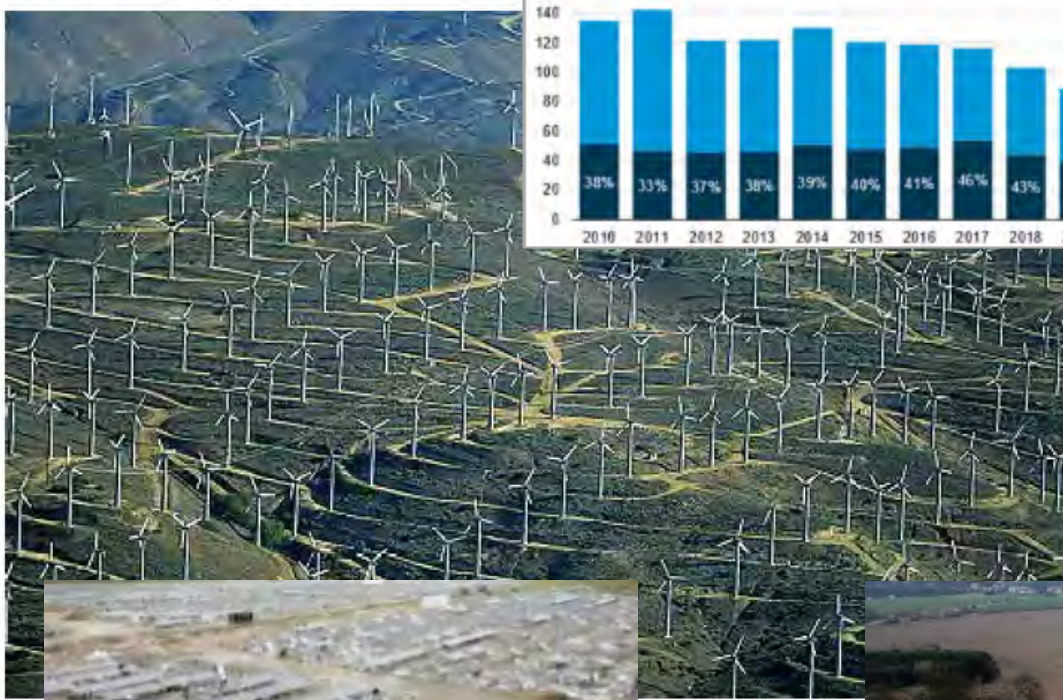
https://www.beg.utexas.edu/files/cee/legacy/2016/CEE_Snapshot-Retail_Electricity_Price_Mar16.pdf



Author based on EIA

Redefining “Sustainability”

Kern County, CA



Copper-colored lubricant sealant on an Andorra SA wind turbine. Photographer: Neil Marlowe/Bloomberg



Unmanned rocks sit in front of a turbine tower. Photographer: Neil Marlowe/Bloomberg



Puerto Rico, post-Maria



Germany's Push for Wind Power Encounters Resistance

Community protests compound problems for an industry the government wants to promote



Fragments of wind turbine blades await burial at the Casper Regional Landfill in Wyoming. Photographer: Benjamin Rasmussen for Bloomberg Green

EV Reality Check, I

Tesla,

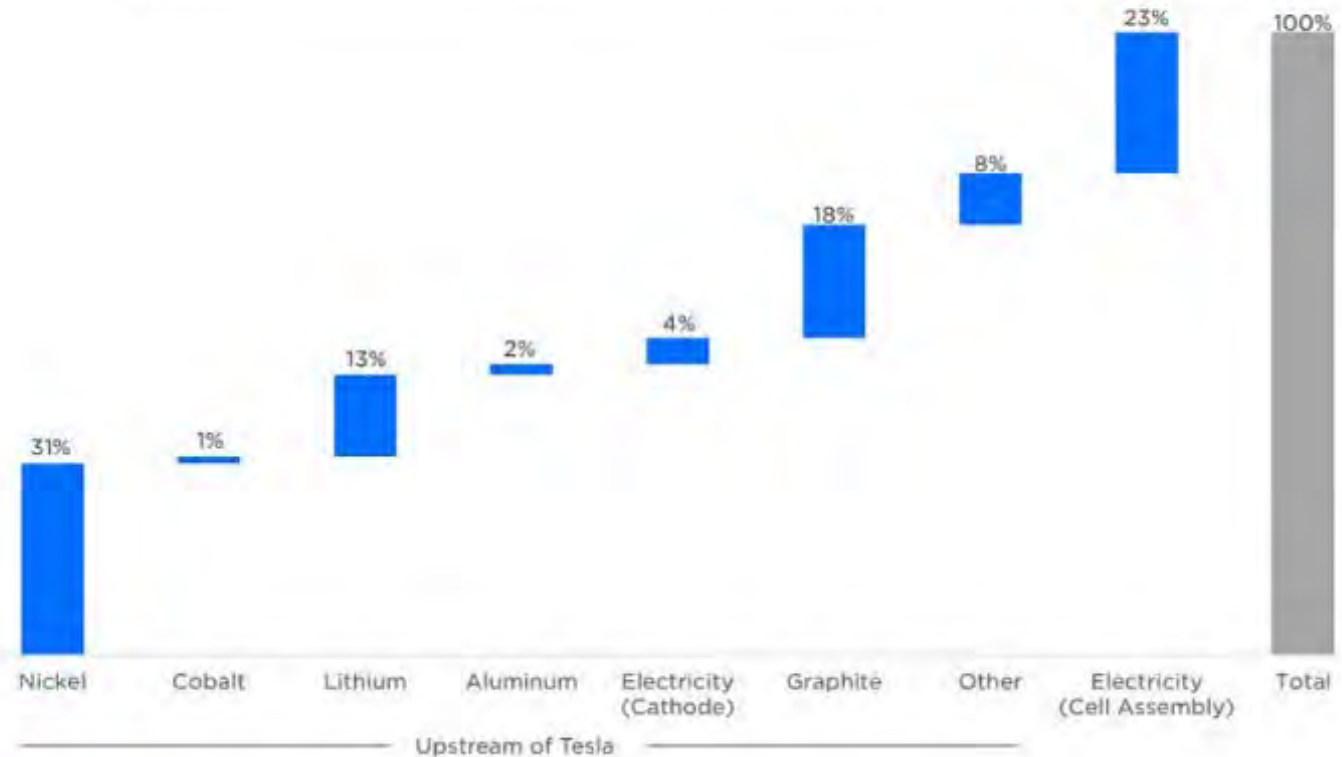
<https://twitter.com/alexjadecove/status/1522593269812662272>

2.3 GHG emissions hotspot identification

In addition to the product-specific LCA described in the Environmental Impact section, Tesla also commissioned LCA service provider Minviro to identify hotspots with high global warming potential across eight specific processing routes from which we currently source cobalt, nickel and lithium.

The hotspot analysis found that main drivers of GHG emissions depend on the different battery compositions, processing routes and countries of origin. Overall, key drivers are the cathode and anode supply chains. Within the cathode supply chain, the hotspots are nickel and lithium, and cobalt was only a minimal contributor. Within the cobalt, nickel and lithium supply chains, chemical processing (refining / smelting) was a larger driver than mining.

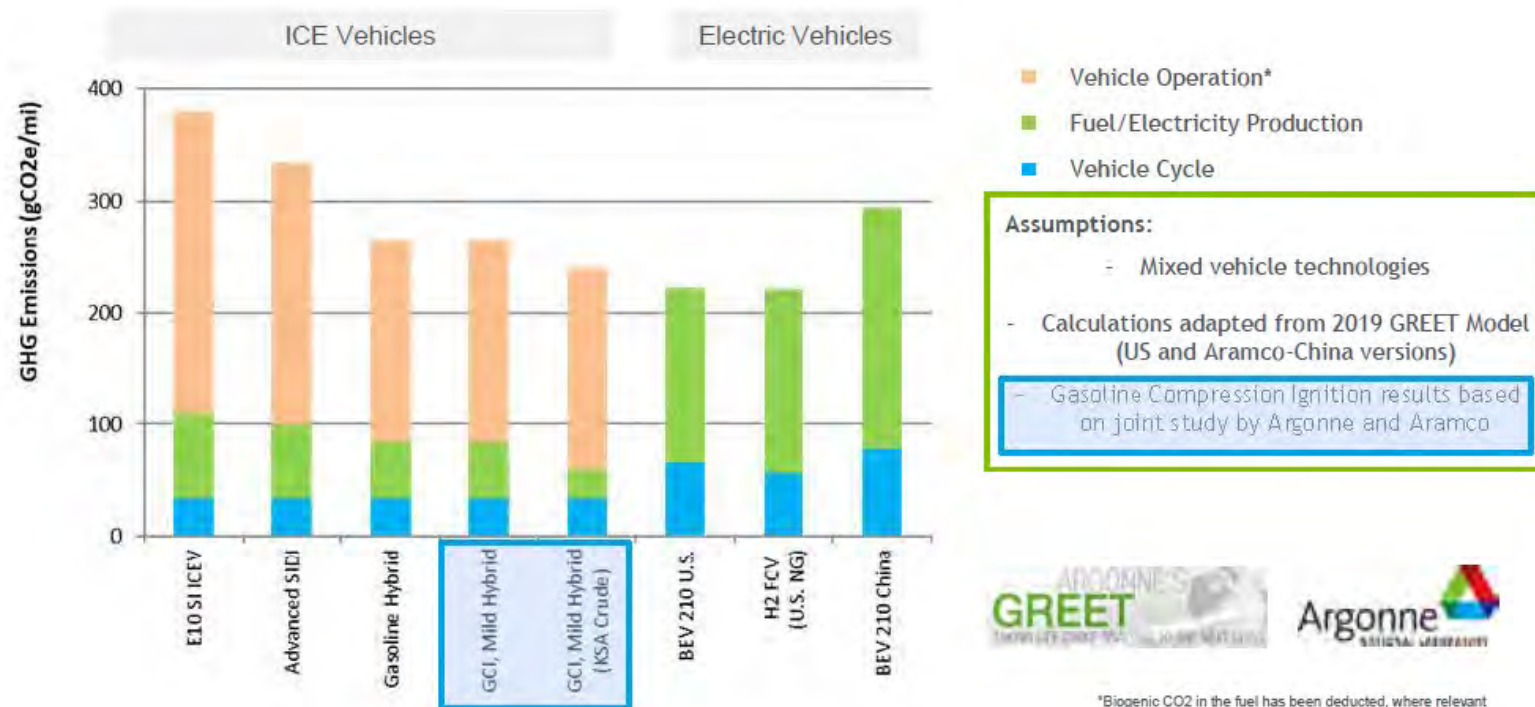
CO₂e Contribution from Materials and Processes within Nickel-Based Battery Supply Chain



EV Reality Check, II

Xi He, Policies to reduce carbon emissions in the transportation sector, APERC Annual Conference, April 25-25, 2022

Life Cycle Analysis



→ The GHG emissions of BEVs are not zero and could be higher than ICEVs.

