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Energy Transition: Re-Designing Organized Electricity Markets

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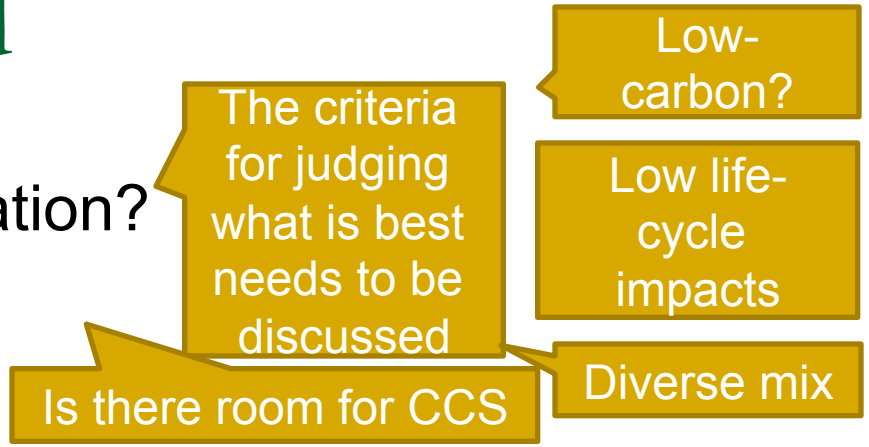
How to continue a transition towards a **deeply de-carbonized** electricity system that

- provides a **reliable** and **affordable** service
- enables **electrification** of the transportation and other sectors to achieve economy-wide de-carbonization
- encourages **technological innovation** to make the system **resilient** to a large number of growing threats

Three main questions that must be continually discussed

1. What is the **best** mix of generation?



2. Which policies and market-design elements are needed to spur **investment** (and avoid retirement) to obtain such ideal mix ?

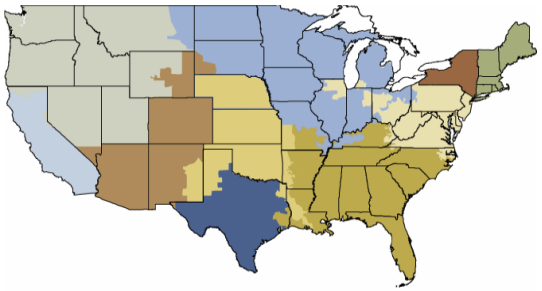
3. How should this fleet be **operated ?**

1. We seem to agree that would like a system with four main characteristics:

- High penetration of **carbon-free sources** for electricity generation
  - Hydro, nuclear, wind, PV, biomass, (maybe CCS)
- High deployment of **non-generation resources** to reduce peak-demand and increase flexibility
  - Demand response, end-use energy efficiency, Battery energy storage, other energy storage
- Departure from a centralized-only system in favor of one where **distributed** and centralized solutions are complementary
- **Electrification** of the transportation and other sectors
  - As a way to continue deep de-carbonization
  - But also to accomplish other golas (e.g. integrate excess wind)

