The Energy Transition:

Opportunities and Challenges

EnergyMusings.substack.com

Allen Brooks
Rice Global Forum
April 6, 2023

Energy Transition Definition

Energy transition: ***change in the composition (structure) of primary energy supply***

Vaclav Smil, 2010, Energy Transitions – History, Requirements, Prospects

Energy transition: ***global energy sector's shift from fossil-based systems of energy production and consumption — including oil, natural gas and coal — to renewable energy sources like wind and solar, as well as lithium-ion batteries***

S&P Global, 2020

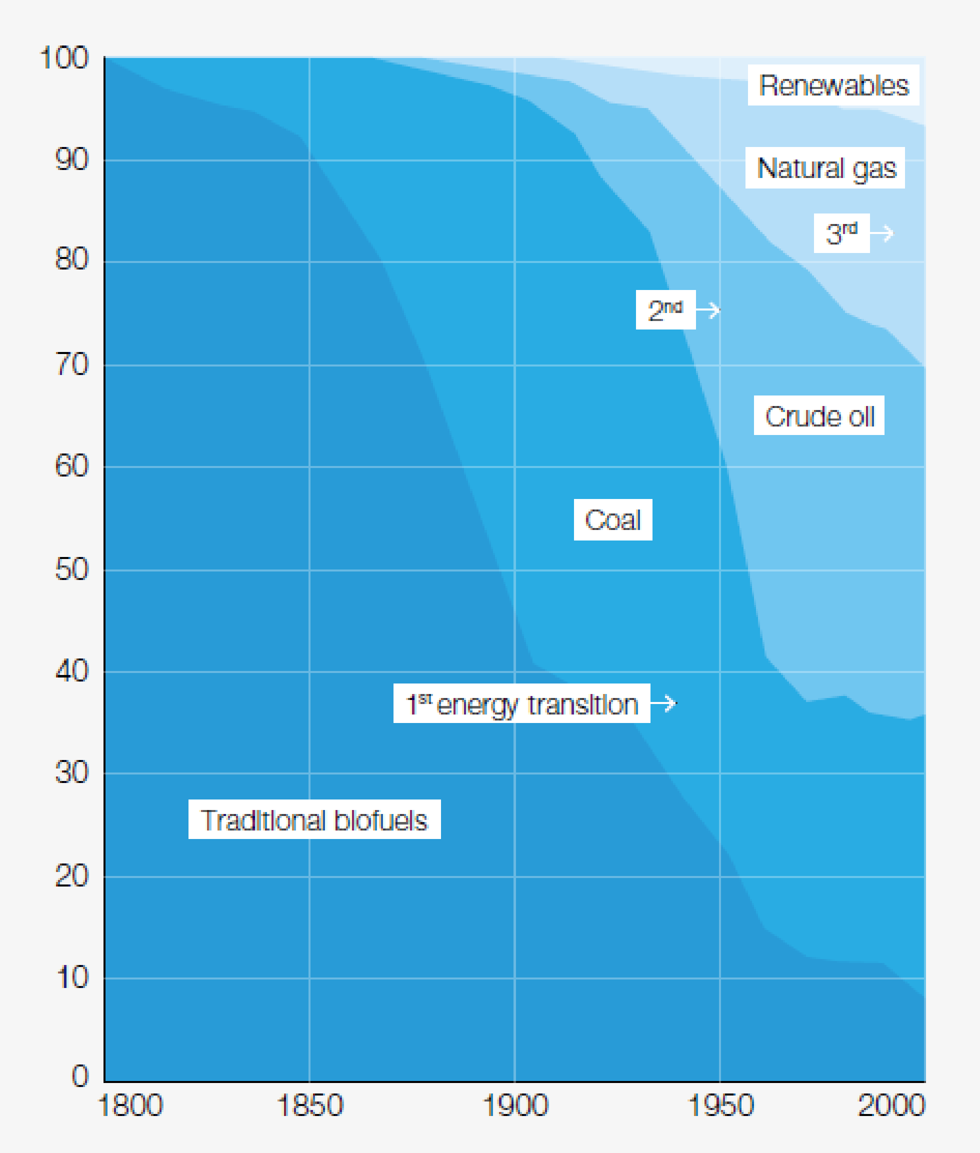
Energy Transition History

1830 – 1950 biofuel (wood) to coal

1950 – 1980 coal to oil

1980 – 2020 oil to natural gas

2020 – 2050 gas to renewables



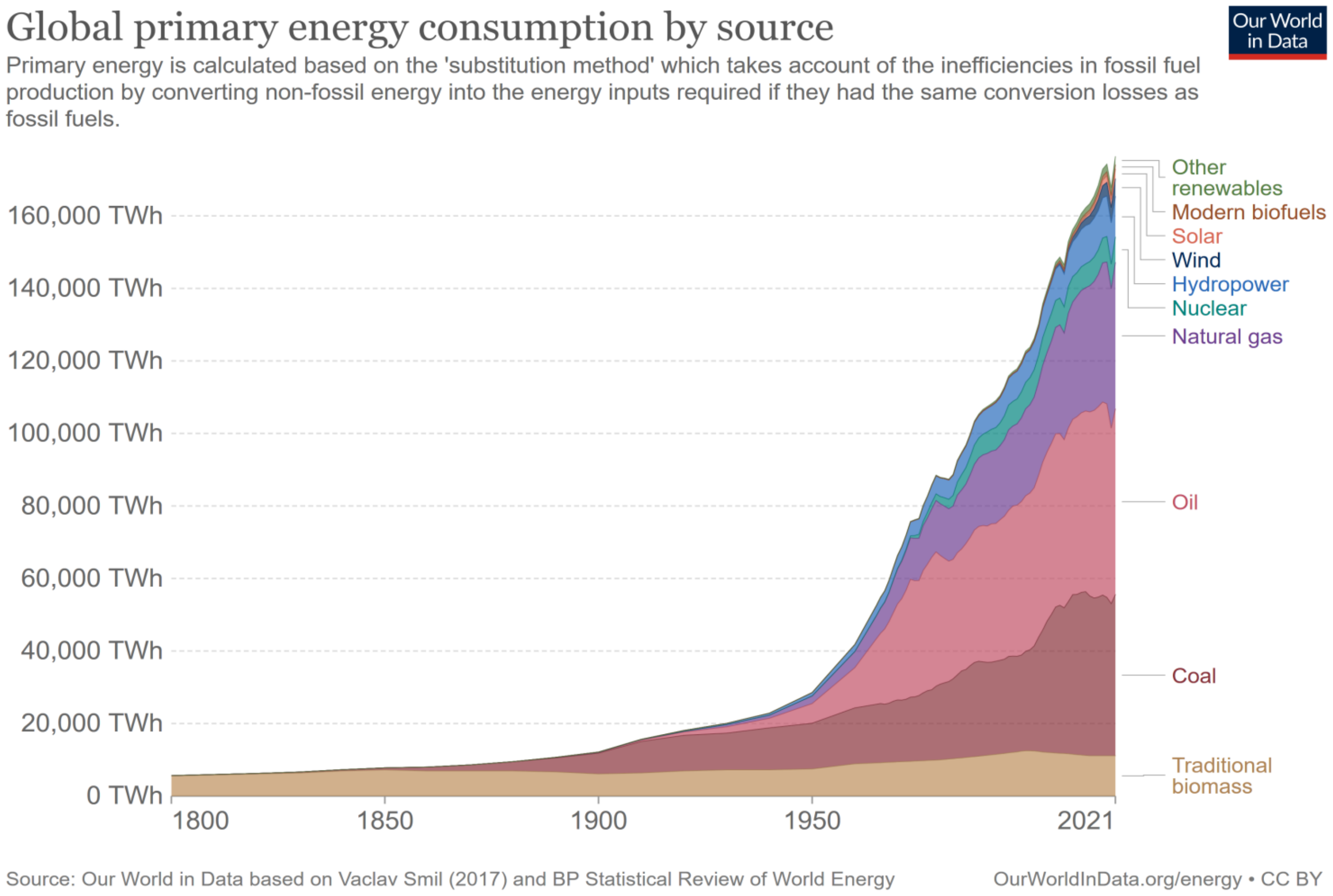
Energy Transition Realities

Transitions Require Decades

Transitions Driven By Fuel Quality And Market Prices

Fuel Physical Realities Are Key Considerations

Wishing And Hoping Is Not A Strategy



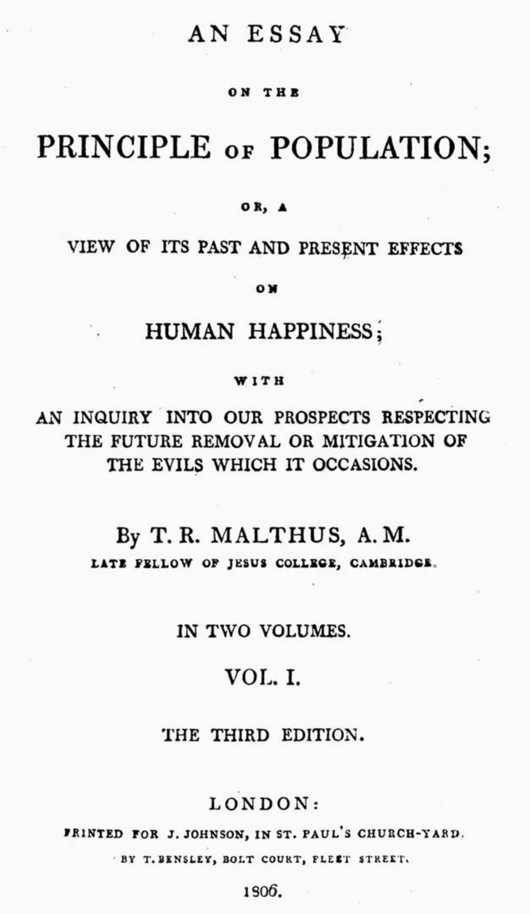
Climate Change Is Driving Transition

Evolution of Climate Change Outrage

World Would Not Be Able To Feed A Growing Population

Thomas Malthus

English economist and demographer



AN ESSAY

ON THE

PRINCIPLE OF POPULATION;

OR, A

VIEW OF ITS PAST AND PRESENT EFFECTS

ON

HUMAN HAPPINESS;

WITH

AN INQUIRY INTO OUR PROSPECTS RESPECTING
THE FUTURE REMOVAL OR MITIGATION OF
THE EVILS WHICH IT OCCASIONS.

By T. R. MALTHUS, A. M.
LATE FELLOW OF JESUS COLLEGE, CAMBRIDGE.

IN TWO VOLUMES.

VOL. I.

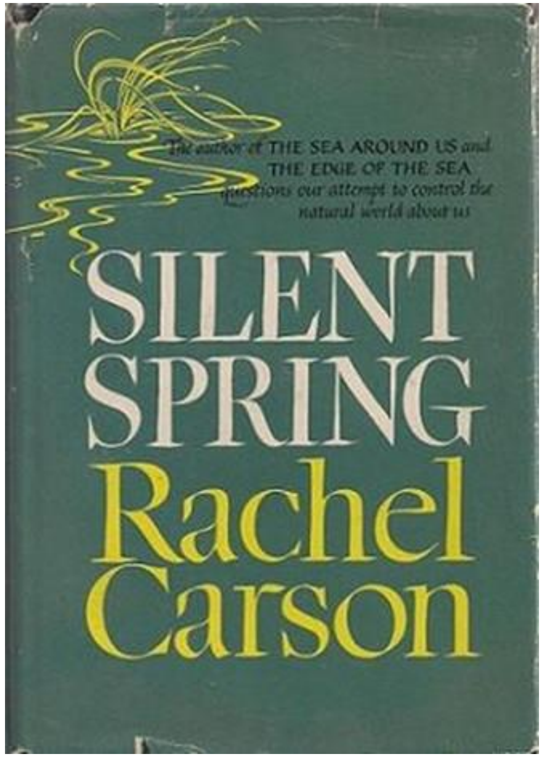
THE THIRD EDITION.

