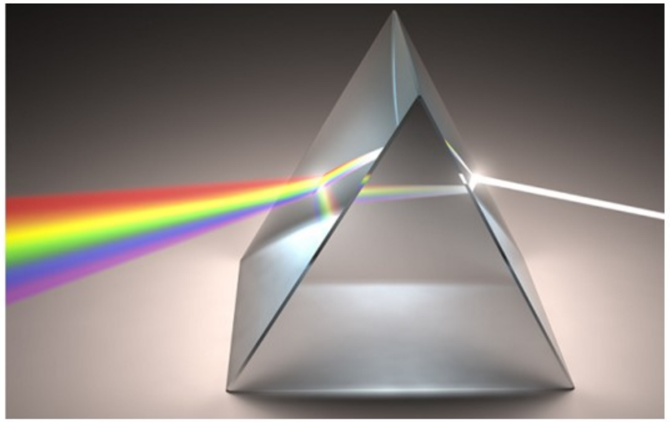

A PRISM-BASED CONFIGURATION MARKET FOR RAPID, LOW COST AND RELIABLE ELECTRIC SECTOR DECARBONIZATION

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WRI & RFF Market Design for Clean Energy Workshop

December 16, 2020

Why use a PRISM in a market?

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What's the biggest machine ever built?

5 Answers

David P. Chassin, Chief Scientist, Grid Integration Systems&Mobility at SLAC National Accelerator Laboratory (2016-present)

Answered February 3 · Author has **270** answers and **297.1K** answer views

The Eastern Interconnection is among the largest single machines ever built. It is in fact a single continent-sized machine that is essential to our survival. The American Academy of Engineering regards electric power systems as the single most important achievement of the 20th Century. Most people don't think of electric grids as single machines. But that's because most people don't understand how electric grids work.

The Eastern Interconnection spans the eastern ⅔ of North America with a single synchronous network of generators, transformers, switches, voltage regulators, capacitors, power lines, and customer loads all operating at the exact same frequency, i.e., 60 Hz. The control systems that govern electric grids are incredibly precise and incredibly reliable. The

An interconnection is a single, giant, synchronized machine.

It quickly falls apart if electricity injections don't always add up to concurrent electricity use.

Meeting this balancing constraint requires the right mix (type and amount) of resources.

Fossil resources are typically "firm." Firm resources are fully available in every hour.

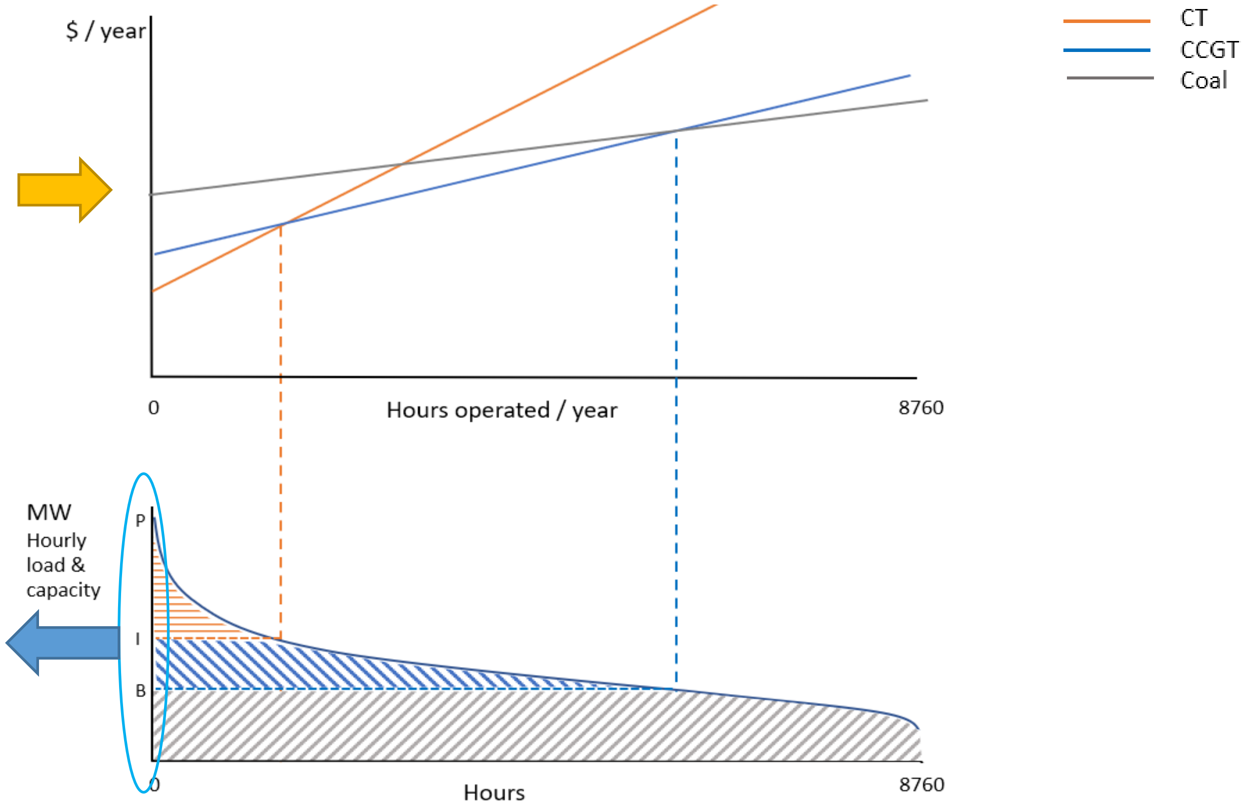
This makes them substitutes across all hours.

