



ANNUAL RESERVES CONFERENCE

SEPTEMBER 25, 2025





KENNETH B. MEDLOCK III, PH.D.

Fellow, Baker Institute, Senior Director, CES Rice University

Kenneth B. Medlock III is the James A. Baker, III, and Susan G. Baker Fellow at the Baker Institute, senior director of the Center for Energy Studies, and director of the Masters of Energy Economics program at Rice University. He also holds adjunct appointments and serves on multiple international energy advisory boards.

He teaches advanced energy economics, supervises Ph.D. students, and has published widely on natural gas, electricity markets, energy pricing, national oil companies, energy transitions, carbon capture, and hydrogen. He has testified before Congress, spoken at OPEC, and advised U.S. and international organizations on energy policy and modeling.

Recipient of numerous awards, including the 2025 OPEC Award for Research, Medlock is active in the United States Association for Energy Economics, the American Economic Association, and the National Petroleum Council. He earned his Ph.D. in economics from Rice University in 2000.

Scan this QR code to contact





Energy Transitions... In Transition?



Ryder Scott 21st Annual Reserves Conference September 25, 2025

Kenneth B. Medlock III, PhD

James A. Baker, III and Susan G. Baker Fellow in Energy and Resource Economics, and Senior Director
Center for Energy Studies, Baker Institute for Public Policy, Rice University

Reality is a binding constraint!





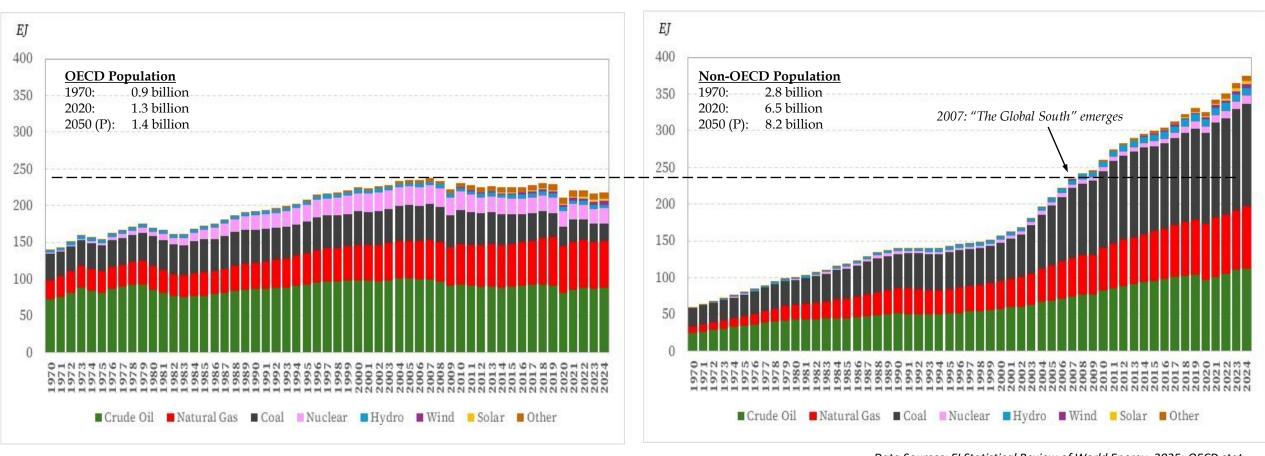
Supply chains matter, and every region is different!

• Comparative advantage, natural resource endowment, human capital endowment, economic development, policy, market design, and cost, among other things, will dictate outcomes.

The evolving energy landscape is a developing nation story



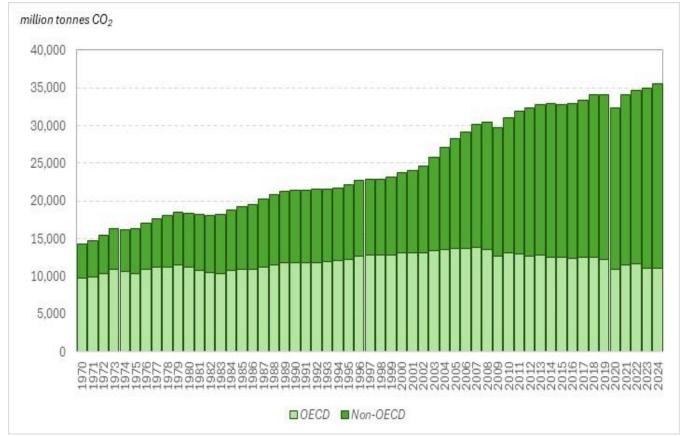
- Energy demand is rising fastest in the developing world, largely driven by hydrocarbon fuels.
 - o EU is 8.78% of global demand; N. America is 18.87% of global demand; developing Asia is 39.70% of global demand.
- Projections for population and economic growth indicate this trend will likely continue.



Regional CO₂ emissions add complexity



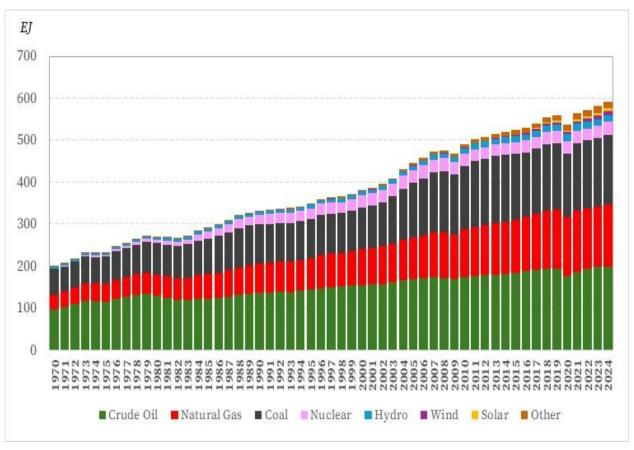
- Non-OECD emissions have grown substantially over the last 20 years. OECD emission have declined.
- Energy demand growth in developing countries will continue.
- Decarbonization requires a portfolio approach carbon capture (nature-based and engineered solutions), renewables, new fuels, carbon-to-value, etc. and there are opportunities throughout emerging value chains.
- <u>BUT</u> CO₂ is not the only issue facing societies poverty, health care, hunger, education, etc. trade-offs!