LONDON:
PRINTED FOR J. JOHNSON, IN ST. PAUL'S CHURCH-YARD,
BY T. BENSLEY, BOLT COURT, FLEET STREET.
1806.

Environmental Movement Begins

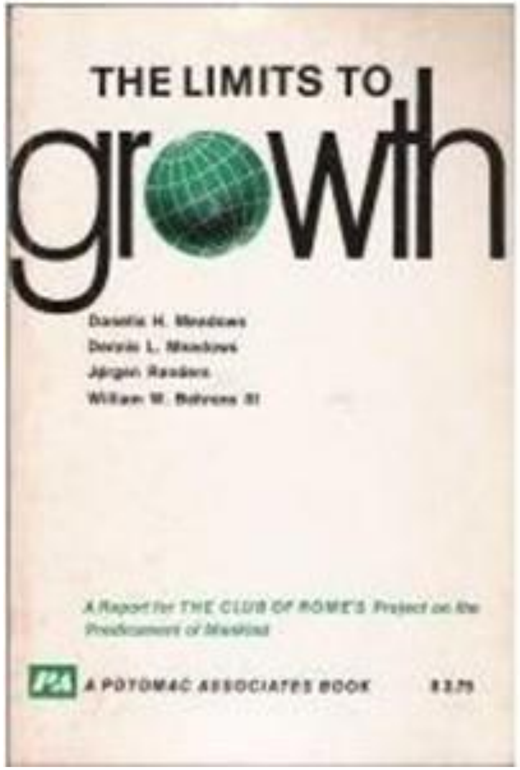
Poisoning The Planet Had To Stop

Rachel Carson



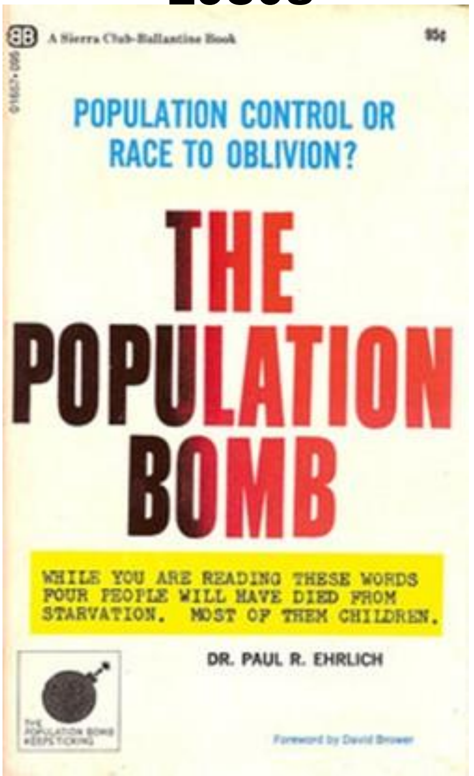
Climate Activism: Analysis To Fear To Alarmism

1960s



MIT/Meadows

1980s



Paul Ehrlich

2000s

Al Gore

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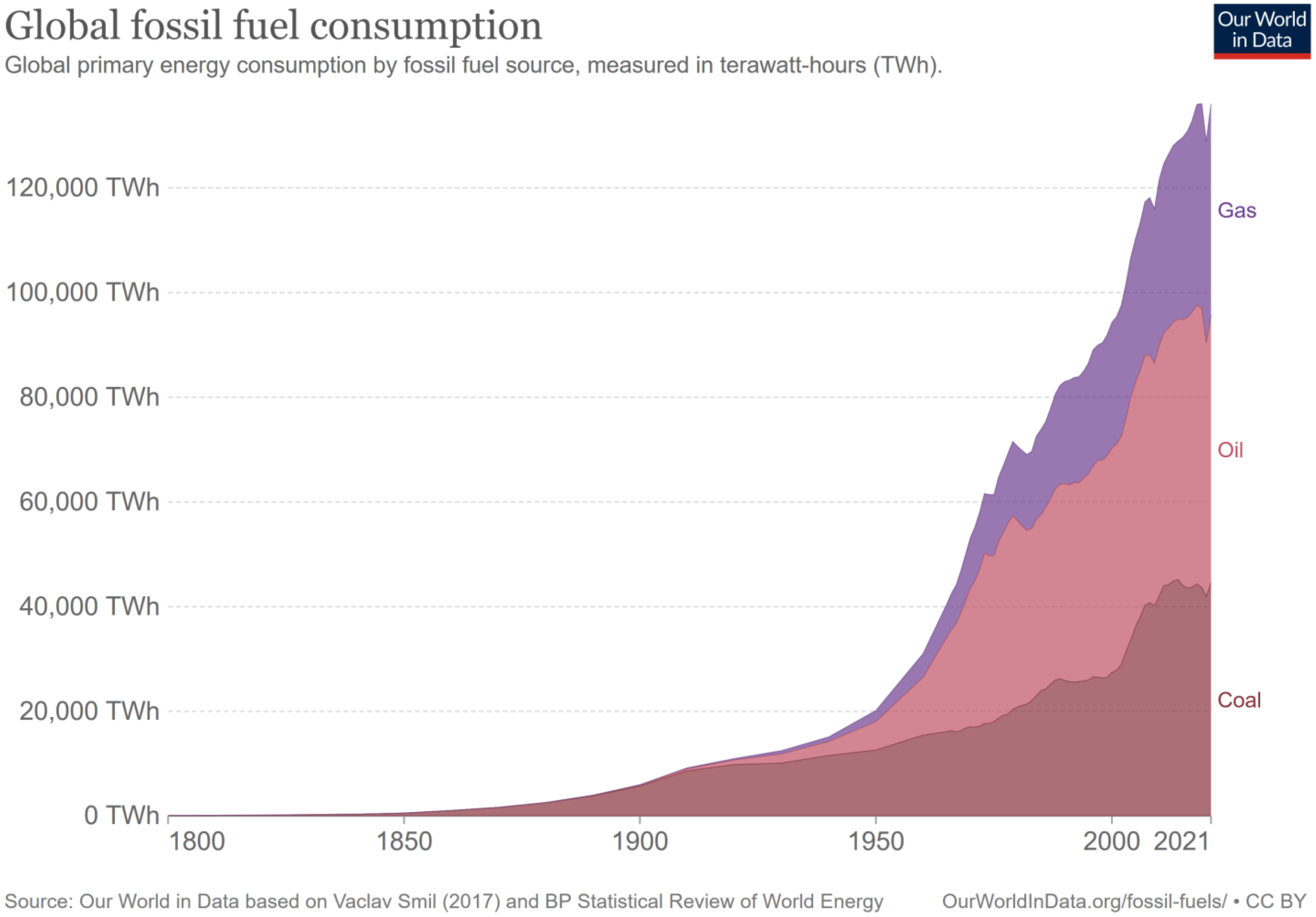
Meet Greta Thunberg and Climate Doomism

"How dare you! You have stolen my dreams and my childhood with your empty words." - **UN Sept. 24, 2019**

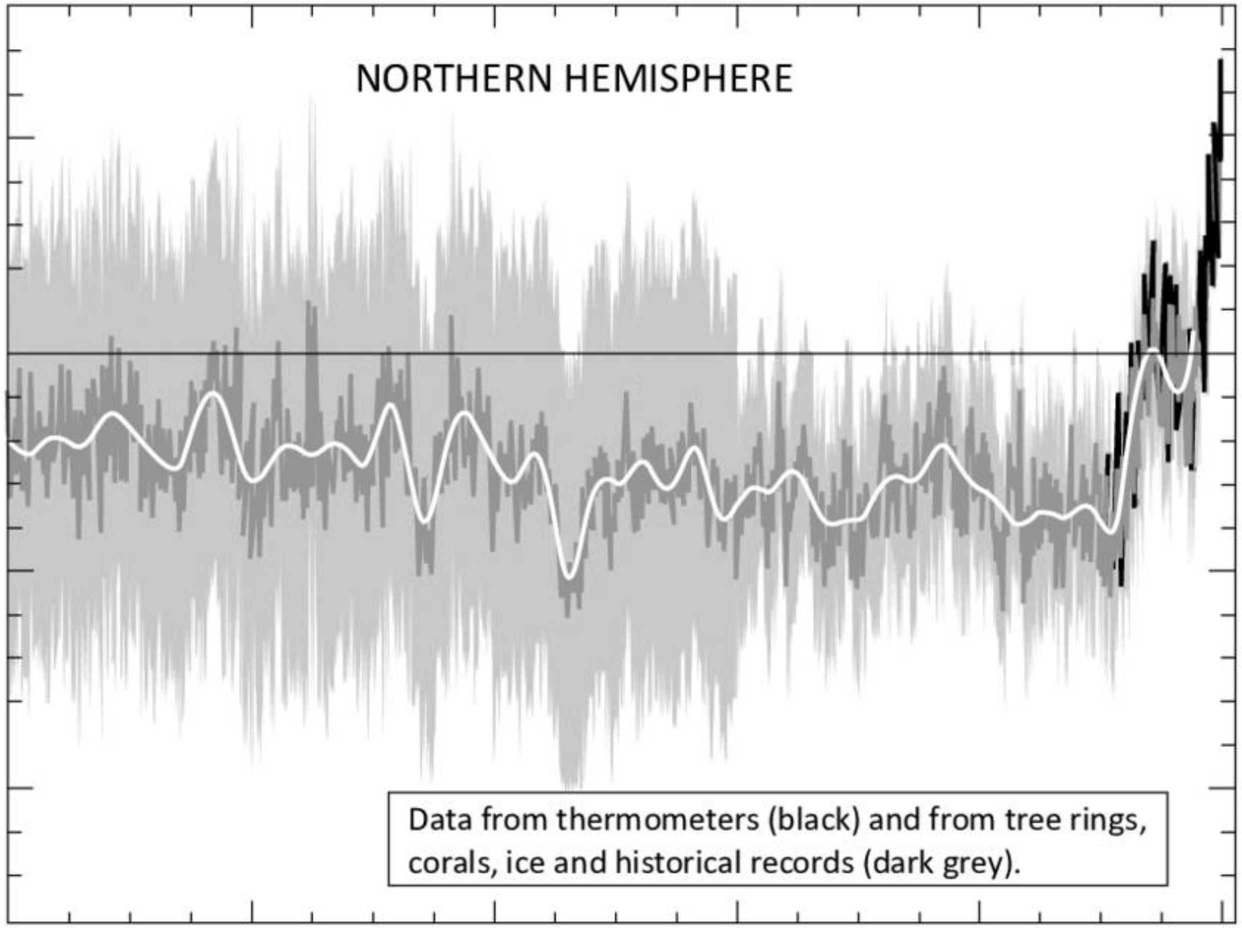
Fossil Fuels: Good vs. Bad

Fossil Fuels Have Improved Quality of Life, Lengthened Live Spans, Reduced Poverty