2. Which policies and electricity-market design elements are needed?

No market today has all what is needed

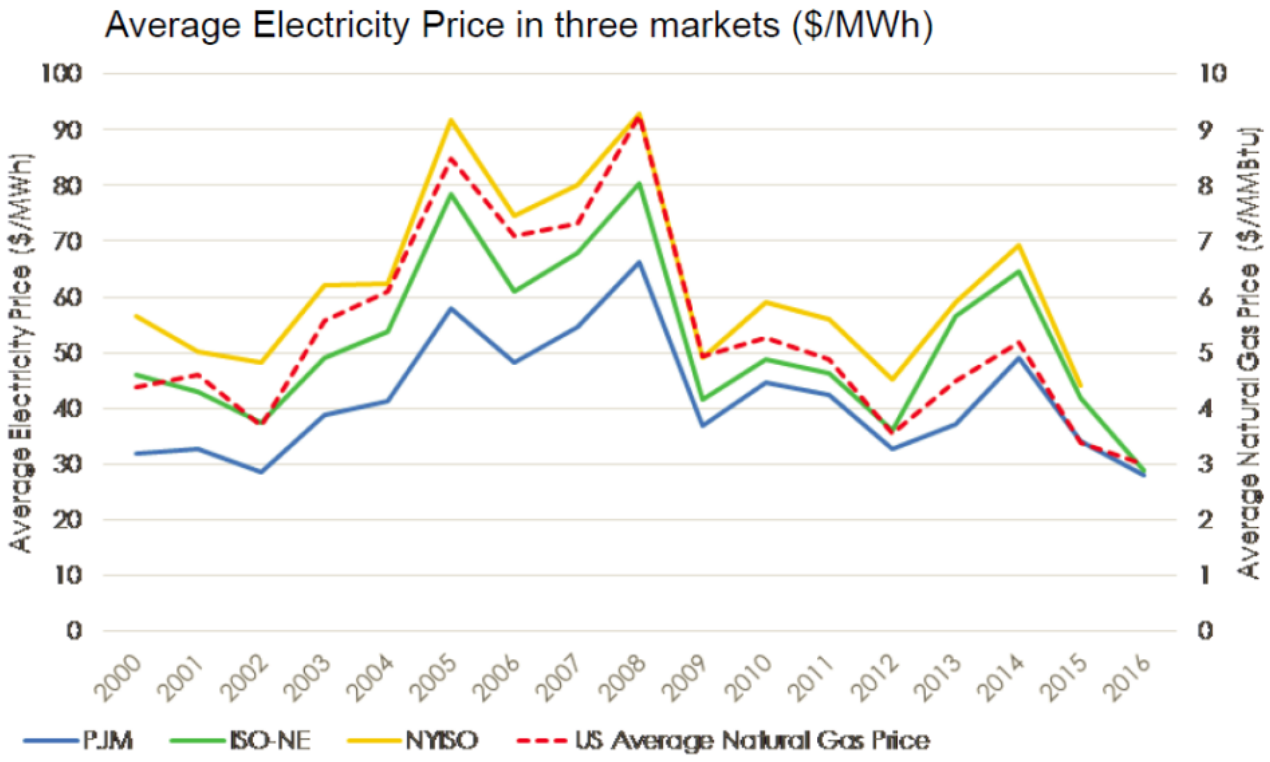


U.S. organized electricity markets have been relatively successful achieving the least-cost generation and reliability (both operational and resource adequacy)

But they do not support other policy goals

U.S. Organized Electricity Markets

Co-optimize **energy and reserves** to ensure **operational reliability standards** are met at **minimum cost**