The reality of scale and regional heterogeneity



- Even with double-digit year-on-year percentage increases for wind and solar over the last 20 years, they are still a small proportion of the total energy mix, 1.53% and 1.30%, respectively, in 2024... the "101 of Scale".
 - Capacity is NOT energy!
- Hydrocarbons account for 86.6% of all energy.
 - o Decarbonization requires multiple solutions, including *net* decarbonization of incumbent supply chains.
- Paths will look different everywhere, and will hinge on "resource" endowments nature, minerals, energy, human capital, etc.
 - This opens a door for impacts from <u>innovation</u> at multiple points along different supply chains.
- The future of energy will also be influenced by each region's level of economic development.
 - Hence, differences in regional <u>growth</u> will matter, as they will dictate needs for supply chain development, especially in emerging markets.
- Nothing is simple. It never has been. The future is complicated by needs for infrastructure, economic growth, and incumbent energy uses.







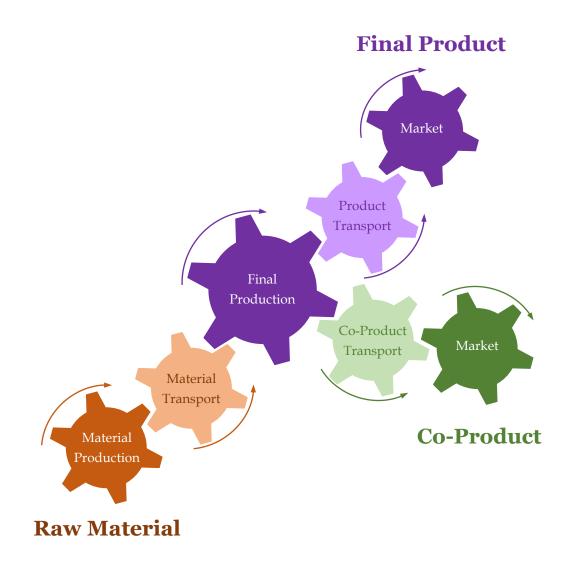
A key concept that translates anywhere in the world to any technology option for understanding the pace and scale of change (in any industry):

Coordination and the Supply Chain

Coordination and the Supply Chain

Baker | Center for | Energy Studies

- Every production process involves a supply chain connecting raw material inputs to a production process to deliver a final product, and potentially a co-product, to end-users. Value must be generated because capital always chases returns.
- Thus, coordination theory plays a central role.
 - o The simplest example is the prisoner's dilemma.
- Along a supply chain, if any part of the complex set of interactions breaks down, coordination failure ensues, and the commercial viability of investments at any point in the supply chain is compromised.
- What about new tech? The widget parable... 😕
- These complexities can lead to the "valley of death" for new energy technologies.







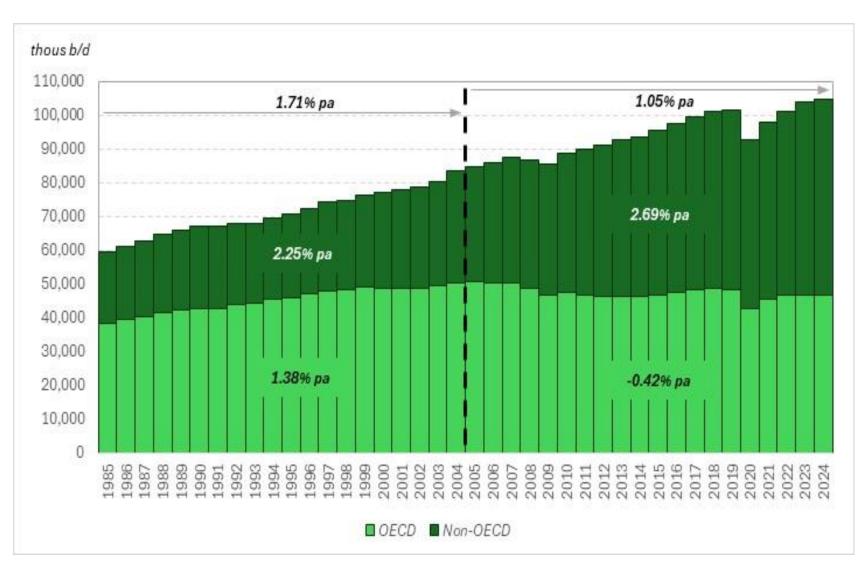
To highlight complexity, consider the largest source of TPER:

Oil

Oil demand is growing, and growth is different regionally



- Global oil demand growth is slowing, but that is not the whole story...
- OECD demand has declined over the past 20 years, which is a shift from the previous 2 decades.
- Non-OECD demand growth has accelerated.
- The future of global oil demand is a developing nation story, but not all developing nations are equal.
- Is a "peak" in demand imminent?