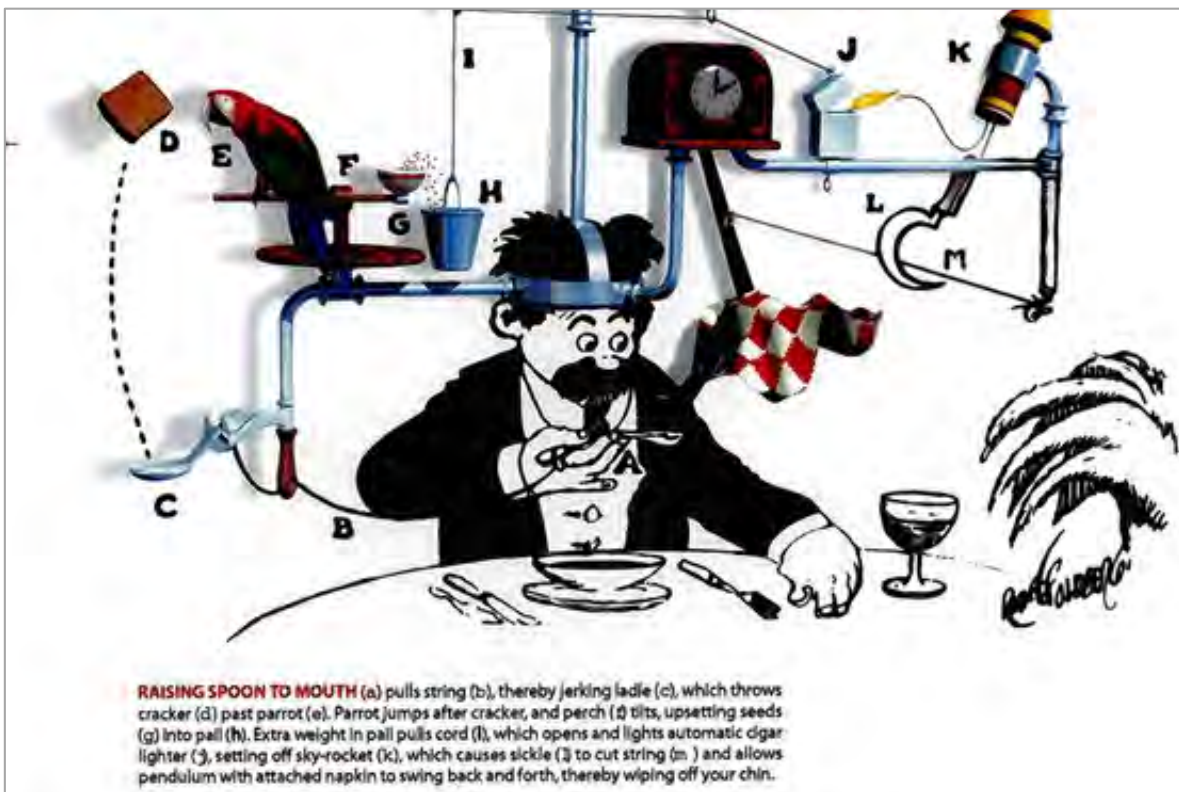
11

Classification: General Use

aramco
research & innovation

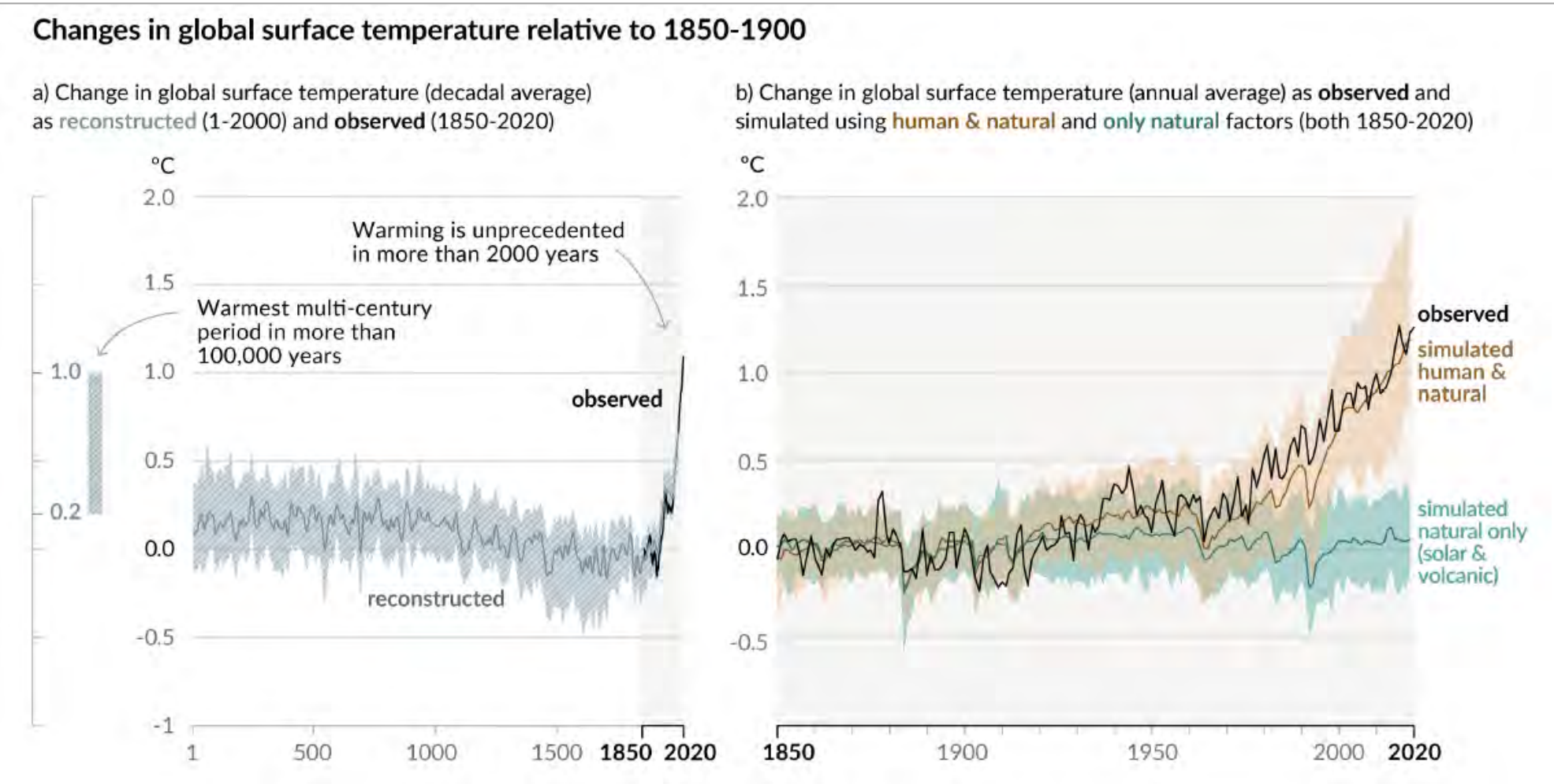
“Follow the Science”

“Roar of the Crowd”



This...

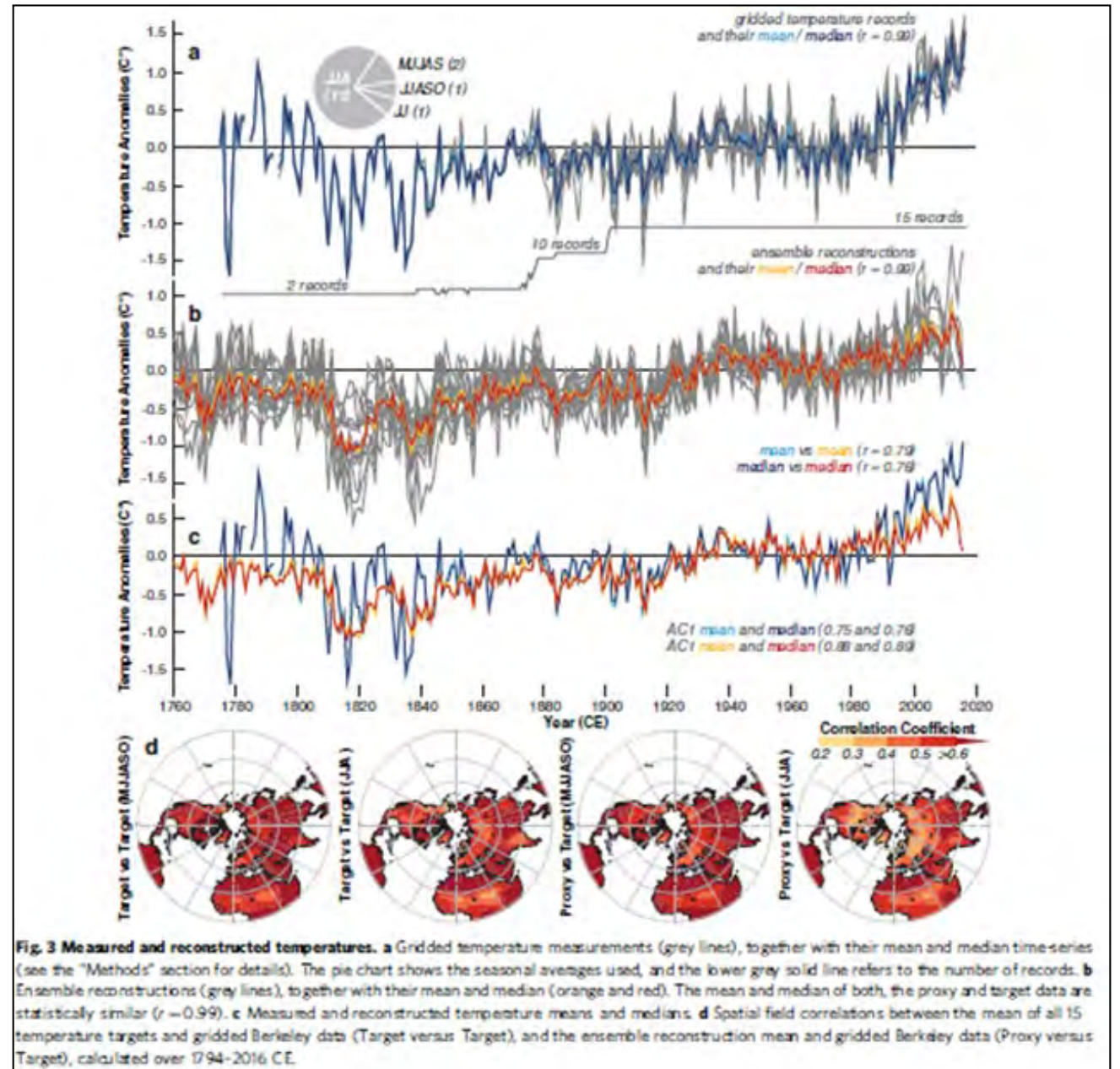
UN IPCC Summary for Policy Makers, AR6 2021



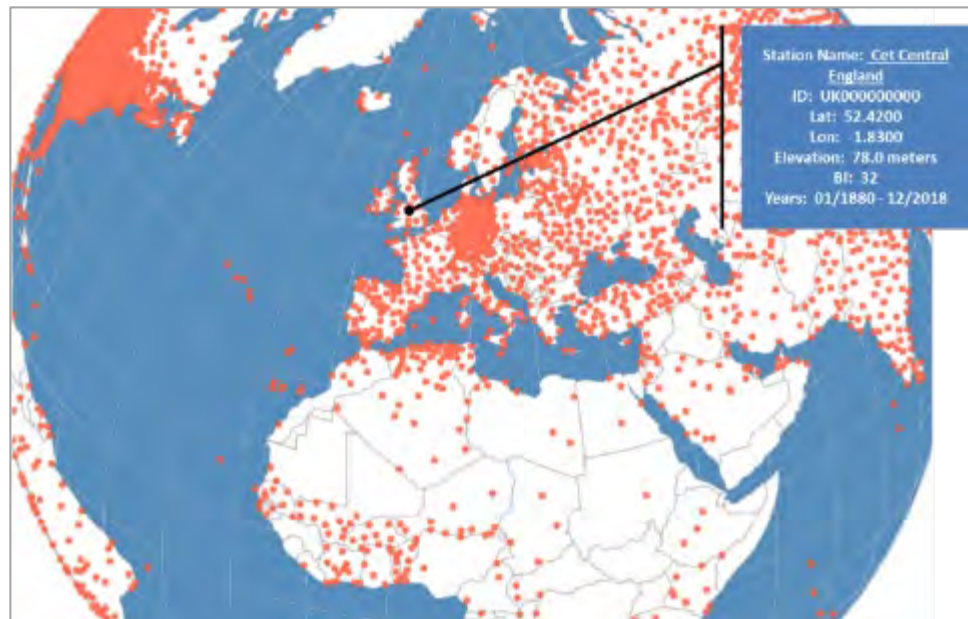
...or that?