Fossil Fuels Create Carbon Emissions That Harm The Planet's Climate



Climate Activism Kicked Off With Michael Mann's Hockey Stick CO2 Chart in 1998

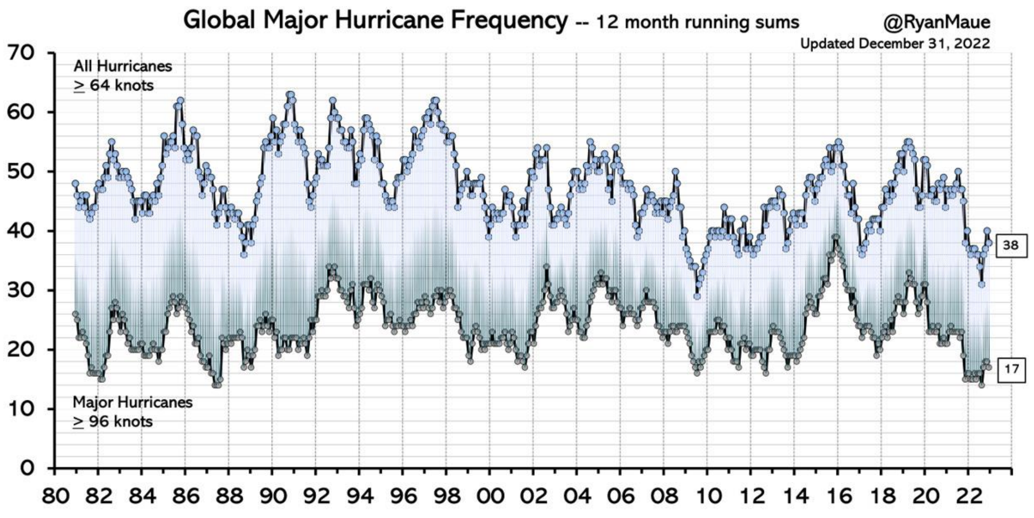


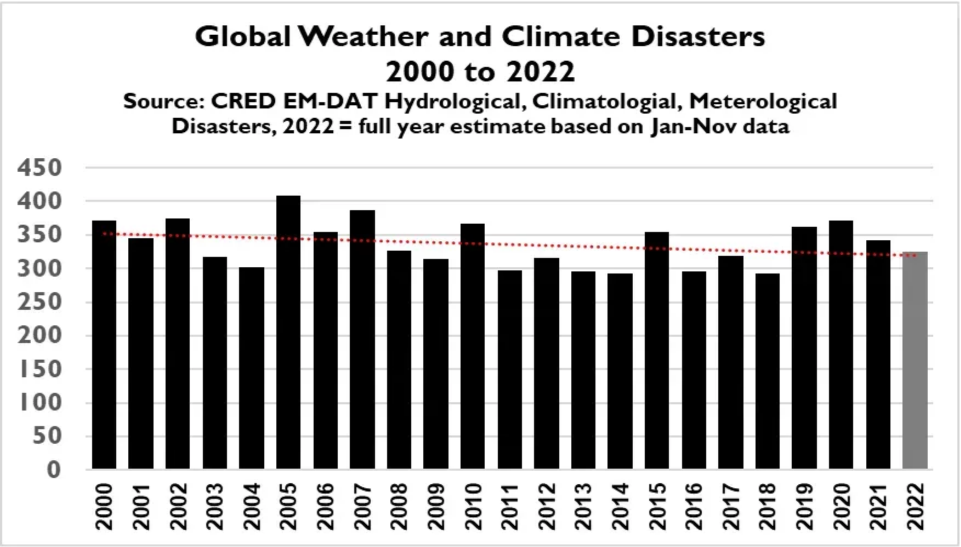
Our Sinking Planet?

Two 2018 studies show the opposite. One of Tuvalu showed total land area increased nearly 3% between 1971 and 2014.

Second study showed nearly 90% of Pacific and Indian Ocean low-lying islands remained stable or increased over the decades.

What The IPCC Is Getting Wrong





Policymaker Summaries Often Ignore The Science That Challenges The Narrative

What The IPCC Gets Wrong With Alarmism

Economic impacts attributable to climate change are increasingly affecting peoples' livelihoods and are causing economic and societal impacts across national boundaries.

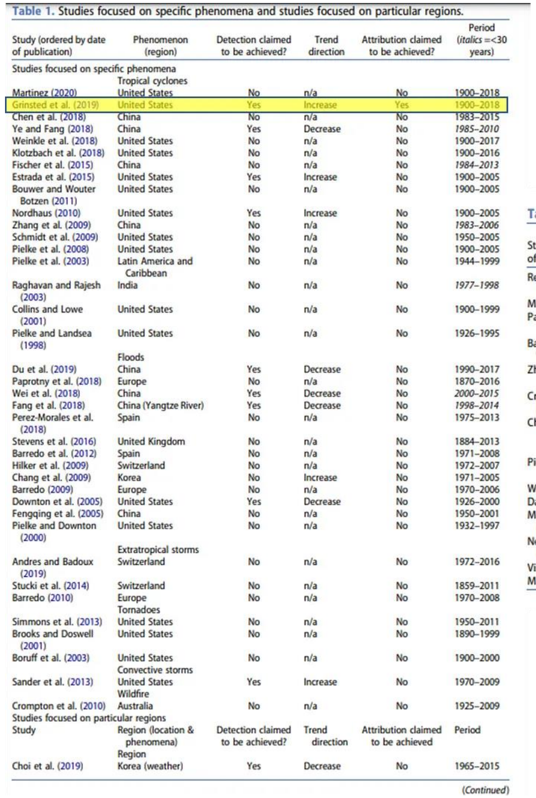


Table 1. Studies focused on specific phenomena and studies focused on particular regions.

Study (ordered by date of publication)	Phenomenon (region)	Detection claimed to be achieved?	Trend direction	Attribution claimed to be achieved?	Period (*italics* =<30 years)
Studies focused on specific phenomena					
	Tropical cyclones				
Martinez (2020)	United States	No	n/a	No	1900–2018
Grinsted et al. (2019)	United States	Yes	Increase	Yes	1900–2018
Chen et al. (2018)	China	No	n/a	No	1983–2015
Ye and Fang (2018)	China	Yes	Decrease	No	*1985–2010*
Weinkle et al. (2018)	United States	No	n/a	No	1900–2017
Klotzbach et al. (2018)	United States	No	n/a	No	1900–2016
Fischer et al. (2015)	China	No	n/a	No	*1984–2013*
Estrada et al. (2015)	United States	Yes	Increase	No	1900–2005
Bouwer and Wouter Botzen (2011)	United States	No	n/a	No	1900–2005
Nordhaus (2010)	United States	Yes	Increase	No	1900–2005
Zhang et al. (2009)	China	No	n/a	No	*1983–2006*
Schmidt et al. (2009)	United States	No	n/a	No	1950–2005
Pielke et al. (2008)	United States	No	n/a	No	1900–2005
Pielke et al. (2003)	Latin America and Caribbean	No	n/a	No	1944–1999
Raghavan and Rajesh (2003)	India	No	n/a	No	*1977–1998*
Collins and Lowe (2001)	United States	No	n/a	No	1900–1999
Pielke and Landsea (1998)	United States	No	n/a	No	1926–1995
	Floods				
Du et al. (2019)	China	Yes	Decrease	No	1990–2017
Paprotny et al. (2018)	Europe	No	n/a	No	1870–2016
Wei et al. (2018)	China	Yes	Decrease	No	*2000–2015*
Fang et al. (2018)	China (Yangtze River)	Yes	Decrease	No	*1998–2014*
Perez-Morales et al. (2018)	Spain	No	n/a	No	1975–2013
Stevens et al. (2016)	United Kingdom	No	n/a	No	1884–2013
Barredo et al. (2012)	Spain	No	n/a	No	1971–2008
Hilker et al. (2009)	Switzerland	No	n/a	No	1972–2007
Chang et al. (2009)	Korea	No	Increase	No	1971–2005
Barredo (2009)	Europe	No	n/a	No	1970–2006
Downton et al. (2005)	United States	Yes	Decrease	No	1926–2000
Fengqing et al. (2005)	China	No	n/a	No	1950–2001
Pielke and Downton (2000)	United States	No	n/a	No	1932–1997
	Extratropical storms				
Andres and Badoux (2019)	Switzerland	No	n/a	No	1972–2016
Stucki et al. (2014)	Switzerland	No	n/a	No	1859–2011
Barredo (2010)	Europe	No	n/a	No	1970–2008
	Tornadoes				
Simmons et al. (2013)	United States	No	n/a	No	1950–2011
Brooks and Doswell (2001)	United States	No	n/a	No	1890–1999
Boruff et al. (2003)	United States	No	n/a	No	1900–2000
	Convective storms				
Sander et al. (2013)	United States	Yes	Increase	No	1970–2009
	Wildfire				
Crompton et al. (2010)	Australia	No	n/a	No	1925–2009
Studies focused on particular regions					
Study	Region (location & phenomena)	Detection claimed to be achieved?	Trend direction	Attribution claimed to be achieved	Period
	Region				
Choi et al. (2019)	Korea (weather)	Yes	Decrease	No	1965–2015

(*Continued*)

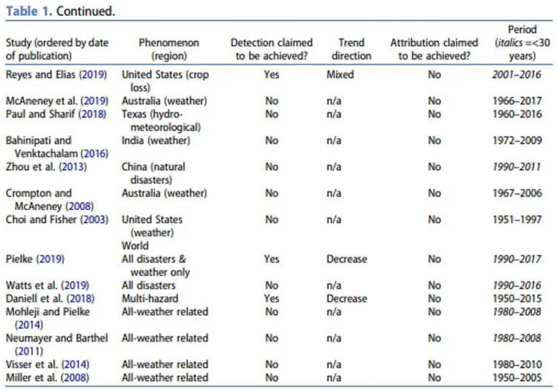
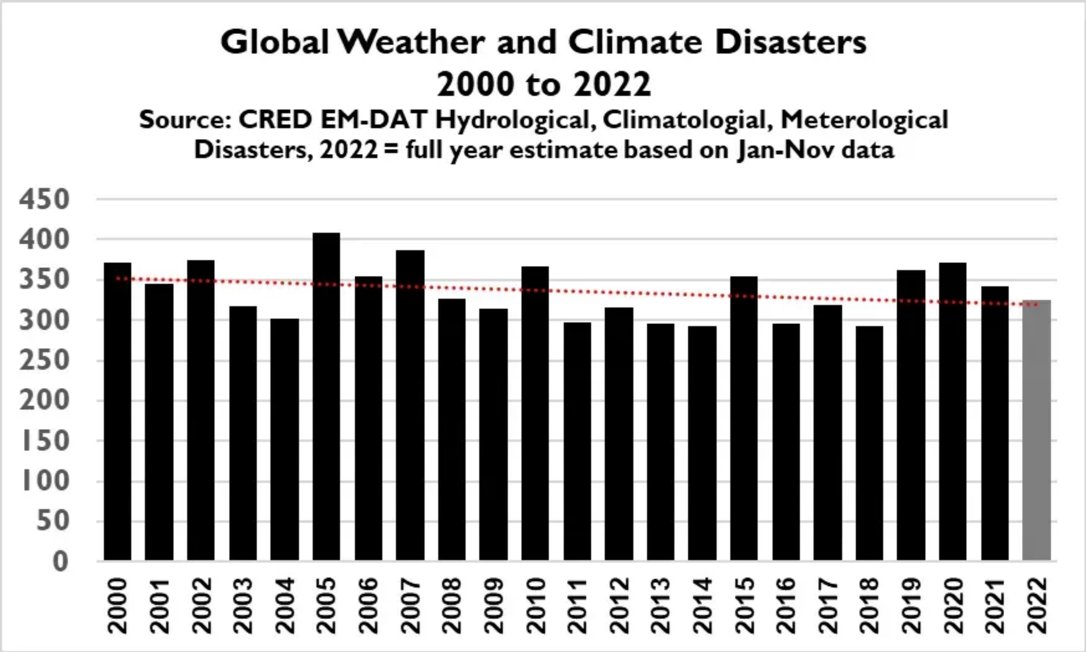


Table 1. Continued.