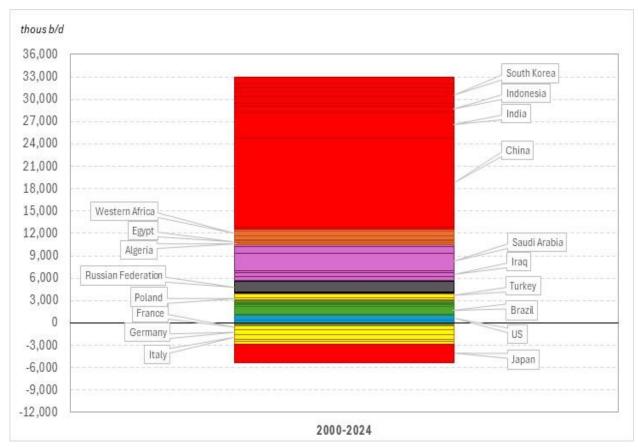


Another view: the global oil market has expanded...

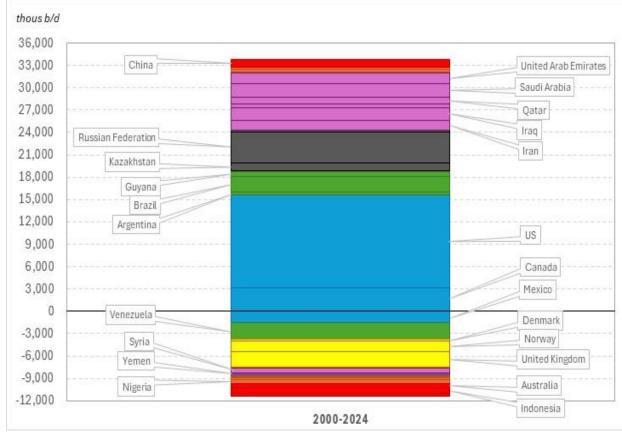


- Supply growth has been from "incumbent" producers, and the emergence of the US, Canada and Brazil. As usual, above-ground issues lead supply decreases.
- Net demand growth since 2000 has been 27.6 million b/d, and that includes 2020! Remarkably, net demand growth from 1977 to 2000 was 18.7 million b/d. So, although the growth rate has slowed, the net increase was larger over the last 24 years.

Change in Liquids Demand, 2000-2024



Change in Oil & Condensate Production, 2000-2024

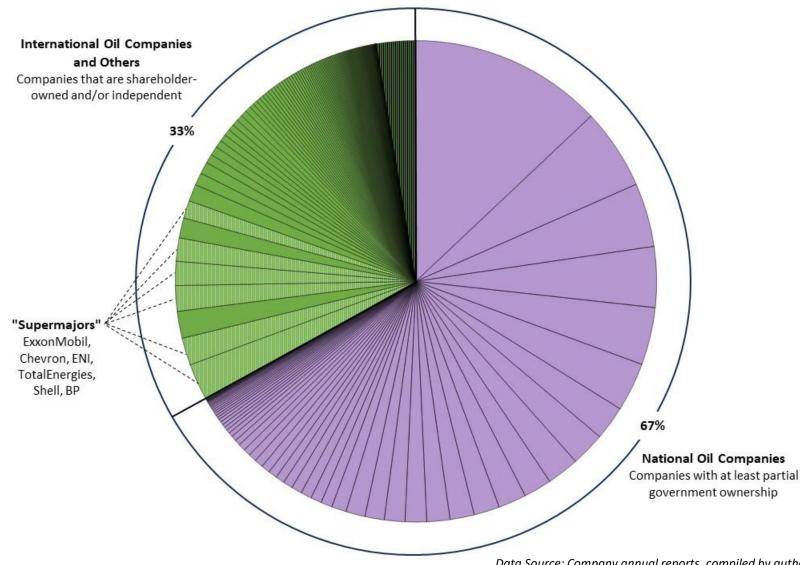


... and production is highly diverse.

Baker | Center for | Institute | Energy Studies

- The oil market is highly diverse, but NOCs deliver the majority of production.
- Shareholder-owned and independent companies account for roughly 33% of global output in 2022.
- "Supermajors" accounted for roughly 10% of global output in 2022, less than the output of the world's largest NOC: Aramco.
- Why raise this? Because market structure matters. It has implications for price, capital allocation, geopolitics, energy security, and energy transitions.