Published June 7, 2021 ahead of UN IPCC AR6 release, August 9, 2021

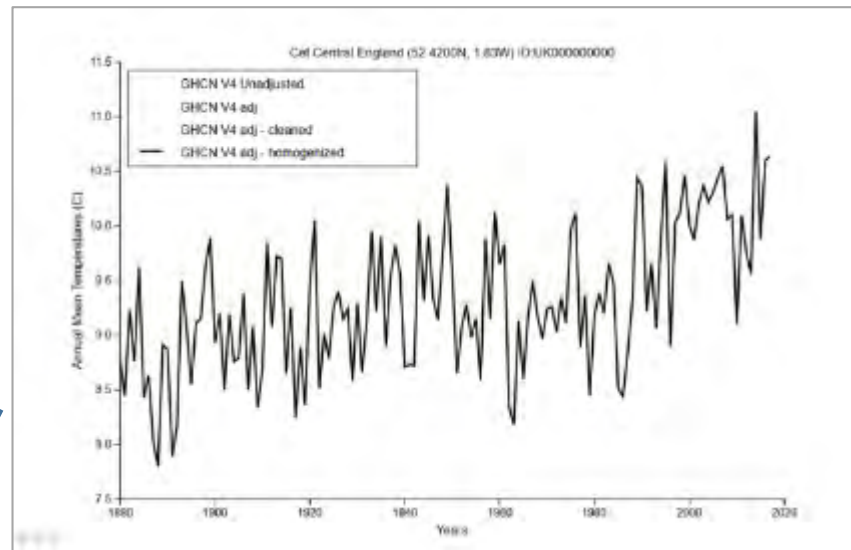
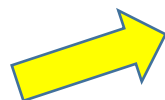
Büntgen, et.al., 2021, The influence of decision-making in tree ring-based climate reconstructions, Nature Communications, V 12, Article number: 3411, <https://www.nature.com/articles/s41467-021-23627-6>



Trust in institutions?



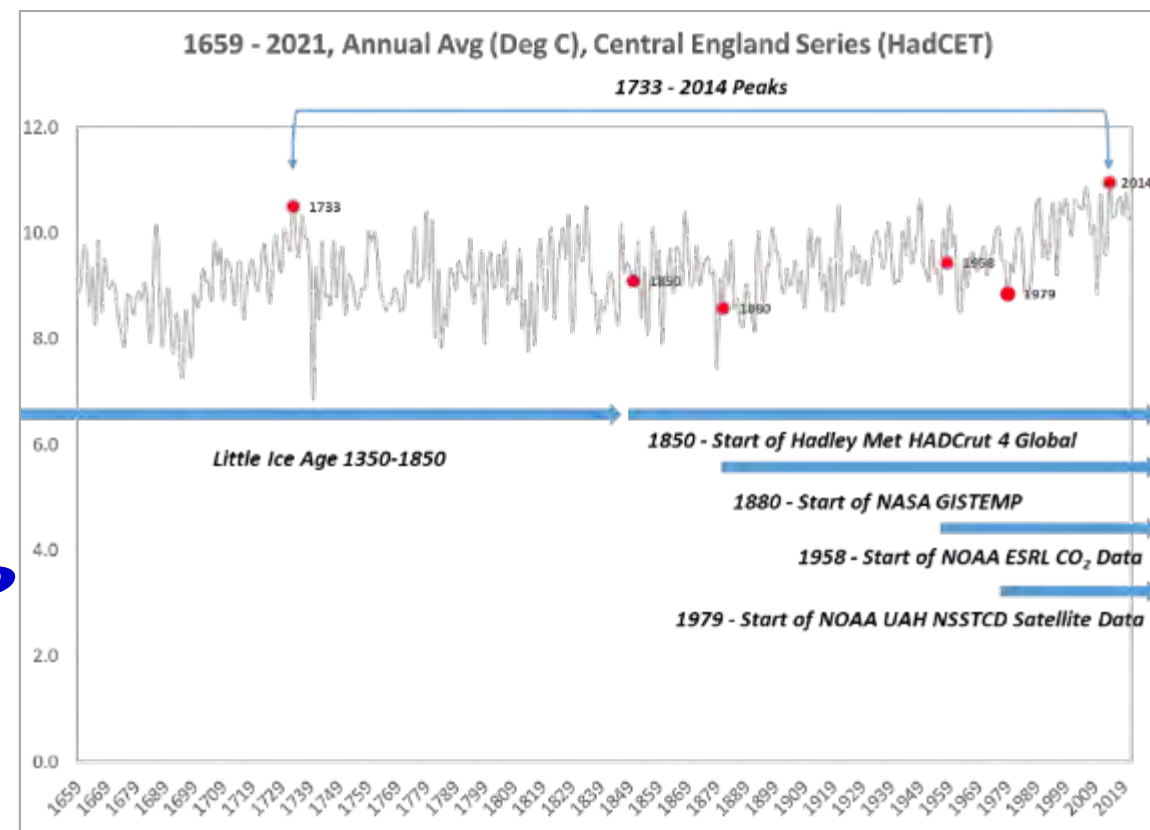
https://data.giss.nasa.gov/gistemp/station_data_v4_globe/



This?

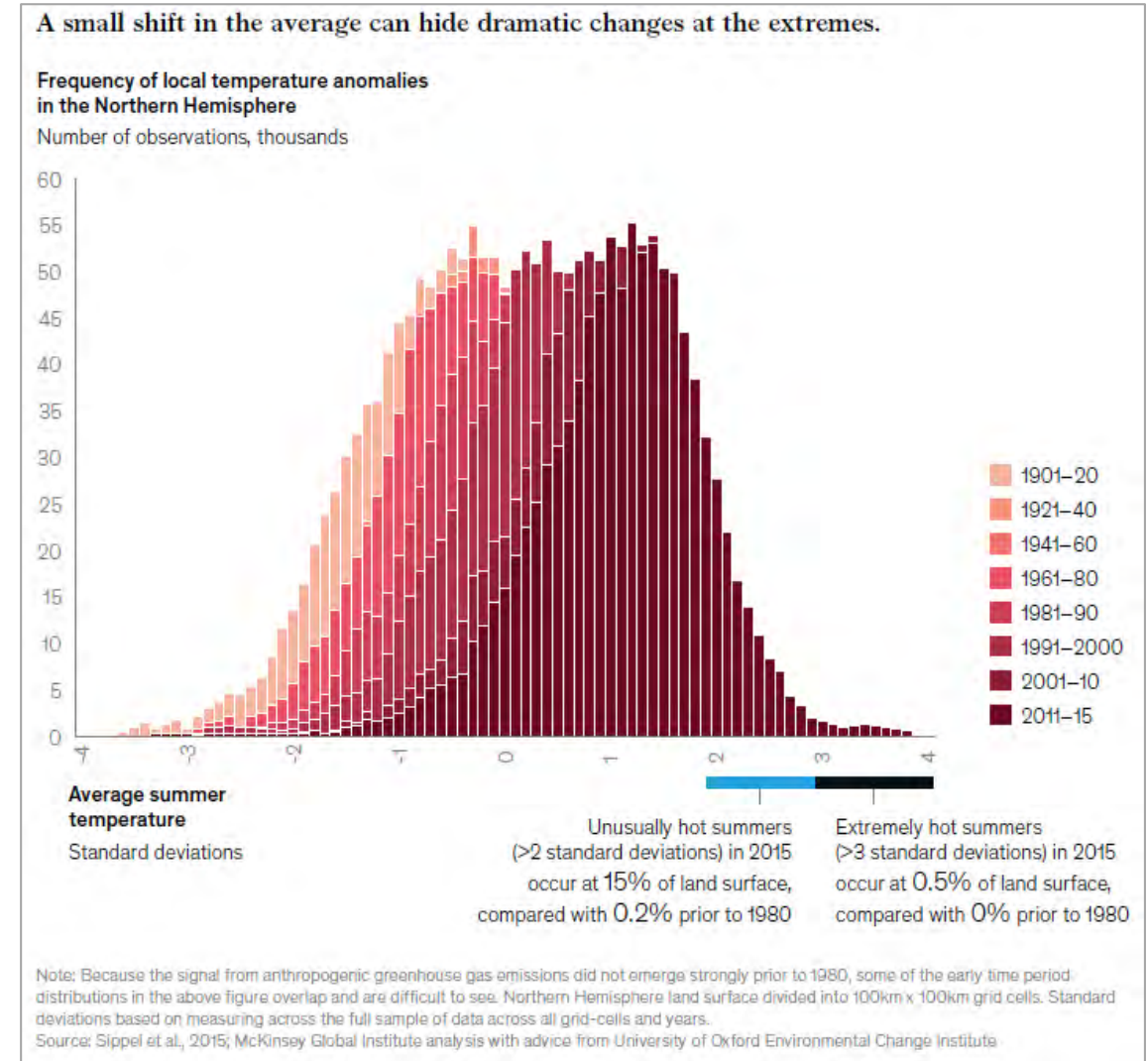
Or that?