And it makes it easy to get the right amount and the best mix to meet the balancing requirement.

Input:

P,I,B fixed and variable cost

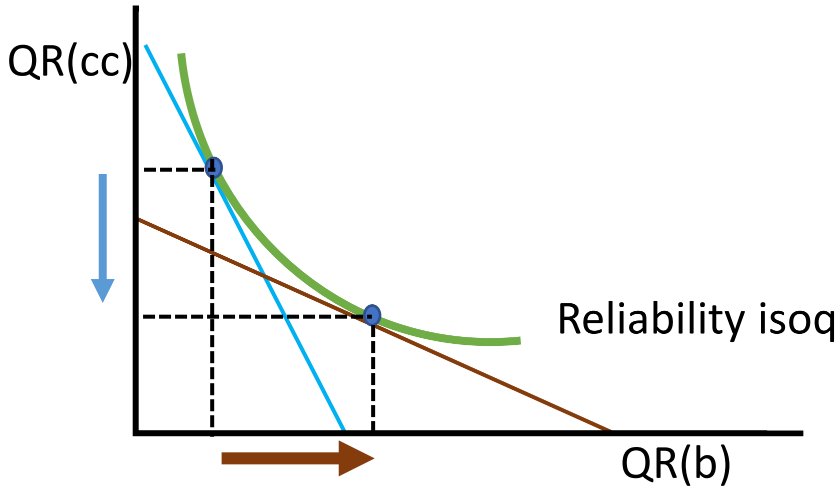
8760 hours of expected load



Output:

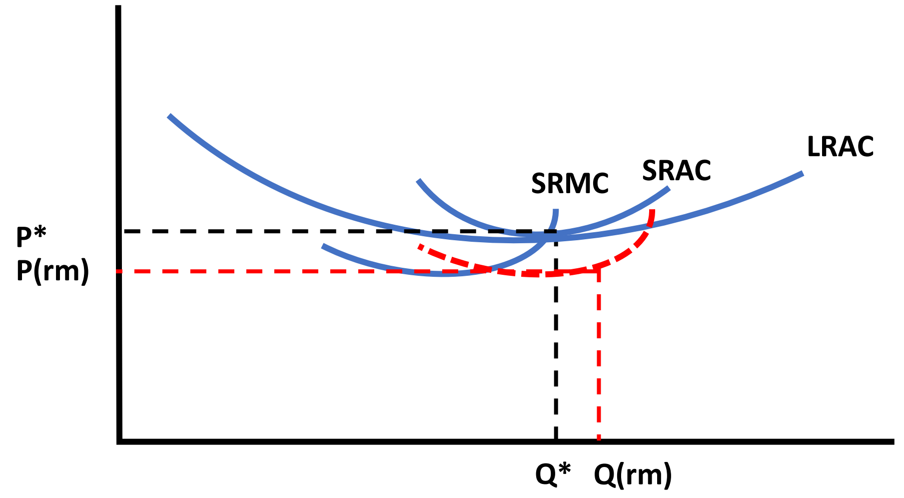
Optimal MW of P, I, B

Market-based optimization with substitutable firm resources



Such individual investments seeking quasi-rents could support *a more efficient, no less reliable* mix -- but:

