Integrating Bottom-up Load Forecasts Into Planning Tools

Energy Systems Integration Group (ESIG)

Session 8

June 15, 2023

Ryan Jones

EVOLVED ENERGY RESEARCH

Agenda

EVOLVED ENERGY RESEARCH

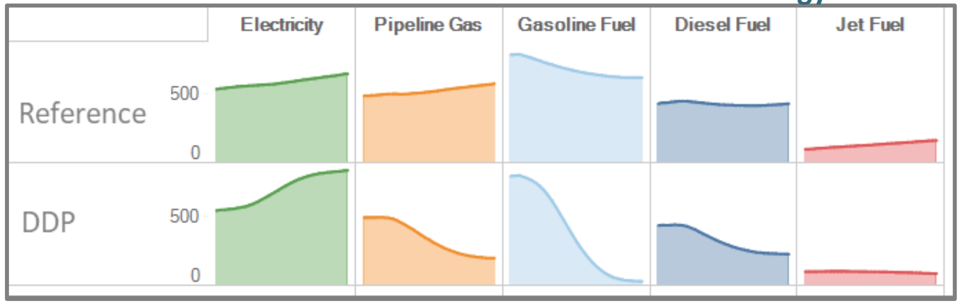
- Temporal resolution
- Sectoral coupling in electricity modeling
- Incorporating distribution systems

Example process for integrating forecasts into analytical tools

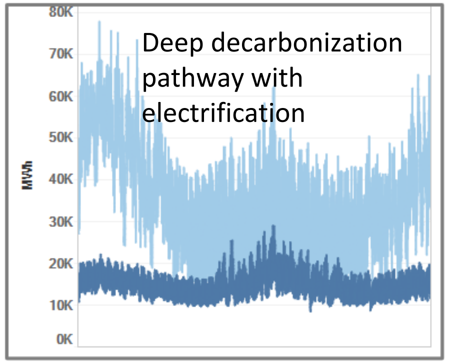
EnergyPATHWAYS (EP) is our demand-side stock-rollover accounting model that produces scenarios based on exogenous service-demand and sale shares

RIO is a supply-side macro-energy model that finds the lowest cost investment and operations plan with best-in-class temporal and spatial granularity

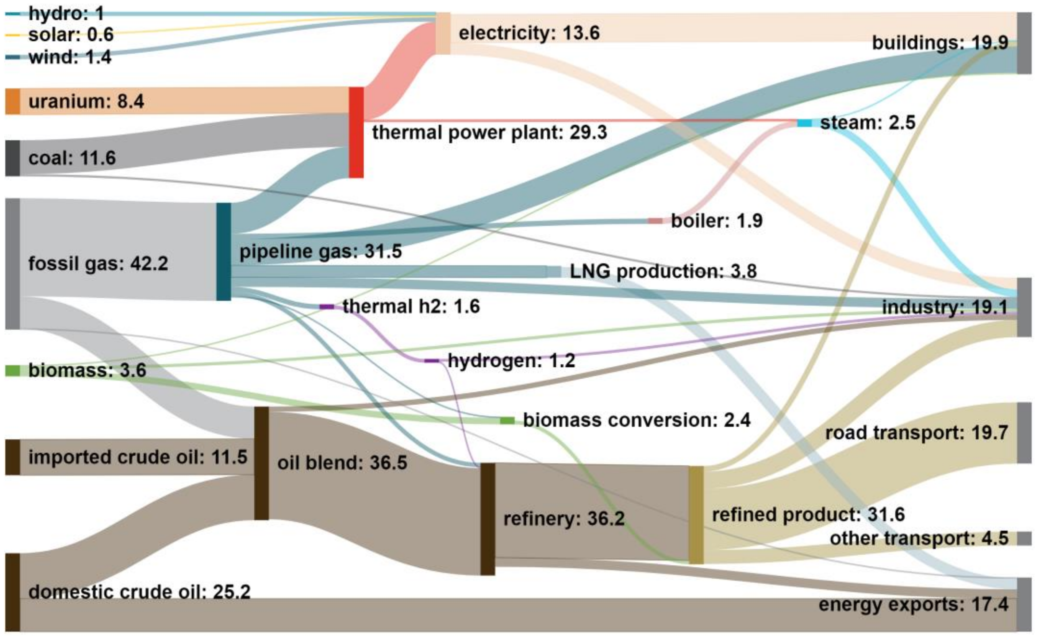
Annual End-Use Energy Demand



Hourly Load Shape

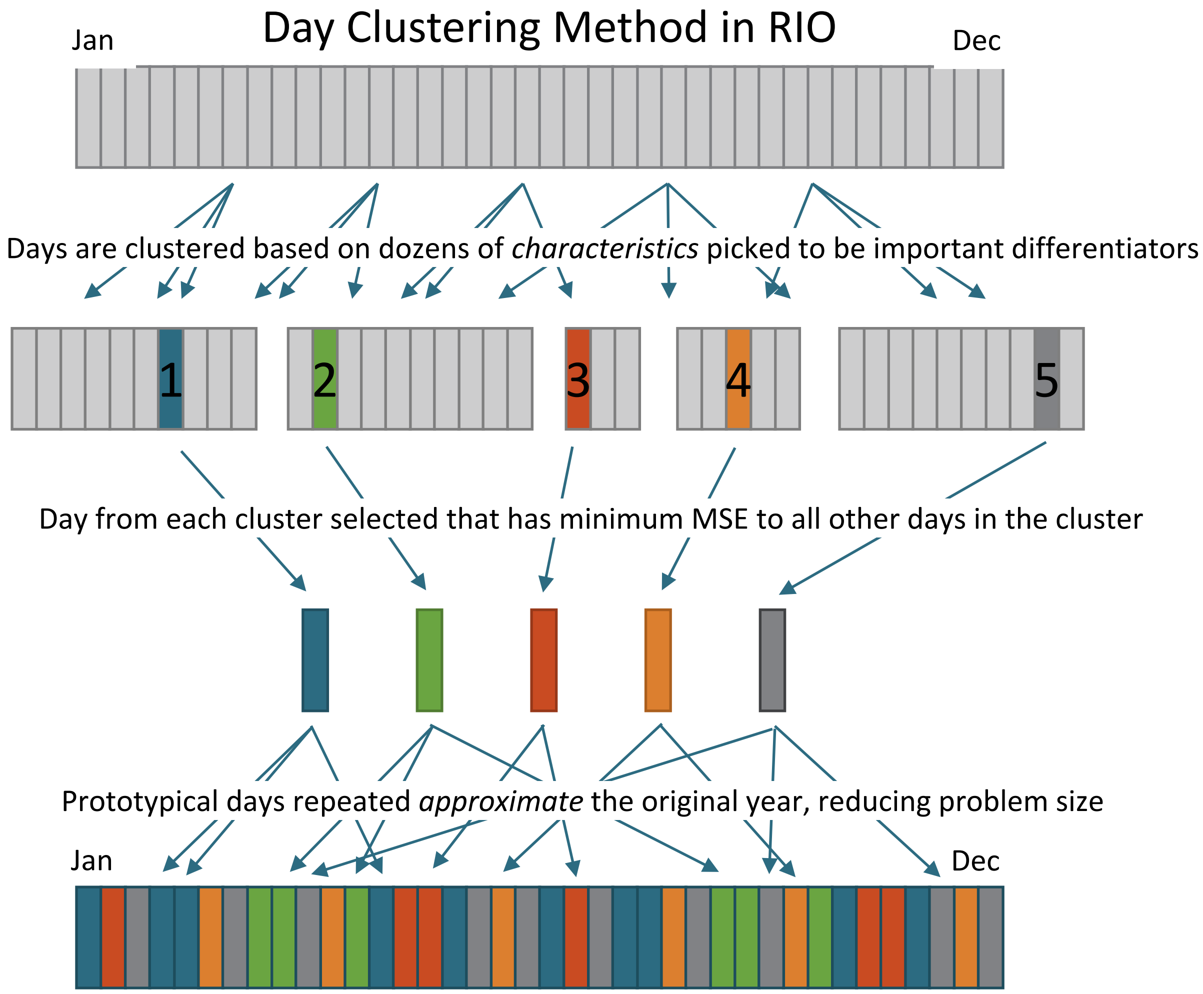


2021 Energy System



Temporal resolution in capacity expansion modeling

- Capacity expansion models use many different time domains depending on problem focus
  - **Duration curves** – inadequate for high renewables systems because chronology is lost
  - **Day/period sampling** – our experience has been that solutions don't stabilize until ~750 well picked time slices per year are utilized
  - **8760s** – Helpful for certain applications, but too much focus within one year can limit ability to look across years