Study (ordered by date of publication)	Phenomenon (region)	Detection claimed to be achieved?	Trend direction	Attribution claimed to be achieved?	Period (*italics* =<30 years)
Reyes and Elias (2019)	United States (crop loss)	Yes	Mixed	No	*2001–2016*
McAneney et al. (2019)	Australia (weather)	No	n/a	No	1966–2017
Paul and Sharif (2018)	Texas (hydro-meteorological)	No	n/a	No	1960–2016
Bahinipati and Venktachalam (2016)	India (weather)	No	n/a	No	1972–2009
Zhou et al. (2013)	China (natural disasters)	No	n/a	No	*1990–2011*
Crompton and McAneney (2008)	Australia (weather)	No	n/a	No	1967–2006
Choi and Fisher (2003)	United States (weather)	No	n/a	No	1951–1997
	World				
Pielke (2019)	All disasters & weather only	Yes	Decrease	No	*1990–2017*
Watts et al. (2019)	All disasters	No	n/a	No	*1990–2016*
Daniell et al. (2018)	Multi-hazard	Yes	Decrease	No	1950–2015
Mohleji and Pielke (2014)	All-weather related	No	n/a	No	*1980–2008*
Neumayer and Barthel (2011)	All-weather related	No	n/a	No	*1980–2008*
Visser et al. (2014)	All-weather related	No	n/a	No	1980–2010
Miller et al. (2008)	All-weather related	No	n/a	No	1950–2005



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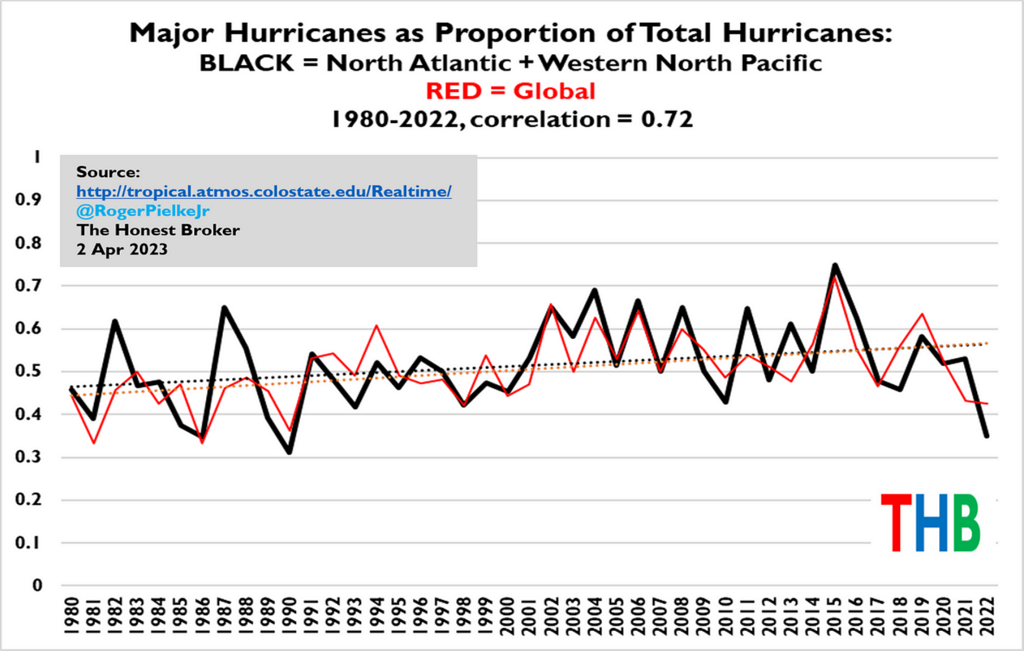
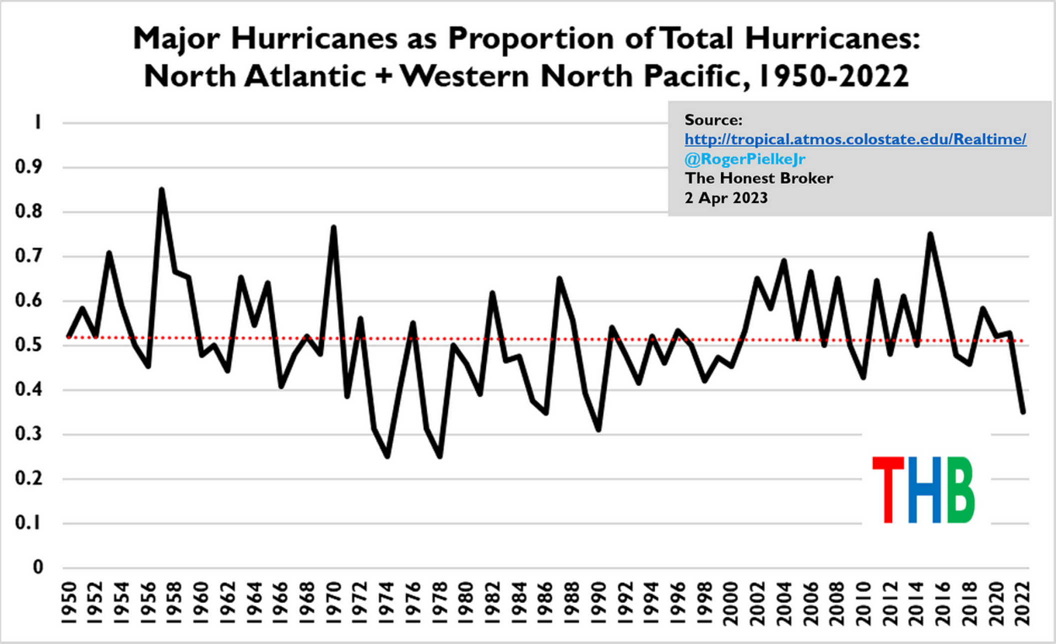
Roger Pielke Explains IPCC Climate Research Gamesmanship

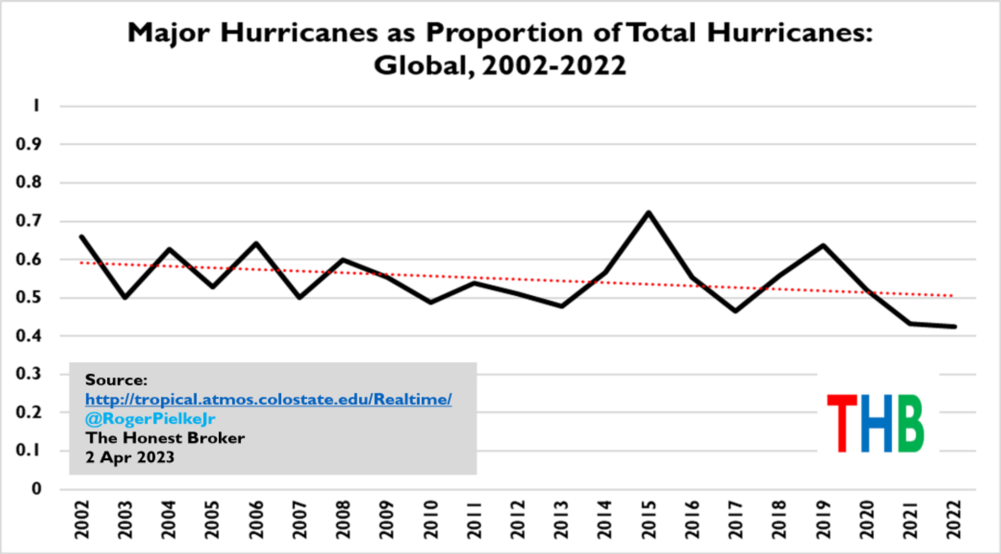




Want to show an increase? Start your analysis in 1980

Want to show no trends? Start your analysis in 1950

Want to show a decrease? Start your analysis in 2002



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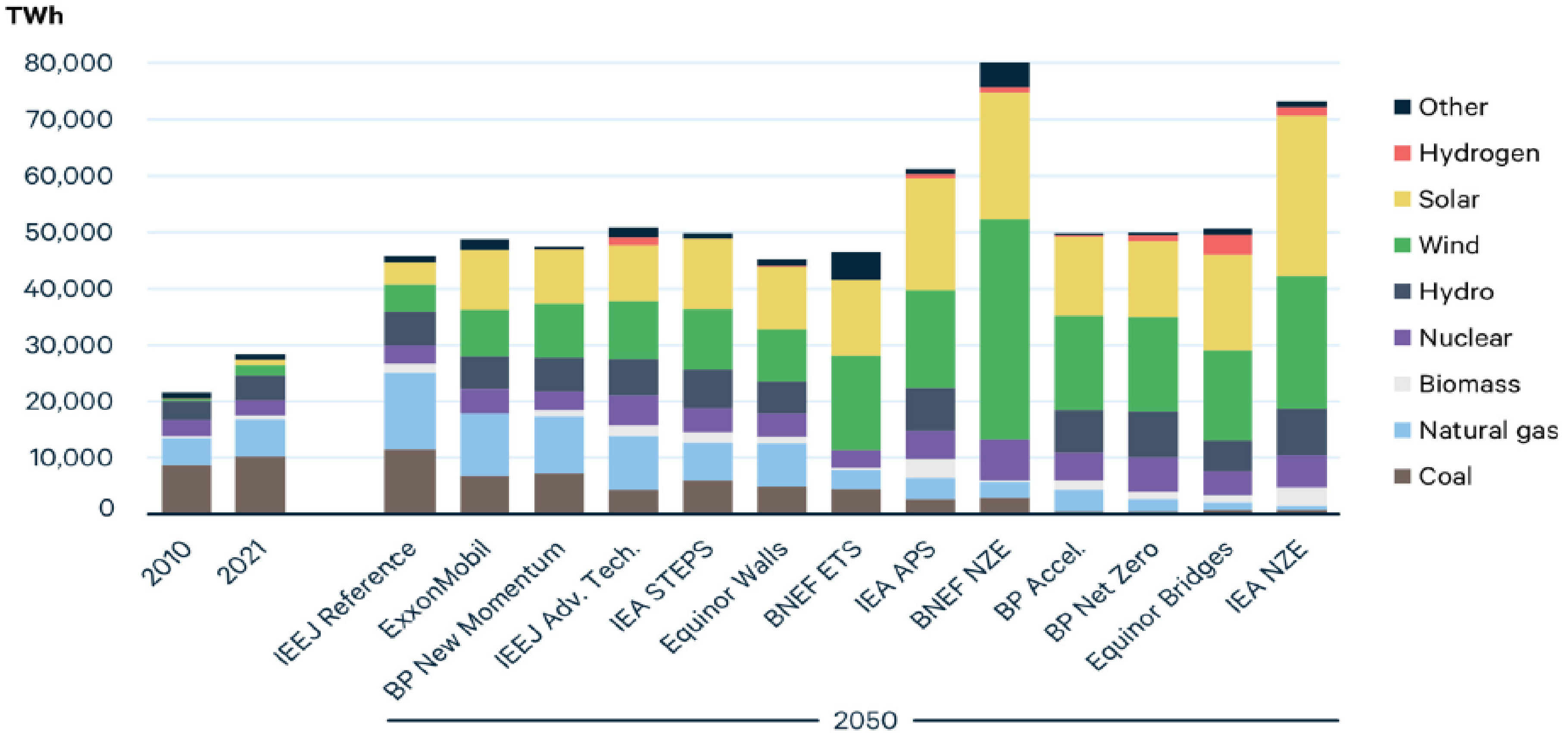
The Energy Transition

- **Opportunities:**
  - Electrify everything
  - More renewables & subsidies
  - New fuels
    - Biofuels
    - Hydrogen
    - Fusion

- **Challenges:**
  - Energy density
  - Hard to decarbonize sectors
    - Heavy duty trucks
    - Air transportation
    - Marine transportation
    - Cement and steel
  - Magnitude of metals needed
  - Additional infrastructure
  - Cost

World Electricity Mix in 2021 and 2050

Every Forecast Has Global Electricity Use Much Higher



Notes: 2050 scenarios arranged in declining order of fossil fuel electricity generation. "Other" includes oil, geothermal, and marine. For BNEF it also includes hydro.