<https://www.metoffice.gov.uk/hadobs/hadcet/>

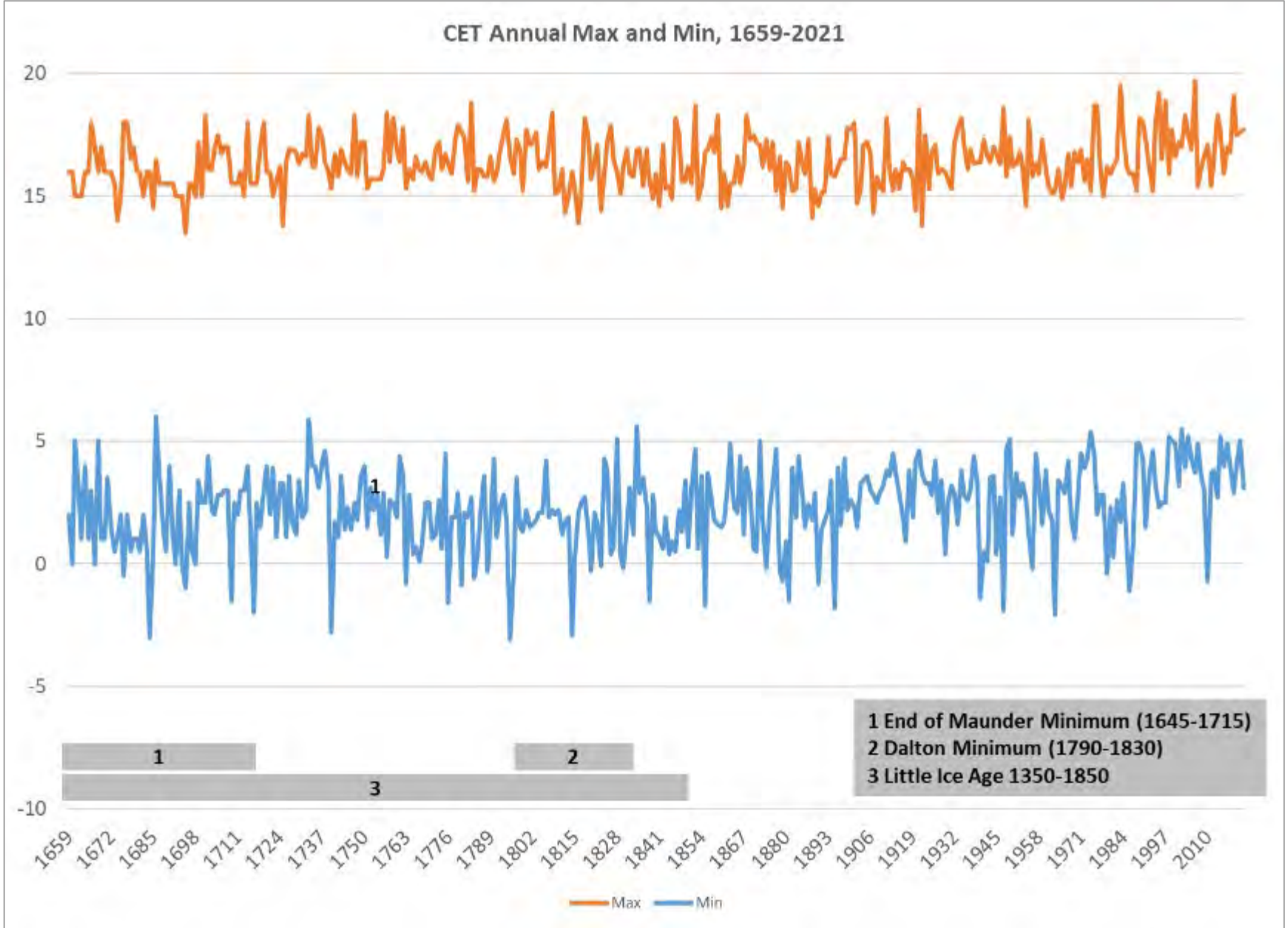


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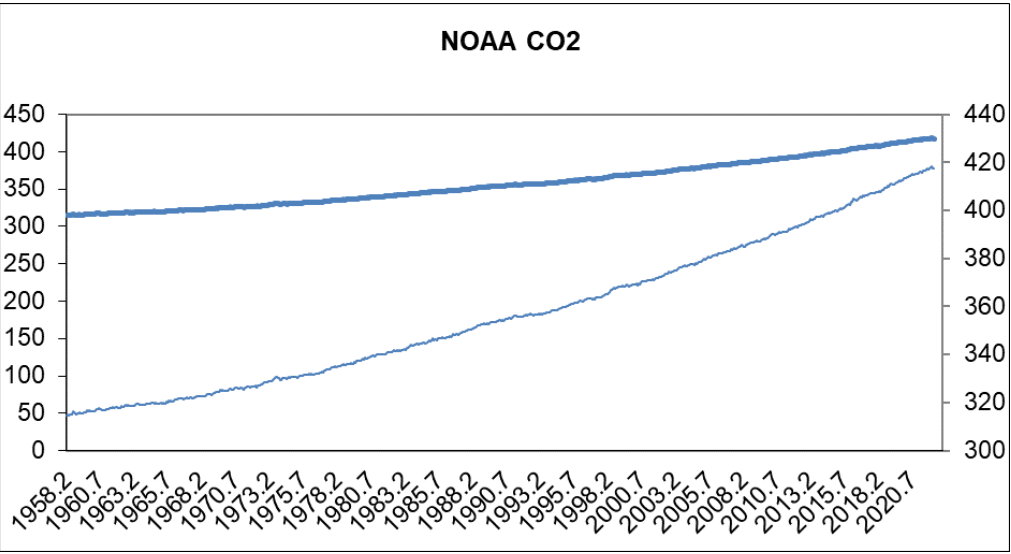
McKinsey Global Institute,
<https://www.mckinsey.com/~media/mckinsey/business%20functions/sustainability/our%20insights/climate%20risk%20and%20response%20physical%20hazards%20and%20socioeconomic%20impacts/mgi-climate-risk-and-response-full-report-vf.pdf>



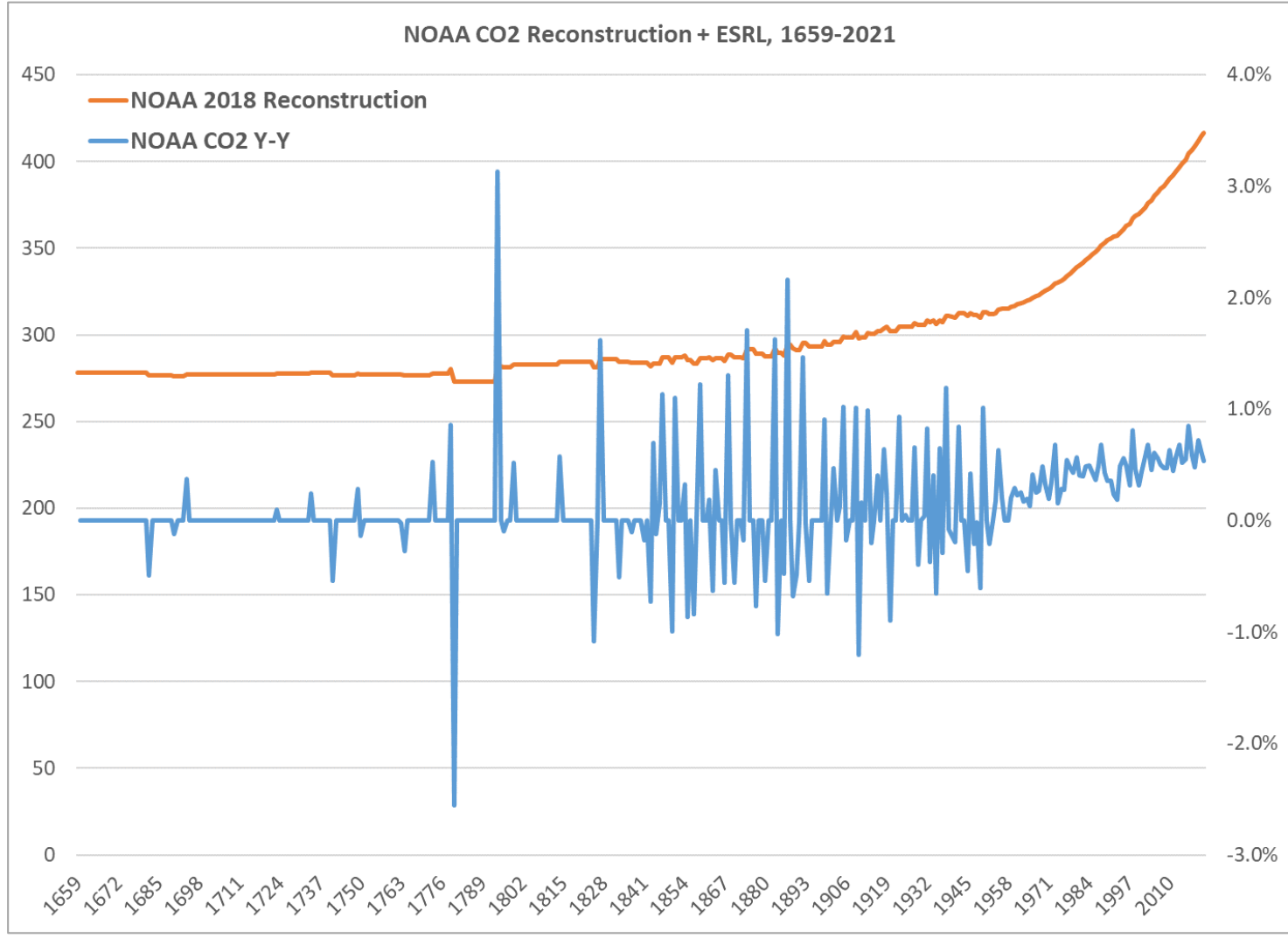
...or that?



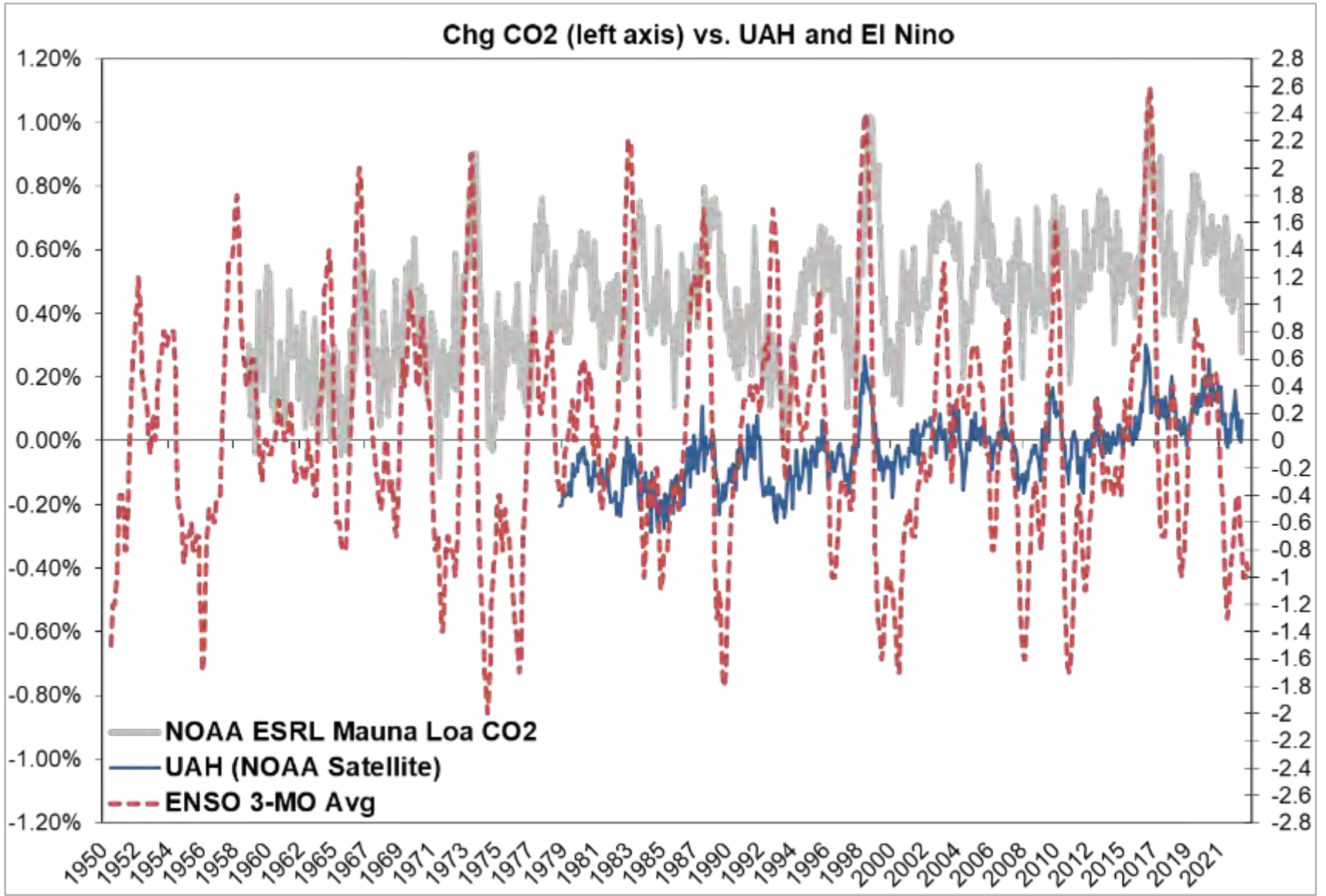
This...



