

# Global Energy Transition in the 2020s: Managing Externalities Takes Center Stage



**Gabriel Collins, J.D.**

Baker Botts Fellow for Energy & Environmental Regulatory Affairs  
Baker Institute for Public Policy, Rice University

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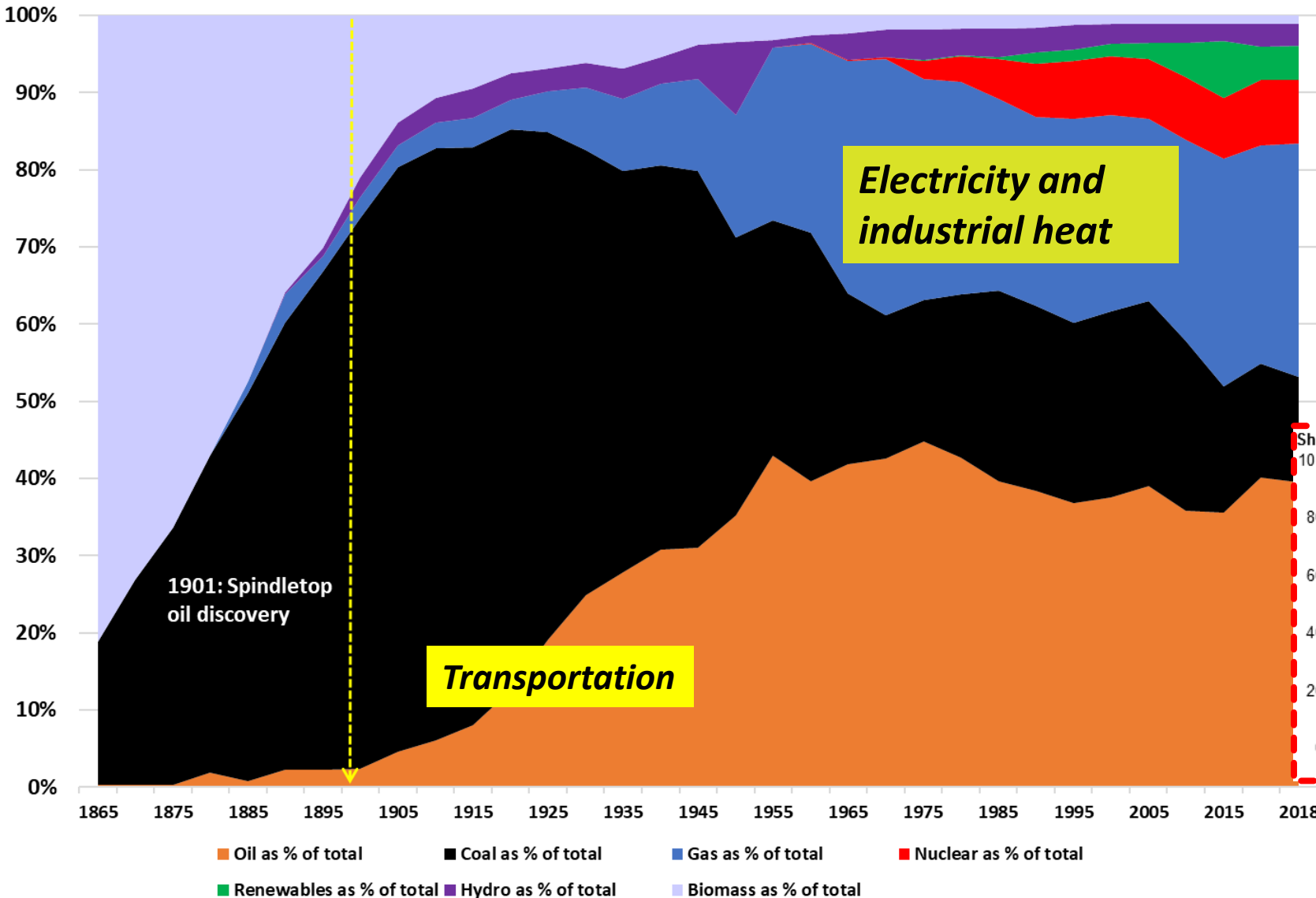


# Thinking About Global Energy Transition in the 2020s

- ▶ We've been in an "energy transition" for the past 200 years, but...devices and systems that produce and consume energy are analog—change is already underway but will likely take longer than we want it to
- ▶ Energy geopolitics are not going anywhere—but we'll experience them in some new forms because lower-carbon energy sources like renewables and nuclear tend to "upfront" the critical material inputs.
- ▶ The world will likely continue on a path of greater electrification, given electricity's local cleanliness at point of use and the fungibility of generation (i.e. an electric motor is the ultimate "multi-fuel" motor, capable of using electrons from coal, gas, oil, nuclear, wind, solar, hydro, and anything else able to spin a dyo).
- ▶ Legacy matters, scale matters, cost matters (intimately related to the first two factors), and reliability matters
- ▶ Retiring baseload energy sources in favor of intermittent generators is a deed very likely to result in punishment through blackouts, electricity price spikes, and unintended consequences such as greater private generator use and liquid fuel demand (think China 2004).
- ▶ The most profound change will be accomplished at the local and national levels
- ▶ It's a bumpy road ahead with massive uncertainty—so let's buckle up!

# The Energy Transition is Constant—And Two Centuries Old

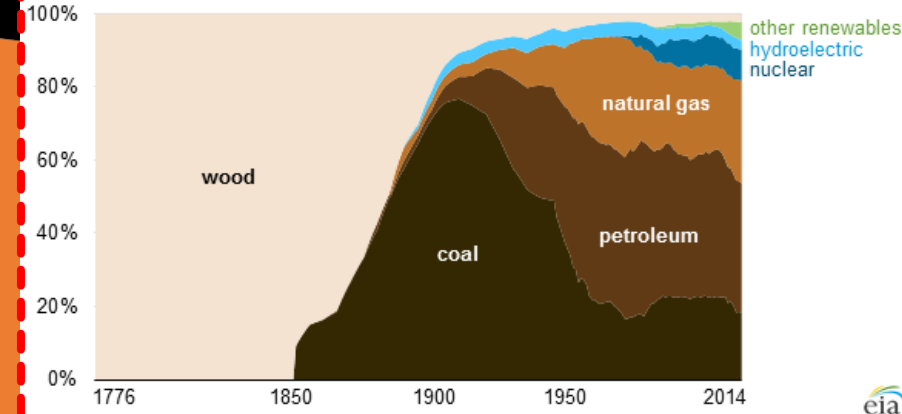
U.S. Primary Energy Sources, % of Total Consumption



**Bottom Line: The US and global energy systems are constantly in transition.**

**Velocity and scale of change matter enormously—and the scale at a global level is in the trillions of dollars.**

Share of energy consumption in the United States (1776-2014)



# How We Think About Energy: Aspirations And Priorities

- ▶ Controllable, convenient energy availability is a very recent phenomenon.
- ▶ *“The fifty million Americans who dwelt in what F. Scott Fitzgerald called ‘that vast obscurity beyond the city’ still moved between birth and death to the ancient rhythms of sun and season. More than forty-five million of them had no indoor plumbing in 1930 and almost none had electricity. They relieved themselves in chamber pots and outdoor latrines, cooked and heated with wood stoves, and lit their smoky houses with oil lamps.”*—David M. Kennedy, *Freedom From Fear: The American People in Depression and War, 1929-1945.* (16)
- ▶ What factors are various populations most acutely sensitive to when it comes to producing and using energy?  
**Affordability, accessibility, reliability. Other things?**
- ▶ How do these various groups think about externalities?



<https://mx.depositphotos.com/103848718/stock-illustration-caveman-discovering-fire.html>

Preferences and priorities that govern our actions involuntarily illustrate the central importance of legacy, scale, and incremental evolution rather than disruptive revolution of local, national, and global energy ecosystems

# Energy is a Force-Multiplier and a Liberator

## Transportation Force Multiplier

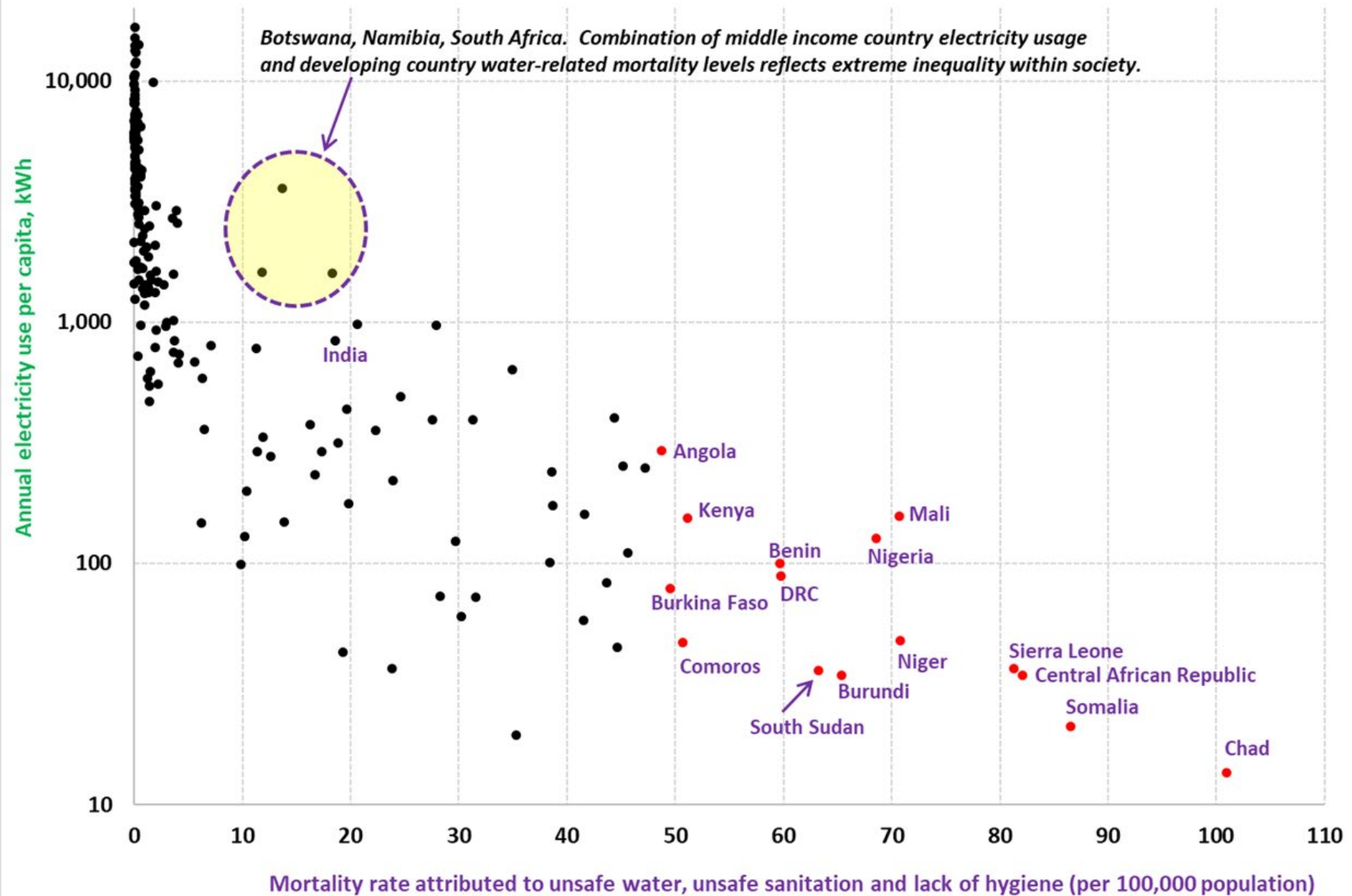
## Liberation



Source: NPR, IWMI

# It's Also a Lifesaver

- ▶ A sample of more than 200 countries and territories analyzed by the author reveals a strong negative relationship between access to electricity and mortality from waterborne illnesses.
- ▶ Sub-Saharan Africa—the world's most broadly energy-poor region—also has the countries with the highest rates anywhere globally of death per capita from unsafe water.
- ▶ Water for human consumption (as well as other uses) embeds an often underappreciated quantity of energy.
- ▶ As an example, every 1,000 gallons of groundwater supplies used in the City of San Antonio embeds an estimated 12 kWh, nearly the energy storage capacity of a Tesla Powerwall (14 kWh).