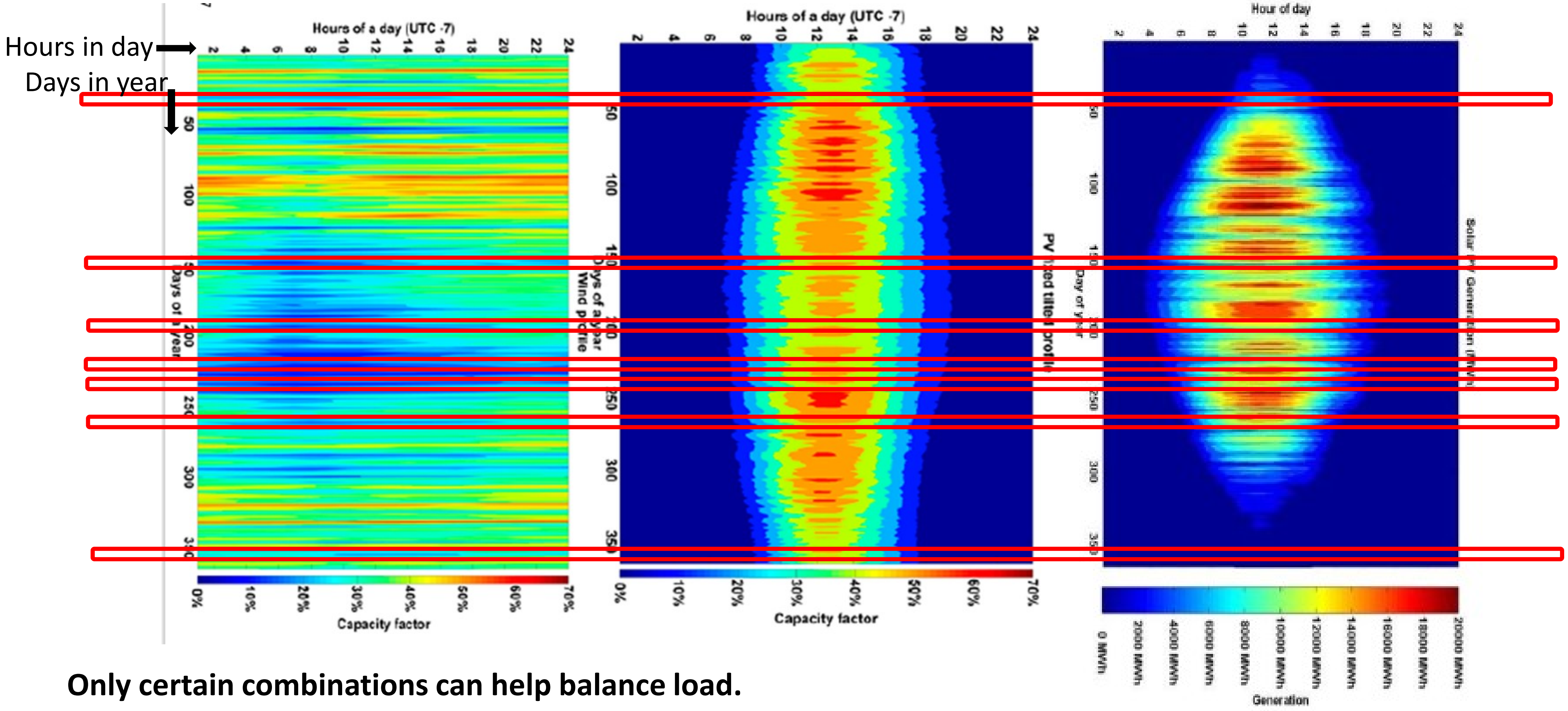
- The price signals that drive new investment are unlikely to drive retirement, leading to oversupply and depressed prices for all resources.
- Many investors can make parallel decisions, leading to massive inefficiencies that can last for decades.



Economic theory suggests SCED-based LMP prices could, over time, *optimize both the mix and the quantity* - but:

- Required planning reserve margins (rm) and other factors can prevent scarcity prices.
- Without a big enough reserve margin, inelastic demand can lead to unacceptable curtailment during scarcity events.

Renewables and storage are not available in every hour.



Only certain combinations can help balance load.

Even the best combinations need specific other clean resources to “fill in” at times.

This means all these clean energy resources are *complements.*

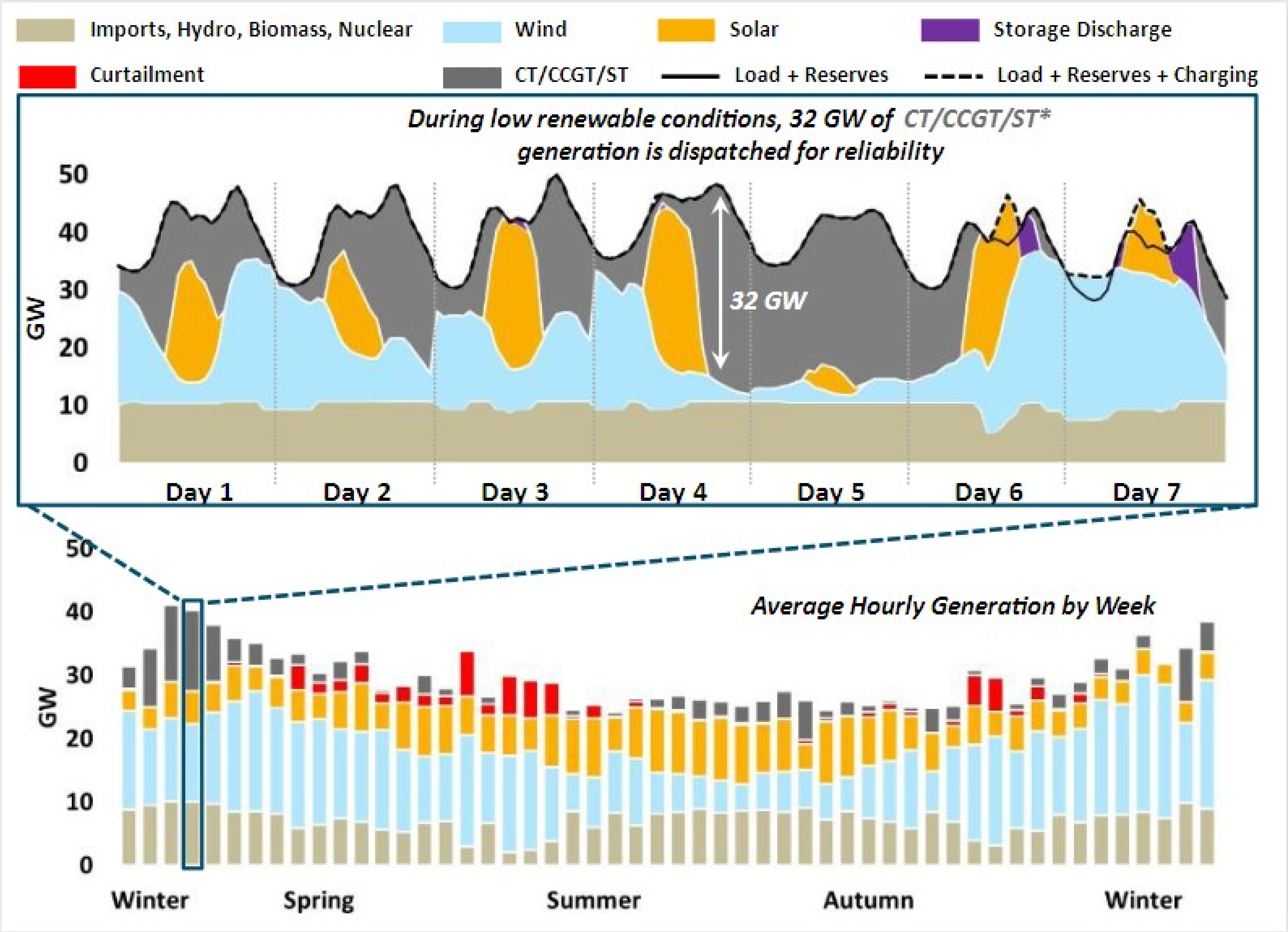
The best complementary combinations can be very costly to identify -- and hard to develop.