Global Oil Production by Company, 2022



Data Source: Company annual reports, compiled by author

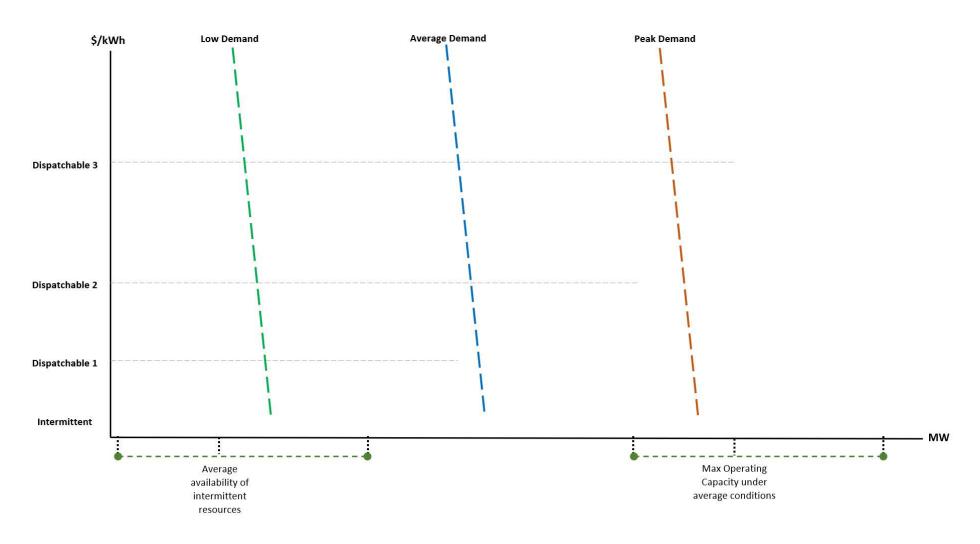




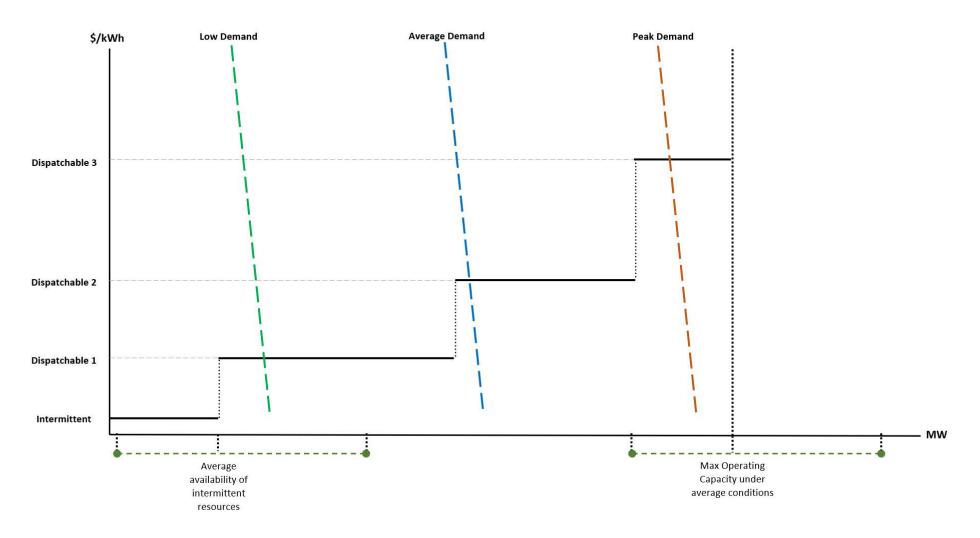
Complexity abounds!

What do we do about intermittency?