Renewables Capacity Not Comparable To Fossil Fuels

Table 1b. Estimated unweighted levelized cost of electricity (LCOE) and levelized cost of storage (LCOS) for new resources entering service in 2027 (2021 dollars per megawatthour)

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M[a]	Levelized variable cost	Levelized transmission cost	Total system LCOE or LCOS	Levelized tax credit[b]	Total LCOE or LCOS including tax credit
Dispatchable technologies								
Ultra-supercritical coal	85%	$52.11	$5.71	$23.67	$1.12	$82.61	*NA*	$82.61
Combined cycle	87%	$9.36	$1.68	$27.77	$1.14	$39.94	*NA*	$39.94
Advanced nuclear	90%	$60.71	$16.15	$10.30	$1.08	$88.24	-$6.52	$81.71
Geothermal	90%	$22.04	$15.18	$1.21	$1.40	$39.82	-$2.20	$37.62
Biomass	83%	$40.80	$18.10	$30.07	$1.19	$90.17	*NA*	$90.17
Resource-constrained technologies								
Wind, onshore	41%	$29.90	$7.70	$0.00	$2.63	$40.23	*NA*	$40.23
Wind, offshore	44%	$103.77	$30.17	$0.00	$2.57	$136.51	-$31.13	$105.38
Solar, standalone[c]	29%	$26.60	$6.38	$0.00	$3.52	$36.49	-$2.66	$33.83
Solar, hybrid[c,d]	28%	$34.98	$13.92	$0.00	$3.63	$52.53	-$3.50	$49.03
Hydroelectric[d]	54%	$46.58	$11.48	$4.13	$2.08	$64.27	*NA*	$64.27
Capacity resource technologies								
Combustion turbine	10%	$53.78	$8.37	$45.83	$9.89	$117.86	*NA*	$117.86
Battery storage	10%	$64.03	$29.64	$24.83	$10.05	$128.55	*NA*	$128.55

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2022*

80s-90s%

20s-40s%

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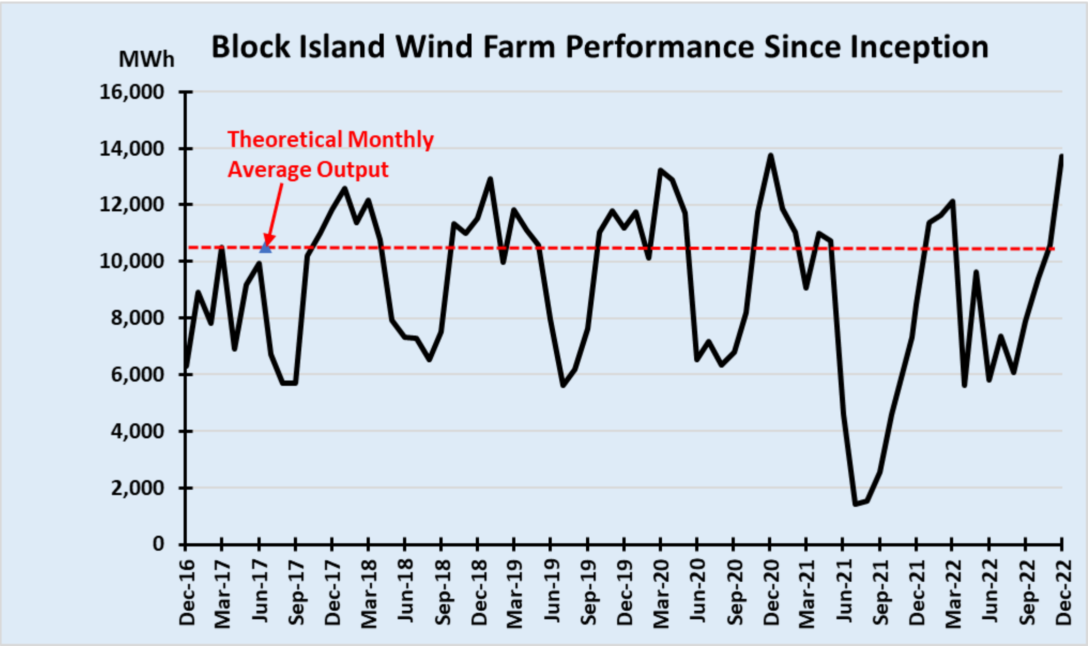
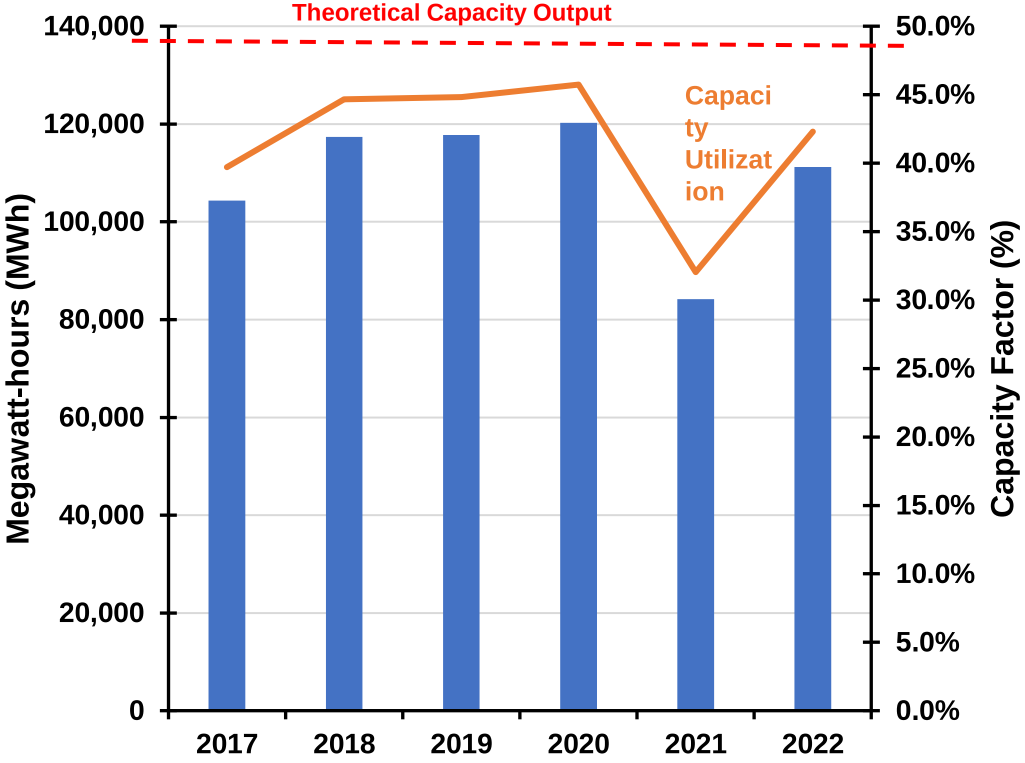
Block Island Wind Output Still Disappoints