Source: CIA World Factbook, Author's Analysis

# Thinking About The Global Energy System: Having Your Burger and Eating It Too

*Energy Sourcing Reality now...*



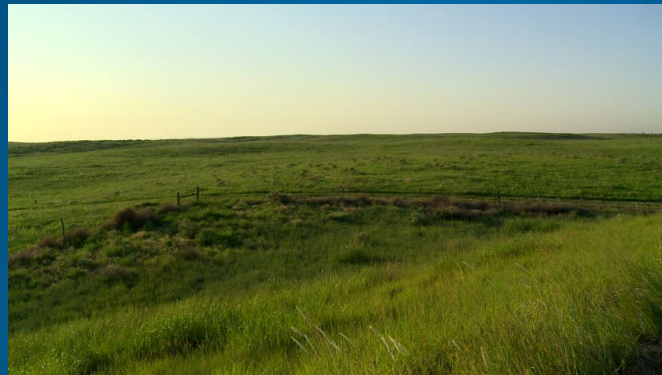
**Many dislike this part...**

Source: Motivar (Argentina)



**But you must have it to enjoy this part...**

*Moving into 2020s: Certain groups want the “energy burger” without the “cow”*



Source: Shutterstock



**at least not at transformational scale**



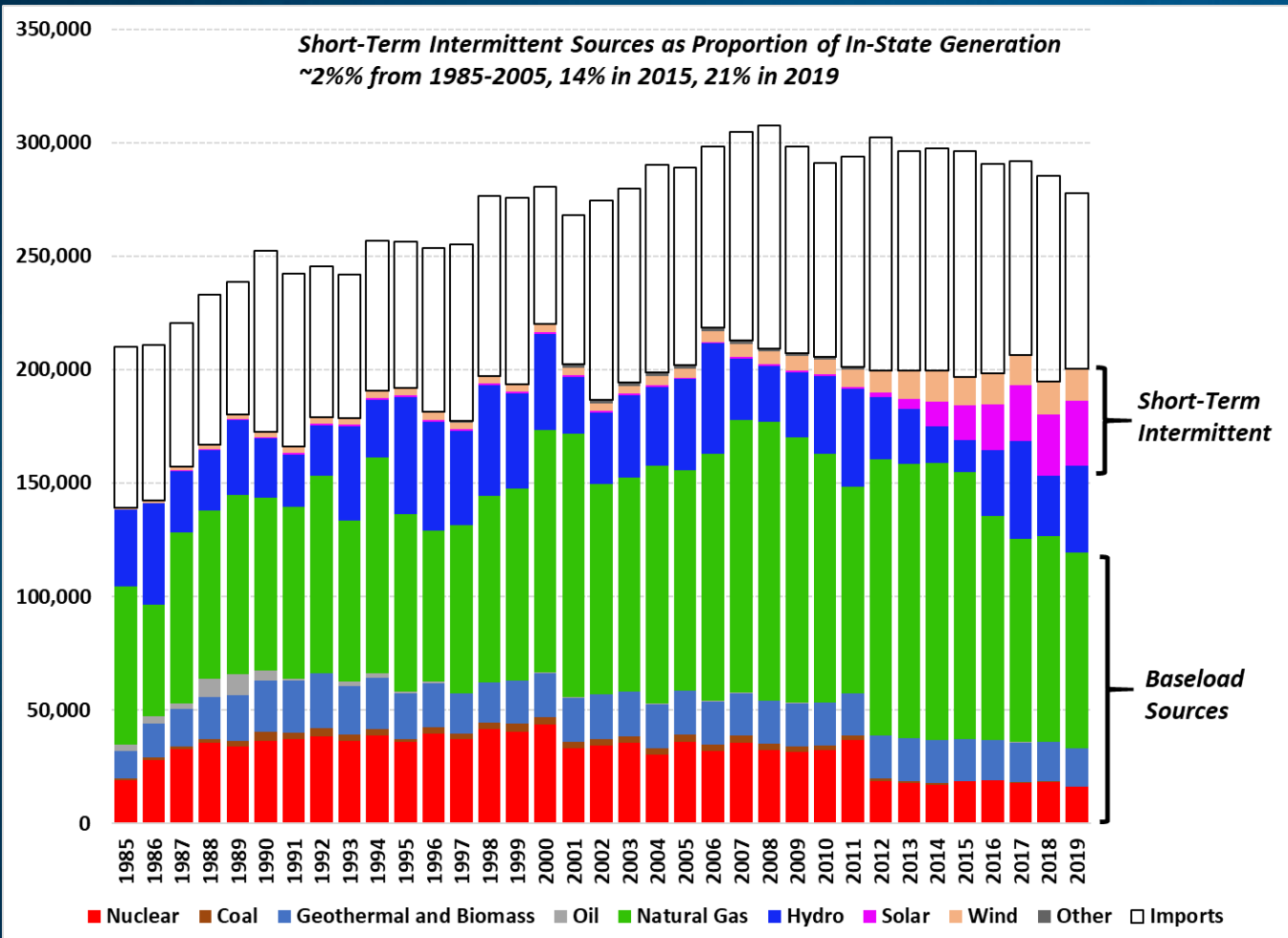
Source: Wikipedia

*Extending the meat analogy, bridging this gap in the 2020s requires a multi-source mindset*



# Pulling Cows From The System Quickly: What Happens to the Meat Market?

## California Electricity Generation By Source, GWh



Source: California Energy Commission

## California Blackouts



► “...California’s experience also underscores a growing consensus among energy scholars: that variable renewable energy technologies are unlikely to meet the grid’s power demand by themselves. They will play an important role, but more firm generating sources, like next-generation nuclear reactors, natural gas plants with carbon capture technologies, enhanced geothermal, and others that can balance out variable renewables, will be required.” —Alex Trembath and Zeke Hausfather, Slate, 19 August 2020 [emphasis added]

Source: BatteryIndustrytech

# The Digital Economy is Also Very Energy-Intensive

*World-scale data centers create electrical loads on par with large electric arc furnace steel mini mills*

**Apple's Maiden, North Carolina Data Center Reportedly uses 100 MW of Electricity, Approximately The Same As an Arc Furnace Capable of Producing 1.4 million Tonnes per Year of Steel.**

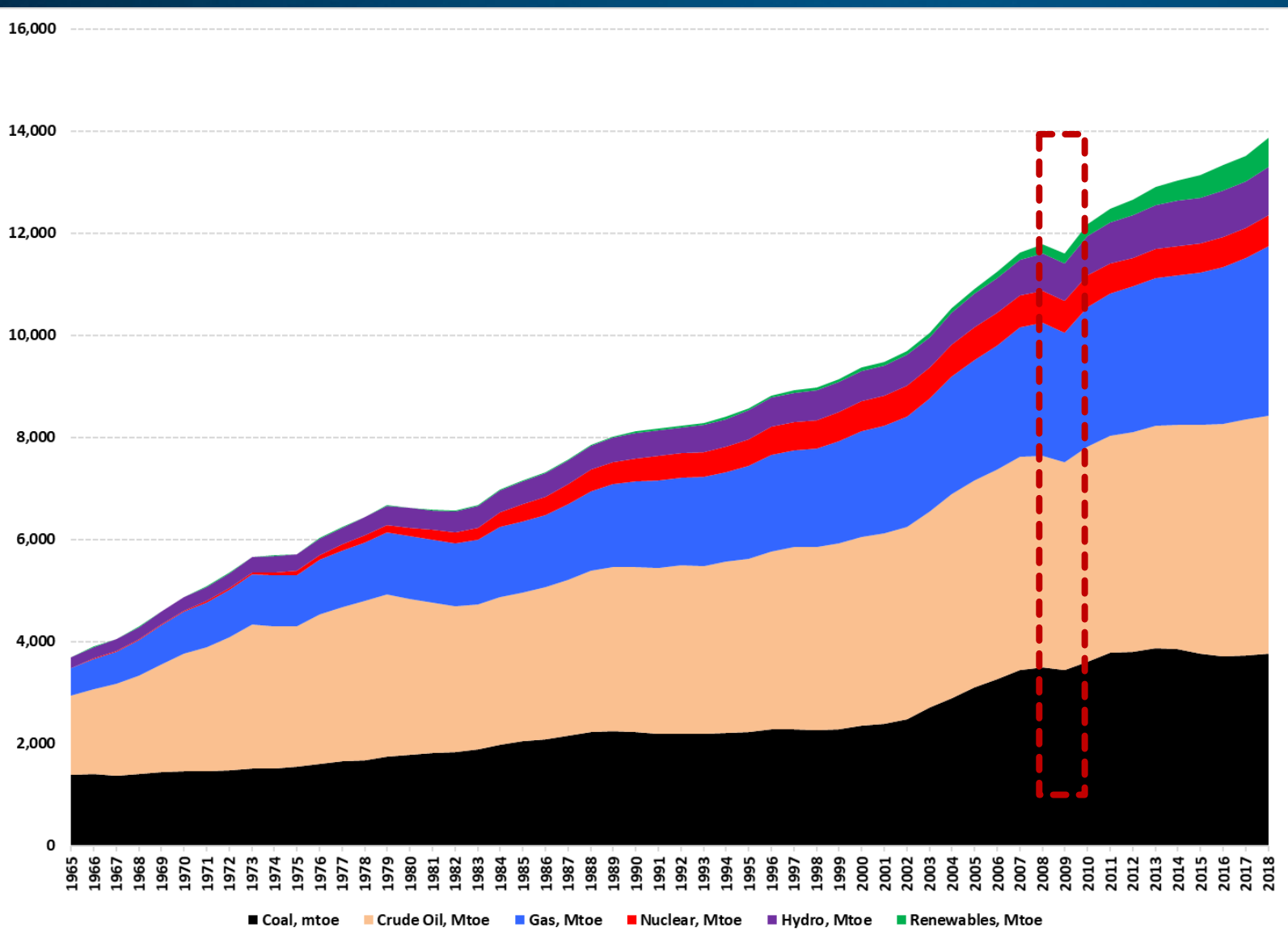


**In Case The Prior Slide Didn't Convince You...Here is Large Data Center in Northern China With Its Own Adjacent Power Plant**



# Energy Transitions: Global Perspective

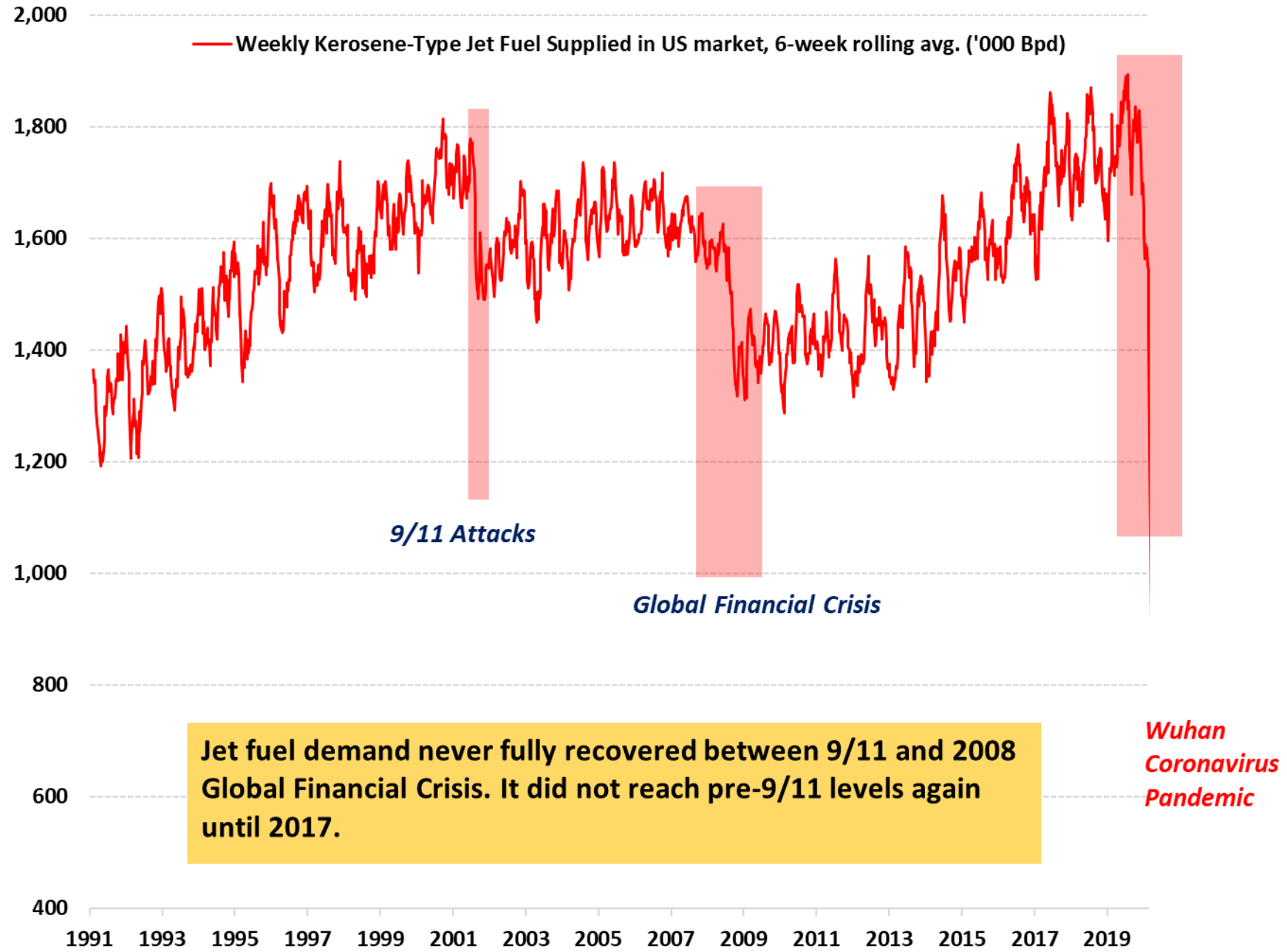
## Global Primary Energy Consumption by Source, Million Tonnes Oil Equivalent