Problematic approaches to resources adequacy

EVOLVED ENERGY RESEARCH

Approach	Approach disadvantage	Solution
Add additional **thermal capacity in post-process step**	LOLP modeling with multiple weather years is a necessary parallel step; however, ignoring reserve margins altogether in capacity expansion can lead to suboptimal outcomes and difficulty representing certain policies, such no-new-thermal.	Use LOLP modeling to verify capacity expansion solutions and work to improve capacity expansion models
Identify super-peak time slices and enforce planning reserve constraints	Renewables and load electrification will shift the most constrained hour to different times of the day and even different times of the year.	Enforce a planning reserve constraint in all modeled hours since any pre-identified period will be gamed by the model
Pre-calculated ELCC (effective load carrying capability) values for renewable resources using a loss-of-load probability model	Works well for near-term modeling, but when changes to load shapes impact when LOLP hours occur, pre-calculated surfaces often overestimate reliability contributions from renewables	Apply hourly derates to renewable production in the hourly reserve constraint based on statistical analysis of renewable profiles

EVOLVED
ENERGY
RESEARCH

Sectoral coupling

Three scenarios illustrating sector coupling

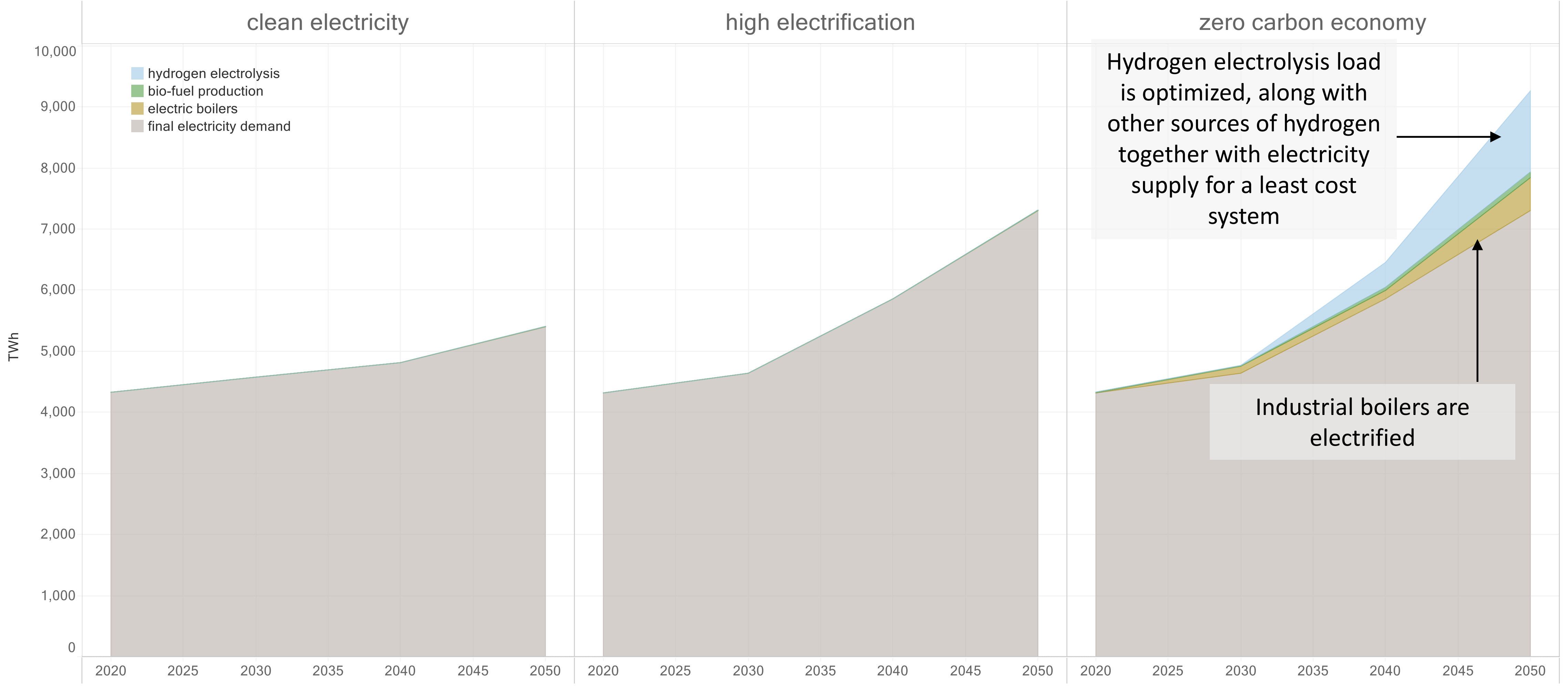
EVOLVED ENERGY RESEARCH

Varying levels of sector coupling

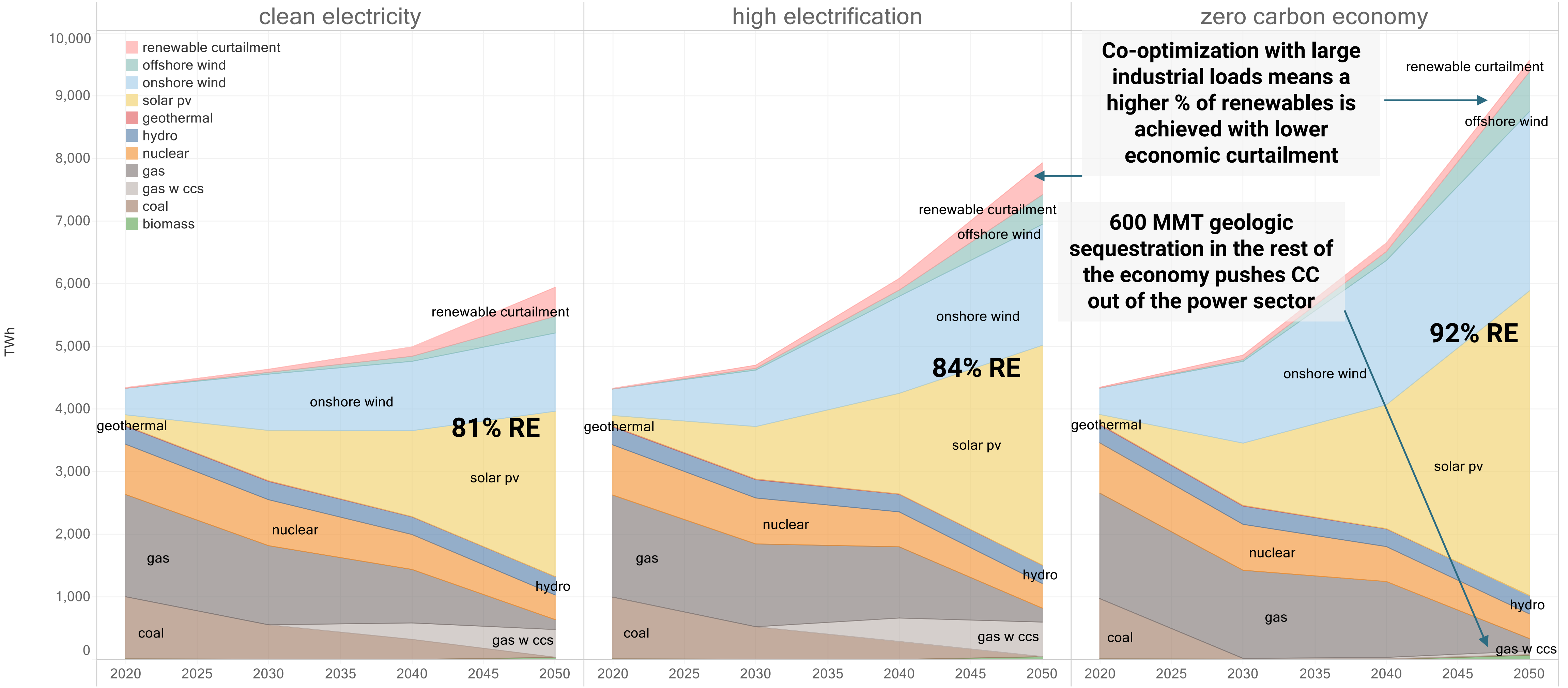
	Clean Electricity	High Electrification	Zero Carbon Economy
Electricity CO_2 target	100% clean by 2050		
Electricity demand	Reference (0.7% AAGR)	High electrification (1.8% AAGR)	
Economy CO_2 target	N.A.		Net-zero Energy & Industrial CO2
Non-electric fuel demand	N.A.		60% reduction (high electrification)
Hydrogen use in thermal power plants	Disabled		Enabled
Energy service demand	2019 Annual Energy Outlook		
Additional assumptions	Continental U.S., 12 region optimal capacity expansion for fuels & electricity, 2020-2050 timeframe w 10-year model timestep, 2011 weather year, 7% WACC, AEO fuel prices		