Electricity When Needed Is Often Not There Or There Is Too Much So Wasted

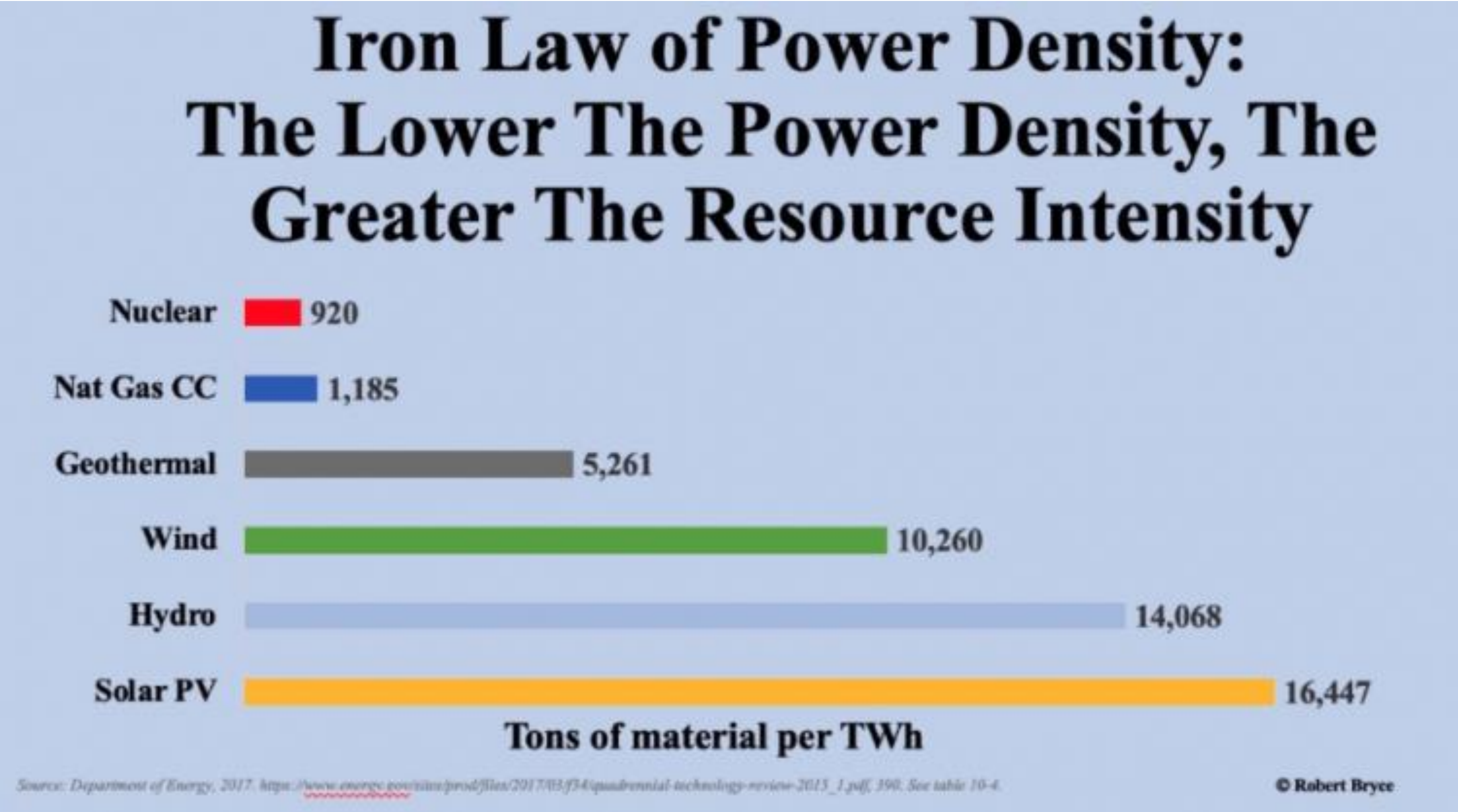




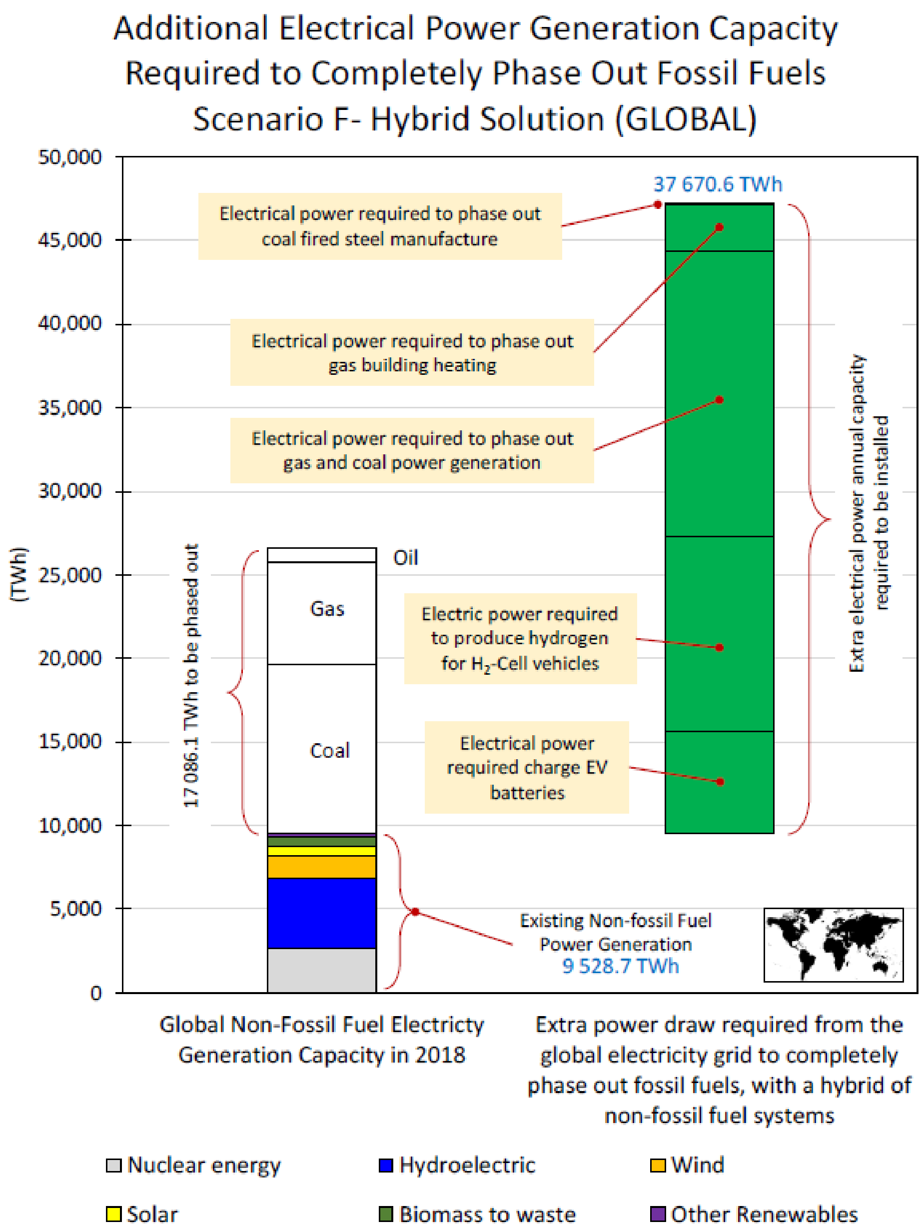
Energy Density of Power Sources

Renewable Land Use For Power Is Ignored By The Proponents

"37,000 square miles for wind farms and 4,700 square miles for solar PV" = the State of Tennessee



Green Power Will Need 2.2 Times The Capacity Of Existing Power Generation From Fossil Fuel



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Electrify Everything = More Power Lines

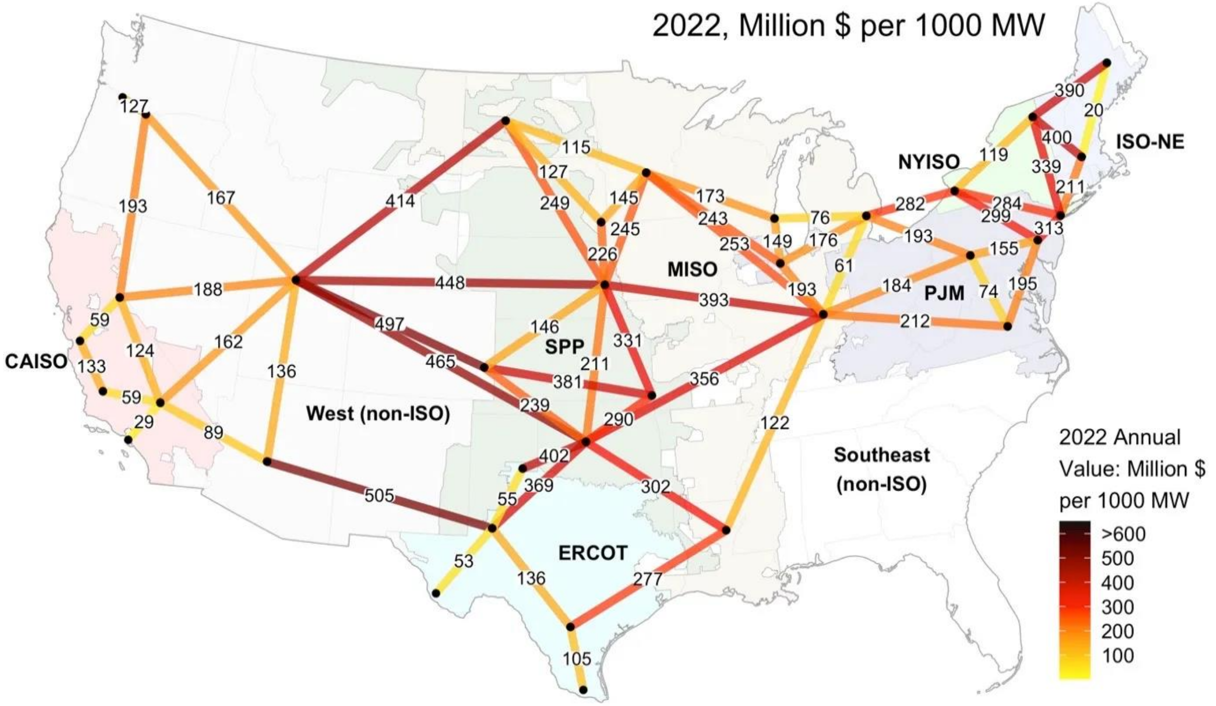
DOE Says We Will Need 60% More Transmission Capacity By 2030

<u>At Current Build Rate:</u>

+60% will need 84 years

+100% will need 140 years

+200% will need 282 years



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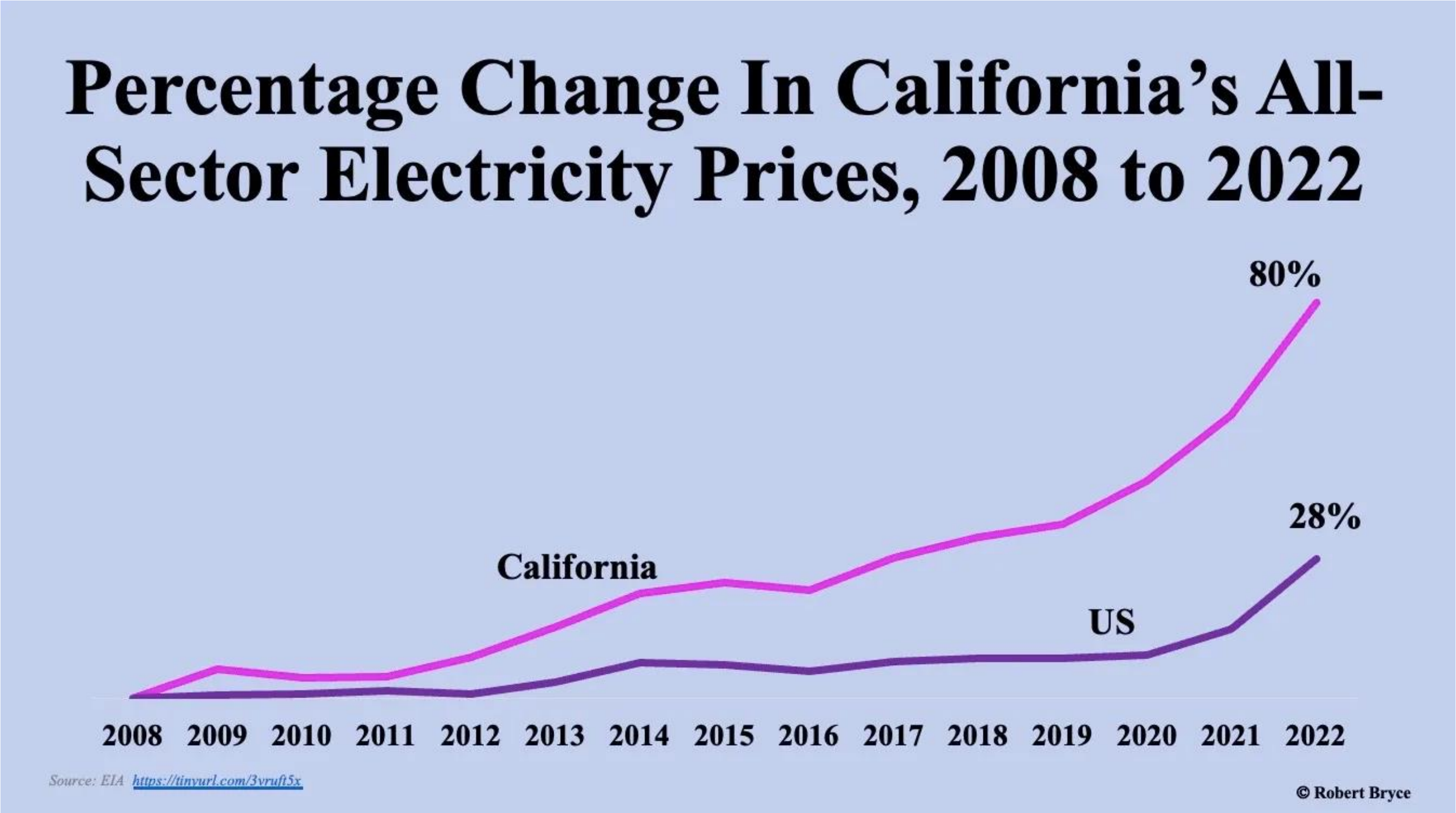
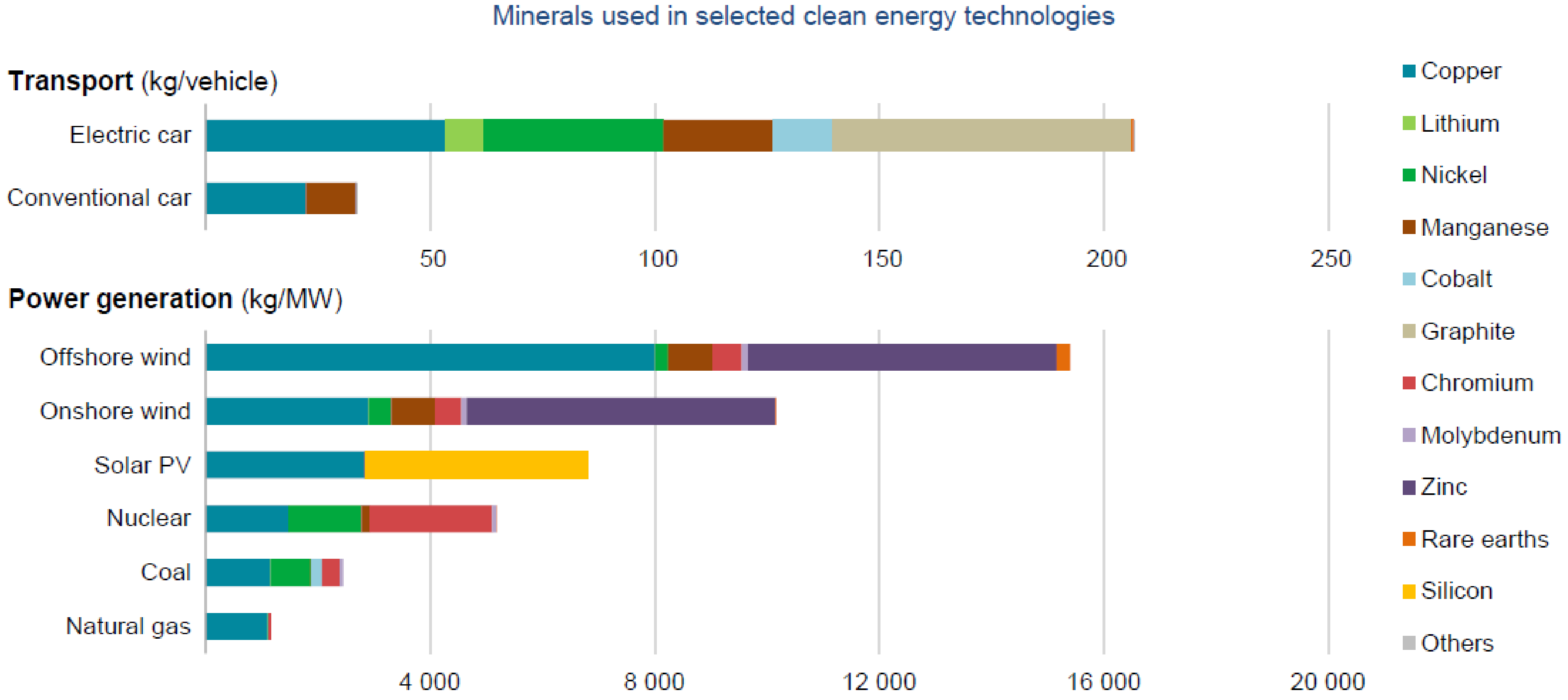
Renewables: Equipment Shortages and Higher Costs