	Coal YoY Change, Mtoe	Oil YoY Change, Mtoe	Gas YoY Change, Mtoe	Nuclear YoY Change, Mtoe	Hydro YoY Change, Mtoe	Renewables YoY Change, Mtoe
1965						
1966	15	119	49	2	15	0
1967	-22	119	43	2	5	0
1968	21	153	58	2	11	0
1969	44	165	68	2	14	0
1970	21	182	67	3	12	1
1971	-8	136	58	7	11	0
1972	16	186	49	9	12	0
1973	44	204	44	12	4	0
1974	1	-41	24	14	29	0
1975	30	-28	0	23	5	0
1976	56	180	60	16	-1	1
1977	48	100	35	23	8	0
1978	19	97	46	19	26	1
1979	78	51	71	5	18	1
1980	43	-124	10	16	7	1
1981	25	-110	14	28	6	1
1982	20	-90	7	18	16	2
1983	56	-17	20	26	19	2
1984	82	66	104	49	14	2
1985	78	4	30	55	9	0
1986	24	88	14	24	6	2
1987	83	61	75	32	6	1
1988	64	104	68	35	15	1
1989	23	52	70	12	-3	3
1990	-26	34	50	13	17	11
1991	-24	2	43	22	12	2
1992	-7	57	8	4	0	2
1993	9	-21	17	16	30	1
1994	13	72	11	9	3	2
1995	12	46	62	22	29	2
1996	56	80	88	19	8	1
1997	3	92	-5	-4	10	5
1998	-17	19	35	9	5	2
1999	12	64	53	21	4	3
2000	78	45	78	13	11	4
2001	-36	33	30	16	-15	4
2002	93	32	64	10	11	9
2003	218	87	57	-12	-1	8
2004	188	146	85	26	40	11
2005	212	53	67	3	25	13
2006	160	53	70	8	25	17
2007	186	64	106	-13	11	24
2008	49	-19	64	-2	42	30
2009	-54	-71	-73	-9	-2	26
2010	159	131	196	15	41	35
2011	173	43	56	-26	15	35
2012	16	53	74	-41	38	36
2013	71	54	38	4	29	49
2014	-3	35	23	11	20	45
2015	-97	81	65	8	1	49
2016	-59	82	86	8	33	50
2017	25	65	83	5	5	-9
2018	41	40	153	15	30	71

# Don't Over-Weight Shocks: Structural Change Generally Drives Commodity Demand Shifts

- ▶ The coronavirus may turn out to be structurally transformation to certain segments of oil demand—such as jet fuel—by causing businesses to re-evaluate the prior mentality of “let’s get on the plane now and fly there.”
- ▶ For other parts of the market—especially those levered to freight—the demand dent from lockdowns will likely be temporary.

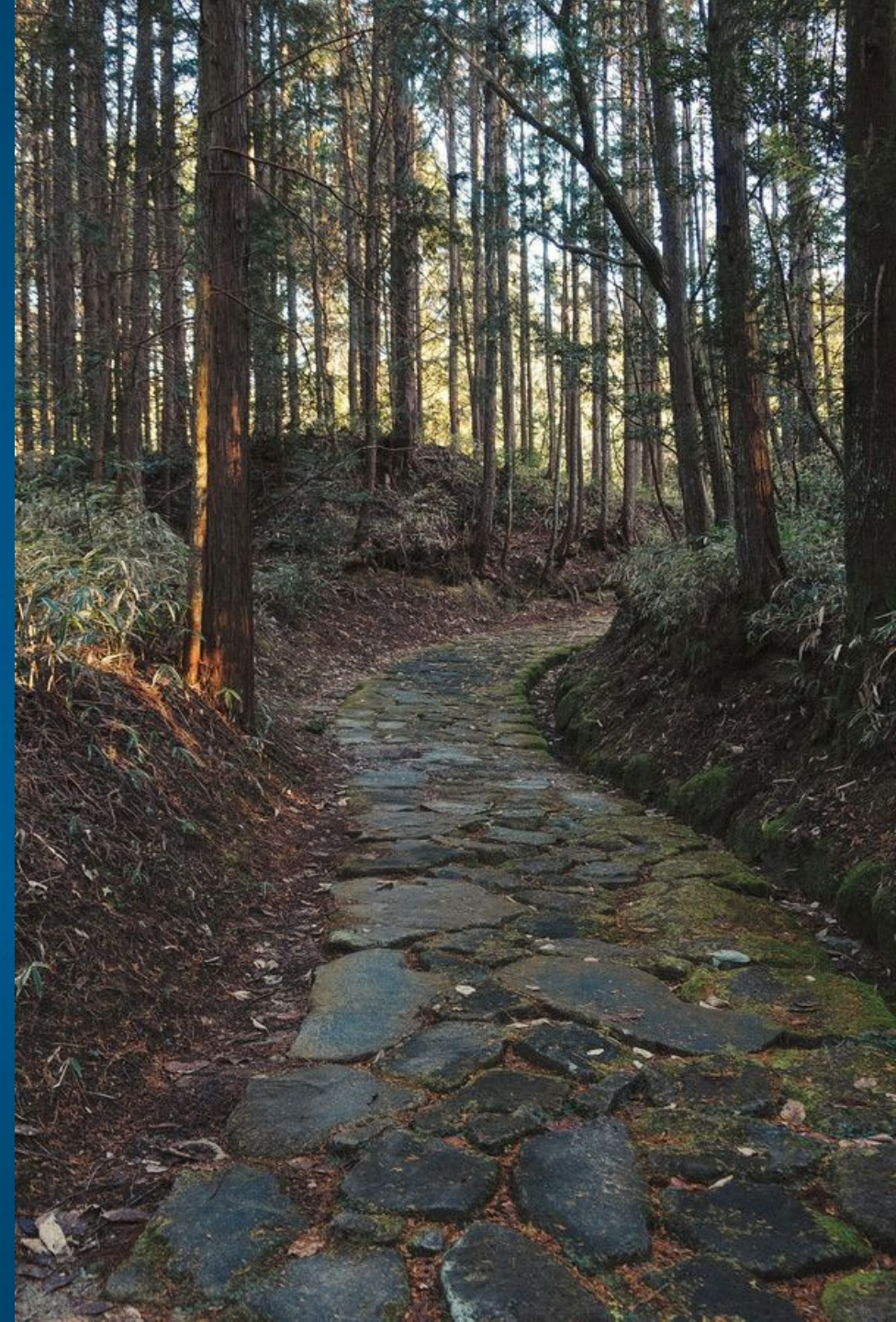


Source: EIA, Author's Analysis

**Four Key Factors Influencing  
Humanity's Energy Sourcing and Use:  
Legacy, Scale, Availability, Reliability**

# What Are “Legacy” and “Scale?”

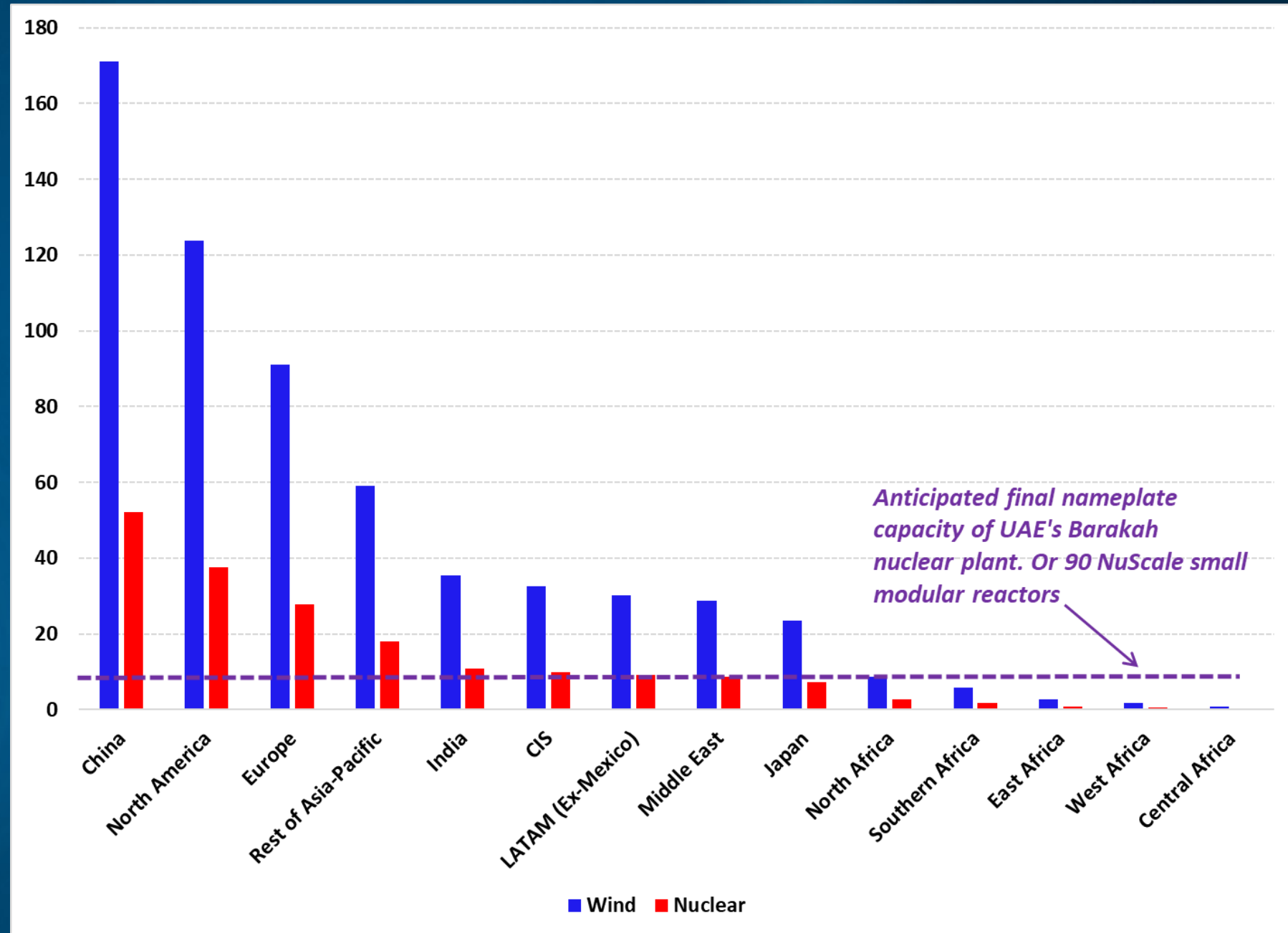
- ▶ “Legacy” in an energy setting refers to the installed base currently used to produce, process, distribute, and consume various energy sources. The sunk capital cost is in the trillions of dollars, with annual global maintenance requirements likely in the hundreds of billions annually. The phenomenal size of these investments, the ecosystems that have grown up around them, and the various constituencies with vested interests in their function—including consumers—makes change an incremental proposition. It’s tough to carve a new path.
- ▶ “Scale” refers to the sheer size of these systems. Scale also provides the heft and relative efficiency from serving a large customer footprint—substituting a \$500 million power plant and large transmission lines for an army of local generators that collectively cost more and require far more sustainment resources per unit of energy produced. Scale often facilitates delivery of services to a maximal number of consumers per unit of capital spent in building and maintaining the system.



# Turnover Arithmetic: Electricity Production

- Key takeaway is that nuclear could make a lot of sense as a decarbonization tool that still ensures steady baseload power supplies. At current construction cost levels, the upfront capital costs of the installed capacities shown in the chart are roughly the same (between \$800 and \$850 billion).
- If modular reactors can be produced at scale, the capital costs could begin to more strongly favor nuclear.
- Factoring in costs of storage and other grid-stability measures further favors nuclear.

