Now What?

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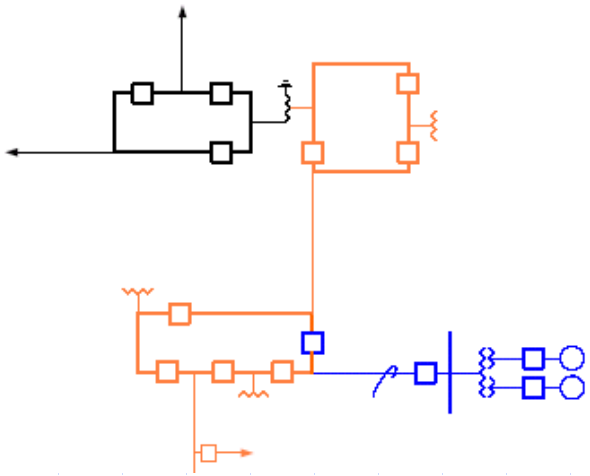
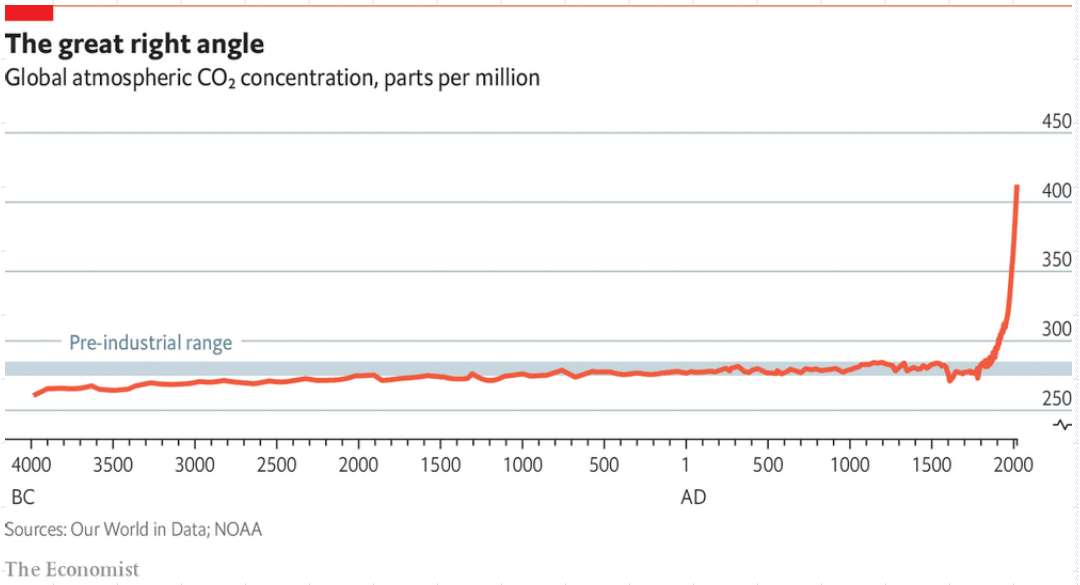


No Pressure But …

"There has never been a collective human endeavour more ambitious than stabilizing the climate."

The Economist

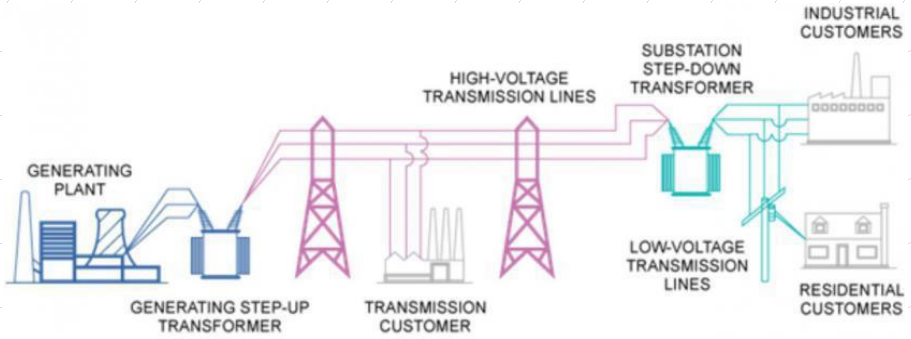


To Recap Our Transition (So Far)

- 30 years ago the U.S. electric industry was largely comprised of cost-of-service regulated, integrated, monopoly utilities.
- Taking a cue from the natural gas industry, the electric industry evolved to many non-regulated, competitive, disaggregated entities.
- This occurred initially in generation, but spread in some cases to transmission, and to retail supply.
- The transition has been "uneven" – to say the least.
- Competition is generally considered to have been a success.

What Won't Change in the Future

- Reality: Basic physical topology of our industry hasn't changed and won't change.



- Reality: Basic product of our industry hasn't changed and won't change.