Source of profiles: A Techno-Economic Study of an Entirely Renewable Based Power Supply for North America. Aghahosseini et al., *Energies* 2017, 10.

Available at http://repec.org

There are so many potential combinations you really need a PRISM analysis to find the ones that work and that cost the least.

Figure 4-10. Illustrative Dispatch over a Critical Week in 2050 (High Electrification Scenario)

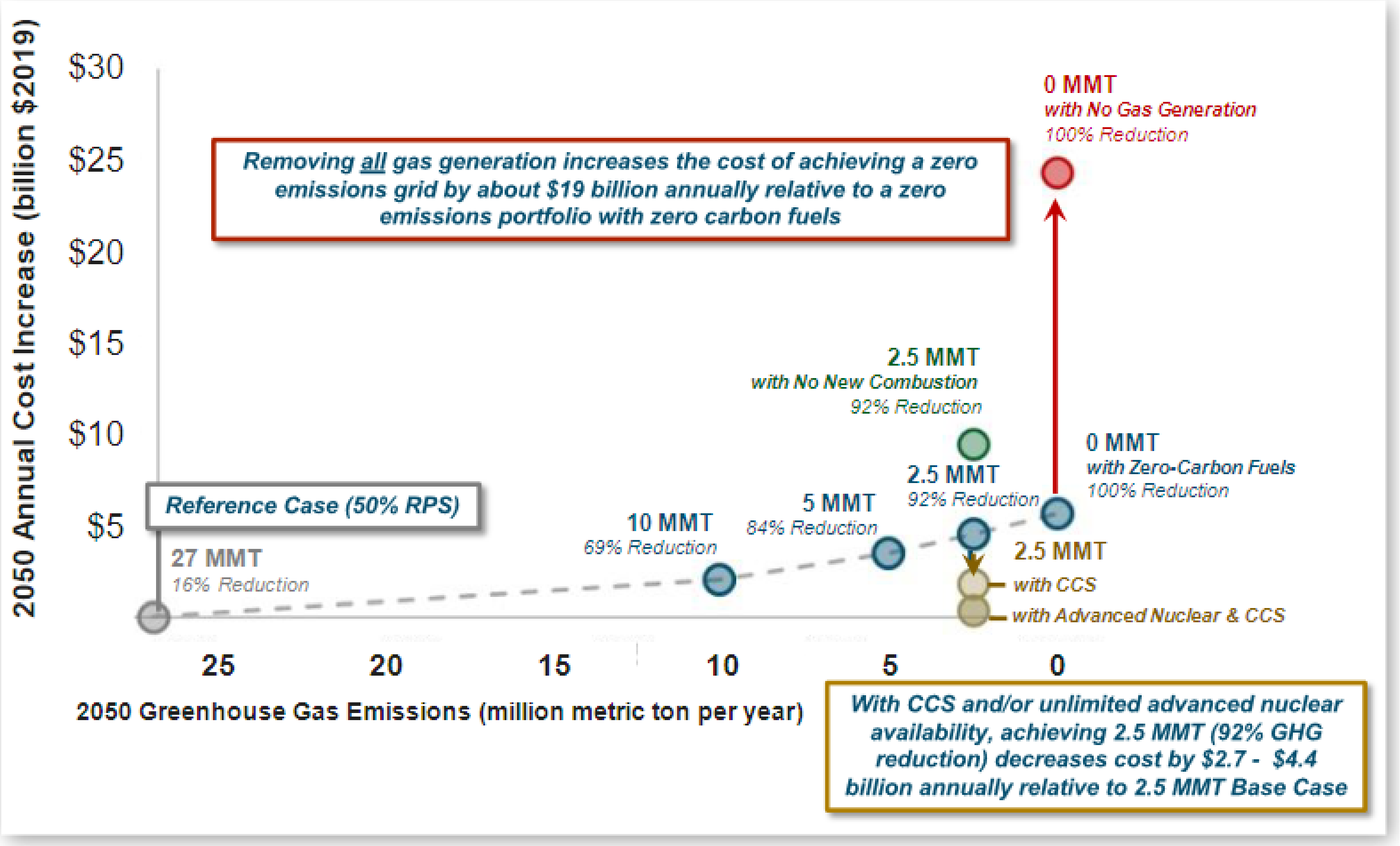


This shows why "clean firm" resources could dramatically reduce costs.