## Installed Capacity Needed to Substitute for 5% of 2019 Electricity Production, GW



Source: BP Statistical Review 2020, Author's Analysis (assuming 25% capacity factor for wind, 82% for nuclear)

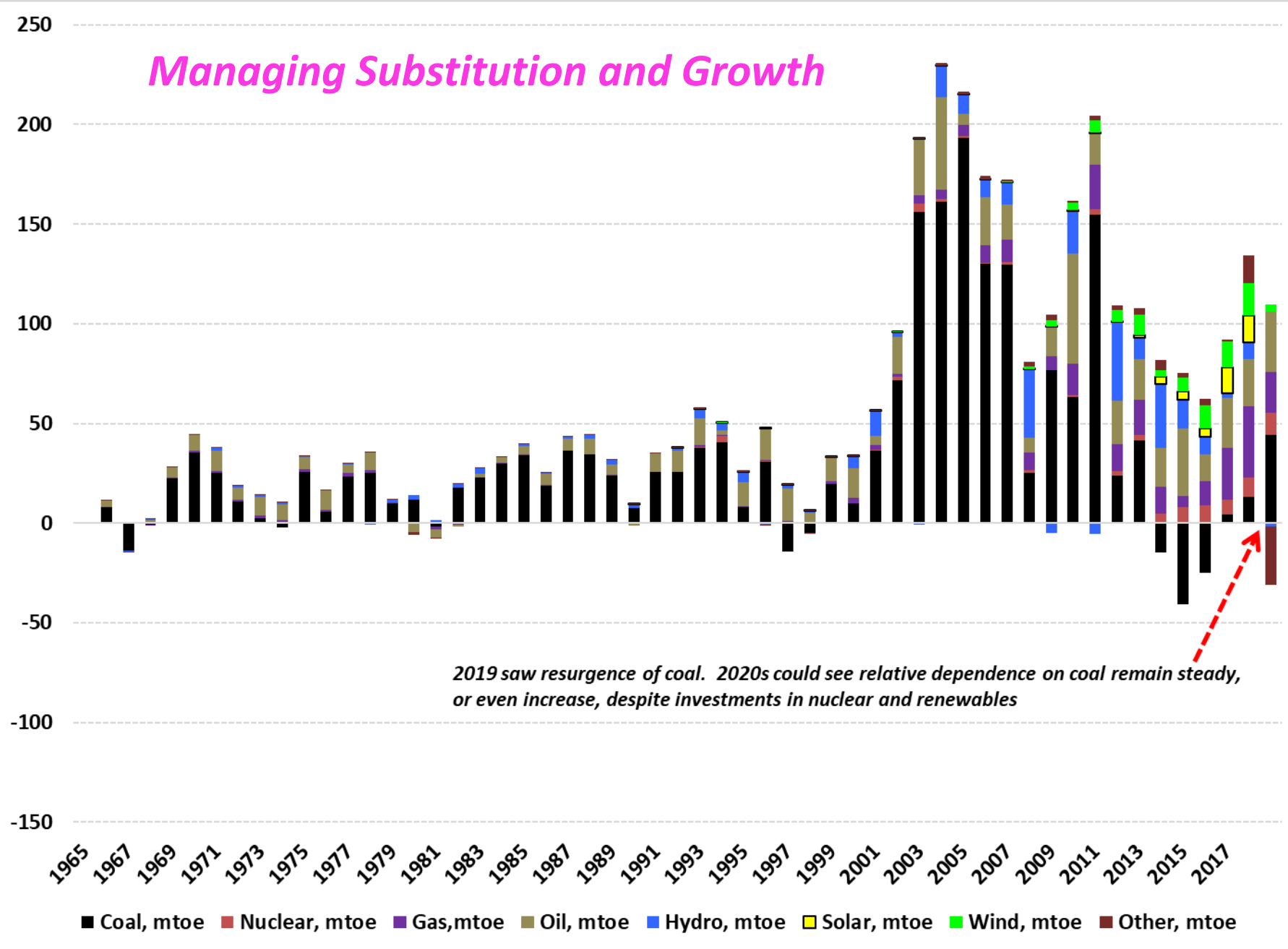
# Scale: China, India, U.S. as The Global Energy Titans

- ▶ Where these three go in the energy consumption and sourcing, so goes also the global emissions balance.
- ▶ U.S. energy transition is primarily about substitution of the existing installed base.
- ▶ China and India have to manage both substitution and deciding what sources will meet future energy demand growth.
- ▶ All three must also make decisions amidst an incipient U.S.-China technology Cold War and rising tensions between China and both the U.S. and India across the diplomatic, economic, and military spectrum. Some potential outcomes of these conflicts may yield a more sustainable energy slate, others not so much.

		Proportion of 2019 Global Total Use	Proportion of Net Global Demand Change Between 2010 and 2019
<i>Scaling: In energy unit terms, the world consumed 10X as much oil as it did renewables</i>	Primary Energy Consumption	46.3%	65.0%
	Electricity Generation	49.9%	72.2%
	CO2 Emissions	50.5%	64.2%
	Oil/Liquids Demand	39.5%	64.1%
	Coal Demand	70.7%	80.6%
	Natural Gas Demand	30.9%	51.7%
	Hydro Demand	40.3%	79.5%
	Nuclear Demand	44.6%	1087.6%
	Renewables Demand	47.2%	50.9%

# China's Energy Supply: "All Sources on Deck"

- ▶ Future increasingly looks like "clean" plus "coal"
- ▶ Gas use likely to rise as well, particular with Power of Siberia (and possible subsequent pipelines) and deepening of Russia-China commodity sourcing relationship.
- ▶ Nuclear share likely to begin rising substantially 2025 and beyond, especially if overall economic growth (and rate of energy consumption) were to substantially slow.

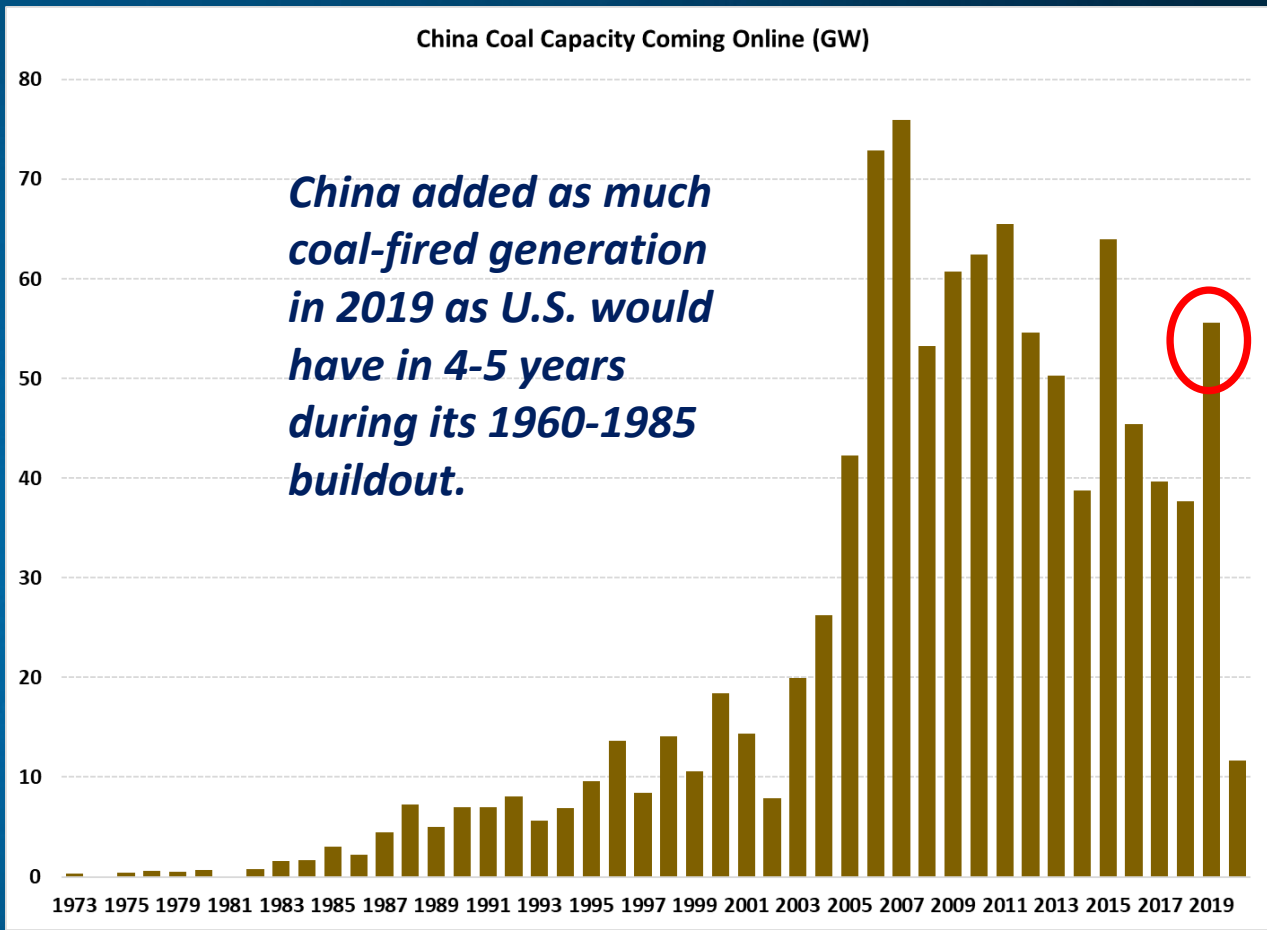
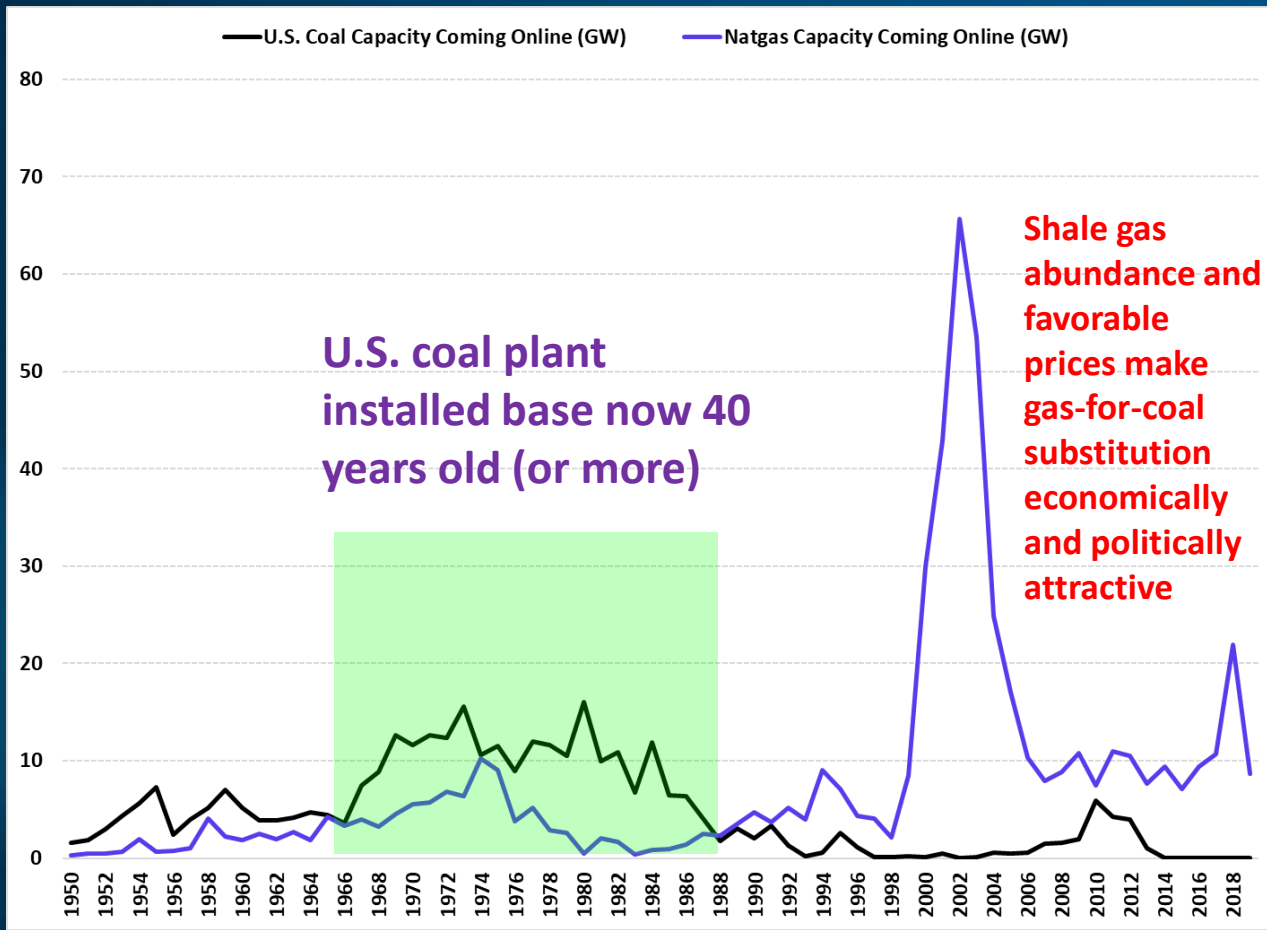


Source: BP Statistical Review of World Energy 2020

# Legacy Influenced by Local Resource Availability and Global Conditions

## U.S. Coal and Gas-Fired Power Generation Capacity Additions

## China Coal-Fired Power Generation Capacity Additions



Source: EIA, Author's Analysis

Source: EndCoal, Author's Analysis

The U.S. example also shows how unexpected macro events can accelerate decoupling from legacy burdens.