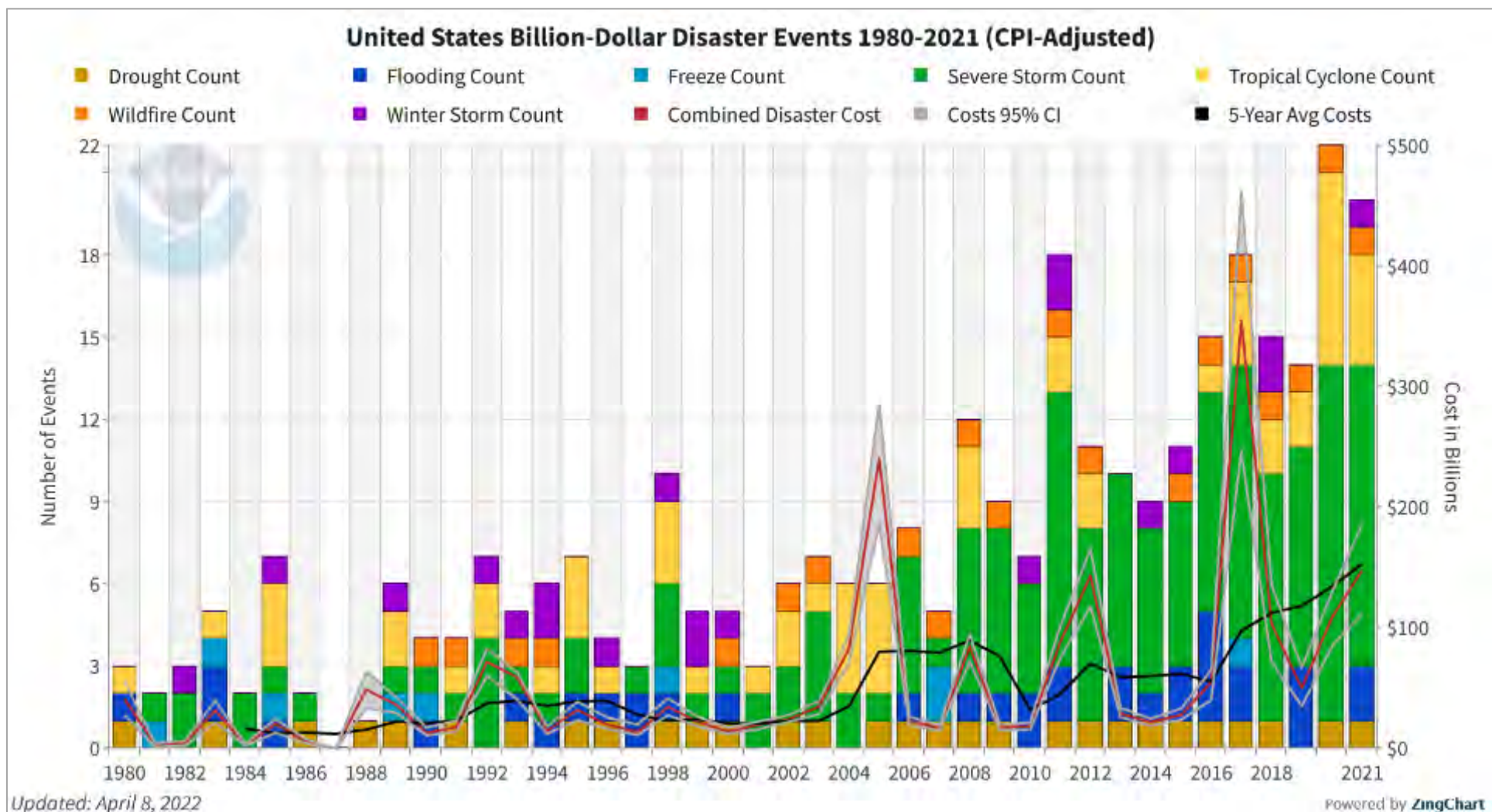
...and this...



...but, that.



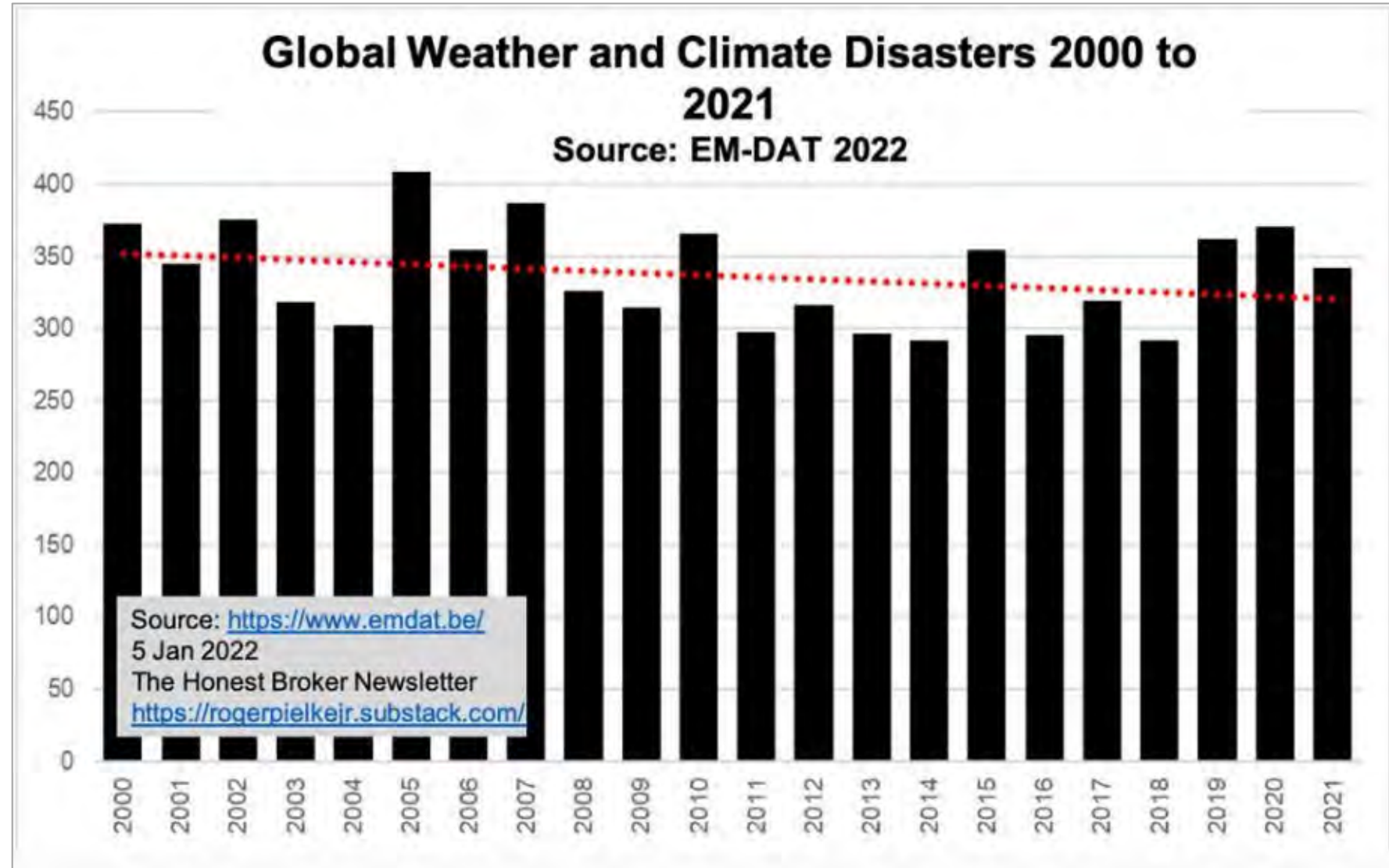
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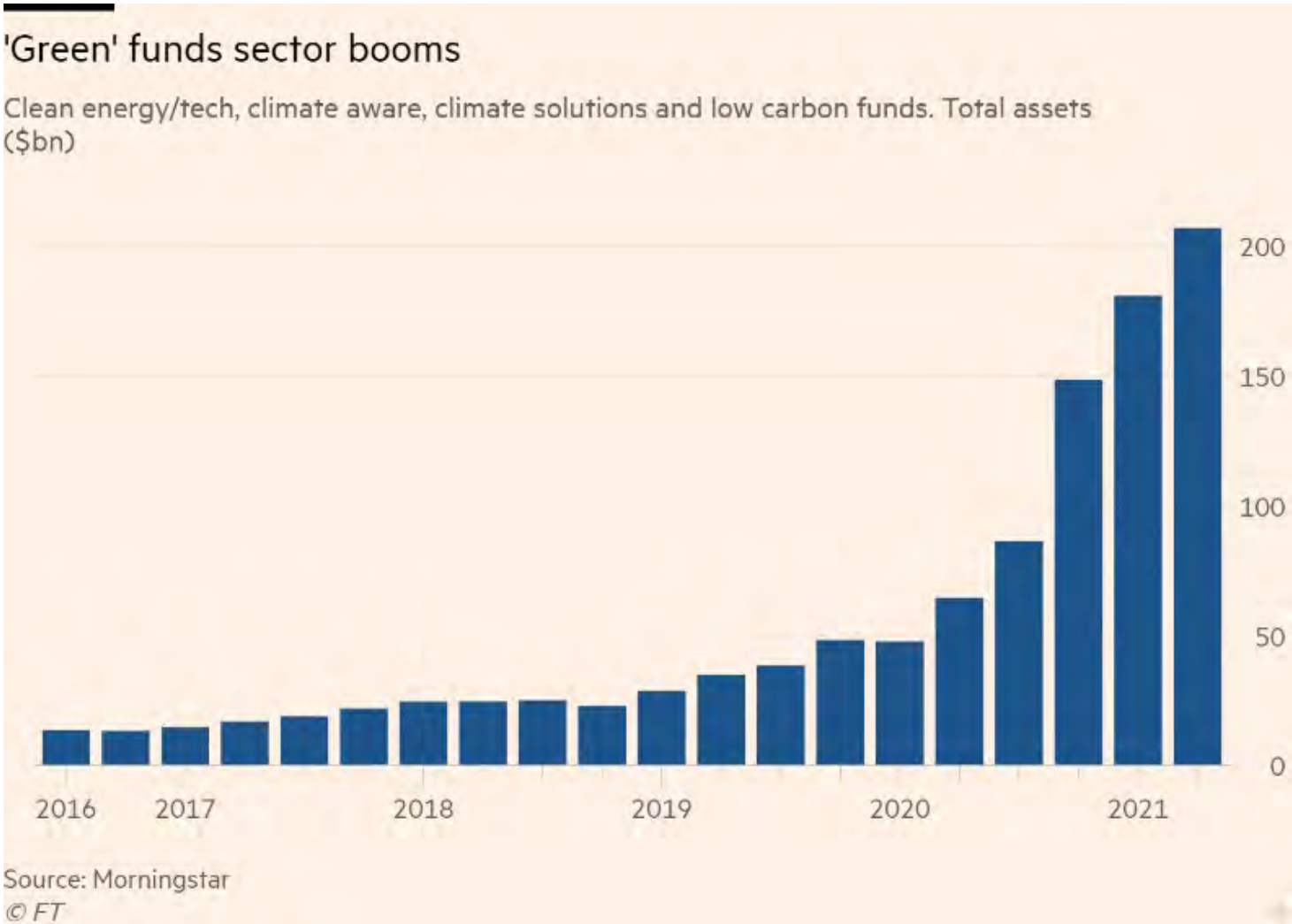
...or that?

Trees, falling in forests.

