Global Energy Transitions: Complex, Massive, and Slow

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Energy’s Importance to Humanity: A Force-Multiplier and a Liberator

**Transportation Force Multiplier**

2-3 kW (2.6-3.9 HP)

15 miles/day

**Liberation (and Productivity)**

373 kW (500 HP)

500+ miles/day

Source: Houston Chronicle, Peterbilt

Source: NPR, IWMI
Energy Abundance Also Improves and Saves Lives

- A sample of more than 200 countries and territories reveals 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 embeds lots of energy: 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
Putting Energy Use in Perspective...
...Helps Us Understand Challenges of “Energy Transitions” That are 200+ Years Old and Constantly Evolving

Source: Our World in Data (Citing Vaclav Smil and BP Statistical Review of World Energy), BP Statistical Review of World Energy, Author’s Analysis
...And the Magnitude and Velocity of Investment Needed to Effect Change

Assumptions:
Wind farm size of 1000 MW, 25% capacity factor; nuclear reactor size of 1400 MW, 85% capacity factor

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

Wind Farms or Nuclear Reactors Necessary to Offset 1% of Global Carbon Energy Use

The gap shows importance of energy density
Chasing a Moving Target: Impacts of Legacy and Scale

...Transitions Likely to be Even Tougher In the Heavy Transport, Aerospace, and Power Sectors
Chasing a Moving Target: Power Sector

Global Coal-Fired Power Generation Capacity, Net Change, MW

Source: Global Energy Monitor, Author’s Analysis

Source: Texasobserver.org
Coal’s American Saga: 95 Years Between Peak Share and Peak Volume

Scale Means Relative and Absolute Usage Peaks May Occur Far Apart
Legacy and Scale Also Matter for Asset Stranding

Global Oil Product Consumption By Type, ‘000 Bpd

Global Oil Refinery Capacity By Region, ‘000 Bpd

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

These same fundamental dynamics are replicated across different segments of the energy value chain.
So What Lies Ahead?
Multiple Energy Transitions Are Underway...
Reality Check: Getting to Zero/Net Zero Is Really Hard

CO₂ Emissions Per Million BTU of Primary Energy Used, Kg

- Coal: 95.35 kg CO₂/MMBTU
- Crude oil: 74.54 kg CO₂/MMBTU
- Natural Gas: 53.07 kg CO₂/MMBTU

China long-term carbon intensity reduction target

Source: BP Statistical Review of World Energy 2021, Author’s Analysis
...When Carbon Centricity Remains a Global Reality

Exajoules

Source: BP Statistical Review of World Energy, Author’s Analysis
...And the Non-OECD Seeks Energy Abundance and Security

*Emissions equity is a multi-dimensional diplomatic challenge*

Even if OECD went to net zero tomorrow, the world reverts to 2003-2004 emissions

Source: BP Statistical Review of World Energy, Author’s Analysis
Carbon Assets Don’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

<table>
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<tr>
<th>Top 10 UK investors</th>
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<td>Climate Resolutions</td>
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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\(^\text{a}\) → US$30 - US$31 WTI/bbl (including current dividend)
  - Operating breakeven\(^\text{b}\) → US$25 - US$26 WTI/bbl (including maintenance capital)

Key Takeaway: One shareholder’s liability is another’s resilient cashflow queen.
Oil Prices Are Historically Volatile...

Source: BP Statistical Review of World Energy 2021, Author's Analysis
...And Increasingly Correlated With Staple Food Prices
...And Resource Endowments Often Drive Energy Sourcing

U.S. Dry Natural Gas Production, BCF/d

China Coal Production, Million Tonnes/Month

Source: EIA, China National Bureau of Statistics, Author’s Analysis
...While Climate and Geostrategic Competition Collide

Blunt Form Translations

“Climate diplomacy is inextricably linked with broader PRC diplomacy and protection of revisionist gains”

“We’re concretely naming some of our ‘core interests.’ We have some others too, like the South and East China Seas.”

“Climate discussions might begin IF Washington makes a big down payment by accepting our revisionist actions.”

“...I'd like to stress that China-U.S. cooperation in specific areas, unlike flowers that can bloom in a greenhouse despite winter chill, is closely linked with bilateral relations as a whole. China has emphasized time and again that no one should imagine they could ask China to understand and support them in bilateral and global affairs when they blatantly interfere in China's domestic affairs and undermine China's interests.”—PRC Foreign Ministry Spokesman Zhao Lijian, 28 January 2021

“The United States should not repeatedly challenge China's rights and interests on issues related to Taiwan, Xinjiang and Hong Kong, and at the same time expect China to cooperate with it on issues of its own concern.”—PRC Foreign Minister Wang Yi, 23 April 2021

“China-U.S. cooperation on climate change cannot be divorced from the overall situation of China-U.S. relations. The United States should work with China to meet each other halfway and take positive actions to bring China-U.S. relations back on track.”—PRC Foreign Minister Wang Yi, 1 September 2021
And Commercial Players May Increasingly Be Forced to Choose Sides
...While Populations Seek Energy Abundance

U.S. Historical Energy Use, MMBTU Per Capita

155 Years of U.S. Primary Energy Use Shifts, Exajoules

Key Areas of Uncertainty Include: Rate of electrification, natural disaster impacts, immigration/U.S. as Regional Haven
Energy Insecurity Can Undermine Climate Goals

Change in Global Energy Consumption By Source (Quadrillion BTU)

Wyoming Coal production (Million Tonnes)

A quadrillion BTU is equivalent to the gasoline usage of 11 million large V8-powered pickups or SUVs each driving 12,000 miles per year.
NEVER GO GROCERY SHOPPING WHILE HUNGRY!

https://www.pidjin.net/2017/08/30/dont-buy-food-hungry/
So What’s the Good News?
We Can Become More Efficient and Energy-Abundant

Total Primary Energy Consumption (Barrels of Oil Equivalent)/Billion USD of GDP*

Intensity Change From 1975-to-2020
All primary energy = -63.3%
Crude oil exclusively = -71.8%

Bumps Ahead, But We Can Do This

- 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.

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. It’s a Global Manhattan Project-scale endeavor, but I’m optimistic we’ll get it done despite bumps in the road.
Thank You!

Comments, Questions, and Hate Mail Can Be Sent to: gabe.collins@rice.edu
Supplemental Slides
Possible Future Directions: U.S. Energy Use By Source

Scenario A: Aggressive Electrification, Conservation, High Renewables Approach (Exajoules)

Scenario B: Energy Abundance, Leverage Our Competitive Advantage Approach (Exajoules)

More biomass, more nuclear, slower EV turnover of vehicle fleet

Source: Net Zero America, Author’s Analysis
Possible Future Directions and X-Factors

• Price as an accelerant—or a retardant—of transition
• Technological snowballing—or reassertion of physical supply chain realities that inhibit scale
• How does the future energy system look as different variables dynamically move around? Key candidates include (1) electrification, (2) nuclear, (3) geothermal, and (4) changes in consumption patterns mediated by demographics in the OECD, lifestyle changes, and carbon pricing.
Bibliography


- Andrew S. Erickson and Gabriel Collins, “Competition with China Can Save the Planet: Pressure, Not Partnership, Will Spur Progress on Climate Change,” Foreign Affairs 100.3 (May/June 2021): 136–49.