Note: Scenarios run for demonstration purposes based on internal EER assumptions

Electricity load

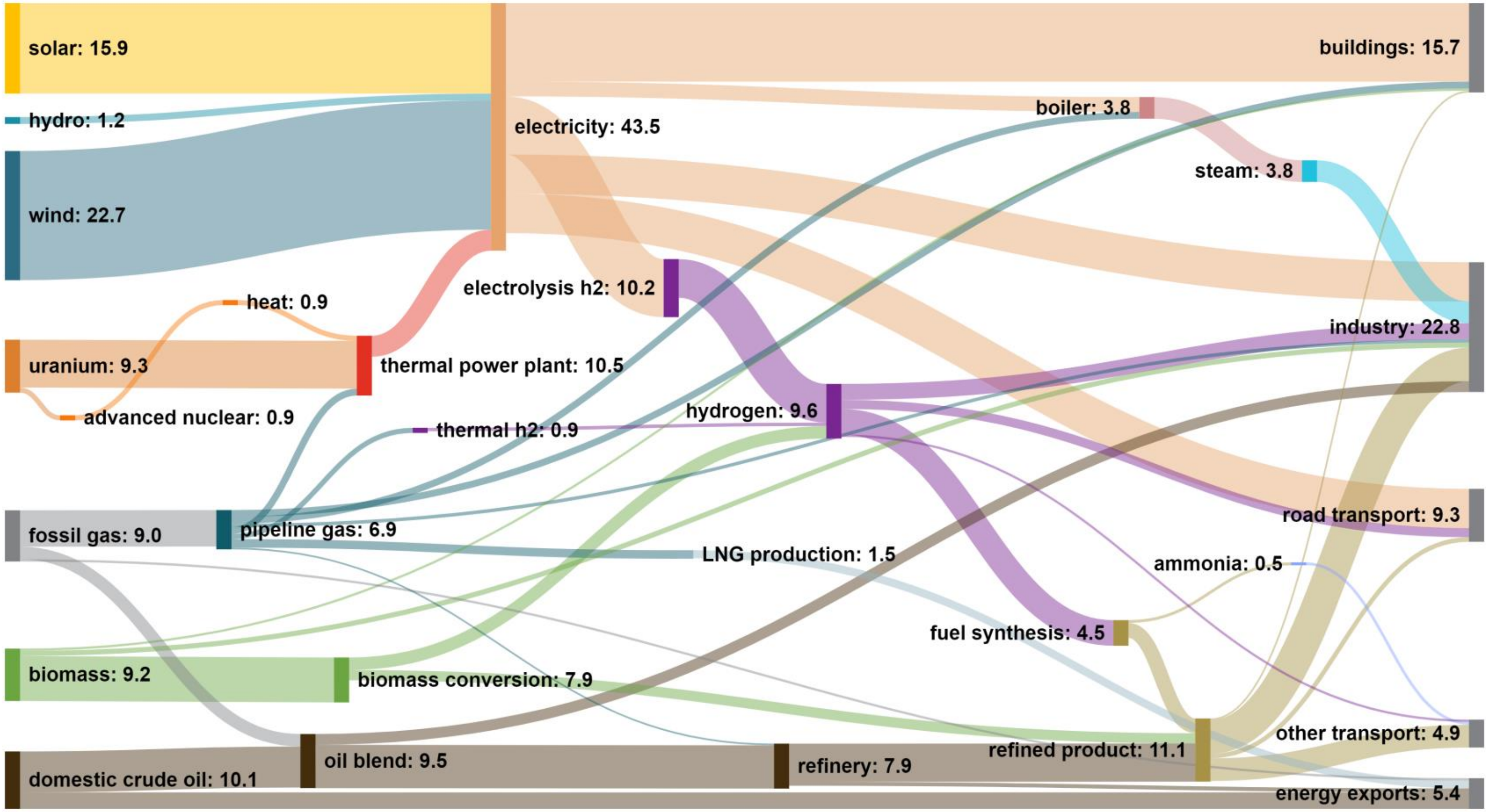


Electricity generation



Low-carbon electricity must be studied in an economy-wide context

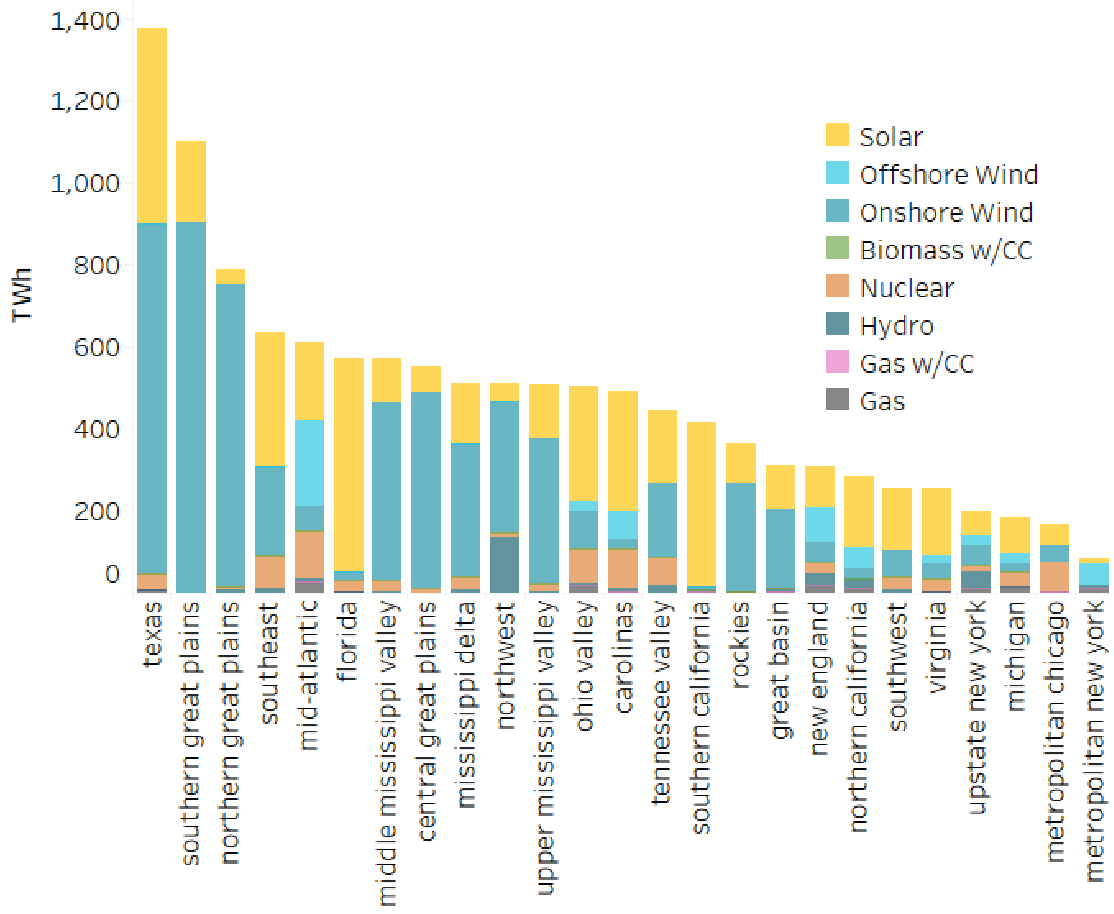
- Hydrogen to industry, transport, and fuels synthesis adds significant electricity load
- Biomass use in hydrogen and fuels means less is available for electricity