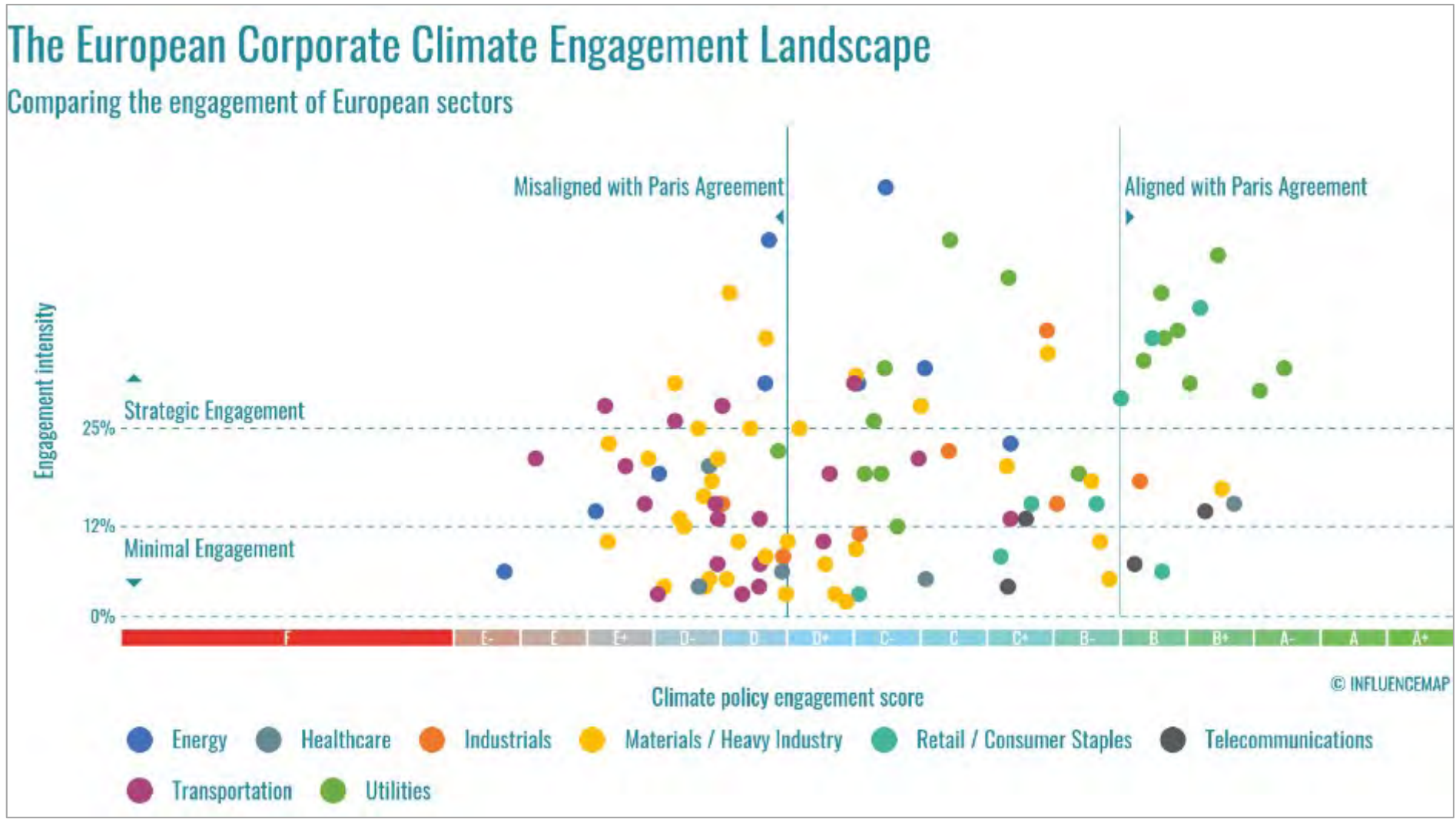
Roger Pielke, Jr., as used in
<https://www.forbes.com/sites/michaelshellenberger/2022/01/10/why-disasters-have-declined/?sh=71ec510e1897>



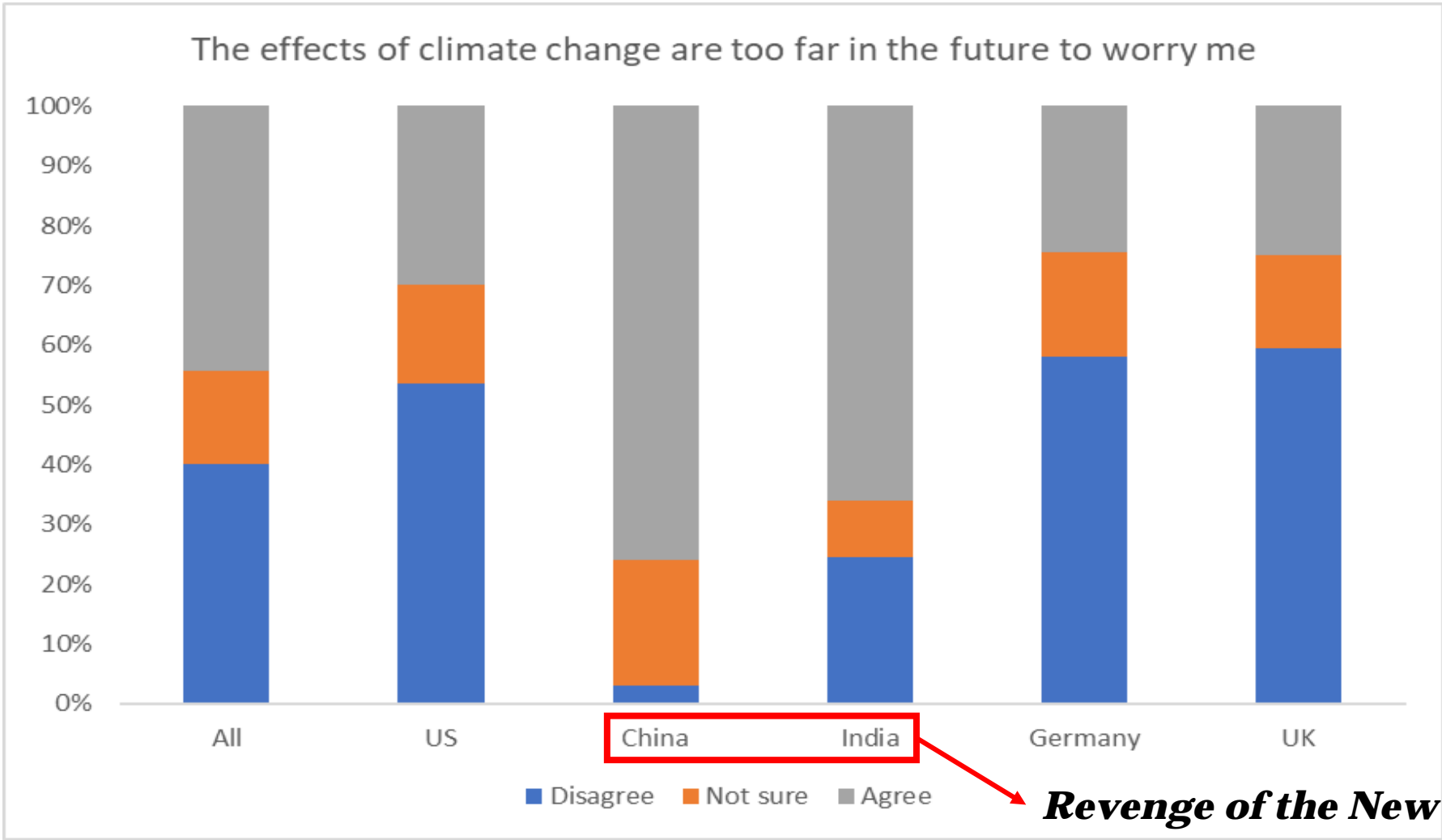
This...



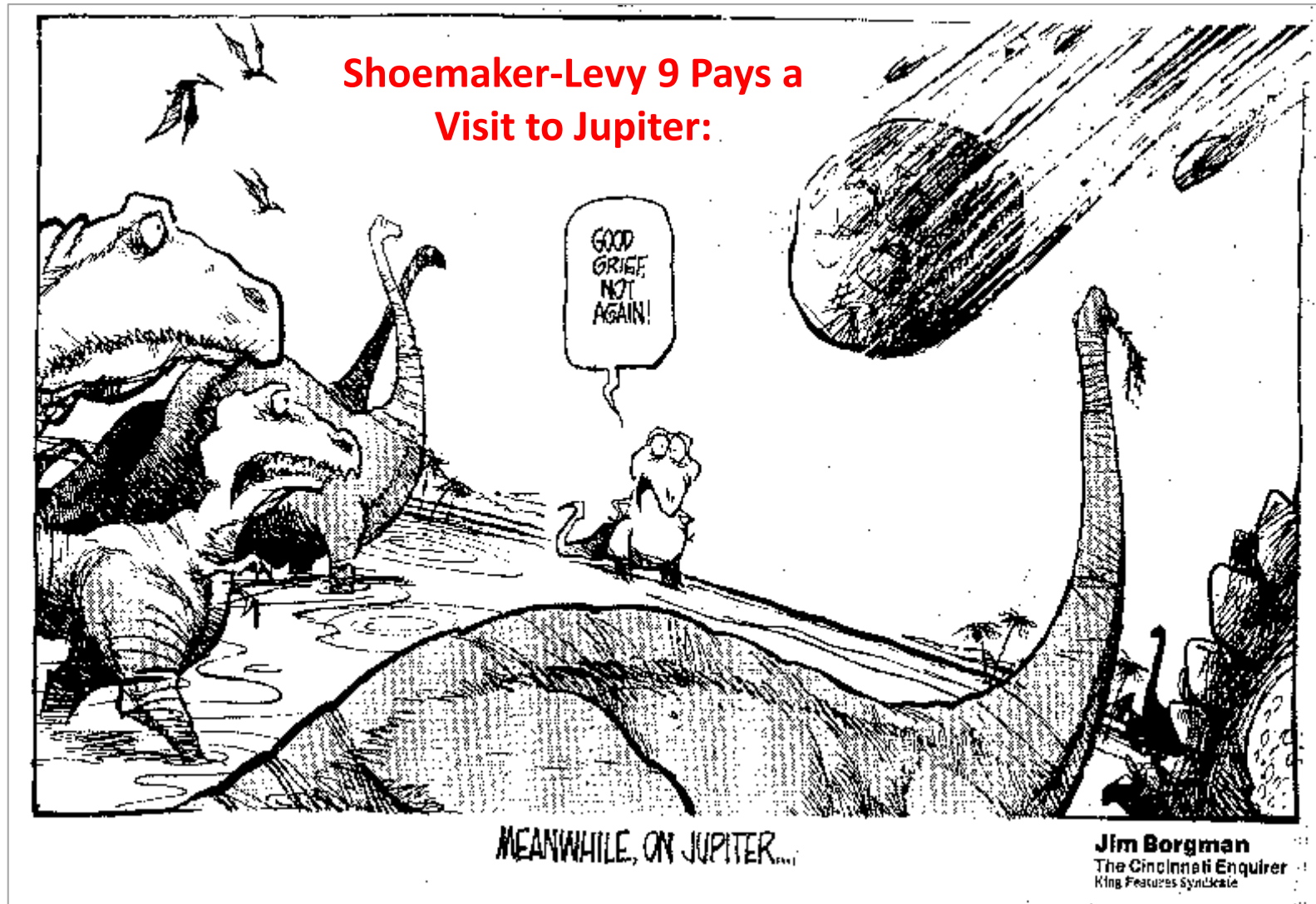
...or that...