What Needs to Change?

- There is a consensus that net carbon emissions must be reduced and ultimately reduced to zero.
- Not only by the electric industry but universally with the electric industry supplying most energy applications.
  - This consensus is assumed here, but scenarios that include adaptation and/or geoengineering should not be dismissed.
- A carbon price (a/k/a tax) would be the best way to accomplish net zero, but apparently that is disqualifying (makes too much sense).
- So we are at 2nd best, 3rd best, 49th best solutions.
- We need to find paths of least resistance and avoid policy blunders.

The Task Is Daunting

- Princeton net-zero study gives us a scenario for what is needed *just this decade*:

A Blueprint for the 2020's – bold investment needed this decade to put the U.S. on a path to net-zero by 2050.

Modeling indicates that similar investments are needed regardless of the net-zero path followed after 2030, so investments can be made with confidence that they will deliver value for the long term.

Priority actions from now to 2030 include:

- Get roughly 50 million electric cars on the road and install 3 million or more public charging ports nationwide.
- Double (at least) the share of electric heat pumps in home heating and triple heat pumps in commercial buildings.
- Grow wind and solar electricity capacity fourfold (to approximately 600 gigawatts), to supply ~½ of U.S. electricity.
- Expand high-voltage transmission capacity by roughly 60% to deliver renewable electricity to where it is needed.
- Increase uptake of carbon stored permanently in forests and agricultural soils by 200 million metric tons of CO_{2e}/yr.
- Reduce non-CO_2 greenhouse gas emissions by at least 10%
- Invest in enabling infrastructure and innovative technologies to create real options to complete the transition to net-zero beyond 2030:
  - Plan and permit additional electricity transmission to enable further wind and solar expansion.
  - Plan and begin building a national CO_2 transportation network and permanent underground storage basins.
  - Invest in maturing key technologies to make them cheaper, scalable and ready for widespread use after 2030, including: carbon capture for various industrial processes and power generation technologies; low-carbon industrial processes; clean "firm" electricity technologies, including advanced nuclear, advanced geothermal, and hydrogen combustion turbines; advanced bioenergy conversion processes & high yield bioenergy crops; hydrogen and synthetic fuel production from clean electricity, and from biomass and natural gas with carbon capture; and direct capture of CO_2 from the air.

Are We on Track for This in 2030?

739 GW of wind and solar capacity operating in 2030; transmission capacity grows by 62%.

2030	Wind	Solar
Capacity installed (TW)		
	0.41	0.32
Land used (1000 km²)		
Total	157	7.75
Direct	1.57	7.06
Capital invested (Billion $$_{2018}$)*		
Solar	-	353
Onshore wind	427	-
Offshore wind	15	-
Transmission added vs. 2020**		
Capacity (GW-km)		200,000
Increase over 2020		62%
Capital in serv (B$$_{2018}$)		330

* Excludes investments associated with 2020 pre-existing capacity. Capital is for additional capacity required to meet total modeled wind & solar generation levels.

** Transmission expansion is mapped to follow existing rights of way (>160 kV); paths are indicative not definitive. Spur lines from solar and wind projects to substations are not shown, but are included in GW-km and investment totals. Capital in service includes capital for transmission expansions and "sustaining capital" (for end-of-life line replacements.)