# The “Innovation Gospel” Versus Legacy and Scale

- “Innovation” and “energy transition” are two of the presently most overused—and misused—words in the English language
- The ability to leverage pre-existing supply chains and human capital turbocharge energy system change as well.
- Here we have “sexy” and “scalable.” To change the world, we also need “sustainable.” Both below examples will be challenged...

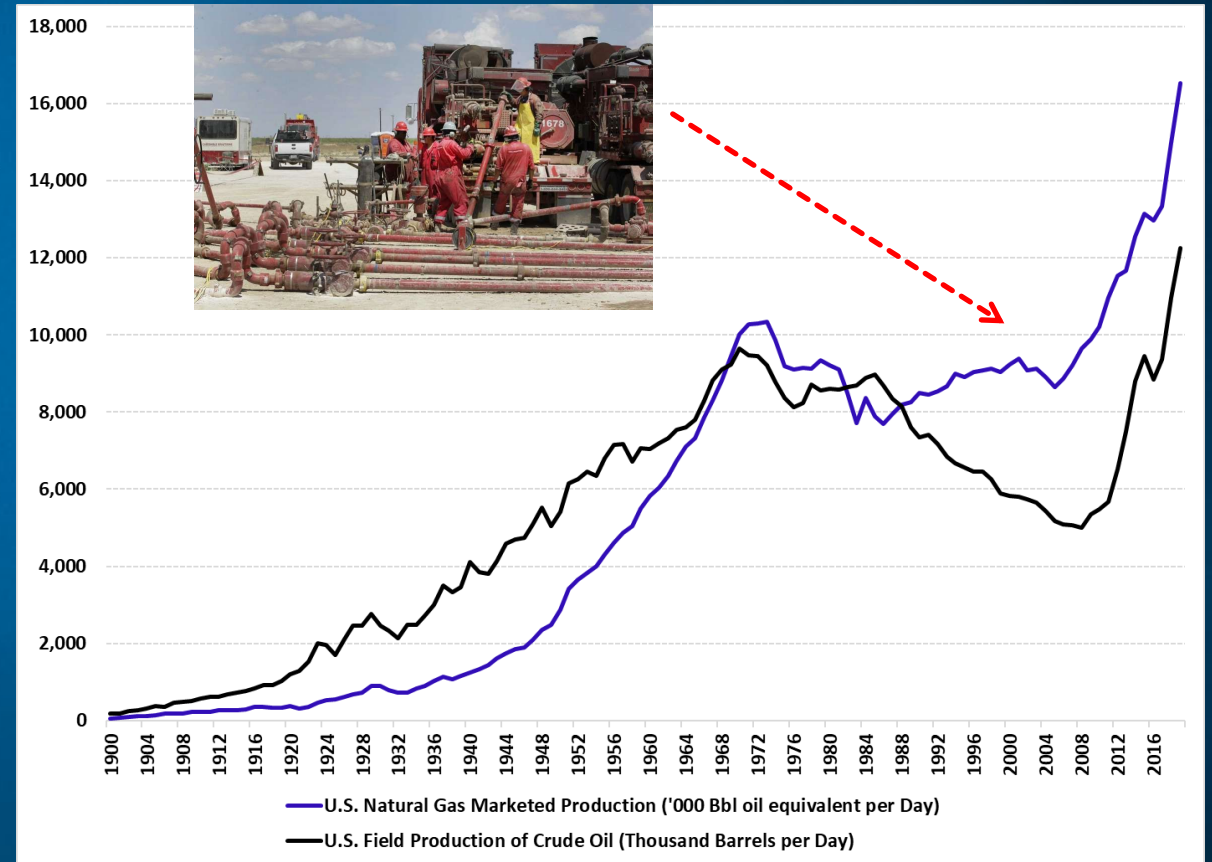
## Energy Innovation: “Sexy” Example



Source: Elektrek

**Tesla rightfully evokes images of high-tech, but the unconventional oil & gas boom also floats atop a raft of proprietary technical innovations.**

## Energy Innovation: “Scalable” Example



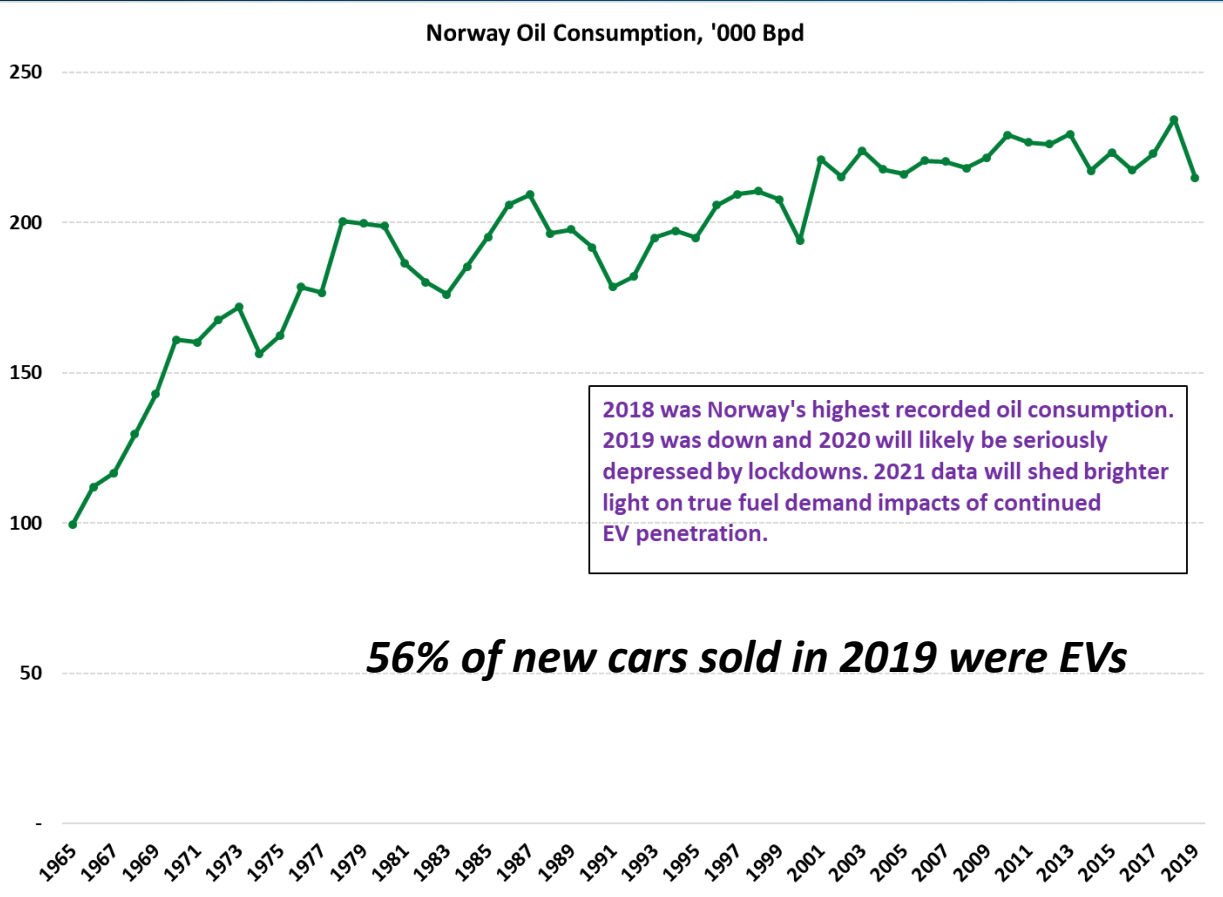
Source: EIA, Houston Chronicle, Author's Analysis

**Legacy and Scale Also Mean That The Pace of Transition to New Energy Sources and The Level of Financial Risk in These Operations Will Likely Be Closely Tied to Market Dynamics of Systemically Important Legacy Fuels, Especially Crude Oil, For Years to Come**



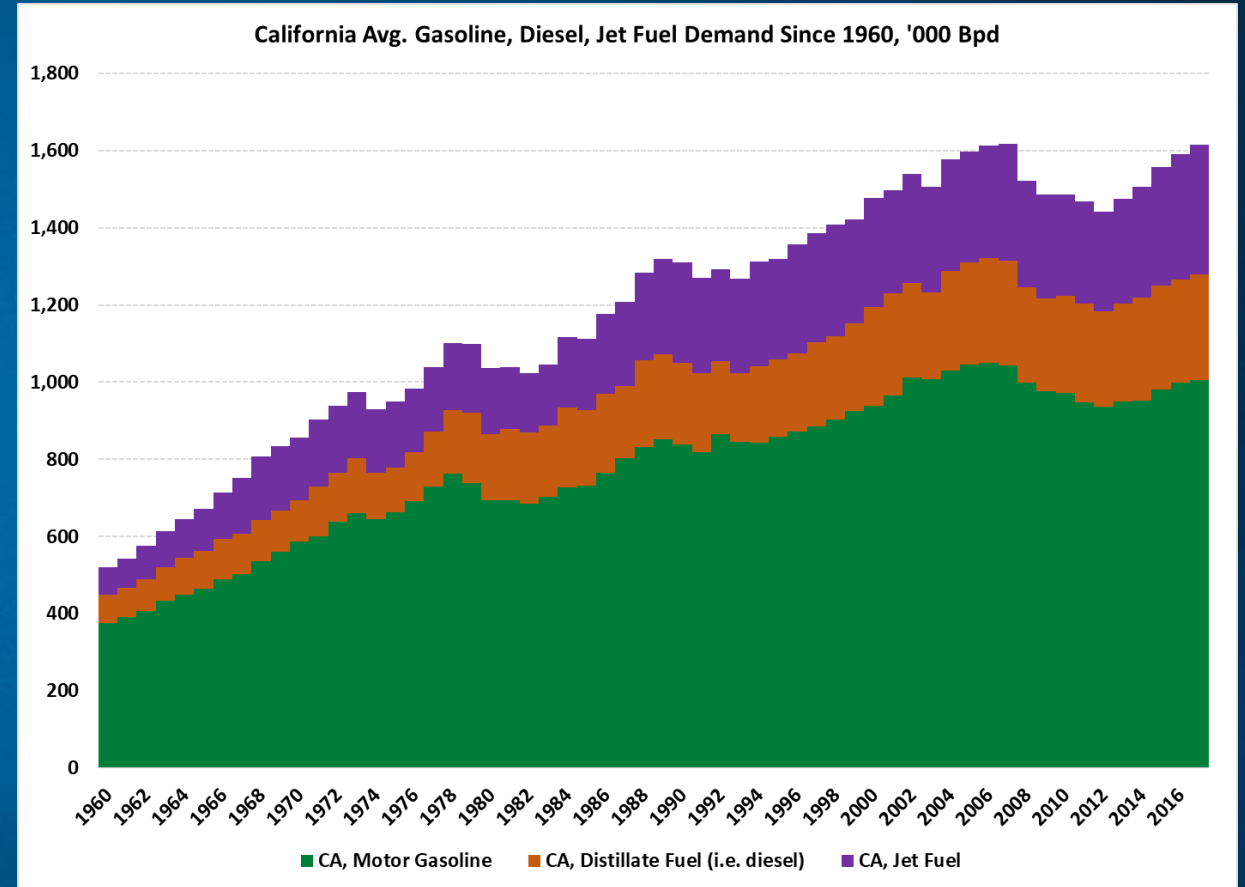
# Oil is “Sticky”: Consider Oil Demand Trends in Key Global EV Markets