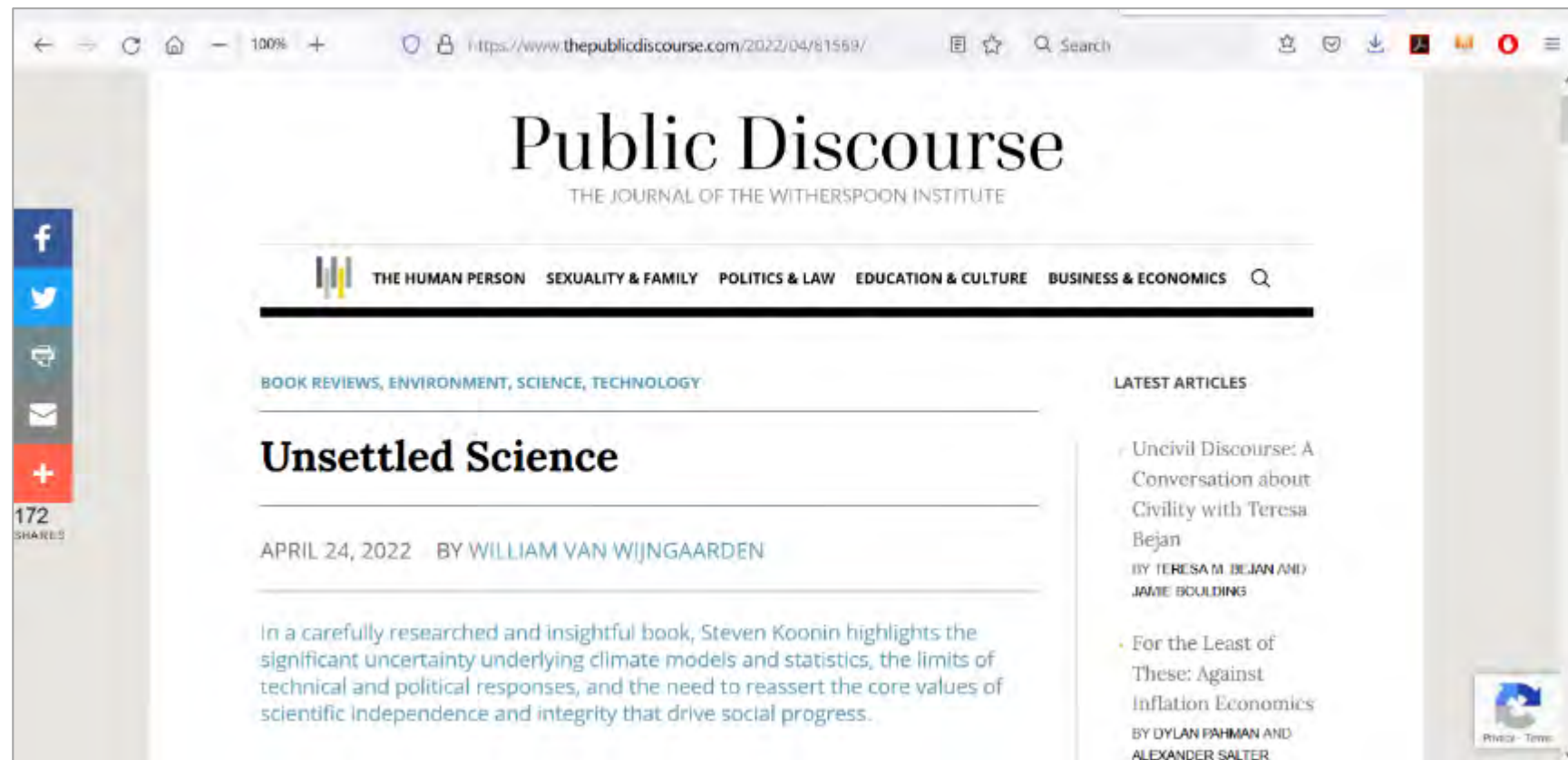
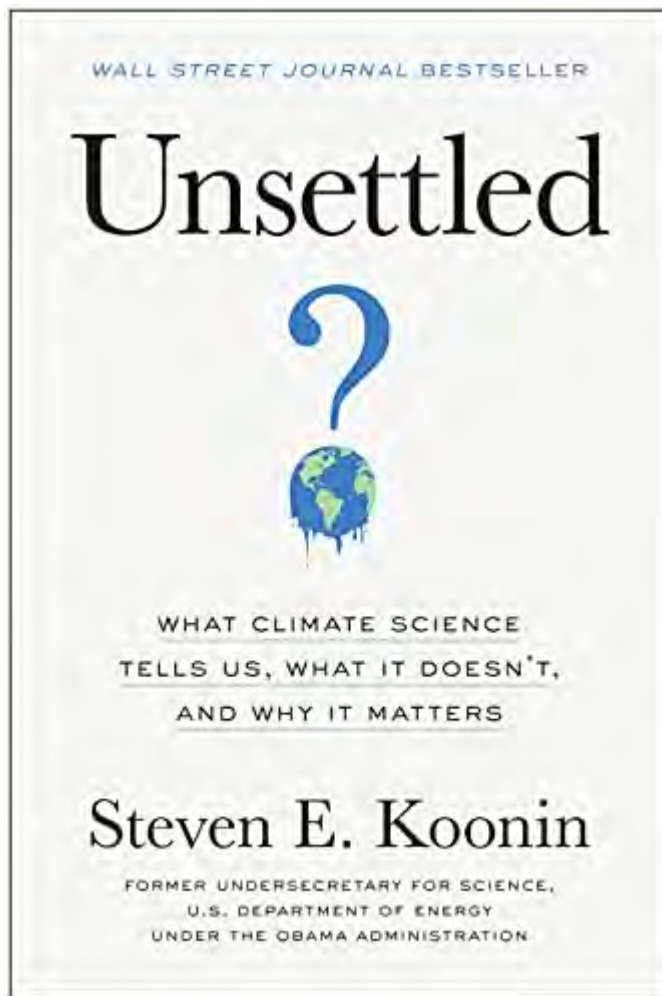
...all to get this.



***“It just goes to show you, it’s always something”**



Summer Beach Read

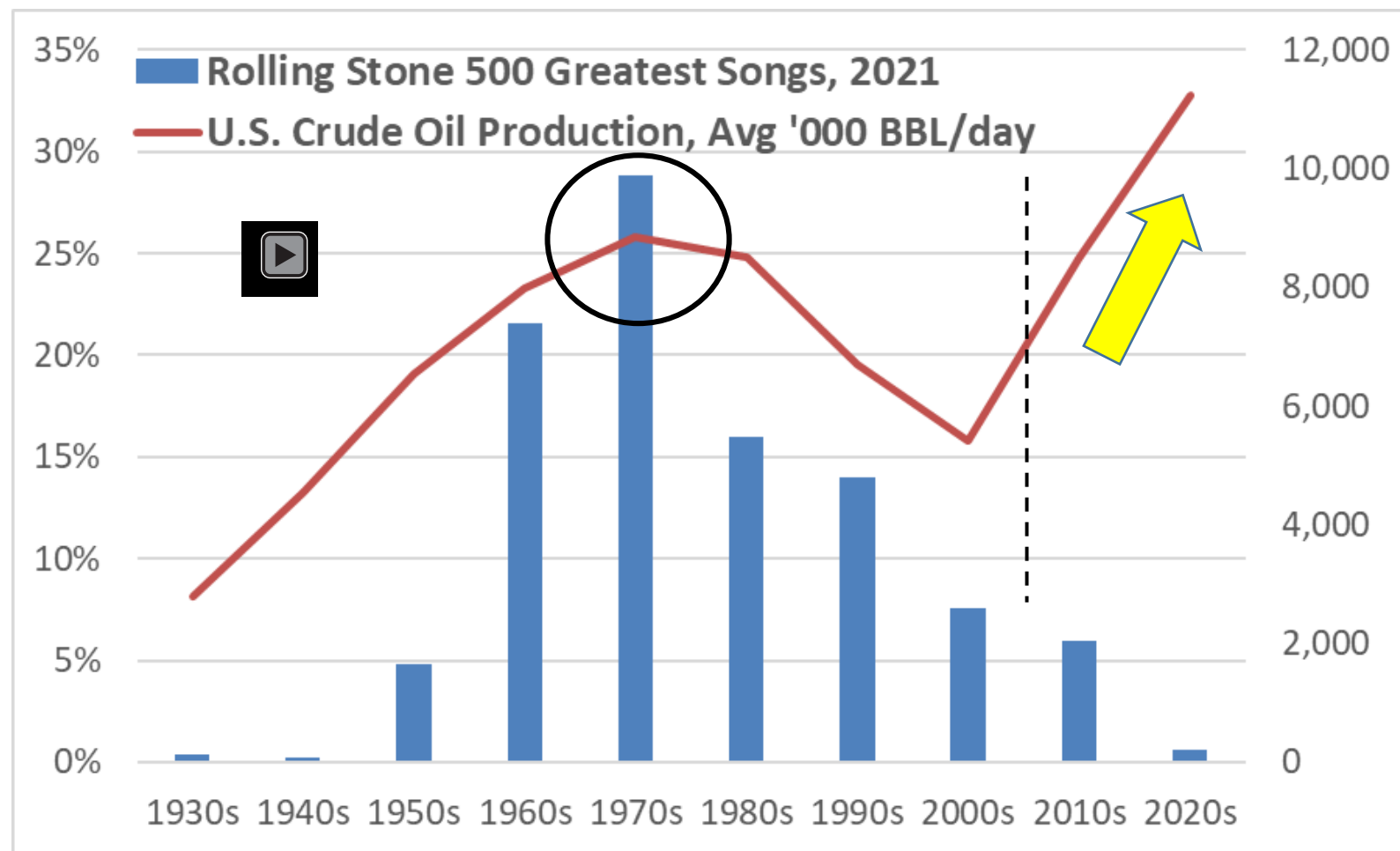


<https://www.thepublicdiscourse.com/2022/04/81569/>

<https://www.amazon.com/>

Summer Beach Music

“The Oil Drum” classic – “peak oil” explained



A Little Something Extra

Lagniappe

“New ideas in science are not always right just because they are *new*. Nor are the old ideas always wrong just because they are *old*. A critical attitude is clearly required of every scientist. But what is required is to be *equally* critical to the old ideas as to the new. Whenever the established ideas are accepted uncritically, but conflicting new evidence is brushed aside and not reported because it does not fit, then that particular science is in deep trouble...”

Thomas Gold, 1989, “New Ideas in Science”, J of Scientific Exploration, V 3, N 2, P 103-112, https://www.scientificexploration.org/docs/3/jse_03_2_gold.pdf (his emphasis)

Density and Lithium Battery Safety

PHMSA HM-215N, O Harmonization

Pipeline & Hazardous Materials Safety Administration, PHMSA

Federal Motor Carrier Safety Administration, FMCSA

Federal Railroad Administration, FRA

Federal Aviation Administration, FAA **2018 FAA Reauthorization, Sec. 333**

Maritime Administration, MARAD

National Highway Traffic Safety Administration, NHTSA

National
Transportation
Safety Board, NTSB

Environmental Protection Agency, EPA

Chemical
Safety
Board, CSB

PHMSA Current

Implements existing law

New

HM-224I

Mandates under Sec. 333



- International Maritime Organization (IMO)
- International Civil Aviation Organization (ICAO)
- United Nations Subcommittee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals
- International Atomic Energy Agency (IAEA)

Making Grid Scale Wind, PV Work, 1

Hydrocarbons →
Fiberglass
Thermoset →
Blades

Chemicals/Plastics

+

Metals

Hydrocarbons →
Plexiglas →
Functional PV



*Incentive to bid
into market to max
negative value of
PTC*

**Wind PTC
~\$24/MWh**

**Non-
dispatchable
power
(intermittent,
cannot be
controlled)**

Solar ITC ~30%

*Incentive to
originate to max
use of ITC*



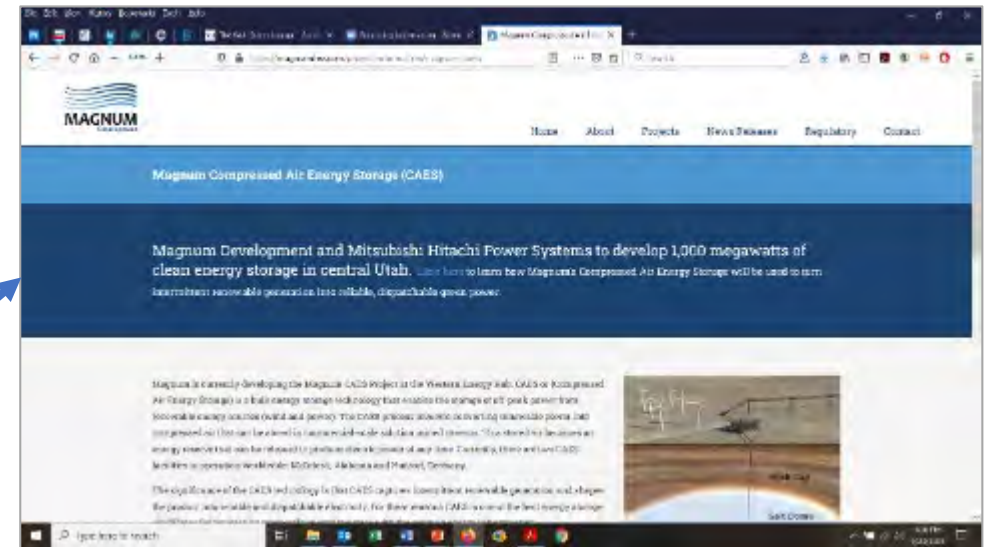
**Load-following natural gas
– spinning reserves to
follow (ramp) intermittent
sources**

Unresolved:

- **Emissions associated with wind, solar operation + natural gas ramping vs optimized used of gas generation capacity.**
- **Full cost of wind, solar with system support vs standalone gas-fired generation.**

Making Grid Scale Wind, PV Work, 2

Potential Disruptor



For more information:

<https://energystorage.org/why-energy-storage/technologies/compressed-air-energy-storage-caes/>

<https://magnumdev.com/project-information/magnum-caes/>

<http://www.apexcaes.com/bethel-energy-center>

<https://www.hvllc.com/>

No shelter from the wind...