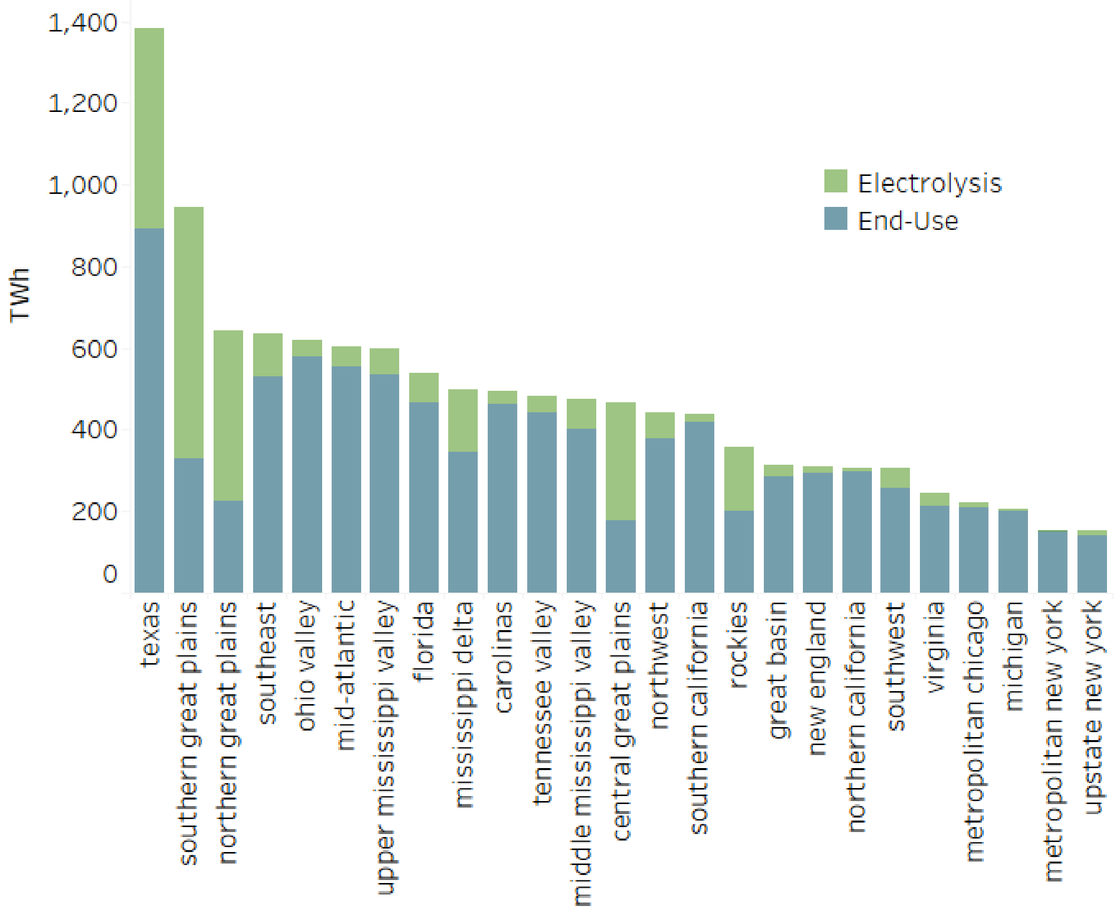


Source: Annual Decarbonization Perspective 2022, Central Scenario

Sectoral coupling can improve reliability through renewable overbuild

EVOLVED ENERGY RESEARCH



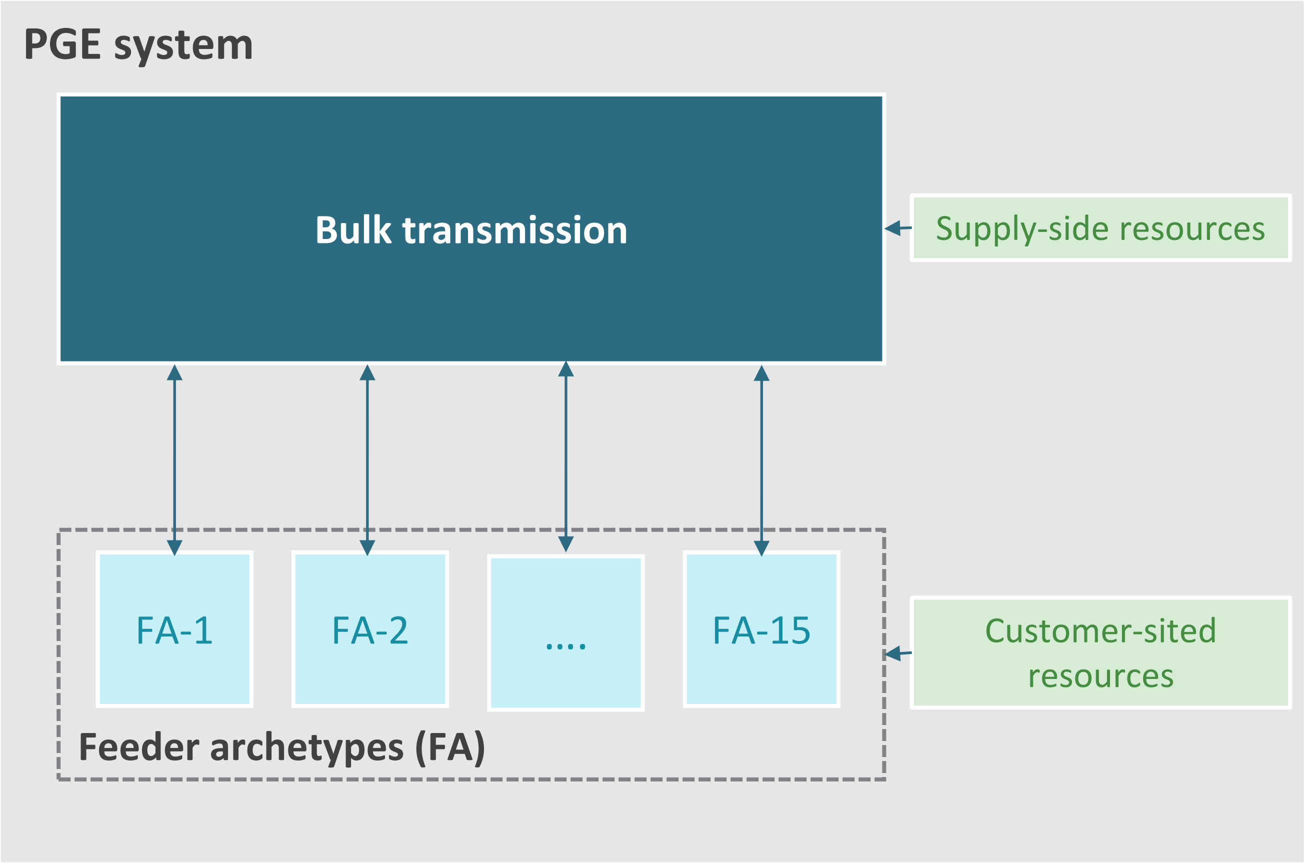


EVOLVED ENERGY RESEARCH

Distribution systems in system planning models

Representing distribution systems in capacity expansion models

- Bulk transmission system is connected to 15 “feeder archetypes” that cluster PGE’s ~700 feeders based on shared characteristics
- 5 ‘customer category’ and 3 ‘feeder utilization’ bins