California Experiment In Net Zero By 2030 Is Costing Citizens $s And Blackouts



Role of Critical Minerals in Clean Energy Transitions

Transportation And Power Generation Need Multiples Of Raw Materials



Hidden Problem With Critical Materials

Declining Ore Grades Pose Significant Problem For Green Energy Transition

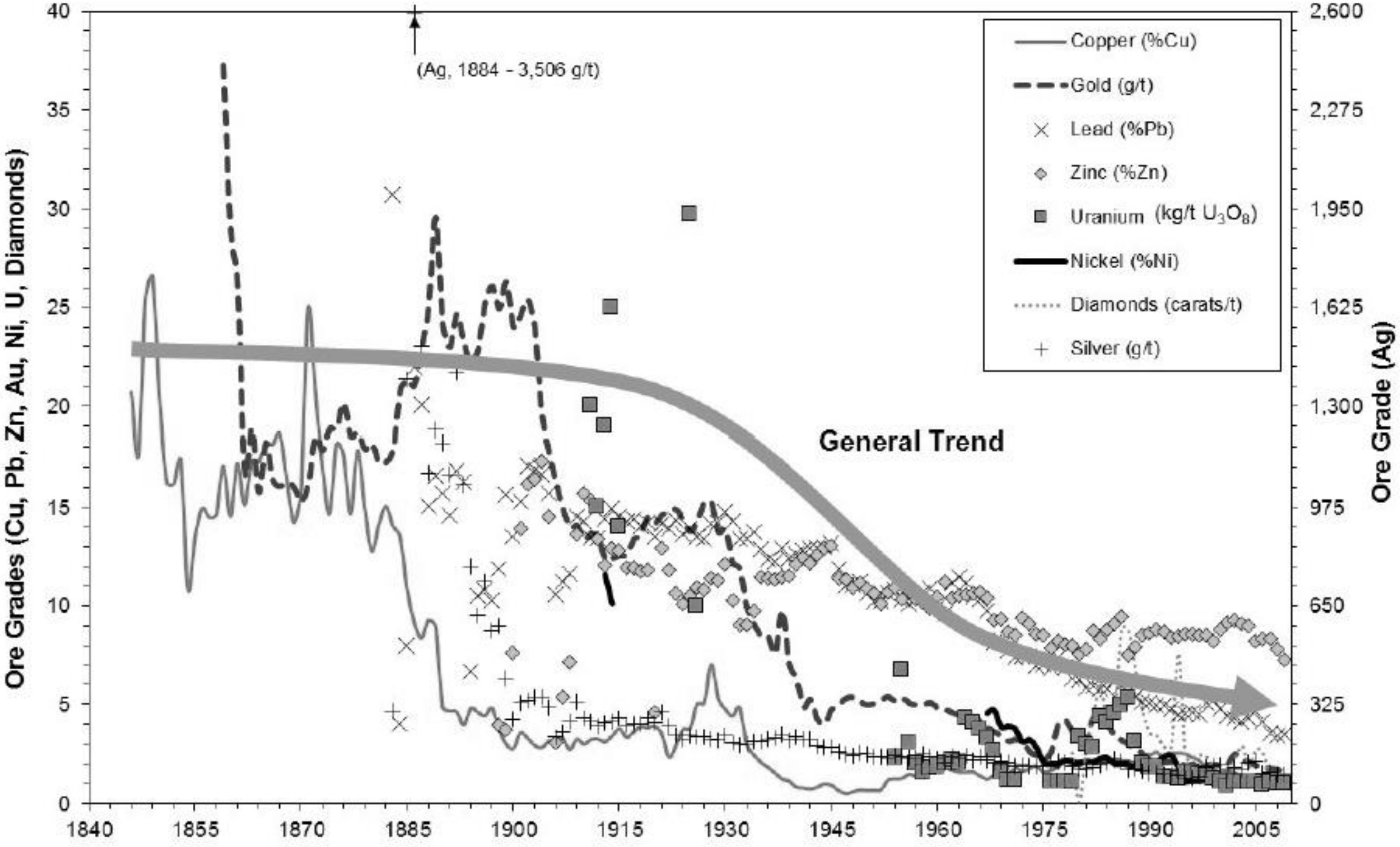


Figure 16. Grade of mined minerals has been decreasing (Source: Mudd 2009- updated 2012, Analyst- Gavin Mudd)

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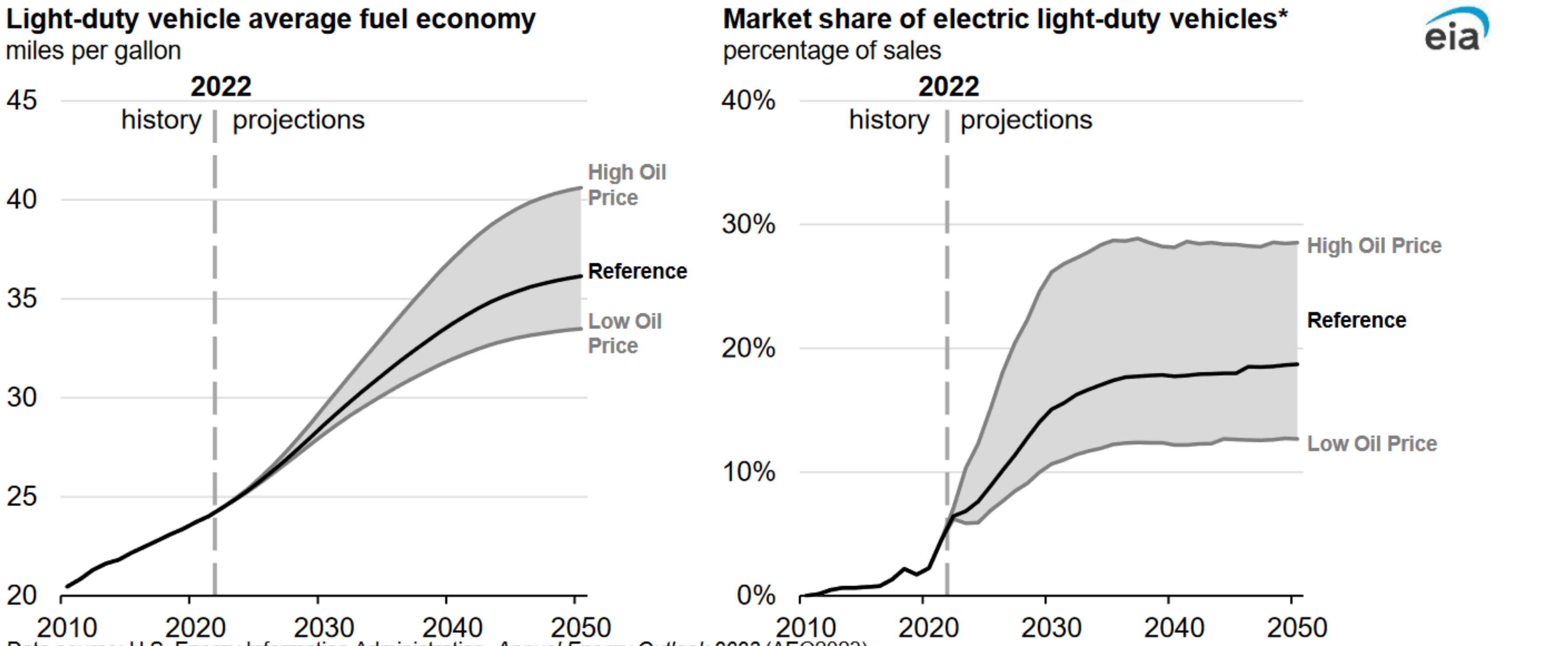
Changing Auto Market Impacts Energy

270 Million Vehicles In U.S. Fleet Means Slow Change To EVs

Light-duty vehicle fuel economy and electric vehicle market share increase through 2050 due to rising CAFE Standards and other incentives



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)
Note: *Includes battery electric and plug-in hybrid electric vehicles. Shaded regions represent maximum and minimum values for each projection year across the AEO2023 Reference case and side cases.

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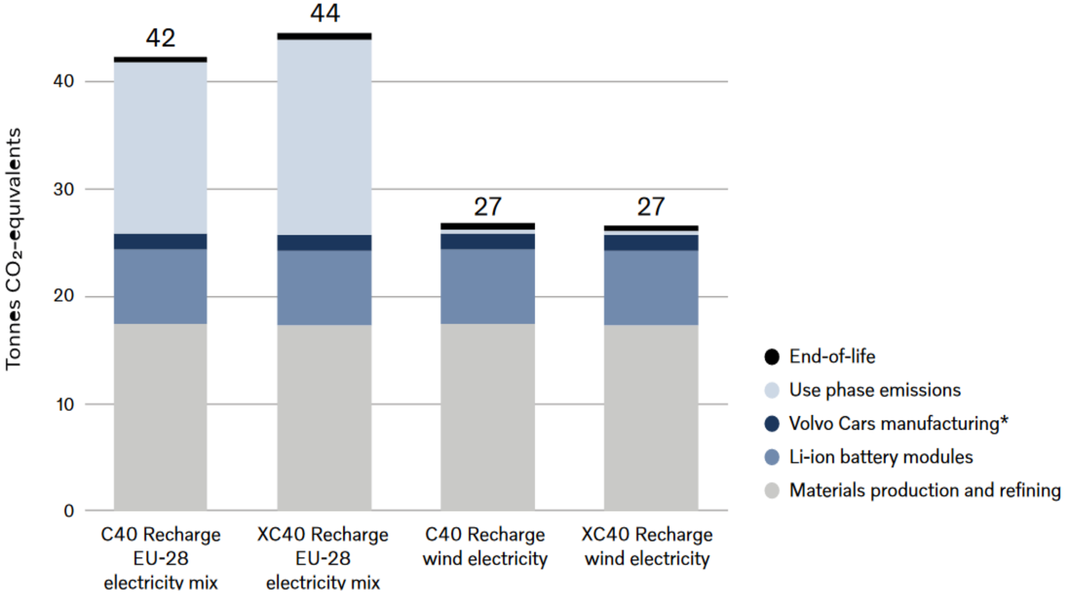
Volvo ICE and EV Models Compared On Emissions

Clean EV Starts With 70% More CO2 Emissions Than Same ICE Model

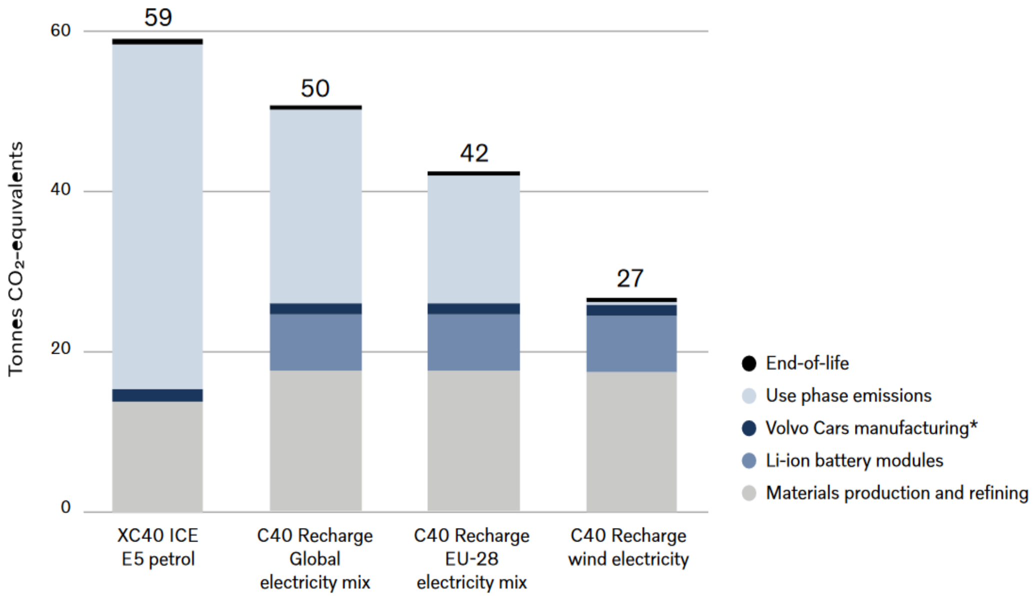
EVs



** Volvo Cars manufacturing includes both factories as well as inbound and outbound logistics.*

Figure i. Carbon footprint for C40 Recharge and XC40 Recharge, with different electricity mixes.
Results are shown in tonnes CO_2-equivalents per functional unit (200,000km total distance, rounded values).