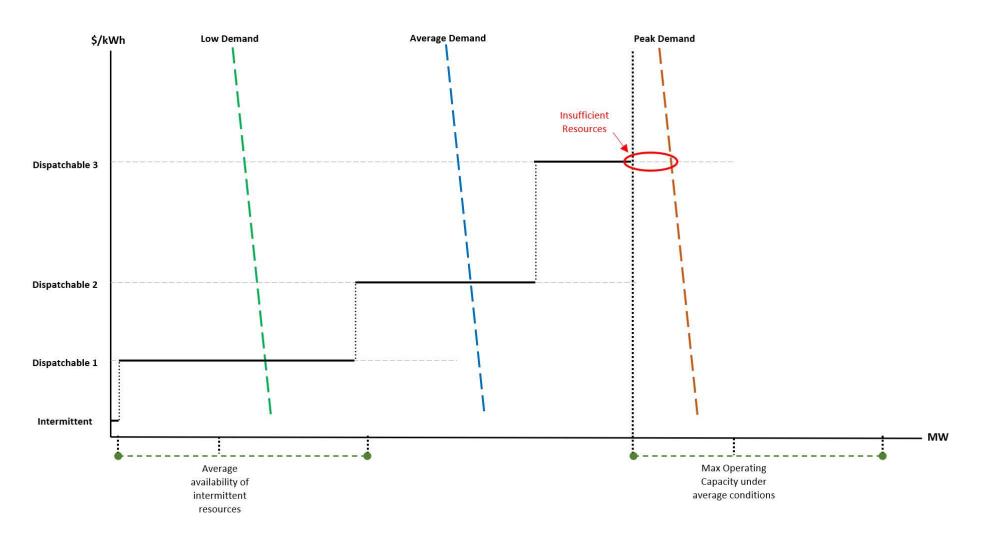




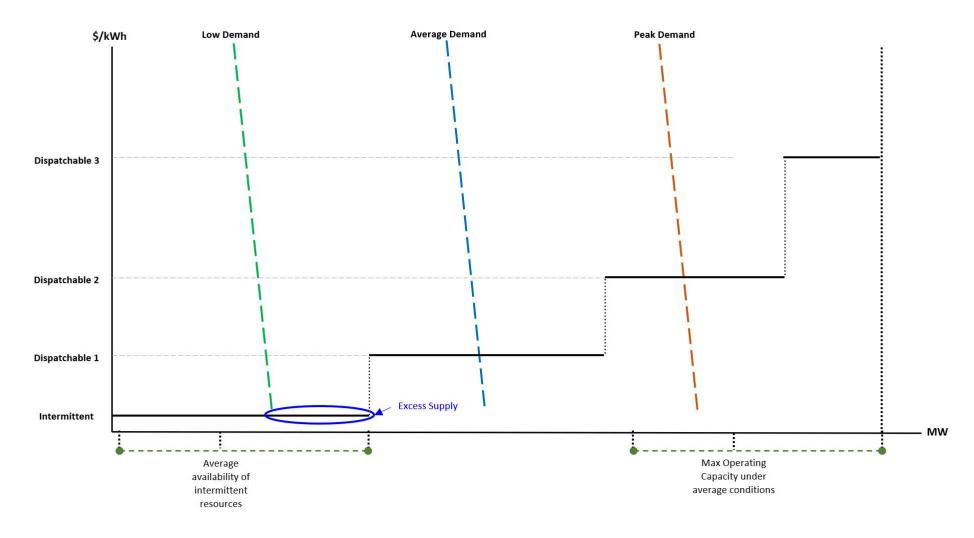










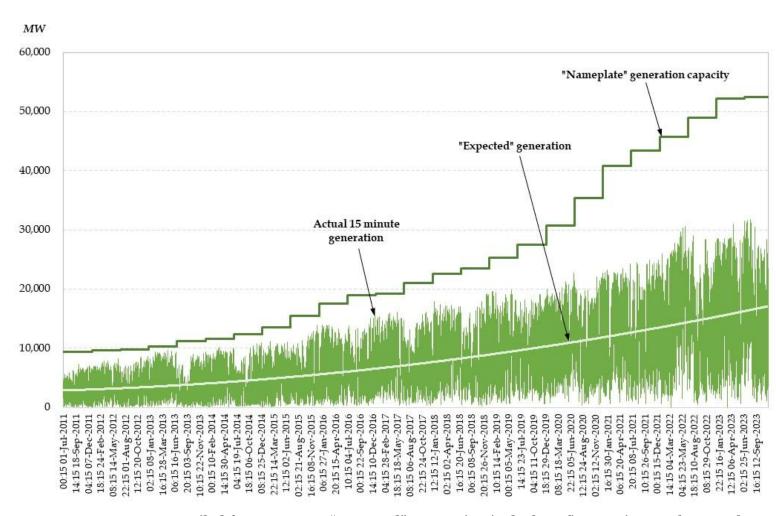




We see this in ERCOT, which presents reliability challenges



- As wind and solar generation capacity grows, average generation grows, which reduces emissions, all else equal.
- This is good for emissions, but averages are irrelevant for **reliability**. Extremes matter.
- Hence, dispatchable backup capacity is required.
- In the end, this raises the capital intensity of each MWh delivered, which presents an economic hurdle associated with cost.
- Reliability matters. Its value must be priced to ensure sufficient redundancy is available to the grid.
 - This is nothing new! Grids have always needed sufficient "insurance" against unexpected outages.



Source: Data compiled from ERCOT. "Expected" generation is the best fit over time to the actual 15-minute generation and is only for illustration. Resource planning utilizes seasonally rated capacity, which is different by season.





Policy intervention

It is always distortionary, but the balance matters.

Commercial returns, market design, and a role for policy



- Attracting investment into each part of a supply chain is dependent on returns. Only positive returns to invested capital will drive scale for any technology.
- If a comparative advantage can be captured, there are tools (market interventions) that can be deployed to facilitate growth. The case is stronger if there are clear non-priced externalities present.
 - Low-interest loans (supply-side)
 - Directly price (tax) externalities (demand- and supply-side)
 - Subsidies for new technologies, i.e., an "infant industry" approach (supply-side)
 - Portfolio standards that mandate specific types of purchases (supply-side)
 - Contracts-for-differences, i.e., a price guarantee (supply-side)
 - Grant programs (demand- and supply-side)
 - Contract structures that provide long-term firm offtake for producers (supply-side)
 - A liquid market that de-risks market entry (demand- and supply-side)
- There are costs and benefits with each intervention. Hence, an objective (not subjective) cost-benefit analysis is needed for each. Moreover, costs and benefits may carry secondary and tertiary impacts that must be considered, i.e., the law of unintended consequences.
- Notably, things that leverage liquid markets tend to facilitate the most scalable changes.

Common instruments currently in use

Commercial returns, market design, and a role for policy



- Attracting investment into each part of a supply chain is dependent on returns. Only positive returns to invested capital will drive scale for any technology.
- If a comparative advantage can be captured, there are tools (market interventions) that can be deployed to facilitate growth. The case is stronger if there are clear non-priced externalities present.
 - Low-interest loans (supply-side)
 - Directly price (tax) externalities (demand- and supply-side)
 - Subsidies for new technologies, i.e., an "infant industry" approach (supply-side)
 - Portfolio standards that mandate specific types of purchases (supply-side)
 - Contracts-for-differences, i.e., a price guarantee (supply-side)
 - Grant programs (demand- and supply-side)
 - Contract structures that provide long-term firm offtake for producers (supply-side)
 - A liquid market that de-risks market entry (demand- and supply-side)

Common instruments currently in use

Market-participant driven outcomes

- There are costs and benefits with each intervention. Hence, an objective (not subjective) cost-benefit analysis is needed for each. Moreover, costs and benefits may carry secondary and tertiary impacts that must be considered, i.e., the law of unintended consequences.
- Notably, things that leverage liquid markets tend to facilitate the most scalable changes.