Feeder bins from PGE study

Feeder Archetype #	Customer Category Bin	Feeder Utilization Bin	Feeder Count	Residential load (% total)	Commercial load (% total)	Industrial load (% total)	Present-day Feeder Utilization (% nominal weak link)
1	**Residential-oriented**	High	59	22%	7%	0%	64%
2	**Residential-oriented**	Medium	60	18%	5%	0%	44%
3	**Residential-oriented**	Low	56	12%	3%	0%	27%
4	**Commerical-oriented**	High	24	2%	9%	1%	57%
5	**Commerical-oriented**	Medium	51	2%	17%	1%	43%
6	**Commerical-oriented**	Low	34	1%	6%	0%	21%
7	**Industrial-oriented**	High	27	0%	1%	26%	65%
8	**Industrial-oriented**	Medium	34	0%	2%	40%	47%
9	**Industrial-oriented**	Low	15	0%	0%	8%	20%
10	**Mixed building**	High	53	13%	14%	2%	62%
11	**Mixed building**	Medium	76	16%	16%	2%	44%
12	**Mixed building**	Low	47	7%	7%	1%	27%
13	**Mixed business**	High	23	4%	6%	9%	63%
14	**Mixed business**	Medium	22	3%	4%	7%	44%
15	**Mixed business**	Low	10	0%	1%	1%	19%
			591	**100%**	**100%**	**100%**	

Distribution impacts by feeder archetype

- Feeders that have low to medium present-day utilization can absorb large amounts of incremental load growth prior to triggering upgrades
- Most avoided distribution capacity occurs on residential-oriented feeders that are already near the planning threshold (67%)

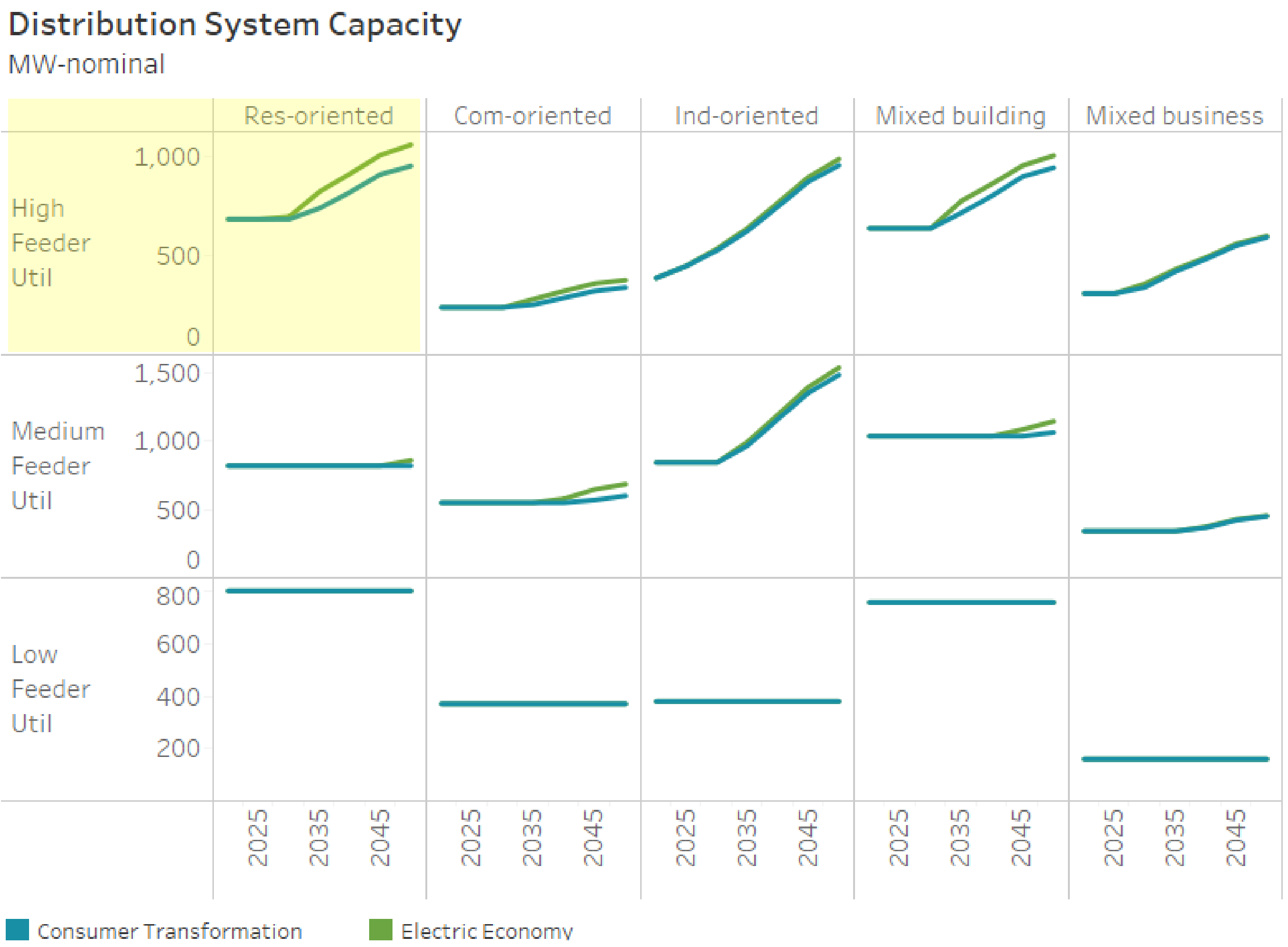
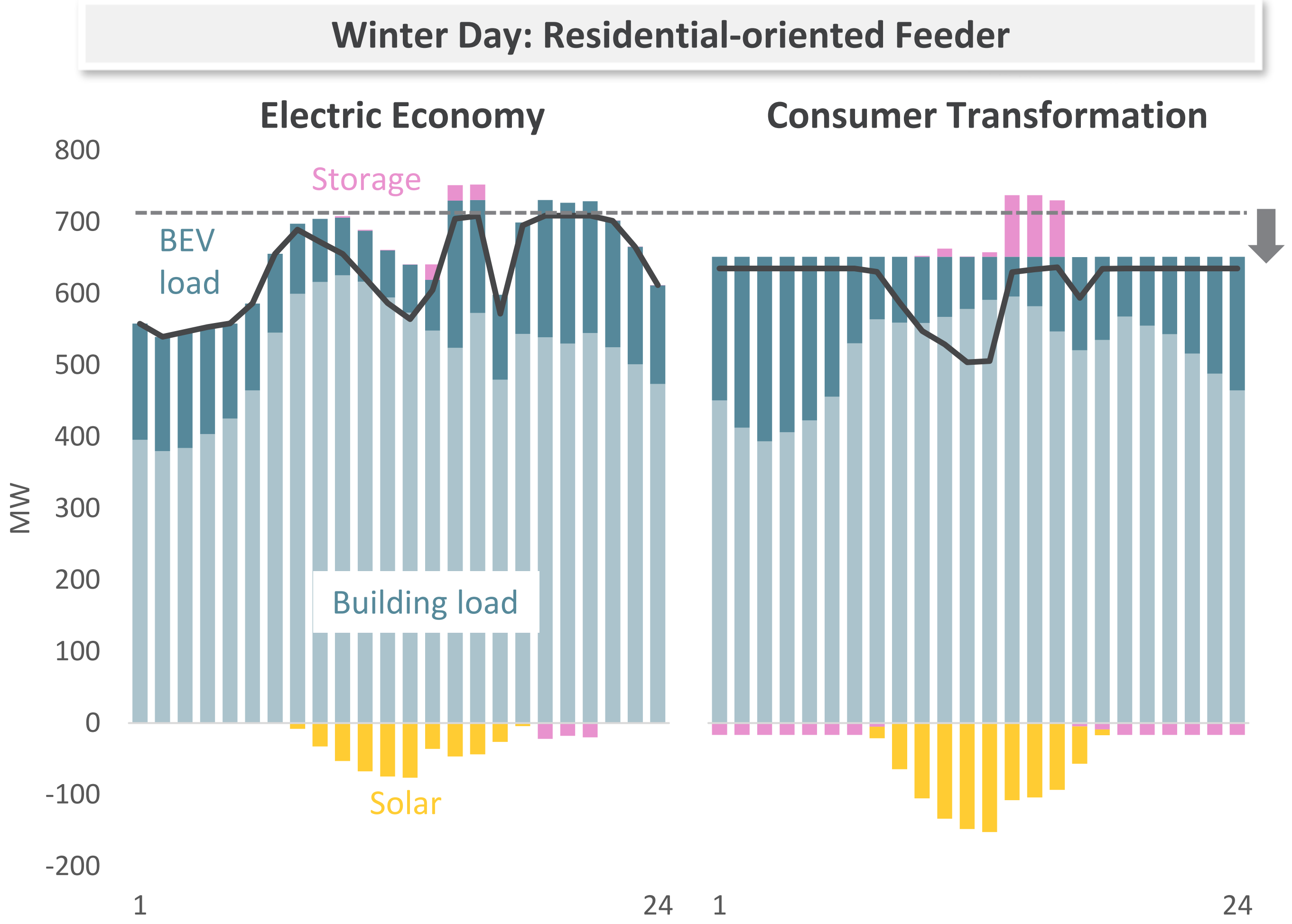