Source: E-three / EFI *Net-Zero New England,* November 2020

The cost of the wrong solution to the problem can be staggering

Figure ES-3. Increase in Electricity System Modeled Costs Relative to Reference Case Across Selected Set of Scenarios in 2050 (High Electrification)



$20 Billion per year for New England

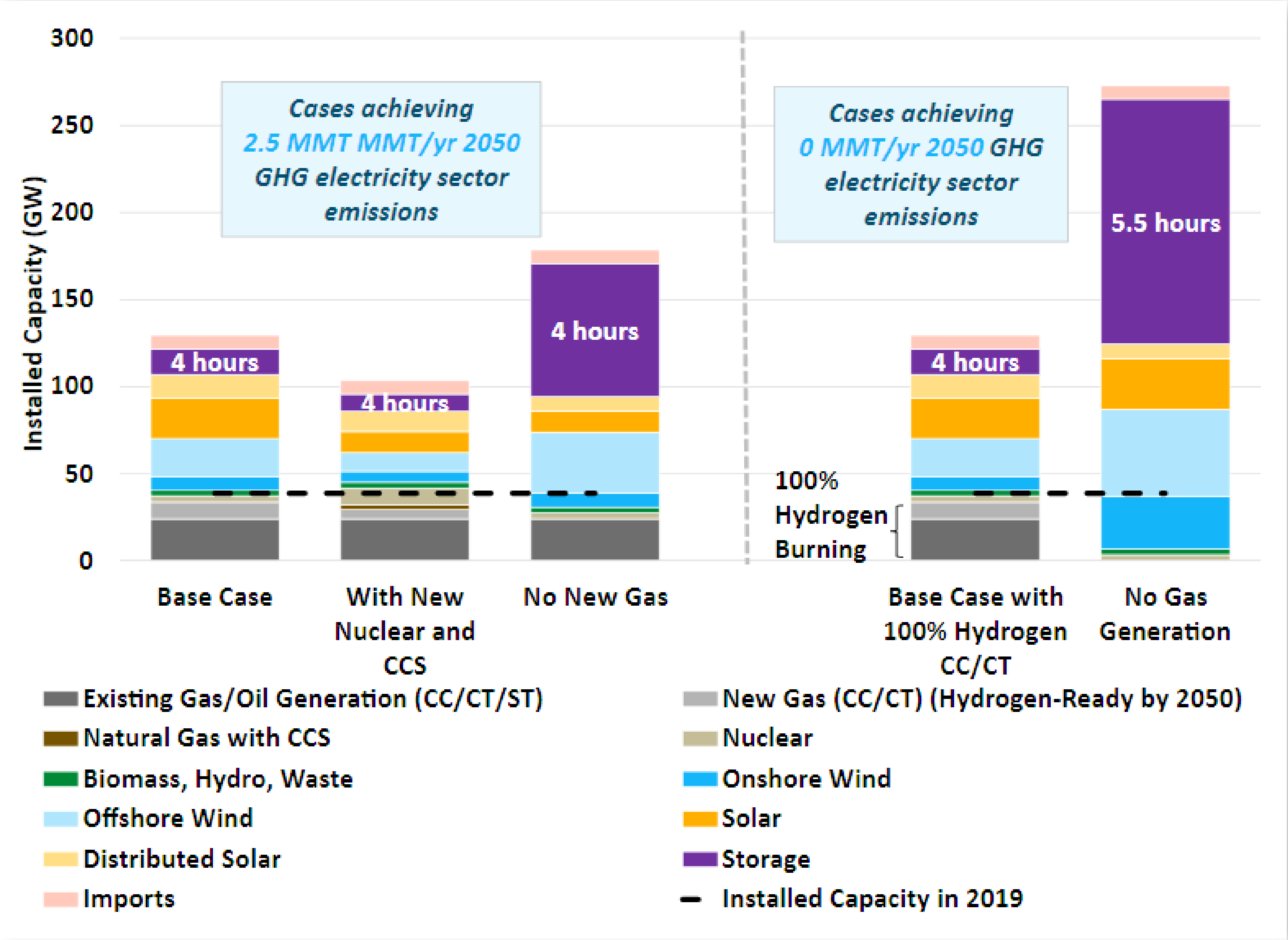
Loss of existing nuclear units can have similar impacts

Source: E-three / EFI, *Net-Zero New England,* November 2020

With no "Zero Carbon Gas," system can only be balanced by ~ 100 GW more batteries and substantially more wind and solar to produce enough extra energy to charge them.