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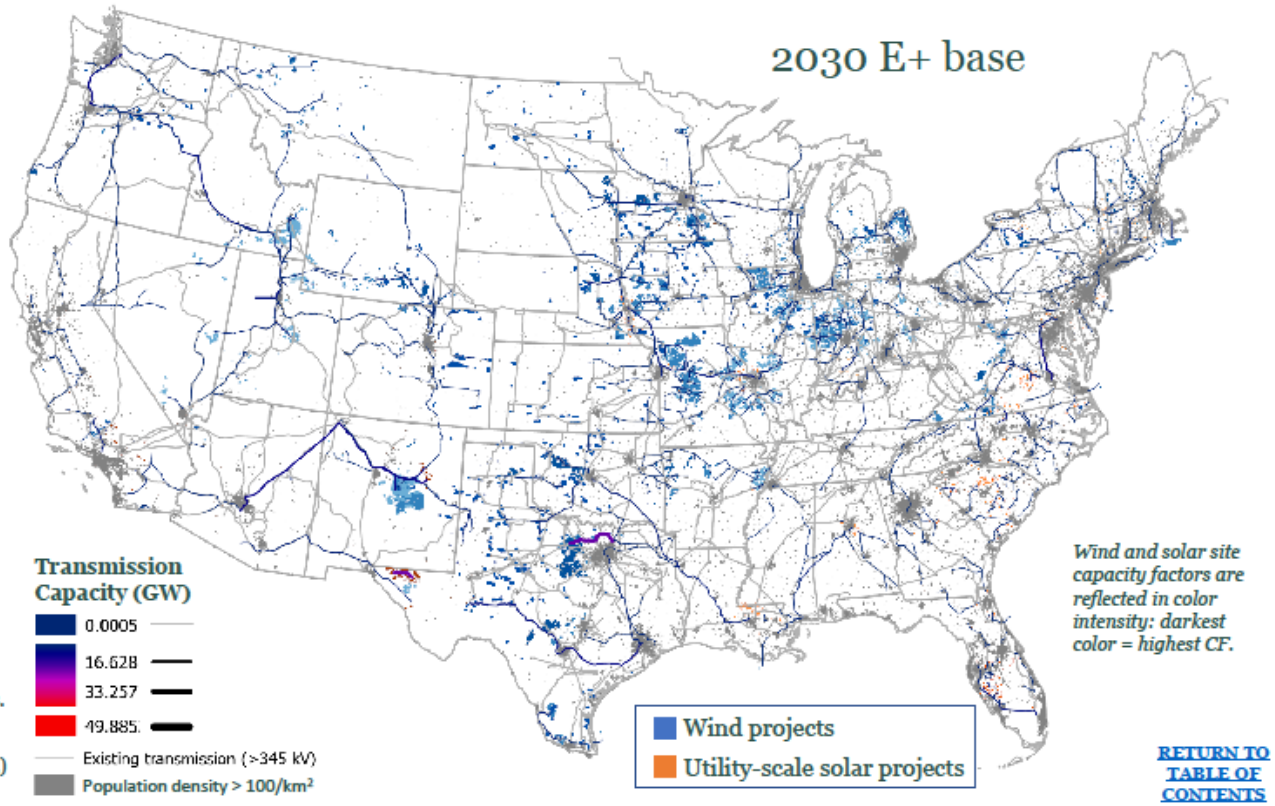

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Public Support Critical

The Economist wrote a few weeks ago:

> Next month world leaders will gather at the COP26 summit, saying they mean to set a course for net global carbon emissions to reach zero by 2050. As they prepare to pledge their part in this 30-year endeavour, the first big energy scare of the green era is unfolding before their eyes. Since May the price of a basket of oil, coal and gas has soared by 95%. Britain, the host of the summit, has turned its coal-fired power stations back on, American petrol prices have hit $3 a gallon, blackouts have engulfed China and India, and Vladimir Putin has just reminded Europe that its supply of fuel relies on Russian goodwill.
>
> The panic is a reminder that modern life needs abundant energy: without it, bills become unaffordable, homes freeze and businesses stall. The panic has also exposed deeper problems as the world shifts to a cleaner energy system, including inadequate investment in renewables and some transition fossil fuels, rising geopolitical risks and flimsy safety buffers in power markets. *Without rapid reforms there will be more energy crises and, perhaps, a popular revolt against climate policies.*

What Could Possibly Go Wrong?

- Just about everything.
- Some examples:
  - Sticker shock from high electric rates.
  - Outages from unreliable resource mix.
  - Opposition to massive greenfield transmission.
- And that's just in the U.S.
  - N.B.: Asia burns three quarters of the world's coal.
  - And as Daniel Yergin points out, for developing countries climate change is *an* existential question, not *the* existential question.

Sticker Shock

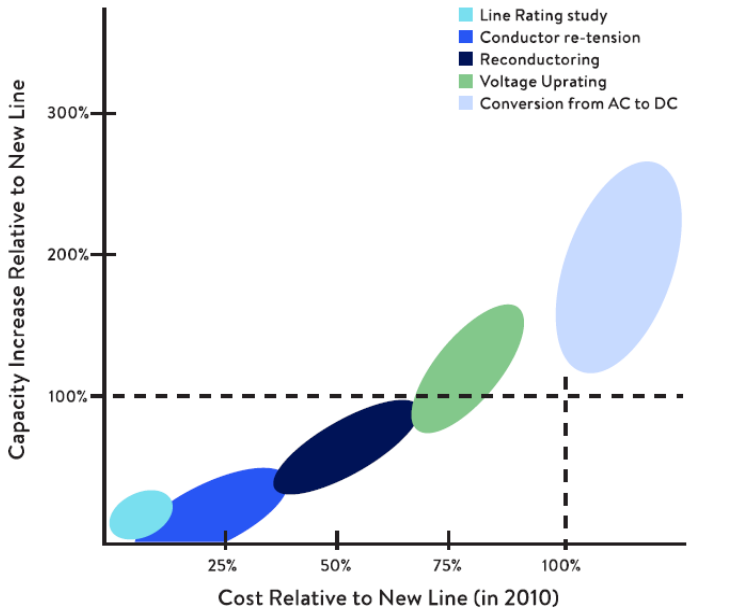
- Most Americans support a transition to clean electricity.
- But not at any price: “Overall and on average, Americans are willing to pay an additional $16.25 per month for renewable energy.” (references at end)
- Considering the trillions of dollars that studies suggest will be necessary, the transition needs to be as efficient as possible to hope to maintain public support.
- What does that mean specifically?
- Making economic choices instead of uneconomic ones.