Illustration of distribution-sited resource impact

- On very cold winter days that set the distribution peak, flexible load is challenged by the persistence of high loads across the day and customer-sited solar quality is low
- In particular, the ability of electric vehicles to shift consumption is limited since there is a dual morning and evening heating load



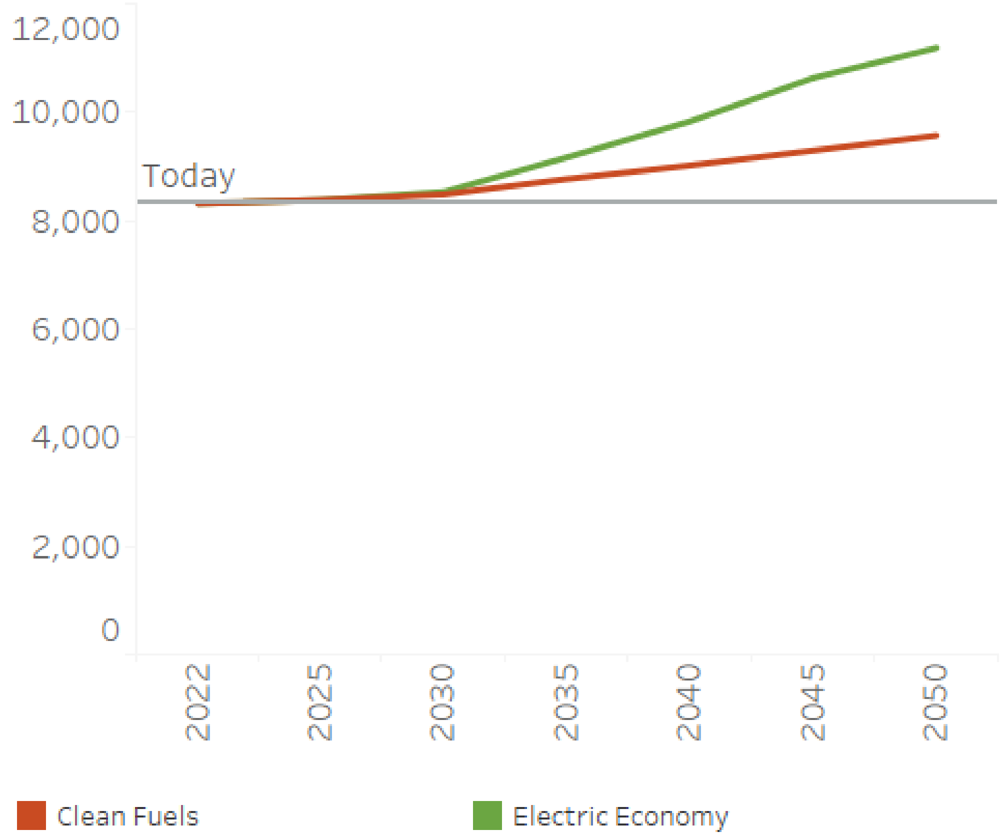
Black line = net distribution-level load sered by supply-side resources