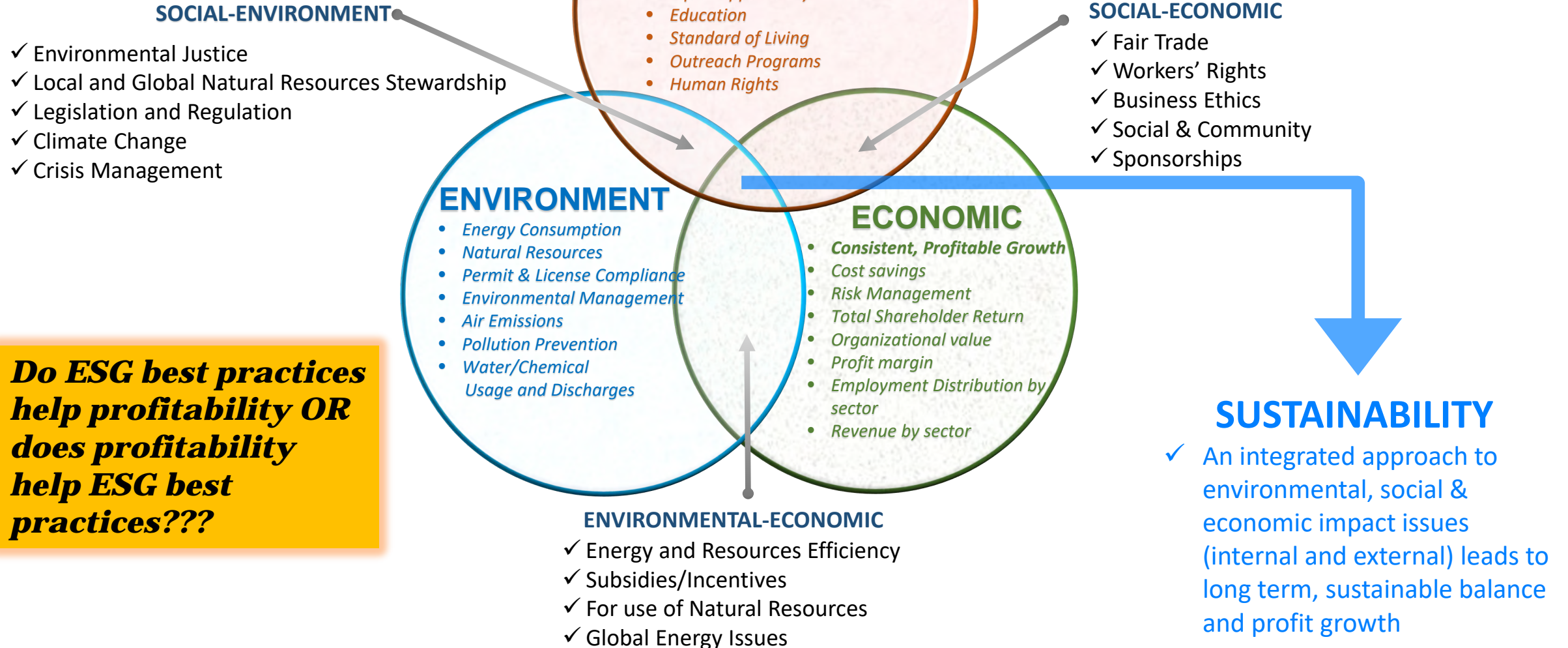


<https://www.bloomberg.com/opinion/articles/2022-02-10/wind-power-a-renewable-darling-is-hurting-from-inflation-supply-chain-issues?srd=opinion&sref=QKIH2Pn>

...and solar storms.



Sustainability: A Systems Approach



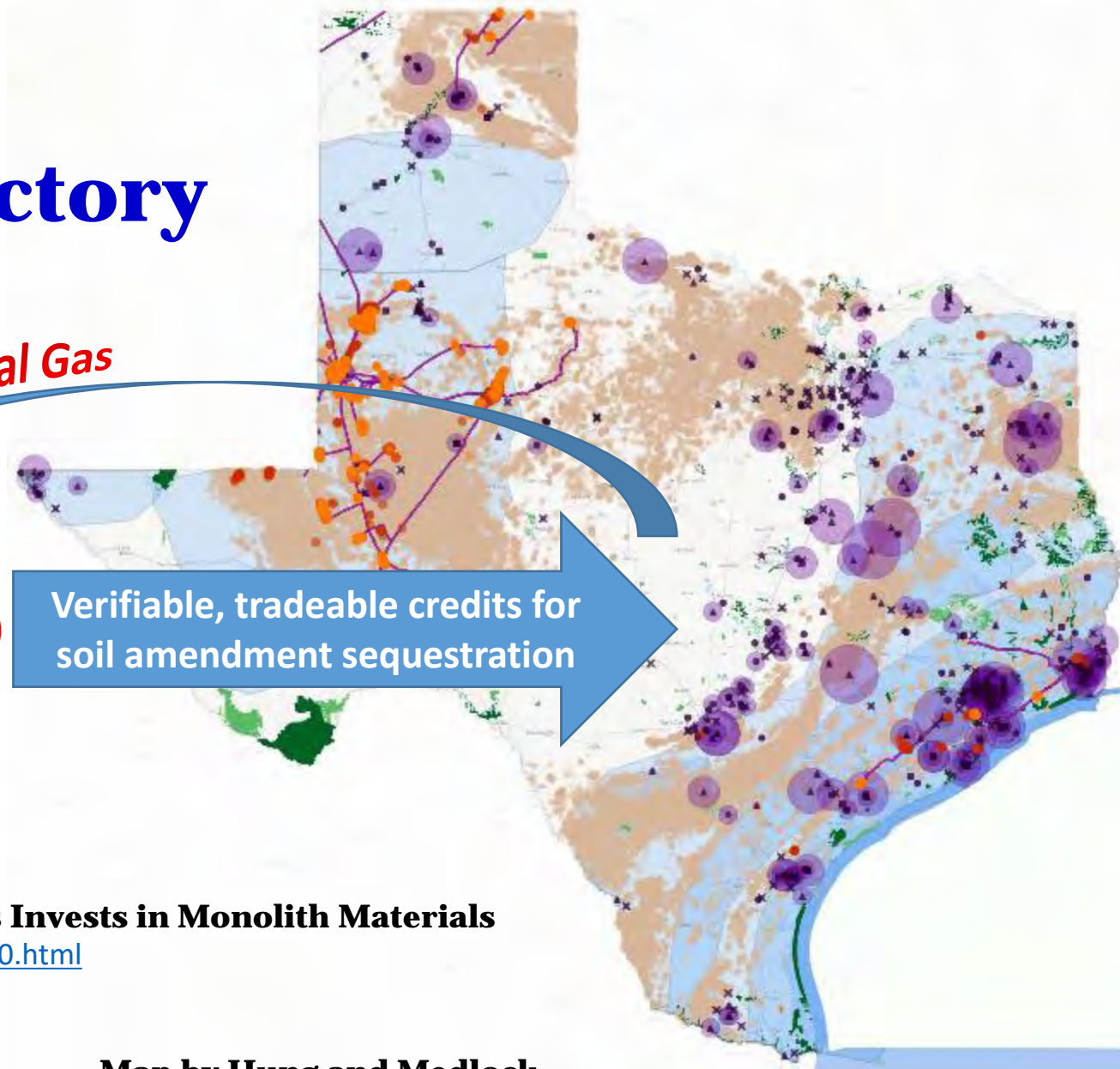


Idea Factory

Natural Gas



Verifiable, tradeable credits for soil amendment sequestration



Legend

CO2 injection wells

- Active CO2 injection wells
- Non active CO2 injection wells

CO2 direct emitters (excl. oil and gas extraction and natural gas pipelines and distribution)

- Chemical manufacturing
- ▲ Electric power generation, transmission, and distribution
- Others
- Other manufacturing
- Petroleum refineries
- × Waste treatment and disposal

CO2 direct emitters: 2018 emissions in tons (same exclusion as above)

- 0 - 513,078
- 513,078 - 1,590,215
- 1,590,215 - 3,476,313
- 3,476,313 - 7,180,671
- 7,180,671 - 14,870,599

CO2 pipelines

State vs Federal lands

- State
- Federal
- Active oil and gas wells
- Saline formation

Mitsubishi Heavy Industries Invests in Monolith Materials

<https://www.mhi.com/news/201130.html>

Map by Hung and Medlock

<https://www.bakerinstitute.org/media/files/files/8e661418/expanding-ccus-in-texas.pdf>

BCarbon: A New Soil Carbon Storage Standard

<https://www.bakerinstitute.org/research/bcarbon-new-soil-carbon-storage-standard/>

Suggested Resources and Links

- M. Michot Foss, J. Koelsch, What China's control of nickel means for the energy transition: <https://www.bakerinstitute.org/research/need-nickel-how-electrifying-transport-and-chinese-investment-are-playing-out-indonesian-archipelago/>.
- CES China Energy Map <https://www.bakerinstitute.org/chinas-energy-infrastructure/>
- CES minerals production/trade visualizations <https://www.bakerinstitute.org/energy-minerals/>
- M. Michot Foss, testimony before the U.S. Senate Committee on Energy & Natural Resources, March 10, 2022, <https://www.bakerinstitute.org/research/senate-testimony-use-energy-tool-and-weapon/>.
- M. Michot Foss, testimony before the U.S. House Subcommittee on Energy on the CLEAN Future Act, May 5, 2021 <https://www.bakerinstitute.org/files/17270/>
- M. Michot Foss, recommendations to the Biden Administration <https://www.bakerinstitute.org/research/minerals-and-materials-energy-we-need-change-thinking/>
- M. Michot Foss, M. Moats, K. Awuah-Offei, G20 technical brief <https://www.bakerinstitute.org/research/framing-energy-and-minerals-future-pathways/>
- M. Michot Foss, A. Mikulska, G. Gülen, Monetizing Natural Gas in the New “New Deal” Economy <https://link.springer.com/book/10.1007/978-3-030-59983-6>
- R.A. Meidl, M. Michot Foss, J. Li, A Call to Action for Recycling and Waste Management Across the Alternative Energy Supply Chains, <https://www.bakerinstitute.org/research/call-action-recycling-and-waste-management-across-alternative-energy-supply-chains/>
- R.A. Meidl, recommendations to the Biden Administration [Waste Management and the Energy Transition](#)
- R.A. Meidl, [Measuring the True Cost](#) of Sustainability: A Case Study in a Green Energy Approach
- R.A. Meidl, [Smart policy](#) and innovative technologies, like advanced recycling, will deliver on climate and sustainability goals
- G. Collins and A. Erikson, [China's Climate Cooperation Smokescreen](#), [U.S.-China Competition Enters the Decade of Maximum Danger](#)
- G. Collins and M. Michot Foss, [Want to Derail the Energy Transition? Take Fossil Fuels Out of the Mix](#), [Energy Transition Valley of Death](#)