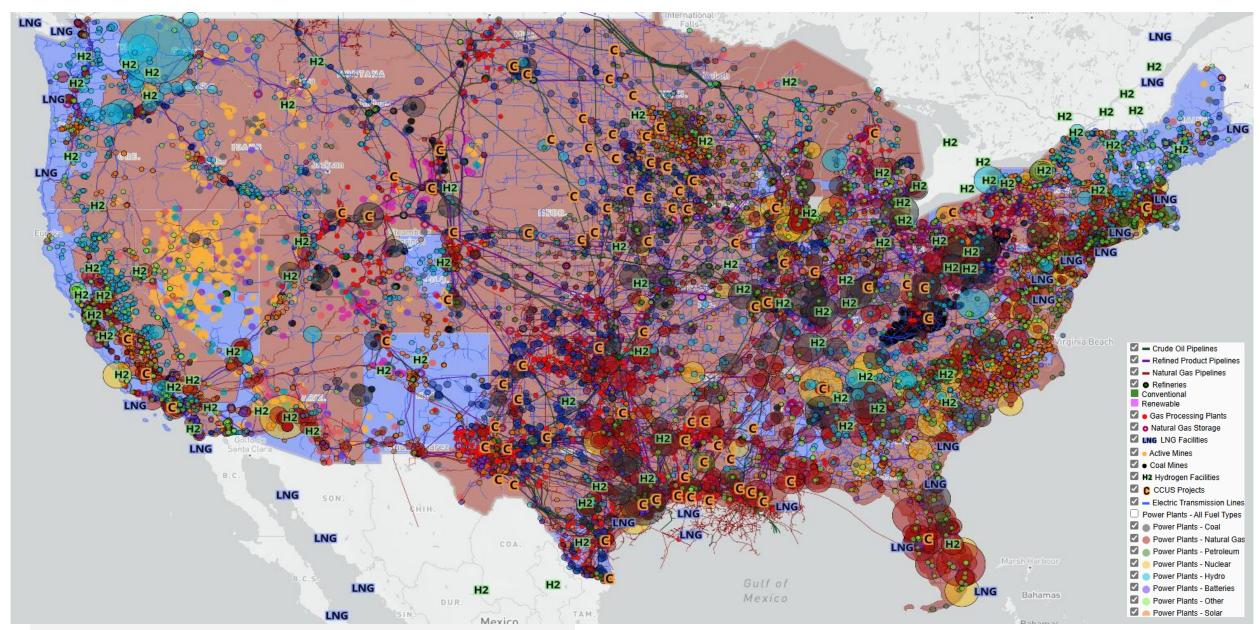
Recent US policy action



- The IIJA, CHIPS Act, and IRA, industrial policy in disguise
 - The <u>Infrastructure Investment and Jobs Act</u> (IIJA) passed the House on July 1, 2021 (vote: 221-201). After amendment, it passed the Senate on Aug. 10, 2021 (vote: 69-30) with broad bipartisan support. Signed into law on Nov. 15, 2021.
 - The <u>Creating Helpful Incentives to Produce Semiconductors</u> (CHIPS) Act passed the House on July 28, 2021 (vote: 215-207). After amendment, it passed the Senate on July 27, 2022 (vote: 64-33) with broad bipartisan support. Signed into law on Aug. 9, 2022.
 - O The Inflation Reduction Act (IRA) was contentious and purely partisan. Originally introduced as the Build Back Better Act, it passed the House on Nov. 19, 2021 (vote: 220-213). After several amendments, the IRA passed the Senate on August 7, 2022 (vote: 51-50) with the tie-breaking vote cast by Vice President Kamala Harris. Signed into law on Aug. 16, 2022.
- HR 1, a.k.a. OBBBA, undoing some while reinforcing other parts of the IRA.
 - Passed using reconciliation along straight party lines.
- Are they "game-changing"? Potentially. Do they promote sustainability? Not really.
 - o The devil is in the details and in agency interpretation.
 - Even then, there is an Achilles' heel(s): Infrastructure and Access. (See <u>Federal Energy Legislation and the Infrastructure Achilles' Heel: The Energy Market Impacts of the IIJA, CHIPS Act, and IRA</u>)

But infrastructure defines legacy and opportunity.





Source: Map: Energy, Environment, and Policy in the US | Baker Institute





What does it all mean?

Energy transitions are wrapped up in the roles of legacy, scale, technology, and comparative advantage

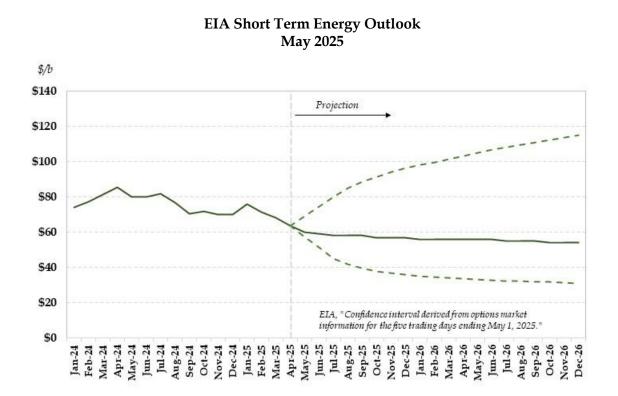


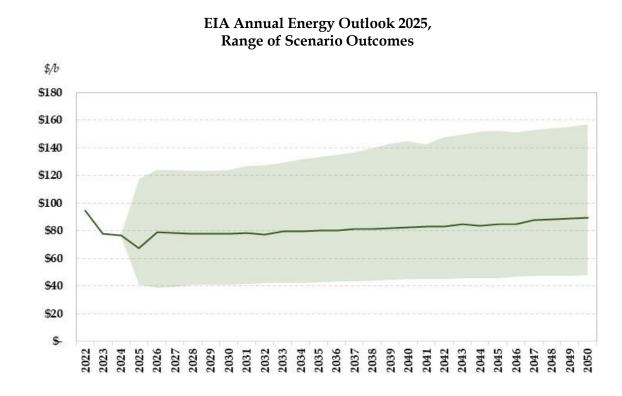
- Technology, scale and legacy are each important factors.
 - <u>Technology</u> signals how fuels will compete. Capital is the vehicle for technology deployment!
 - o <u>Scale</u> matters because energy systems are large and must accommodate growth and access.
 - o <u>Legacy</u> of infrastructure and energy delivery systems is the footprint for change. Legacy is different everywhere.
- <u>Economics</u> matter. The *principle of comparative advantage* is key to understanding what will happen where. Cost-benefit must be favorable for sustainable diffusion of new technology.
 - Key Point: All costs along a value chain matter, not just the energy source: enter *coordination theory*. Any new technology must avoid overly burdensome fixed costs (barrier to entry) if it is to be successfully adopted.
- Finally, policy and geopolitics shape, and are shaped, by all of the above.
 - What's old is new again! *Energy security* will remain a central consideration.
- The most impactful yet oft understated "transitions" affecting energy markets in the last 20 years: (1) the shale revolution in the US and (2) demand growth in Asia.
 - o (1) is tech, (2) is economic growth. These two factors will shape the future as well.