ICEs



** Volvo Cars manufacturing includes both factories as well as inbound and outbound logistics.*

Figure ii. Carbon footprint for C40 Recharge and XC40 ICE, with different electricity mixes.
Results are shown in tonnes CO_2-equivalents per functional unit (200,000km total distance, rounded values).

Volvo's Carbon Footprint and When EV and ICE Breakeven

km Needed To Breakeven On CO2: Cleanest - 49k, Europe Grid - 77k, And Global Grid - 110k

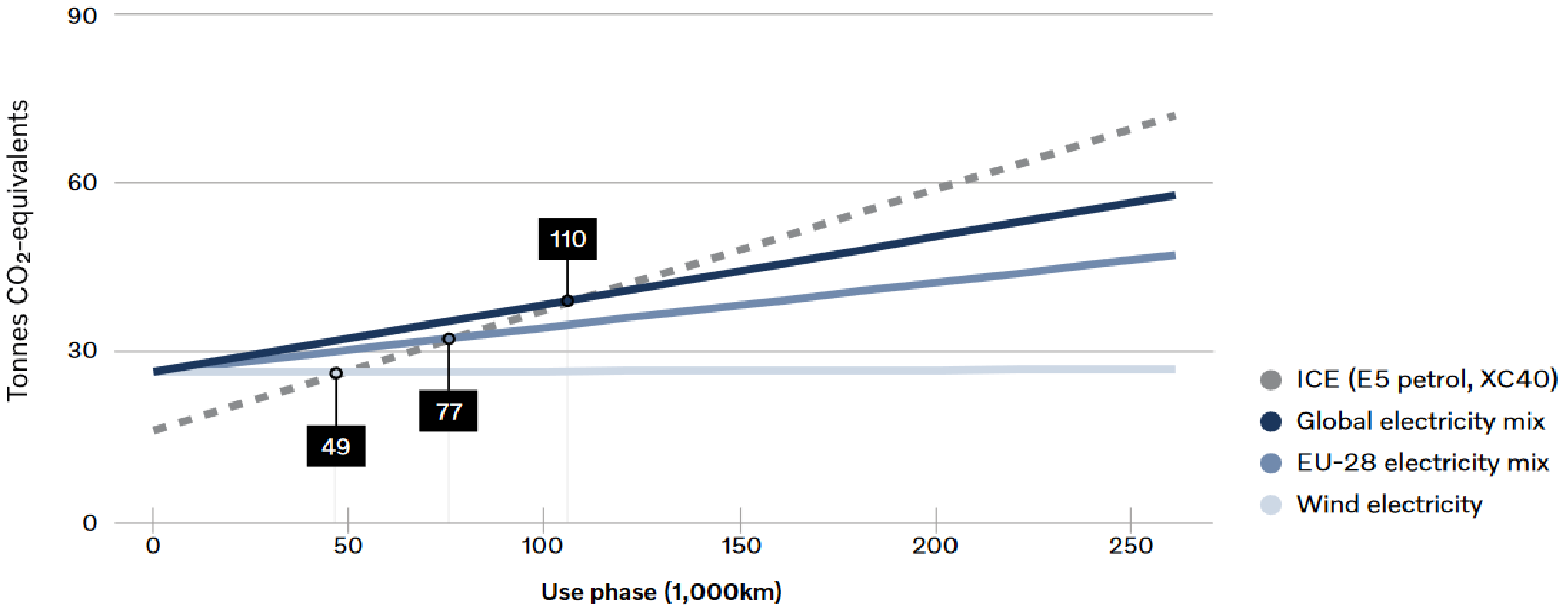
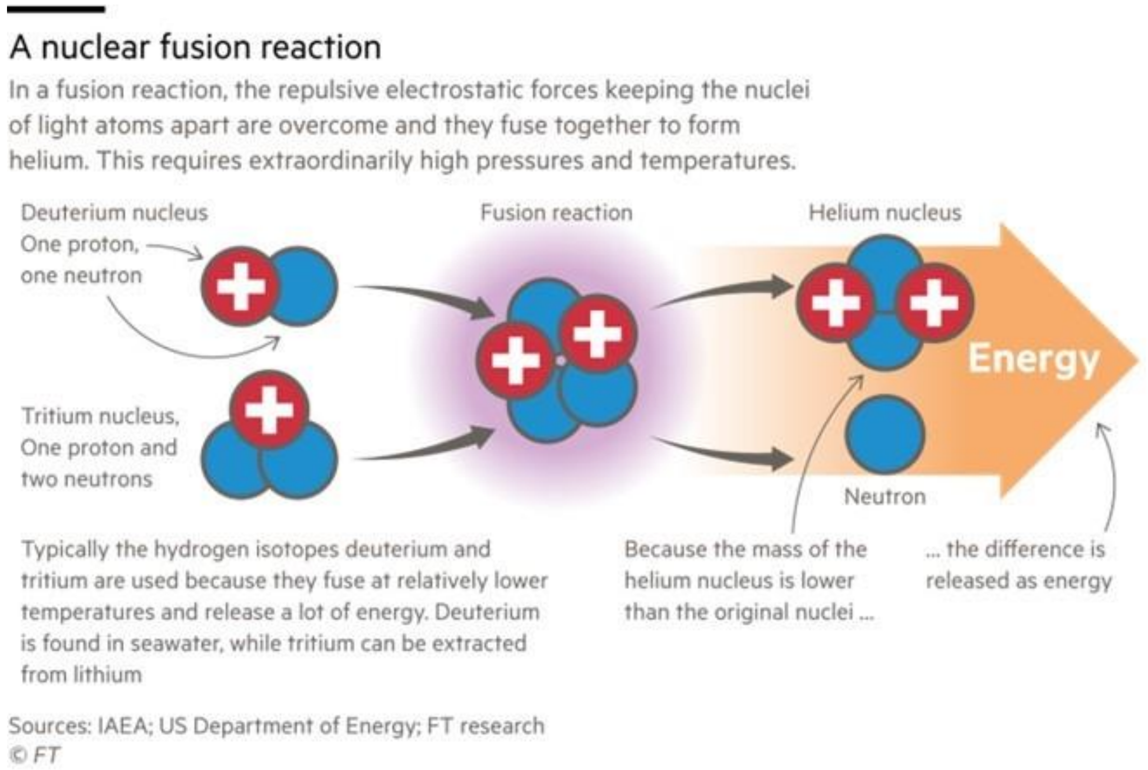
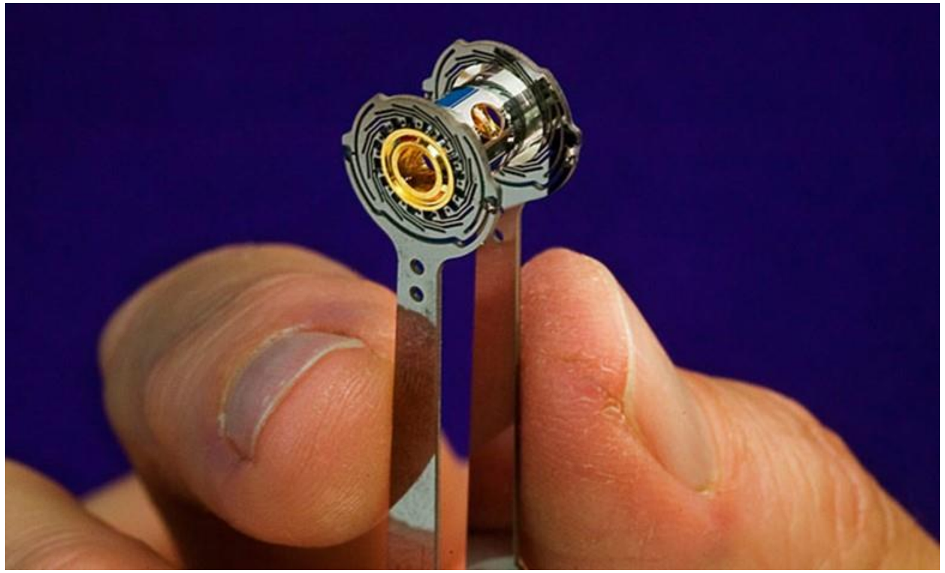


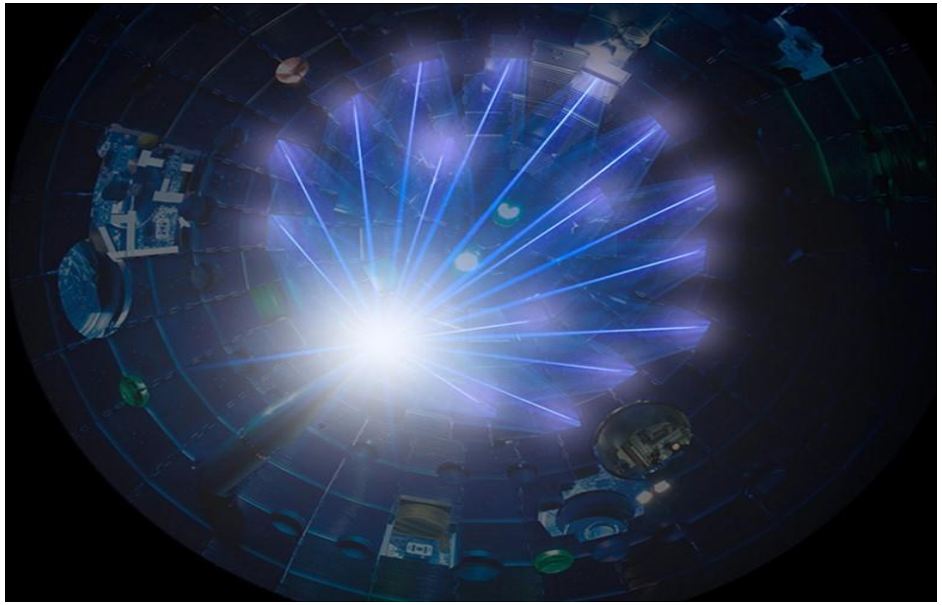
Figure iii. Break-even diagram: *Total amount of GHG emissions, depending on total kilometres driven, from XC40 ICE (dashed line) and C40 Recharge (with different electricity mixes in the use phase). Where the lines cross, break-even between the two vehicles occurs. All life cycle phases except use phase are summarized and set as the starting point for each line at zero distance.*

Is Fusion Energy The Hope For The Future?

400 MJ of Power Needed For 3 MJ of Energy







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Conclusions:

Energy Transition Is More Complex Than Policymakers Understand

Energy Transition Will Take More Time Than Expected

Energy Transition Will Cost Much More Than Predicted

Mandated Deadlines Will Be Pushed Back Or Abandoned