Economic Choices

- Grid solar and onshore wind, backed by fast-start, fast-ramp gas generation (potential future hydrogen conversion).
- Existing nuclear - closures of Indian Point and Diablo Canyon are tragic (Diablo closure ≥ $14B extra costs).
- Demand response, esp. retail time-of-use pricing.
  - Why spend unnecessarily on high-cost supply-side resources where retail demand will respond to wholesale price signals?
- Energy efficiency: Aggregate carbon emission reduction from LED lighting is 3X that of home solar.
- HVAC buildout in existing transmission rights of way.
- Transmission system optimization no brainers:
  - Unique emergency ratings for contingencies (in operations *and* planning).
  - Ambient line ratings now and, ideally, dynamic line ratings.
  - FERC can prescribe these now in RM20-16.

More on Transmission Optimization

- Existing technologies, like composite conductors and heat-dissipating coatings.
- EPRI examples:



- Problem: Regulatory structure for transmission owners favors new facilities over optimization.

Uneconomic Choices

- Home solar instead of grid solar. Home solar costs 5X more.
- Offshore wind instead of onshore wind. Offshore wind costs 2-3X more.
- Massive HVDC transmission lines.
- Batteries: Still expensive, esp. longer duration use.
- Microgrids and DERs: Generally uneconomic (possible future exception: EVs as integrated DERs).
- Socialized interconnection costs.
- New nuclear.

New Nuclear - Natrium

- Lazard says new nuclear has capital cost midpoint of $10.3MM/MW and levelized energy cost of $167/MWh.
- Gates' TerraPower *said* its 345 MW Natrium sodium-cooled fast reactor would cost $1 billion, which equates to $2.9MM/MW, and have a levelized energy cost of $50-60/MWh. That would be (have been) amazing.
- $100 billion has been spent over six decades on this "advanced" technology, to generate roughly 0 MWh (sodium does not play well with water or air).
- TerraPower now says its first reactor will cost $4 billion - 4X prior claim - with taxpayers on the hook for half of that. Clinch River, Take 2?

Outages from Unreliable Resources

- On-demand electricity is an essential service; it must remain Job 1 as human need *and* political necessity.
- There is no mix of zero-carbon resources that can maintain reliability at costs resembling those of today.
  - Peak-hour analyses using short-duration batteries do not account for intermittent resource droughts.
- Given this reality we must have a flexible natural gas fleet that continues to drive coal plant retirements.
  - The cheaper natural gas is, the more coal plants will retire.
  - New gas plants emit 2/3's less carbon than displaced coal plants.
- Increase in low-variable-cost intermittent resources reduces energy prices, making capacity markets more important for adequate dispatchable resources.

Massive Greenfield Transmission

- Massive greenfield HVDC transmission lines seldom make sense for many reasons.
- They are also politically brutal as shown time and again, most recently in Maine (even though only a third of that line is greenfield).
- The Princeton net-zero study wisely relies on buildout of existing transmission rights of way.
- ERCOT-Eastern Interconnection HV*AC* interties need not trigger FERC jurisdiction over ERCOT.
- Let's not go down a rabbit hole that is economically and politically untenable.

In Conclusion

- There is a path forward amid myriad Scylla and Charybdis, but it will require wise policy judgments.
- Competition, economic choices, technology and reliability should be our watchwords in pursuing climate goals.

Thank you.

References

Documentation and data for statements in this presentation are in articles published in *RTO Insider* and *Fortnightly* available here, http://www.energy-counsel.com/recent-publications.html. Any questions/comments please feel free to email me at huntoon@comcast.net.

Princeton net-zero final report and summary (just released) are here: https://netzeroamerica.princeton.edu/the-report.

Daniel Yergin article, with many important insights, is here:
https://www.theatlantic.com/international/archive/2021/11/energy-shock-transition/620813/

Polling data on support/willingness to pay for clean electricity transition are here:
https://climatecommunication.yale.edu/publications/who-is-willing-to-pay-more-for-renewable-energy/.

EPRI report on means of increasing transmission capacity is here: http://mydocs.epri.com/docs/public/EPRI-Report-LeveragingExistingInfrastructure-20210804.pdf.

For costs of solar, wind and nuclear the latest Lazard figures are here:
https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf.

Regarding Natrium and sodium-cooled fast reactors: https://www.foreignaffairs.com/articles/2021-07-08/nuclear-energy-will-not-be-solution-climate-change, https://fissilematerials.org/library/rr08.pdf, https://www.cnbc.com/2021/11/17/bill-gates-terrapower-builds-its-first-nuclear-reactor-in-a-coal-town.html.