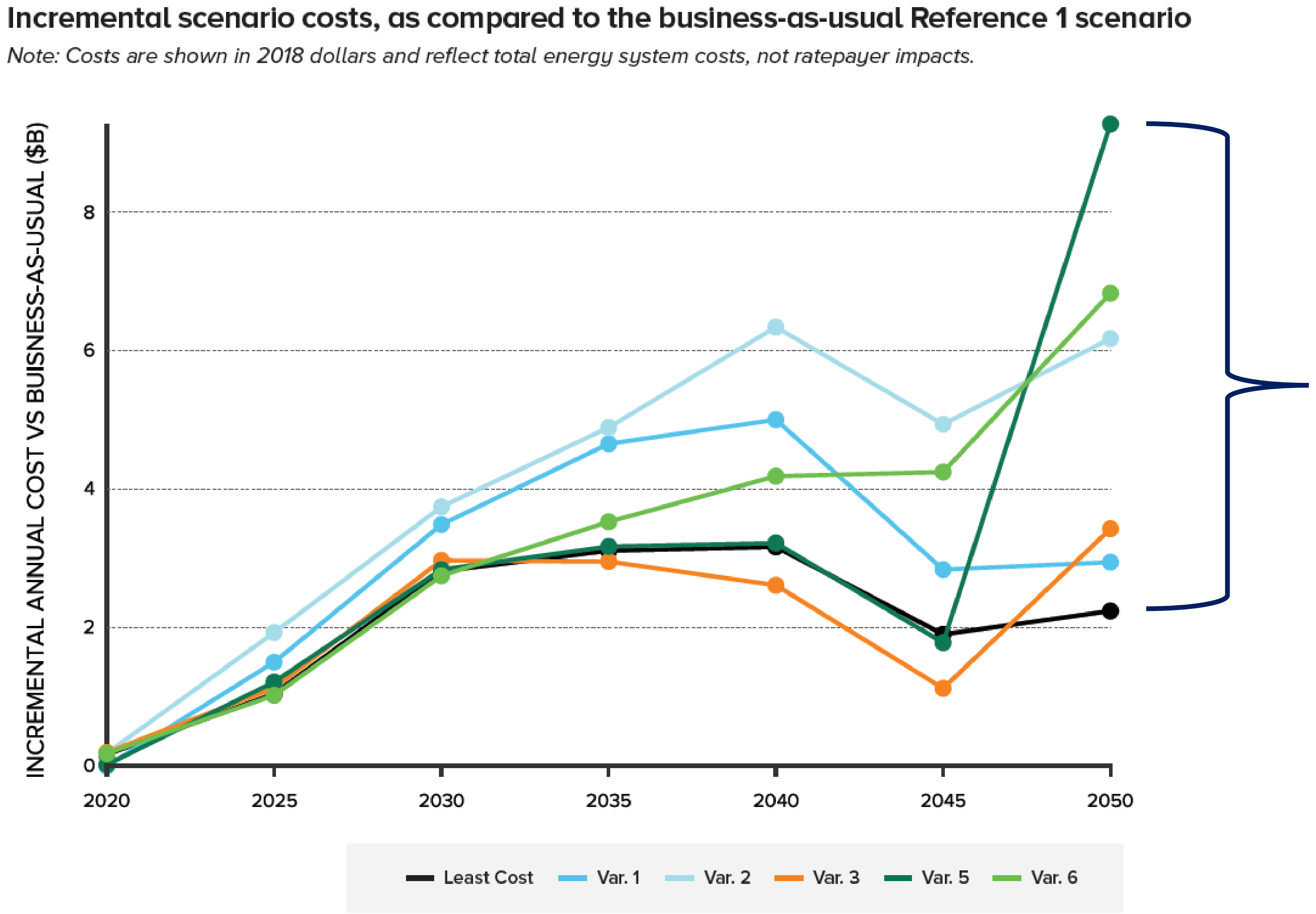
This is why it costs $20 B more in 2050.

Figure 4-19. Sensitivity Results Limiting/Expanding Firm Capacity Options: Total Installed Capacity in 2050 (High Electrification Scenario)



Source: E-three / EFI *Net-Zero New England,* November 2020

Similar cost impacts from not retaining existing nuclear and not adding ZCG turbine capacity



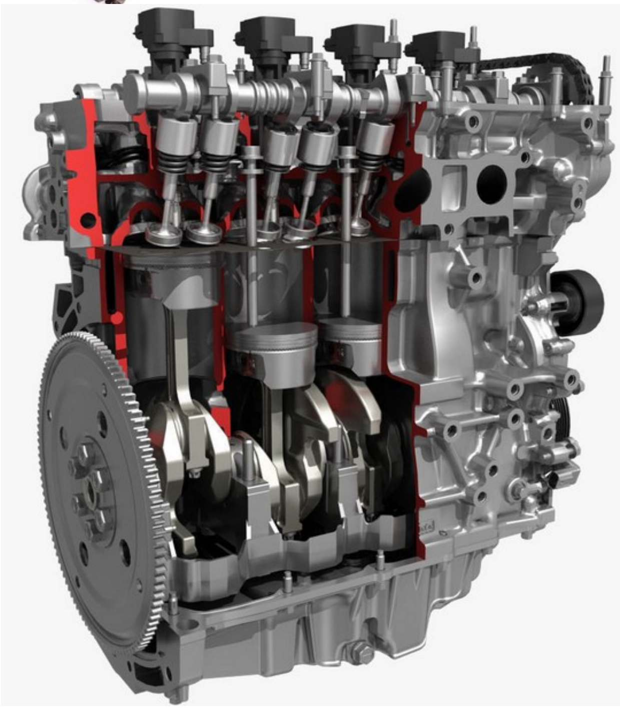
$7 B more/ year primarily due to closing nuclear plants and not building new gas-turbine assets in NJ.