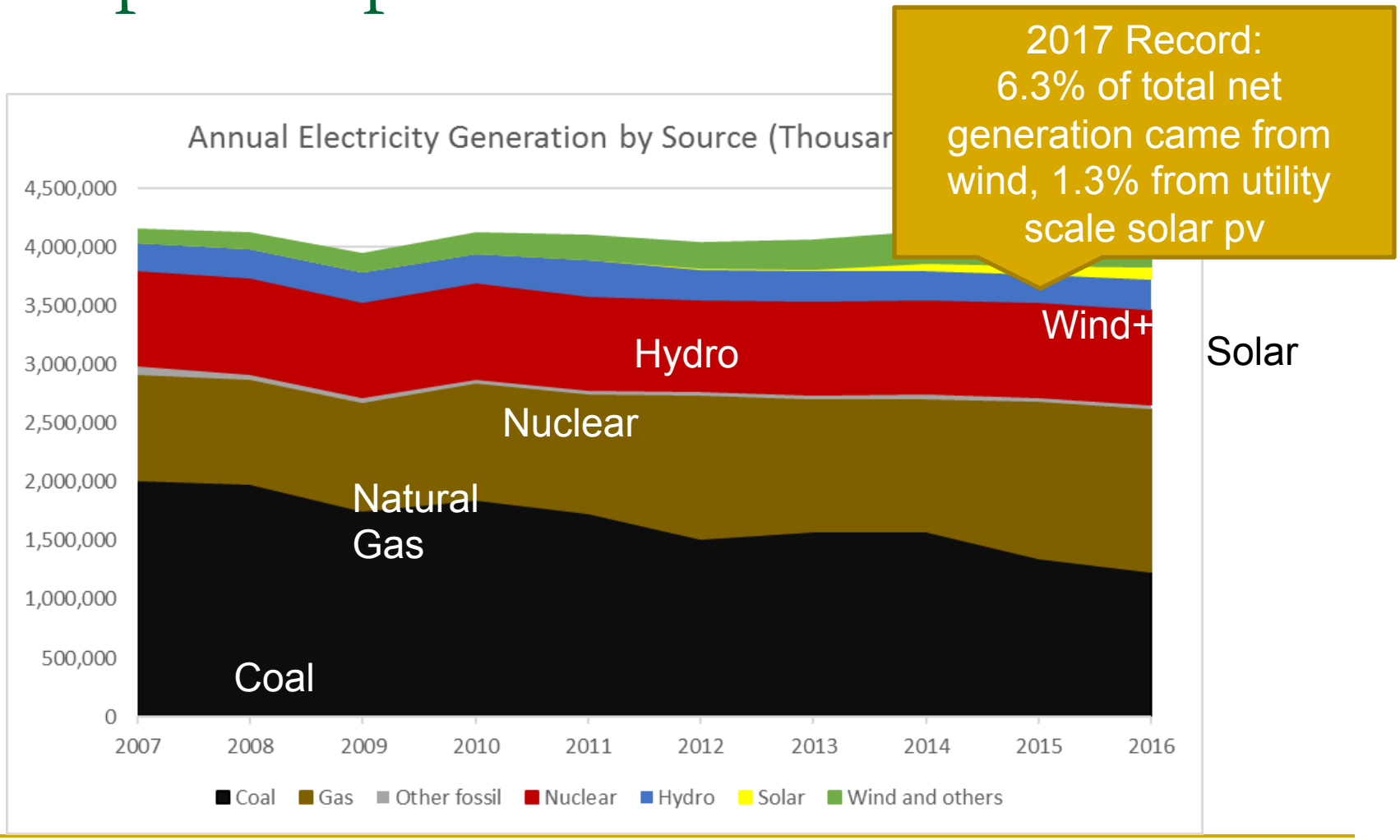
U.S. Organized Electricity Markets

Run **Capacity Auctions** to ensure that installed **power generation capacity** in the system **exceeds projected peak-demand** by a **required margin**

Successes:

- Most markets have a generation capacity that is higher than their targeted reserve margin
- Integration of non-traditional resources that contribute to generation resource adequacy at low cost
  - Demand Response
  - Energy Efficiency
  - Generation upgrades
- Investment in new generation capacity at costs lower than anticipated
  - NGCCs

Policy programs and market developments have spurred penetration of renewables



But markets were not designed to integrate energy from uncertain/variable sources

To face the challenges posed by increased renewables, a number of modifications have been made to both

- Energy – Ancillary services Markets
- Capacity markets

Modifications to energy/ancillary services markets

- Finer time granularity for both day-ahead and real-time commitment and dispatch
  - 5minutes
- "Look-ahead" algorithm for dispatch in Real-time
  - Rather than optimizing dispatch for the next-five minutes, considering the next two or three periods as well
- Ramp-capability products
  - To ensure enough up and down ramp-capability from conventional resources to cope with variability and uncertainty of wind and solar

Modifications to capacity markets

- To value and procure capacity in terms of main attributes such us
  - Seasonal availability (all year, summer, winter)
  - Location
  - Flexibility
- To allow all capacity resources to compete
  - Generation resources
    - New
    - Existing
    - Upgrades
  - Demand response
  - Energy Efficiency

2. Which policies and electricity-market design elements are needed?

1. A clear policy

2. A market-design aligned with it

A clear policy…

Recognizes that in this industry every decision involves **trading one risk for another**

For example:

What is the right level of capacity-reserves?

1. A low level results in higher costs due to
    1. Load shedding
    2. Payments for shortages of spinning and non-spinning reserves, and regulation service
2. A high level results in
    1. Higher capacity payments

Align market incentives with policy objectives

- Introduce **Environmental Dispatch** or incorporate environmental considerations in the **Economic Dispatch**
  - Dispatch resources to meet demand at a minimum cost while abiding environmental constraints

  Or

  - Include environmental cost in the marginal costs and continue with economic dispatch

Align market incentives with policy objectives

- Introduce market clearing mechanisms that **account for the characterization of uncertainty of renewables**
  - Consider designs that approach **Stochastic Market Clearing (SMC)**
  - We simulate the implementation of SMC in a test system similar to PJM but with 10% wind and show that it would
    - Reduce total costs by 1%
    - Reduce CO2 emissions by 3.5%
    - Integrate more wind

Align market incentives with policy objectives

- Provide the right economic signals (allow revenue stacking) throughout the entire grid for all agents and resources
  - consuming,
  - generating,
  - storing
  - and trading electricity
- For the services they provide
  - Contributing to reliability
  - Contributing to resiliency
  - Meeting GHG objectives
  - Based on **the location** the service is provided
  - Based on **the time** the service is provided

In what follows I will describe a project seeking to understand the advantages of different market designs

- A lot of previous work looks at the improvement of the different components of the market design but only two studies look at all the elements
- Those who look at all the elements, do so for a small window of time and a small system
- We look at a whole year, at a system that replicates PJM but with more wind (12%)