So, where are we headed?



- This should not be a politically charged question, but...
- We held a Chatham House Rule workshop in August 2023 bringing forecasters from different agencies around the world together to discuss *Forecasting Oil Markets in a Politically-Charged Environment*.
- Everyone who is doing technical analysis is being pushed to adopt various assumptions, some of which are questionable.
- IEA is perhaps the most notable, as indicated by statements at COP28, which were rebutted forcefully by the OPEC secretariat.

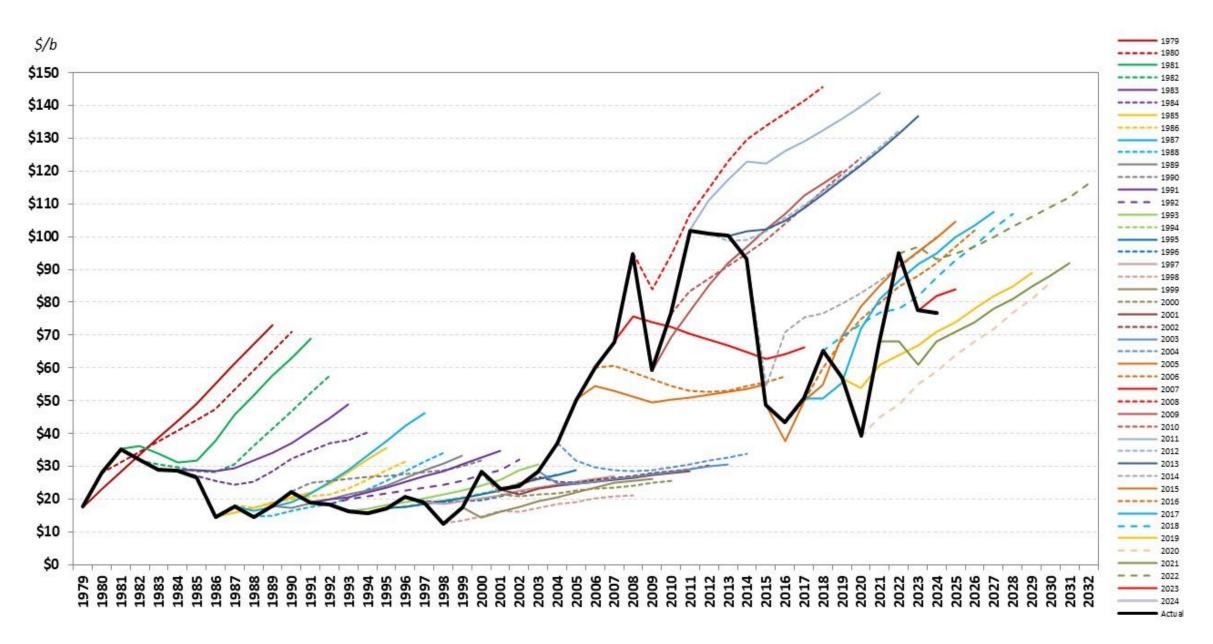


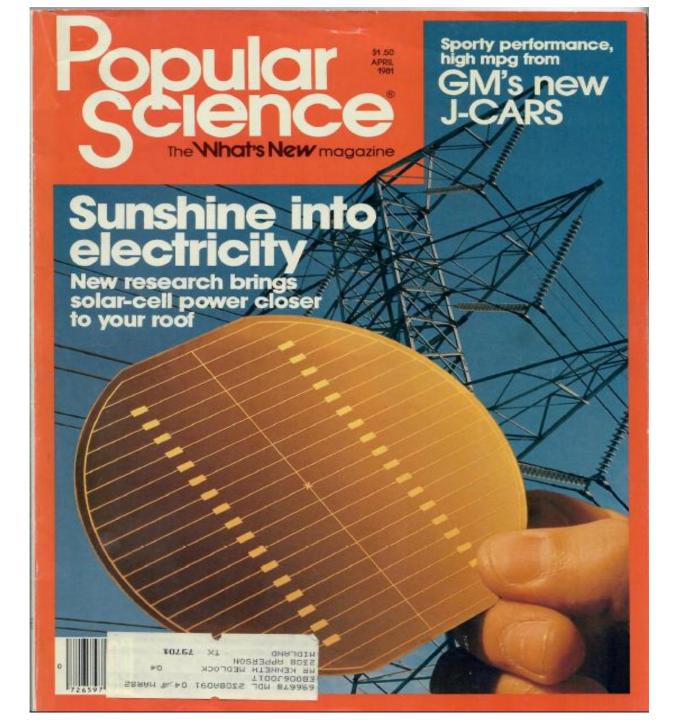


Data are sourced from EIA STEO (May 2025) and EIA IEO (2023).