## Norway—World’s Highest EV Penetration Rate



Source: BP Statistical Review 2020

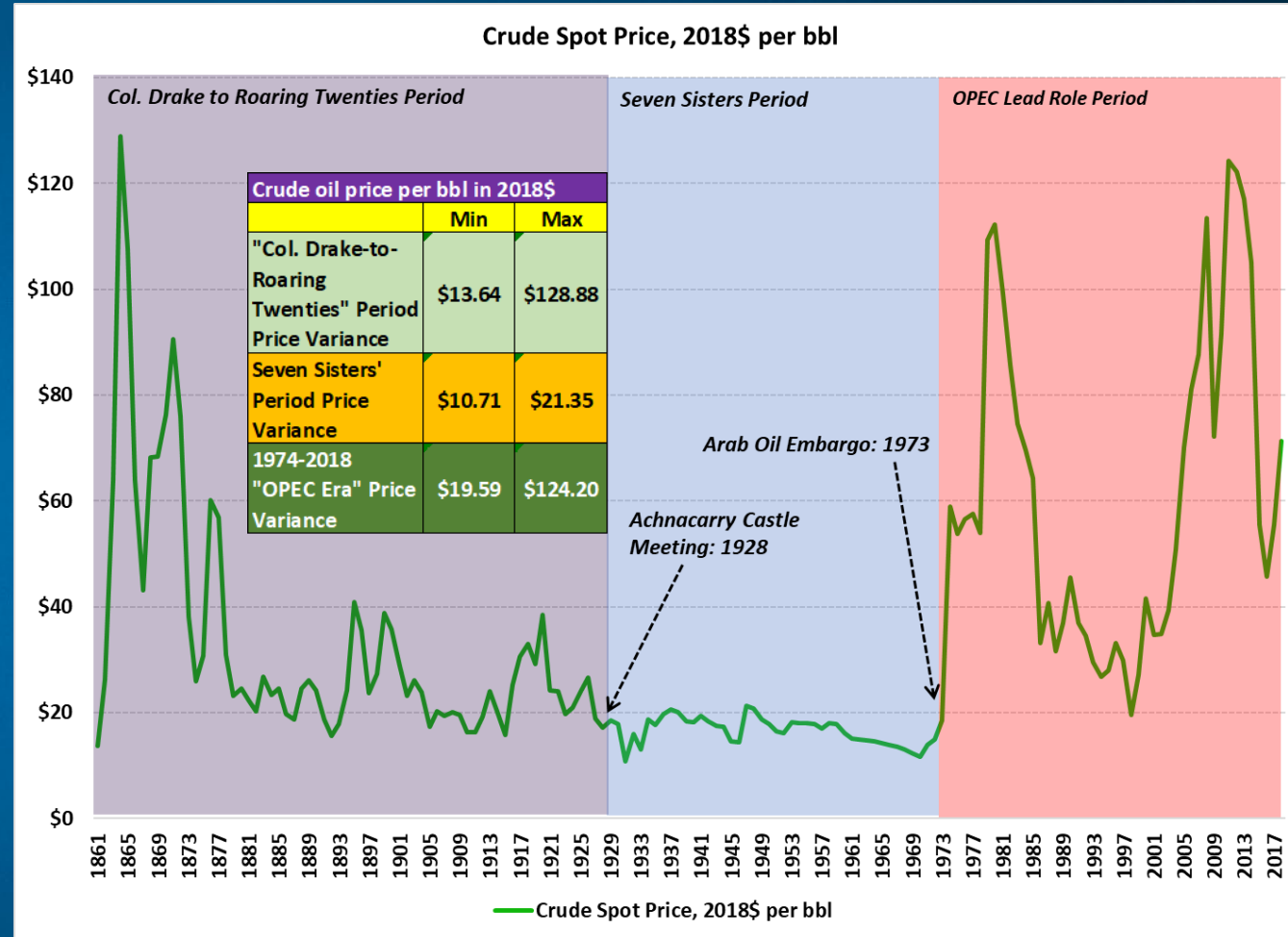
## California—US EV Share Leader, World’s 15<sup>th</sup> Largest Oil Consumer



Source: EIA

# Oil Prices Are a Volatile Thing to Be Linked To

**Bay of Fundy: Not For Everyone, But Fishing Still Very Much Feasible Despite Extreme Tides**



- ▶ What would the “uncertainty discount” need to be to entice investors back to oil & gas upstream assets?

Sources: <https://novascotia2014.files.wordpress.com/2014/01/fundy-tides-comparison4.jpg>, BP Statistical Review of World Energy 2020, Author’s analysis

**Sustainable Energy Transition Demand  
Intellectual and Policymaking Sobriety**

# Thinking Objectively About What Natural Disasters Mean

- ▶ Sometimes nature unleashes unusual fury: Hurricane Harvey in 2017 (or the Great Hurricane of 1780 when there was much less CO2 in atmosphere)
- ▶ And sometimes the problems are greatly exacerbated by where we have chosen to live (tornadoes in Dixie Alley, flooding along Gulf Coast) and how we've intervened in natural metabolisms that are thousands of years old (fire in California)
- ▶ We also need to be humble about humanity's influence on the Earth's climate.

www.propublica.org/article/they-know-how-to-prevent-megafires-why-wont-anybody-listen

PROPUBLICA They Know How to Prevent Megafires. Why Won't Anybody Listen? Newsletters Search Donate

## They Know How to Prevent Megafires. Why Won't Anybody Listen?

This is a story about frustration, about watching the West burn when you fully understand why it's burning — and understand why it did not need to be this bad.

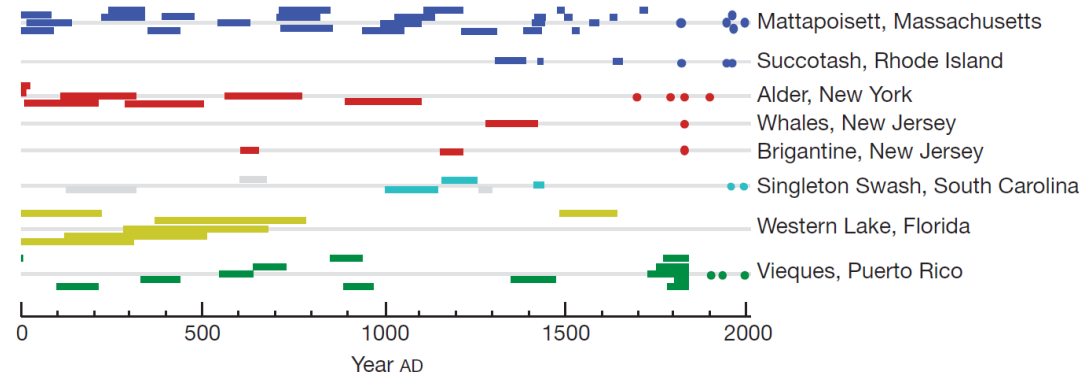
by Elizabeth Weil, Aug. 28, 1:30 p.m. EDT

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What a week. Rough for all Californians. Exhausting for the firefighters on the front



**Figure 1 | Overwash sediment records of landfalling hurricanes.** Event histories are shown for New England (blue), Mid-Atlantic (red), the southeastern US coast (turquoise; grey denotes oyster-bed events not used for reasons discussed by ref. 28 and in the Supplementary Information), the

Gulf Coast (yellow) and the Caribbean (green). The horizontal width of the shaded rectangles indicates the  $\pm 1\sigma$  age model uncertainties. Circles indicate historical hurricane events.

# Carbon Assets Won't Just Go Away: Divestment Likely Creates a "Selldown" Ecosystem

## Exhibit A: Oil Sands



Source: Intl. Business Times

### What publicly-traded oil Majors increasingly see

### What buyers in the "selldown ecosystem" see

https://follow-this.org/resolutions-results/

HOME FOLLOW THIS IN THE MEDIA SUPPORT US

Top 10 UK investors

### Climate Resolutions

Investor	Total Assets	Shell			Equinor	BP
		2017	2018	2019		
Legal & General	€ 1,131 billion	✗	✗	—	✗	
Insight	€ 692 billion			—	○	
Aberdeen	€ 563 billion		✗		✗	
Schroders	€ 493 billion	✗	✗	✗	✗	
HSBC	€ 398 billion					
M&G	€ 373 billion		✓	✓	✓	
AVIVA INVESTORS	€ 366 billion	✓				
RAIFFEIS BANK	€ 193 billion		✗	—	—	
AON	€ 135 billion					
ROYAL LONDON	€ 126 billion	○	✗	—	✗	

✓ for  
 ○ abstain  
 ✗ against  
 — no shares

### Canadian Natural Advantages

- Large, Long Life Low Decline asset base lowers risk profile
  - Represents ~750,000 bbl/d or ~77% of total liquids production
    - ~450,000 bbl/d of no decline SCO production
  - Resilient through commodity cycle
  - Minimal net asset value erosion during periods of low prices better protects creditors and shareholders
  - No/Low reserve replacement risk
  - Minimal geological, production and execution risk

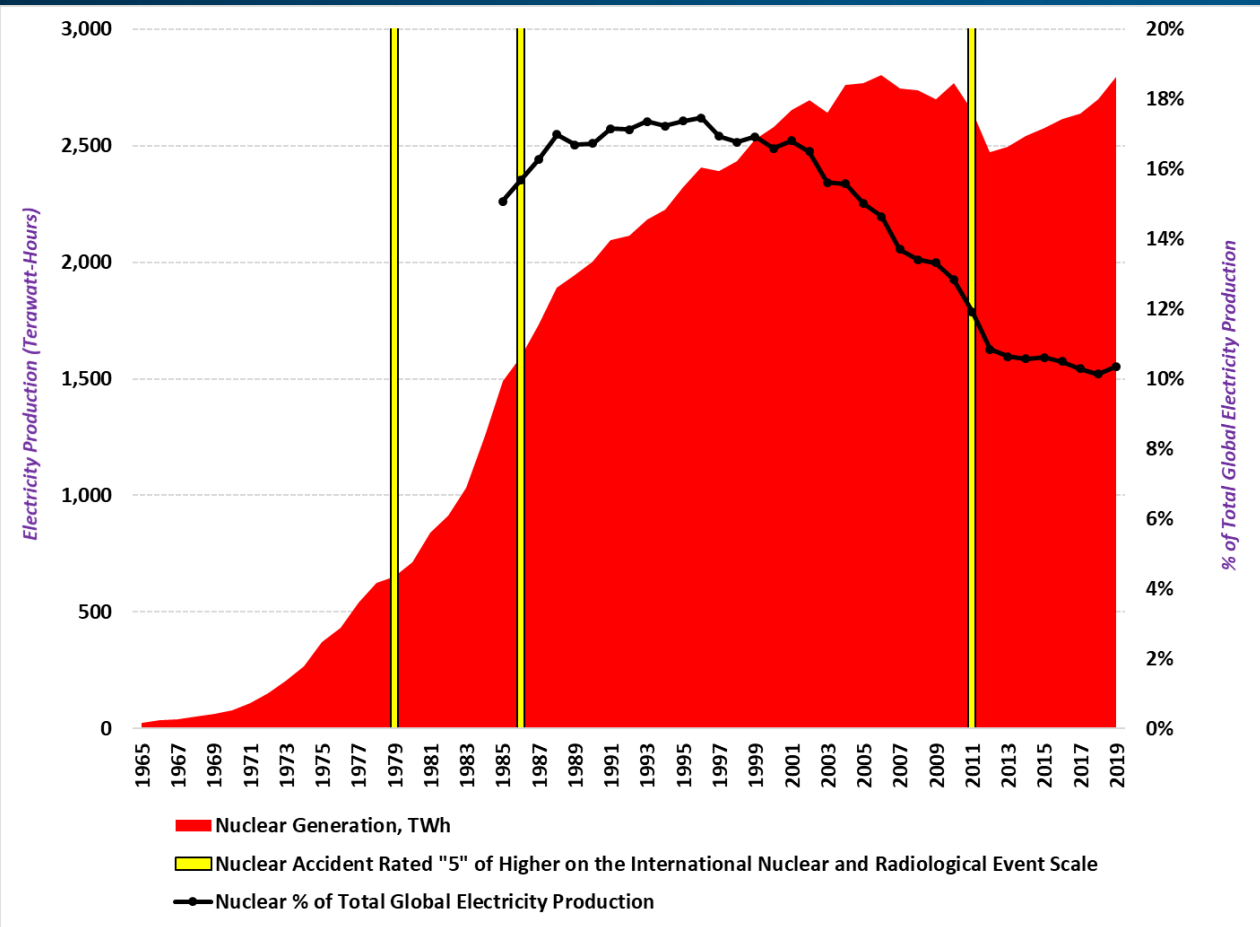
- Free cash flow generation
  - Free cash flow breakeven<sup>(2)</sup> → US\$30 - US\$31 WTI/bbl (including current dividend)
  - Operating breakeven<sup>(3)</sup> → US\$25 - US\$26 WTI/bbl (including maintenance capital)