Source: New Jersey BPU *2019 Energy Master Plan*, Integrated Energy Planning analysis

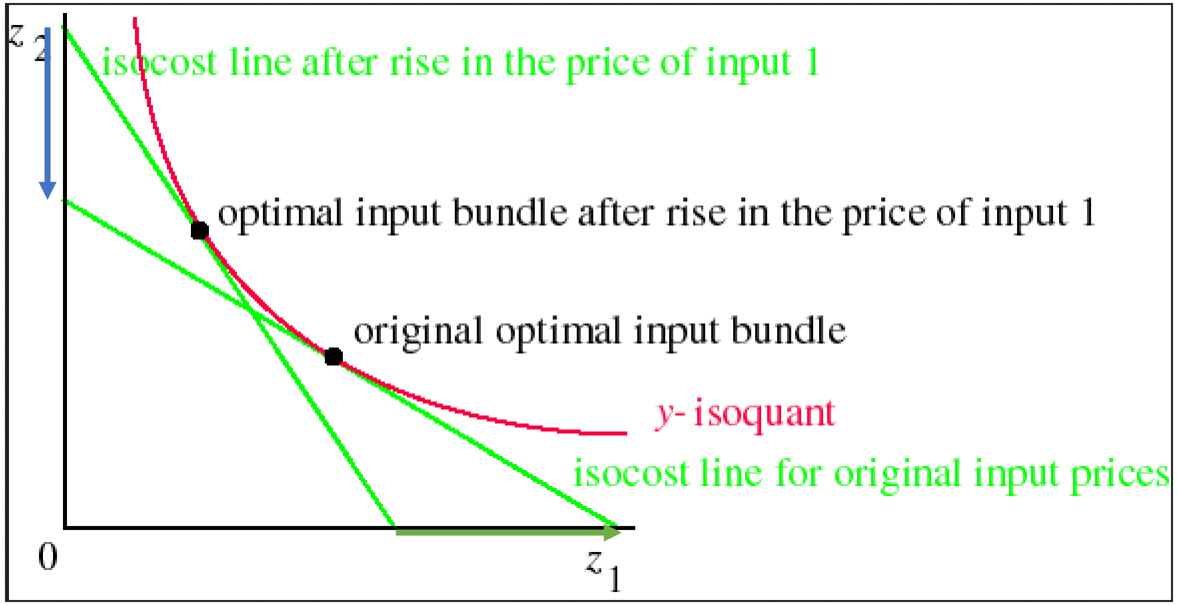
The need to find complementary resources to decarbonize the power sector creates three new problems for markets to solve:

1. **Very high information costs for using clean energy resources to meet balancing constraint.**
    - Thousands of data points with billions of possible permutations to evaluate.
    - These costs - much higher than for fossil resources – are a hidden barrier to entry for variably intermittent and time-limited (VITL) resources.
2. **Challenging and complex coordination costs across different technologies, locations and project developers.**
    - Needed complements will deploy radically different technologies, be developed and owned by competing companies, and can be hundreds or thousands of miles apart.
    - Resource "A" is only efficient if someone else develops resource "B" and someone else develops "C" concurrently, instead of "D" and "E".
3. **Much higher risks of failure to solve above problems.**
    - Prohibitively high costs of decarbonization
    - Uncontrolled climate crisis

Can we get insights from how competitive firms find the least cost, efficient mix of complementary inputs?

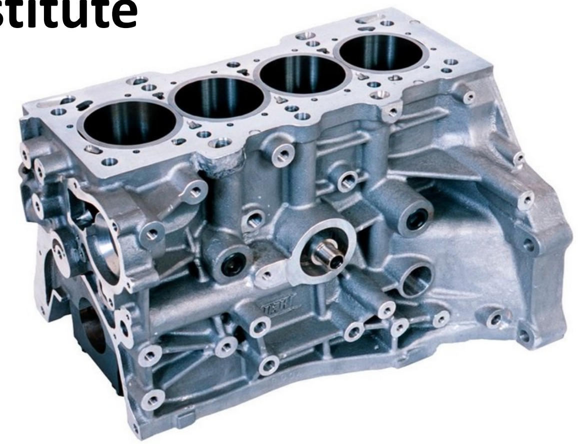


Decentralized market optimization works for substitute inputs but not for complementary ones



$\nRightarrow$

Lower piston prices don't make auto companies substitute



More pistons **for** **fewer engine blocks**

Instead, they use *central managerial optimization* and *contracts* to get just what they need, when they need it:

1. **Identify complementary inputs needed to produce the output.**

2. **Seek competitive offers for all those inputs.**

3. **Identify the lowest cost combination of inputs that can produce the output. (Math may be needed!)**

4. **Contract with those input sellers to supply the needed amounts, when they are needed.**

(Q: Where do all power companies already participate in such a process?)
(A: In every security-constrained economic dispatch LMP market.)

This approach inspired the “configuration market” approach

A PRISM-based Configuration Market : overview

Market hosting, timing and targeted resources

- Hosted by RTO, a joint state board under FPA S. 209, or other regional entity (e.g., like EIM).
  - New procurement round every three years.
  - Clean resource developers invited to submit sealed bids for amortized all-in project cost, based on a technology-specific, pro-forma draft contract.

Winner selection process

- PRISM-based tools select combination of projects that, in combination with existing resources:
  - Have GHG emissions within PRISM declining carbon constraint
  - Ensure system can balance generation and load every five minutes
  - Meets above constraints at lowest cost

Payment to winners and settlement

- Winning bidders are awarded financial swaps with load (similar to tolling agreements).
  - Load pays as-bid prices to projects, projects must offer in SCED market and pay SCED revenues to load.
  - Penalties are deducted from fixed cost payments for failure to meet contract performance requirements
  - Swap tenor may vary with resource types, depending on financing needs.