Note: In the IEO forecast plot, the IEO forecast is merged with the STEO forecast for 2024 and 2025 for consistency.

Forecasting is inexact, and consensus is a dangerous place to be. | Center for Energy Studies | Center for Energy

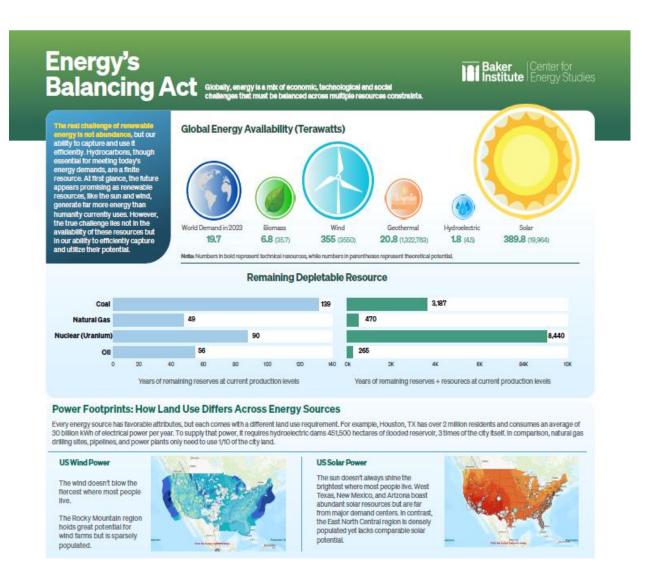


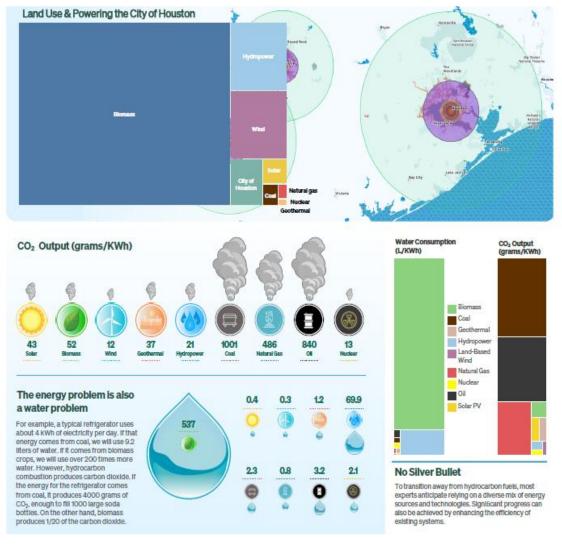


Despite our best efforts, we have no idea what will happen, and change will generally happen slowly...

... but we do know there will be trade-offs...







See: https://www.bakerinstitute.org/dashboard-energys-balancing-act

... bringing tremendous opportunities for innovation...

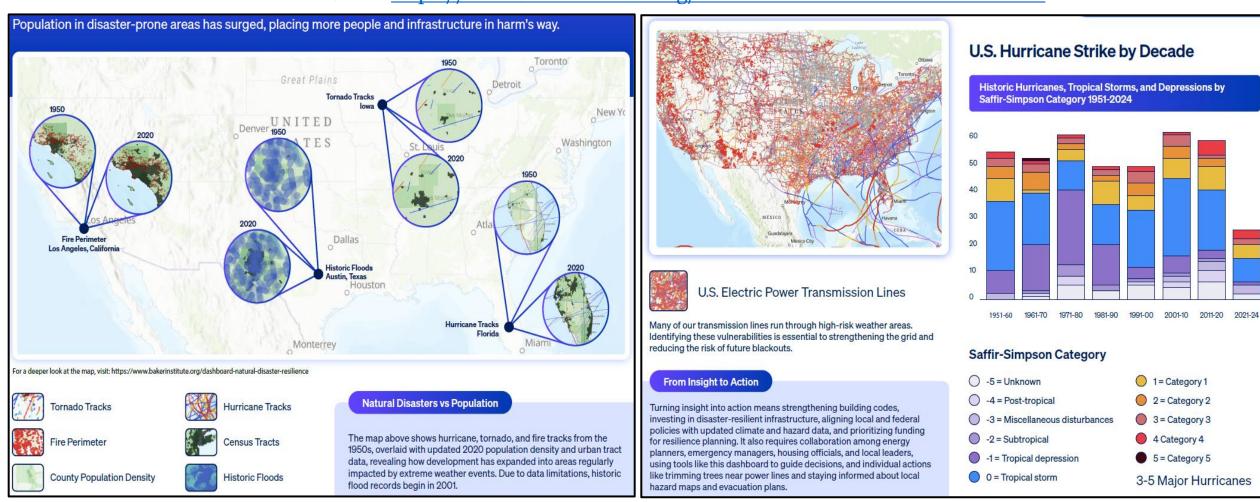
... and an enduring emphasis on resilience.



- No economic problem that adds a constraint yields a lower cost outcome! Hence, trade-offs!
 - Marginal damages of emissions versus the marginal cost of abatement of damages.

"Natural Disaster Resilience Dashboard"

available at https://www.bakerinstitute.org/ces-data-and-research-visualizations







<u>Center for Energy Studies | Baker Institute</u> <u>Baker Institute Center for Energy Studies (CES) | LinkedIn</u>

Speaker Contact Information

Email: medlock@rice.edu

Office: +1-713-348-3757

LinkedIn: Ken Medlock | LinkedIn