Comparing clean fuels pathways with high electrification

EVOLVED ENERGY RESEARCH

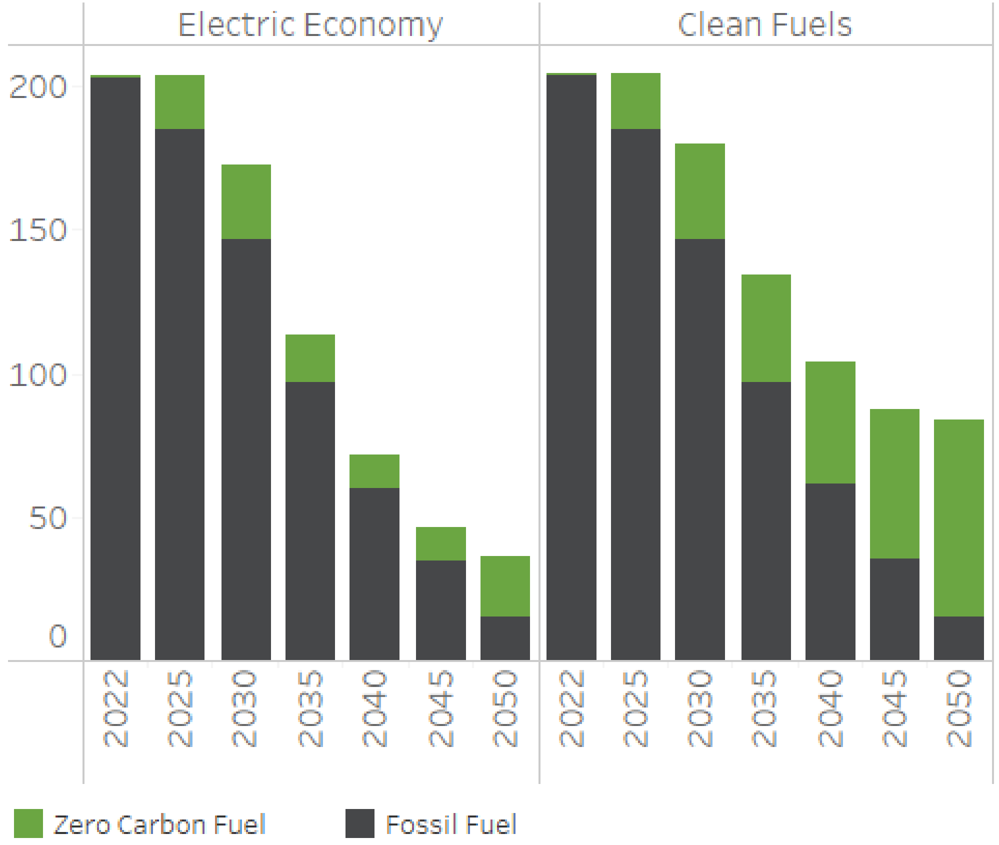
Distribution System Capacity

MW-nominal



Liquid Fuels and Pipeline Gas Supply

TBtu



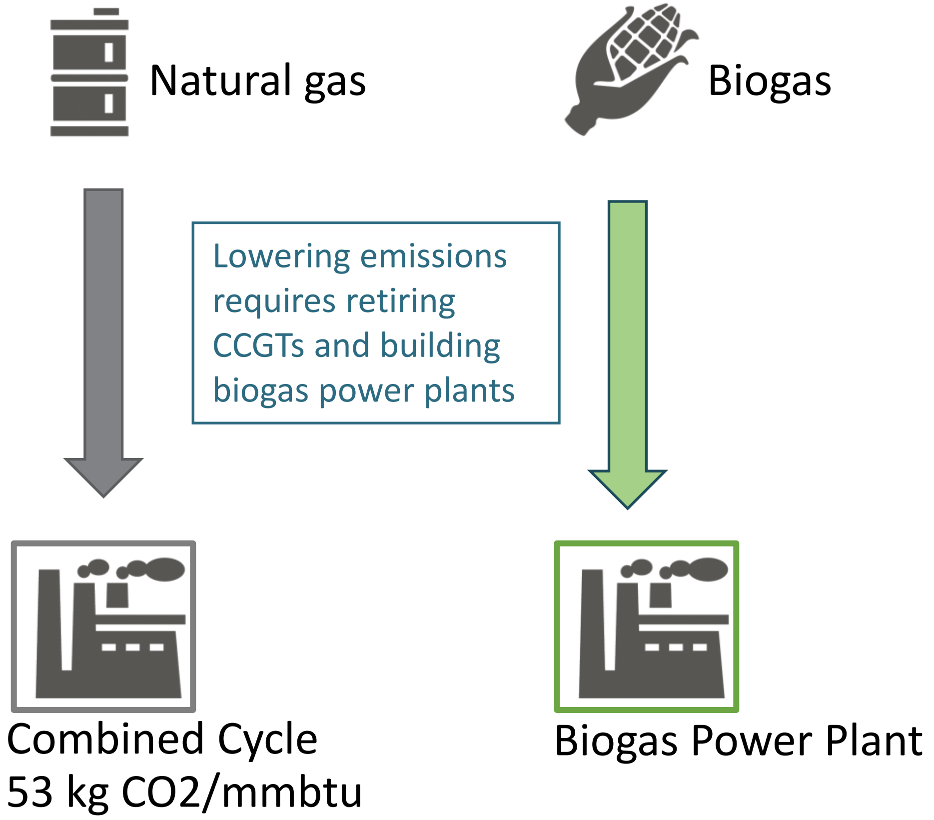
THANK YOU

EVOLVED
ENERGY
RESEARCH

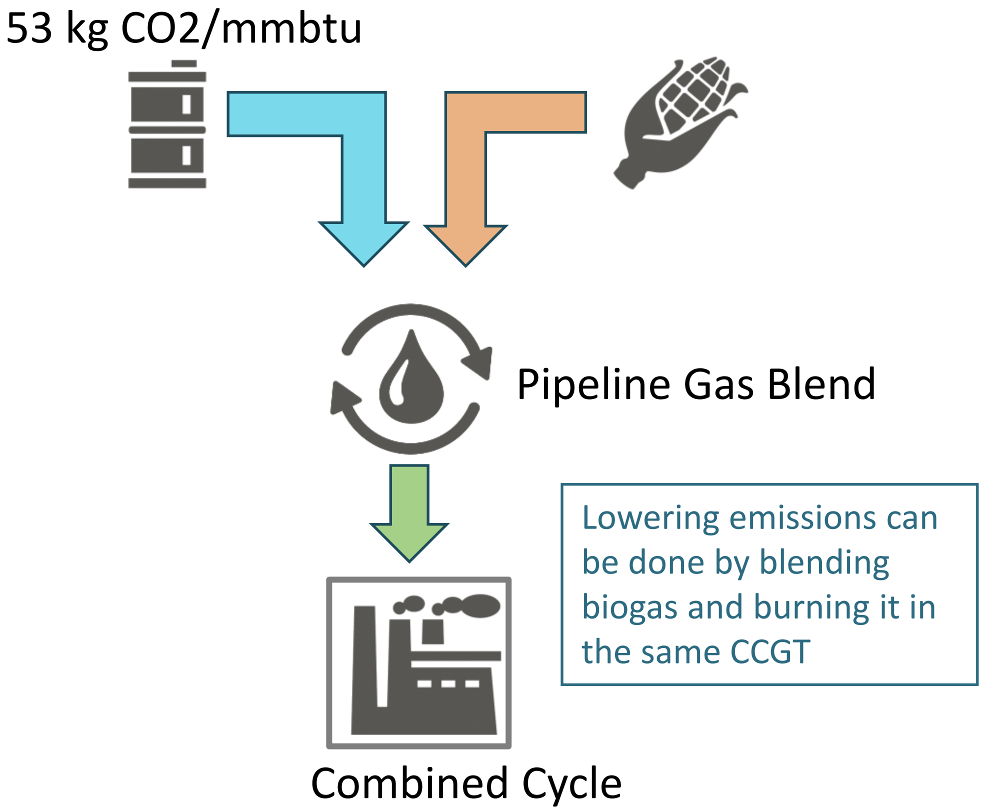
Fuels accounting in electricity modeling

EVOLVED
ENERGY
RESEARCH

Power Plants Connected to Fuels



Power Plants Connected to Blends

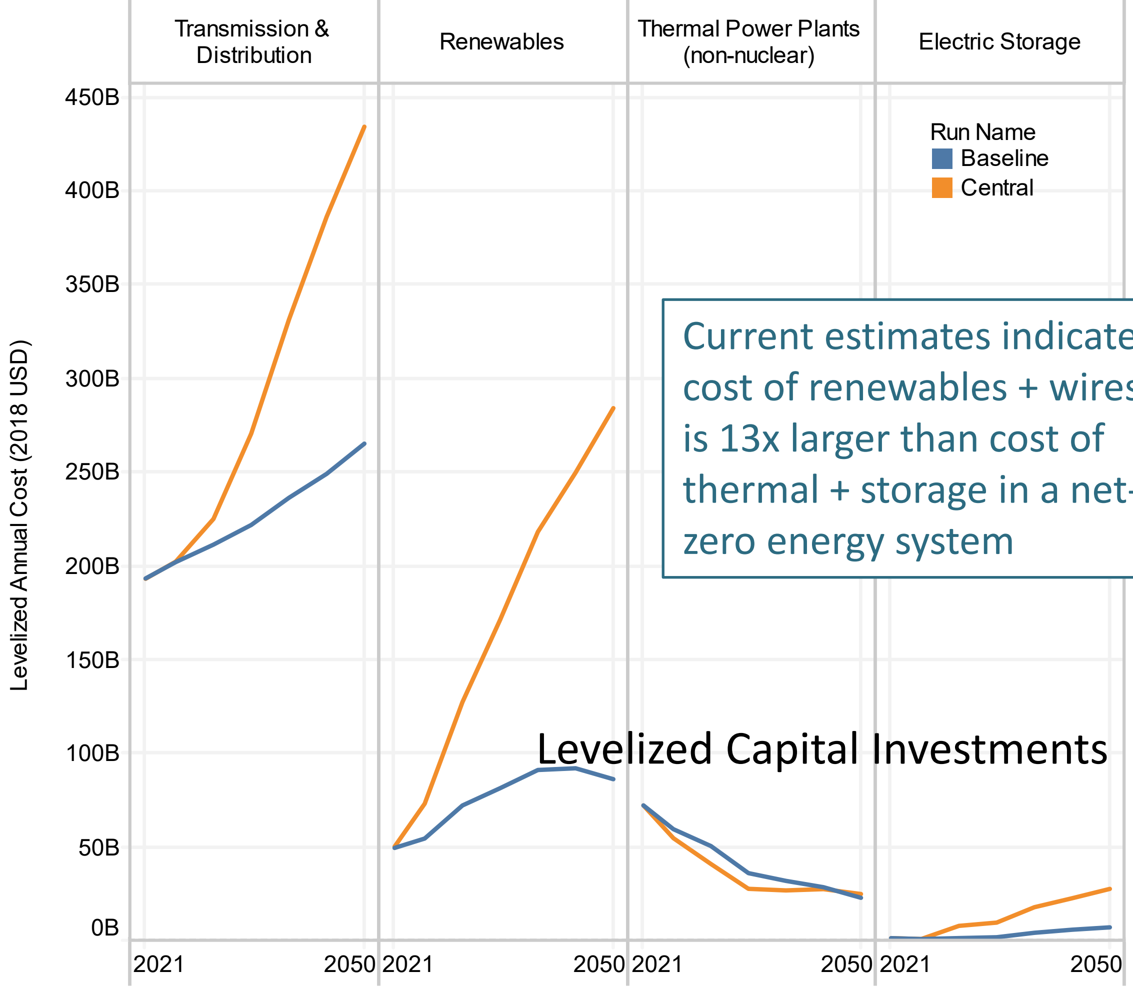


Decision making in the face of uncertainty

EVOLVED ENERGY RESEARCH

- Resource adequacy (RA) modeling is based on probabilistic methods for extreme events
- When difficult to give probabilities to uncertain trends, RA modeling has tended to ignore them
- The importance of precision in assessing probabilities depends on the relative cost/benefit of different actions within a realized future