**Key Takeaway: One shareholder's liability is another's resilient cashflow queen.**

# Closing Thoughts

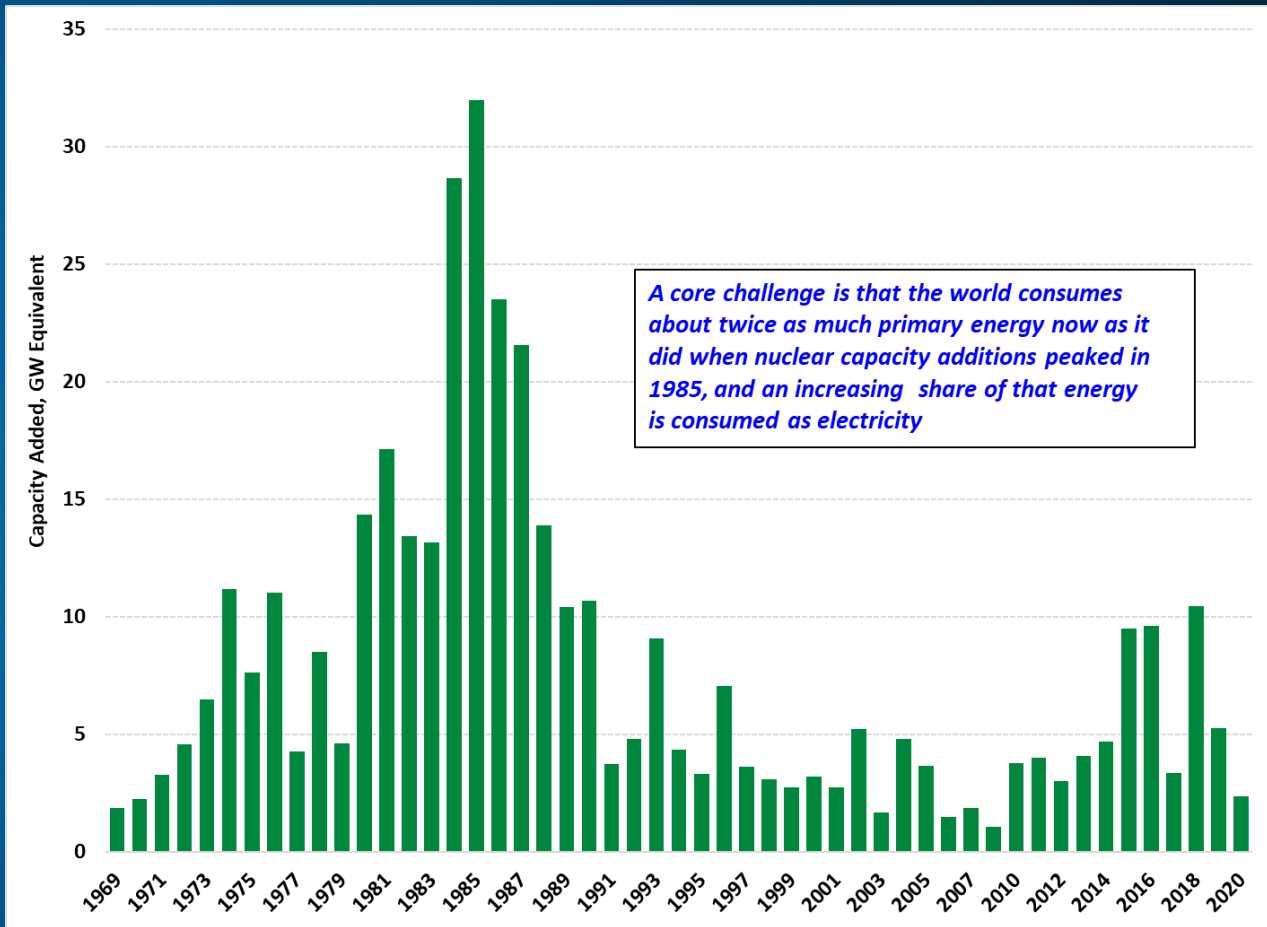
# The Global Energy Portfolio Will Need to “Glow” a Bit to Turn Sustainably Green

## Nuclear Electricity Production vs. Key Incidents



Source: BP Statistical Review of World Energy, Author's Analysis

## Nuclear Reactor Annual Global Capacity Additions, GWe



Source: World Nuclear Association, Author's Analysis

# Energy Costs Not Just a Technocratic Enterprise: Public Opinion Matters

## Newtonian physics



Source:  
<http://mitchlanaillustration.blogspot.com/search/label/Sir%20Isaac%20Newton>

Increasing the economic burden of something as fundamental to life as energy can trigger pre-existing social stressors.

## Potential Political Newtonian Physics of Energy Price Increases

Ivory Coast: 2016



Iran: 2019



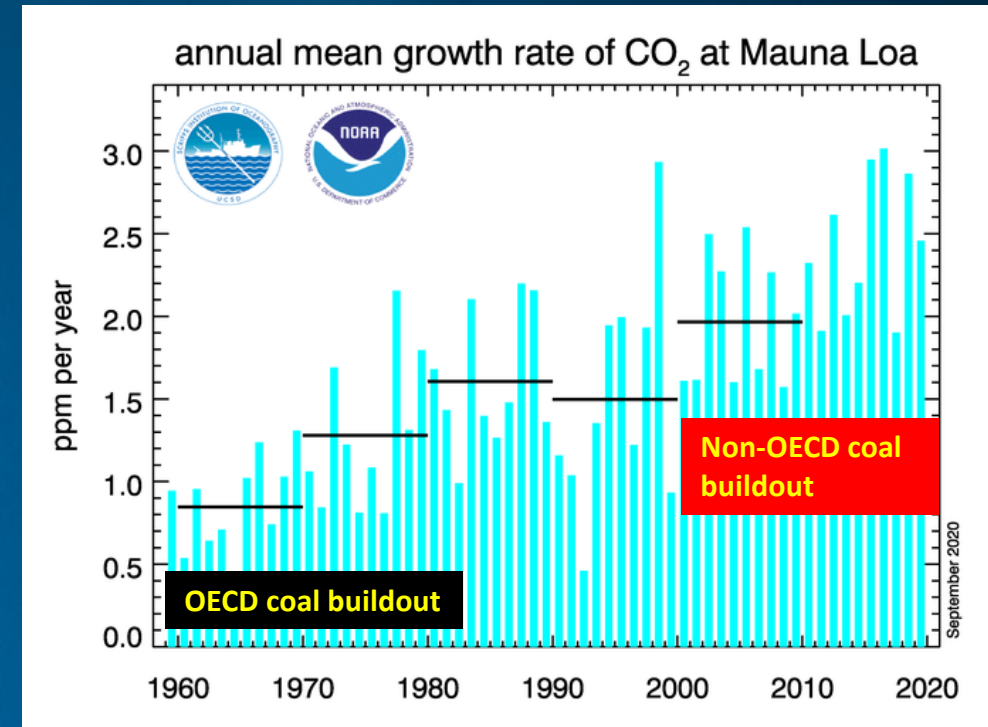
France: 2018-Present



Source: iAfrica, Daily Telegraph, NBC News (clockwise)

# Bumps Ahead, But We Can Do This

- ▶ As my colleague Dr. Ken Medlock noted recently, *“Even if OECD emissions dropped to zero now, global emissions would still exceed 1995 levels.”*
- ▶ Atop this arithmetic reality is a second challenge—the coal buildout that happened in the OECD world in the 1960s and 1970s has happened only in the past 15 years in key non-OECD energy consumers—and indeed, still goes on at scale today.
- ▶ Decades of additional high non-OECD carbon emissions are thus being baked into the global carbon equation.
- ▶ Coal combustion also emits toxic compounds such as mercury that we cannot build capture systems or sinks for the way we are likely poised to do for carbon.
- ▶ As we enter the 2020s, we embarking on a future path that will likely include continued energy source transition, more direct capture of carbon, more nuclear, more resource geopolitics, and resilience and adaptation measures implemented at much larger scale than before.



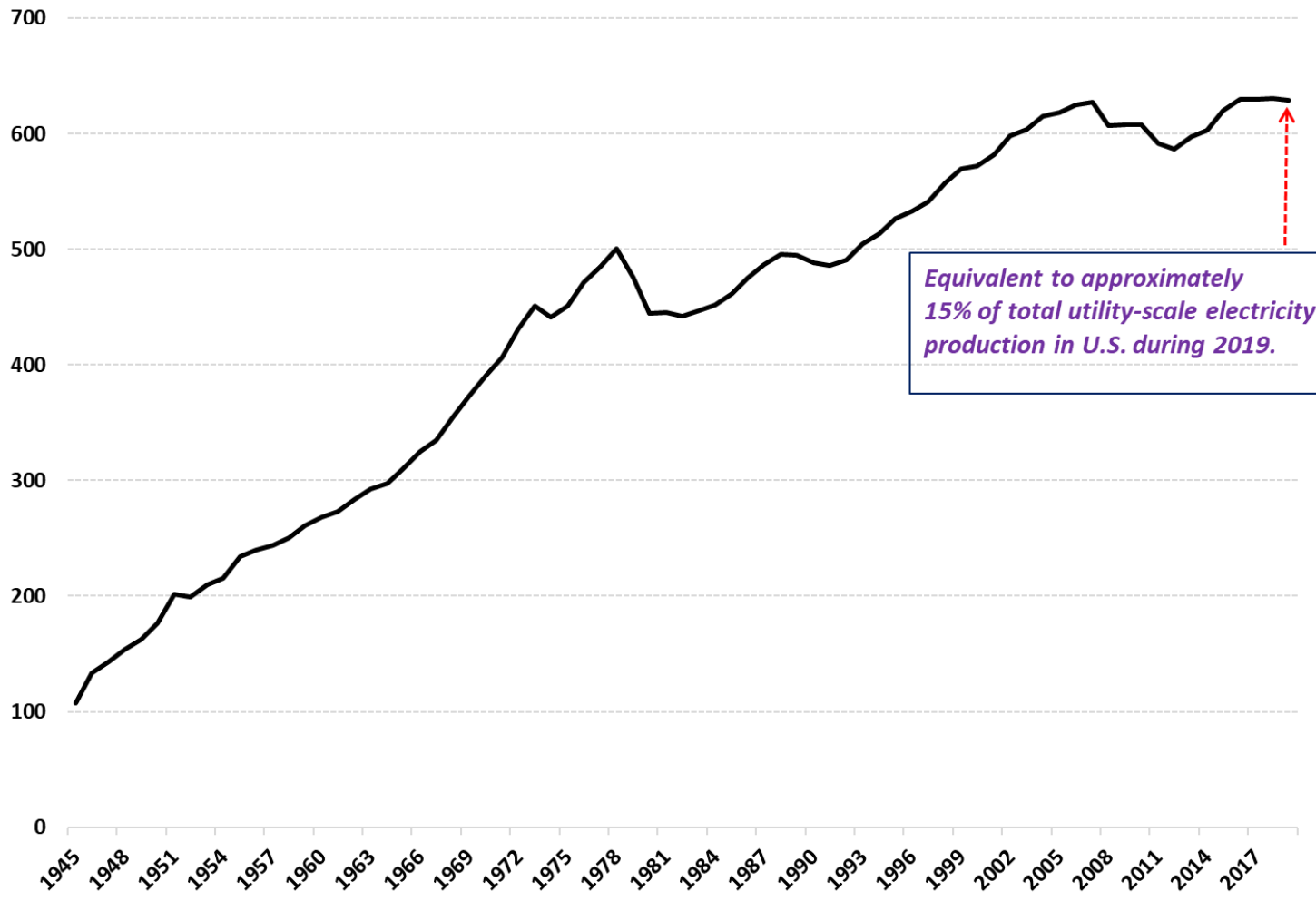
<https://www.esrl.noaa.gov/gmd/ccgg/trends/gr.html>

***A tough decade lies before us, but we can do this. The very fact the humanity has industrialized so successfully and that we are forced now to confront emissions issues on this scale is of itself a cause for some celebration given where we were as a species just 500 years ago. At the same time, billions of our kin still suffer from energy poverty. Getting clean and getting available poses knotty challenges, but I'm optimistic we'll get it done despite bumps in the road.***