Goal

- Ensure development of whatever clean energy resources are needed for reliable, low-cost decarbonization while avoiding
  - Massive information costs (relative to fossil resources) regarding contribution to system balancing, and
  - Expensive financing due to growing revenue risk in SCED-based markets.

Critical details

1. **Optimization basics over time**
2. **Carbon constraints in PRISM MIP**
3. **Resource adequacy**
4. **Existing units and retirement**
5. **Transmission and other “condition precedent” dependent resources**
6. **Self-supply options**

1. Optimization basics – time dimension

- "**Stepwise myopia" (new, current period optimization) every 3 years, to avoid "perfect foresight" forecast to 2050 in each incremental market round.**
- **Existing resources and load represented in PRISM data and optimization based on publicly available data.**
- **Winning resources selected for least-cost *system* solution to carbon and balancing constraints.**
- **Outside of PRISM market, same tools and data are used for specific forward looking scenario analyses**
    - **Designed to address key inter-temporal challenges without "perfect foresight" in market clearing.**

2. Carbon and balancing constraints in PRISM

- Balancing constraint requires model to select resources that will be able to meet load plus reserves in each "dispatch interval", while paying selected resources their fixed and any variable costs.

- Declining carbon constraint requires resources selected to also result, in balancing system, in system-wide emissions within the declining carbon constraint.
  - Carbon constraint anticipated to be key forcing function for new resource additions.
  - Future period carbon constraints can be addressed in current auction through a variety of means (e.g., only zero carbon new resources selected, or through scenario analysis approach below.)

- GHG budget declines annually at pre-set levels, consistent with IPCC or other authoritative climate science recommendations on avoiding warming greater than an acceptable threshold (1.5 degrees C).

- GHG budget established voluntarily by members (and included in any tariff filed at FERC), or adopted in response to policy requirements.

- PRISM-based market would reduce emissions via physical deployment of clean resources that displace fossil energy in the SCED market, without an explicit carbon price on fuels. (Similar to CES impact.)

3. Resource Adequacy

- "Resource adequacy" means having the right mix (type and amount) of resources to provide an acceptable frequency of load-shedding events needed when there is insufficient energy to balance load.
- The PRISM balancing constraint applies to every dispatch interval, at "peak" load and at other times of system stress, such as extended lulls in wind and insolation.
- Conjecture: this feature could evolve to support new approaches to resource adequacy:
  - Identify the load-shedding frequency due to any given aggregate supply mix
  - Identify the marginal contribution to load-shedding frequency due to alternative sub-portfolios
- If so, a PRISM-based market could be designed to provide any "floor" level of resource adequacy
  - e.g., to assure no more than 1 load-shed event in 6 years.
- This would encourage higher and more frequent scarcity prices in the SCED market than today's common 1-in-10 standard.
  - More scarcity pricing would support more demand-side engagement in market.
  - The PRISM market would continue to ensure an efficient mix of capital-intensive clean energy resources is deployed and can get low cost financing.

4. Retirement and bids from existing units

- The declining carbon constraint will continually deploy new, clean resources.
- This will lead to falling SCED prices, until sufficient existing resources retire, restoring prices temporarily to those associated with “floor” RA level of scarcity.
  - Retirement of less efficient, high-emitting resources is critical for decarbonization to work.
  - But clean or low-emitting existing resources (nukes, seldom-used gas assets) that are needed for low cost decarbonization could also be pushed into retirement by falling SCED prices.
- To address this, such resources can bid their going-forward costs into the configuration market.
  - If the PRISM clearing process finds they help meet balancing and carbon constraint at least cost, they are awarded swap contracts based on their going-forward costs.
  - Otherwise, they retire and are replaced as needed by clean energy resources that meet these constraints at even lower costs.

5. Scenario analysis for “chicken and egg” resource problems.

- Many potential clean energy projects are contingent on other things happening first:
  - New solar, wind and electricity-to-fuels (ETF) projects may need new transmission in order to participate in LT market.
  - DERs may need new distribution system infrastructure and control systems.
  - New clean firm technologies may need learning-by-doing and scale deployment opportunities.
- PRISM tools would be used, outside of market, for forward-looking scenario analysis to help identify and support the most efficient solutions for such “conditions precedent.”
  - Efficient transmission for new clean resources is proposed through regional transmission plan.
  - Efficient distribution system architecture and management systems is explored through state DSP.
  - Appropriate emerging technologies needing help across the “valley of death” are invited to bid in PRISM market “set-asides” without competitive pressure from existing resources.
  - Forward carbon-budget compatibility rules for PRISM market clearing could be explored through appropriate scenarios.
- Once conditions precedent are approved or established, projects dependent on them would be invited to bid into the configuration market.

6. Self-supply options.

- **Participants in the configuration market will have two different self-supply options: Buy all /Sell all (BASA) and Virtual Optimization (VO).**
- **Under the BASA approach, LSE simply bids its own resources into long term market and continues to participate as before. New net revenues offset some or all of its configuration market settlement costs.**
- **Under the VO approach, an LSE asks the market operator to evaluate its clean energy portfolio using the PRISM tools and data.**
  - **If the portfolio increases total system costs, the portfolio is only accepted if the LSE pays for the higher system costs.**
  - **If the portfolio decreases total costs, the LSE can elect to convert to a BASA and receive the difference.**

THANK YOU