https://www.cartoonistgroup.com/cartoon/Frank+and+Ernest/2013-08-07/100238



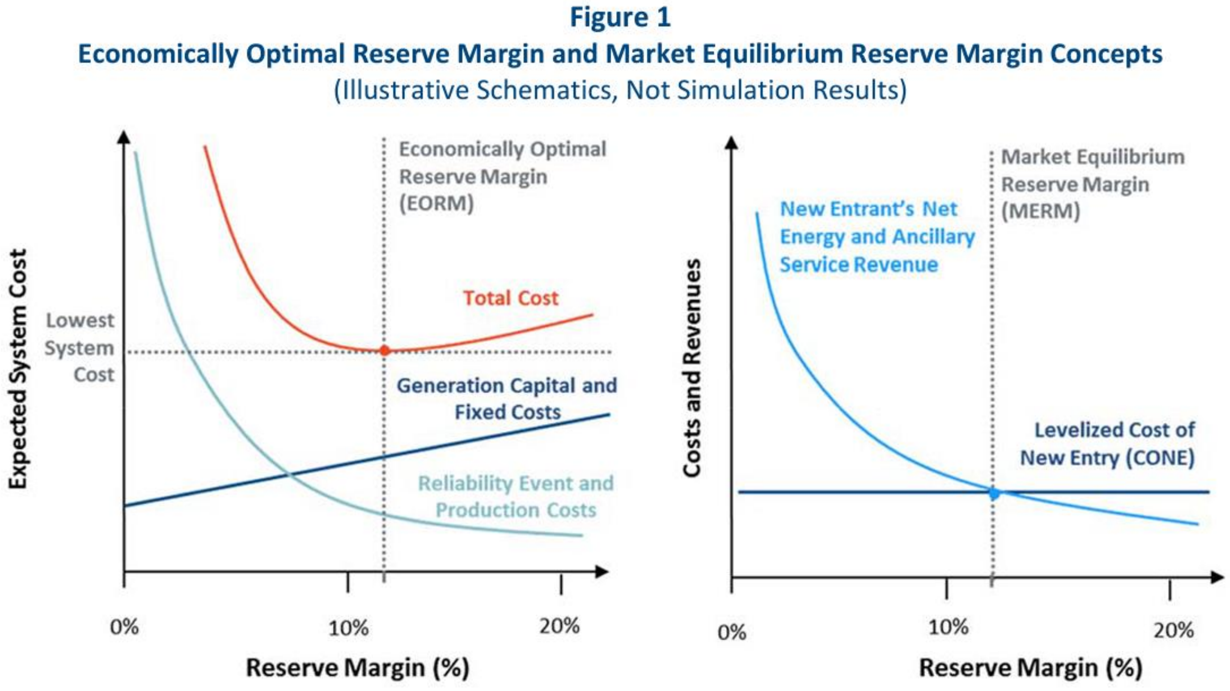
Current estimates indicate cost of renewables + wires is 13x larger than cost of thermal + storage in a net-zero energy system

Source: Annual Decarbonization Perspective 2022

Multiple factors are threatening system reliability

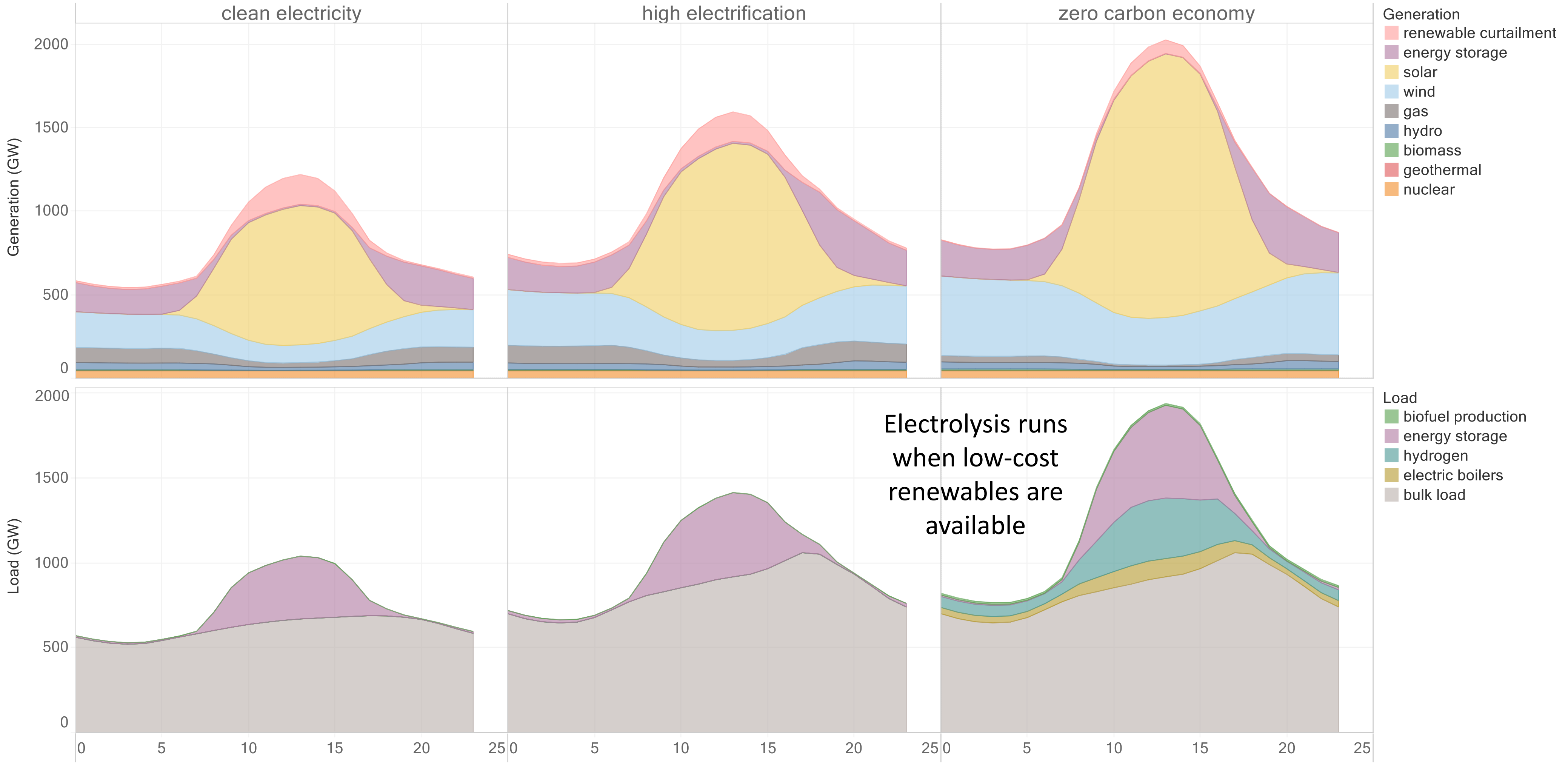
- Impacts of climate change
- More rapid electrification than expected
- Unrepresented covariance between outages
- "Reliable Imports" based on historical experience
- Slow siting, permitting, and construction
- Over-crediting of DR and distributed storage resources
- Accelerating retirement of coal
- Resistance to new thermal power plants

Recent focus on economic efficiency resulting in downward pressure on reserve margins



Brattle, 2018 Update: Estimation of the Market Equilibrium and Economically Optimal Reserve Margins for the ERCOT Region

Average 2050 daily supply & demand



Excluded dynamics when integrating forecasts

EnergyPATHWAYS is strong at exploring long-term ‘what if’ scenarios and weak at forecasting customer behavior and establishing a long-term economic outlook

Missing Dynamic	Impact on Results	Rational for Exclusion
Endogenous customer adoption	Potential for scenario inconsistencies, overly smooth customer behavior (especially in the near-term)	Customer adoption frequently is not ‘economically rational’; When it is, ratemaking often changes or blunts signals sent by energy system fundamentals
Price elasticity of demand	A Carbon Price may reduce service demand, further reducing emissions, and increasing societal cost	Most elasticity is low outside of key industrial subsectors; policy choices could mitigate such impacts; comparable service demand makes communicating cost easier
Early retirement of equipment	Sufficient changes in operational cost could speed-up customer adoption	Helps add realism through friction; equipment with residual life often gets repurposed or sold as ‘used’

Assessing Reliability Becomes Challenging in Low-Carbon Electricity Systems