**Extras**

# Why Scale Matters: The Potential Impacts of Potential Electric Vehicle Futures on Power Infrastructure in the U.S.

Annualized EV Power Consumption to Offset 50% of Gasoline Demand, TWh



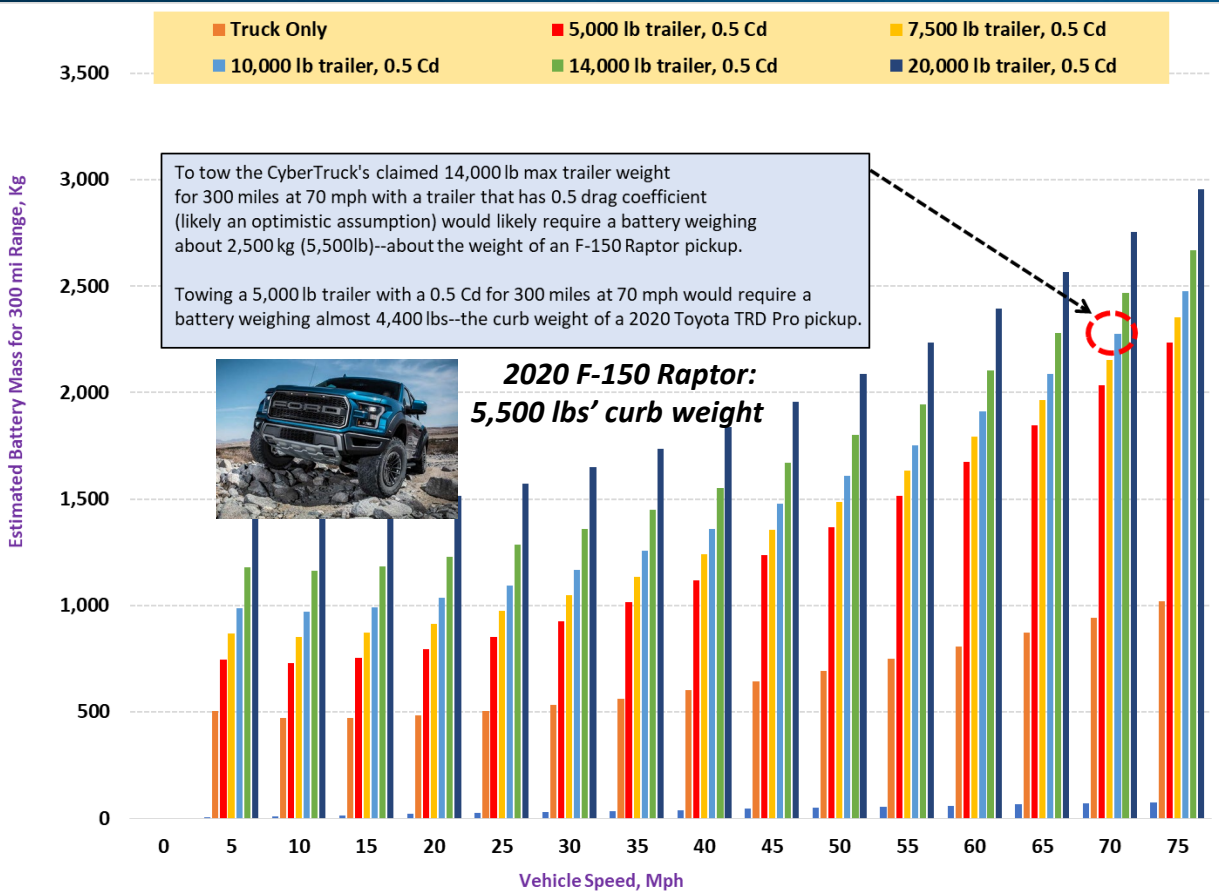
Source: EIA, Author's Analysis

- ▶ Assume that (1) gasoline has a “raw” energy content of 1,481 kWh per barrel and (2) adjust that number on the basis of EVs having a 4:1 fuel use efficiency advantage over ICE vehicles.
- ▶ Those parameters mean that for every 10% of U.S. gasoline demand displaced by EVs (using 2019 demand as the baseline), the amount of electricity required is approximately 3% of total power generated in the U.S. by utility-scale facilities.
- ▶ Thus, a 50% displacement of gasoline demand by EVs would require a 15% increase in U.S. power generation output, assuming that vehicle usage did not change.
- ▶ The roughly 630 terawatt-hours of electricity needed to accomplish that displacement could require more than \$100 billion in new capital investment if supplied from natural gas-fired power plants. (assuming 57% capacity utilization and a construction cost of \$837/kW, per EIA 2018 data)

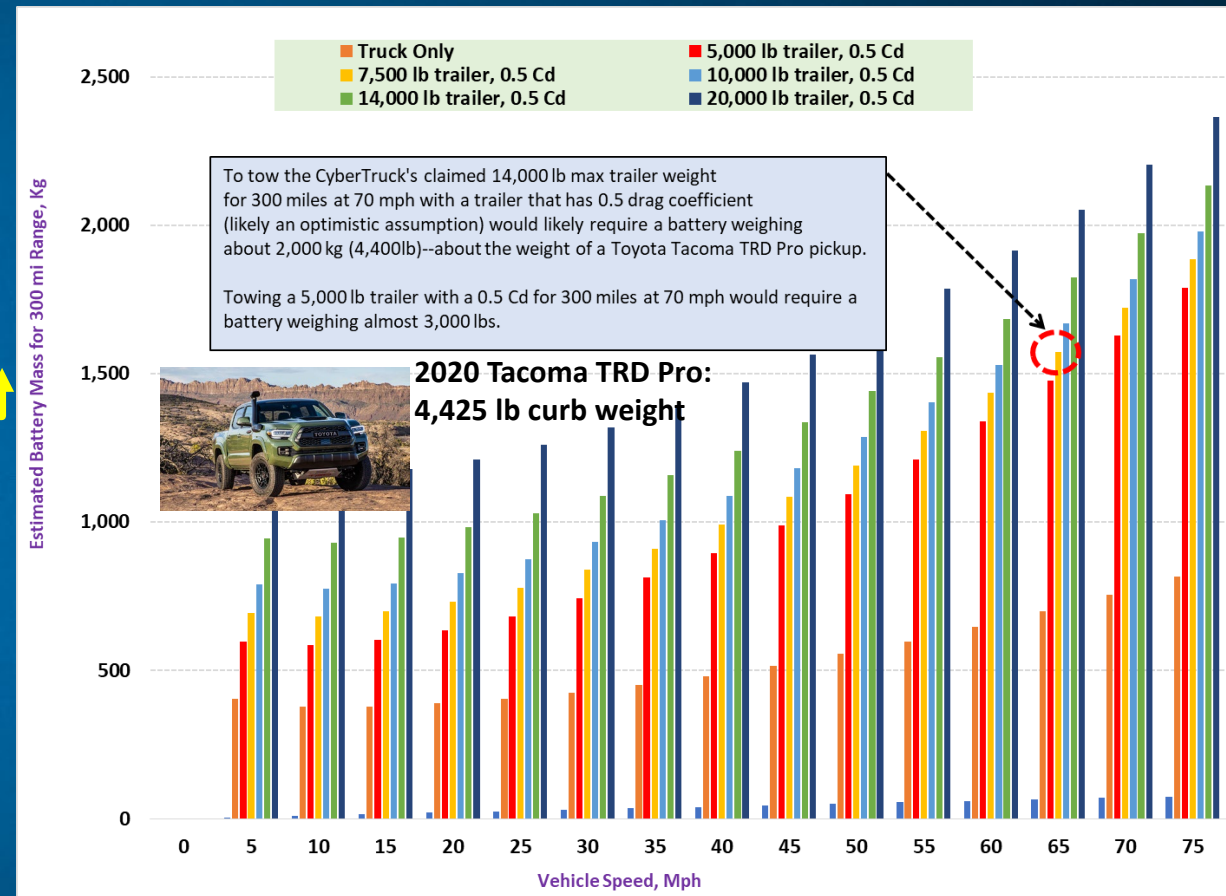
# Physics Still Matter

Electric Full-Size/HD Pickups or SUVs Will Need Large, Heavy Battery Packs to Approach ICE Vehicle Tow/Haul Capabilities

## Estimated Cybertruck Battery Pack Weight-to-Range Assuming Energy Density of Current Tesla Batteries (0.17 kWh/kg)



## Cybertruck Battery Pack Weight @ 25% Higher Energy Density

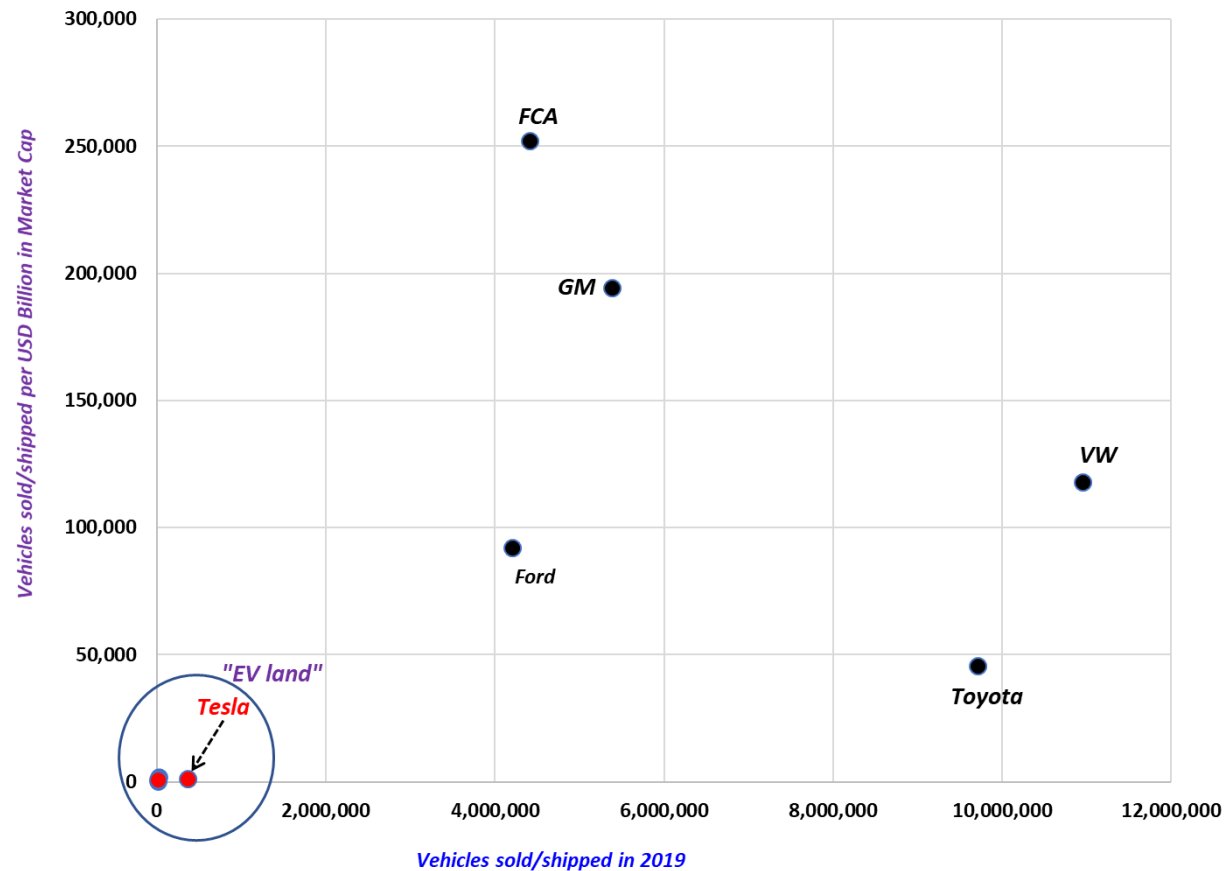


Source: CarMax, CleanTecnica, Ford, Author's Analysis

- Battery mass exacerbates the EV towing/hauling disadvantage because a battery which does not get lighter even as the engines drain it of energy. This battery burden thus constantly counts against a vehicle's load carrying capacity and may also worsen efficiency as more of it becomes dead weight upon discharging electrons during a journey.**

# Too Many Eggs in The “Disruption Basket?”

## Vehicles Sold/Shipped Annually Per Billion USD in Stock Market Value



## Ford vs. Tesla Share Price Change Over Past 5 Years

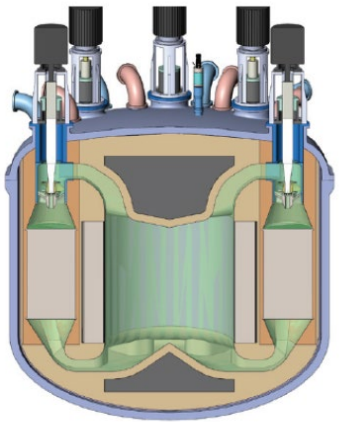


- **Tesla’s market capitalization now exceeds that of FCA, Ford, GM, and Toyota...COMBINED.**
- **These firms shipped more than 23 million vehicles in 2019—more than ¼ of global passenger vehicle sales. Tesla shipped 1/3 of a million vehicles—0.4% of global passenger vehicle sales.**
- **Markets price forward growth potential, but can Tesla scale up 50-fold? Probably not...**

Source: Company Reports, Bloomberg Markets, Author’s Analysis

# Perspective on New Energy Sources—Lessons From Underappreciated Sources

## Small Modular Nuclear Reactors...



MCFR conceptual design



Not your best guys...



But US Navy, you should talk to...

- ▶ SMRs are very new to the civilian world
- ▶ But they've been intensively used in challenging maritime environments for decades by the U.S., Soviet/Russian, Chinese, UK, and French navies.
- ▶ Collectively these organizations have deployed hundreds of reactor units and have thousands of person-years' worth of operational experience.
- ▶ Not all of this would—or could—be transferred to the civilian sector. But the ability to translate best practices from the U.S. Navy, in particular, could benefit the operations of SMRs being developed now that are likely to be much safer and more user-friendly than what one would find on a Los Angeles-class attack submarine, for instance (USS Scranton pictured to the left).

For further data on modular nuclear power in naval applications, see: James Conca, "How The U.S. Navy Remains The Masters Of Modular Nuclear Reactors," Forbes, 23 December 2019, <https://www.forbes.com/sites/jamesconca/2019/12/23/americas-nuclear-navy-still-the-masters-of-nuclear-power/#2ecc08056bcd>