Energy Efficiency &
Renewable Energy

Wind Dispatchability and Storage
Interconnected Grid Perspective

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Electric Power Grid
Variability & Flexibility

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SOURCES of VARIABILITY:

- System Loads (customers)
- Variable Generators (Wind & Solar)
- Schedule & Dispatch Errors
- System Outages

SOURCES of FLEXIBILITY:

- **Market Operation**
- Dispatchable Generators
- Dispatchable Loads
- Energy Storage

Flexibility must match Variability

Challenges for Wind Power

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PROBLEMS:

- Wind has limited dispatchability and is variable **and uncertain**
- Wind output is not usually coincident with peak load
  - Wind is an energy resource, not a capacity resource

CHALLENGES:

- Operators must maintain system frequency at 60 Hz
- Operators must balance generation to load and schedules

SOLUTIONS:

- Reduce wind variability **and uncertainty**
  - Accurate Forecasting
  - Wind Output Management
  - Wind Curtailment
- Utilize grid flexibility
  - Existing Flexible Generation
  - Balancing Aggregation
  - Markets & Contracts
  - Demand Response
  - Energy Storage

Grid Operations with Wind

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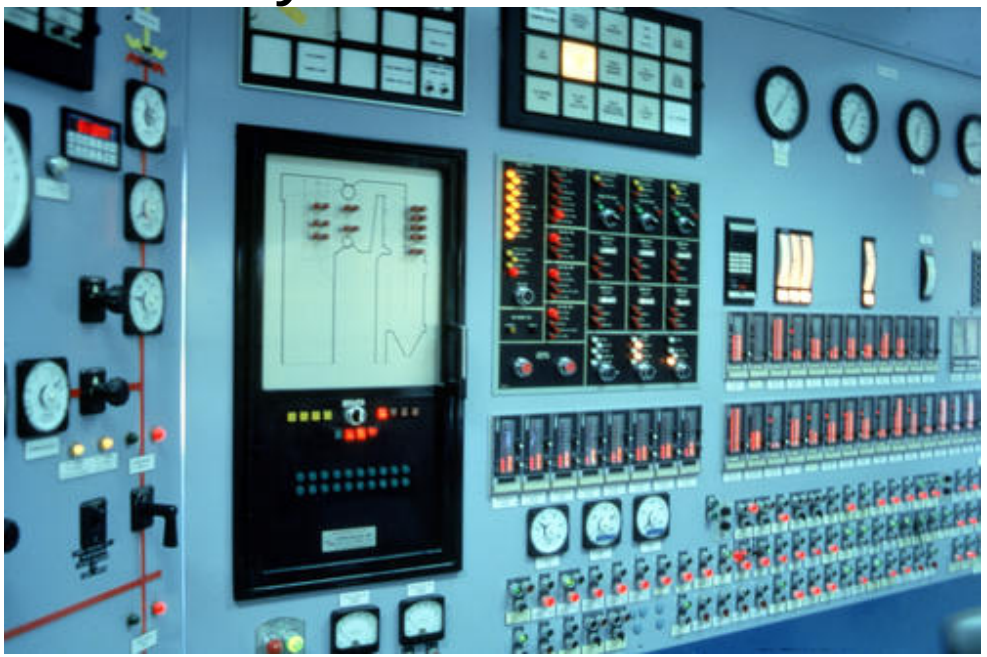
- Wind adds to overall system variability **and uncertainty**
- Existing Power system flexibility is designed to handle tremendous amounts of variability from loads

It is only necessary to balance the overall system incremental needs imposed by wind variability and uncertainty



It is not necessary or desirable to manage wind's variability** and uncertainty **on a project by project basis

Sources of System Flexibility

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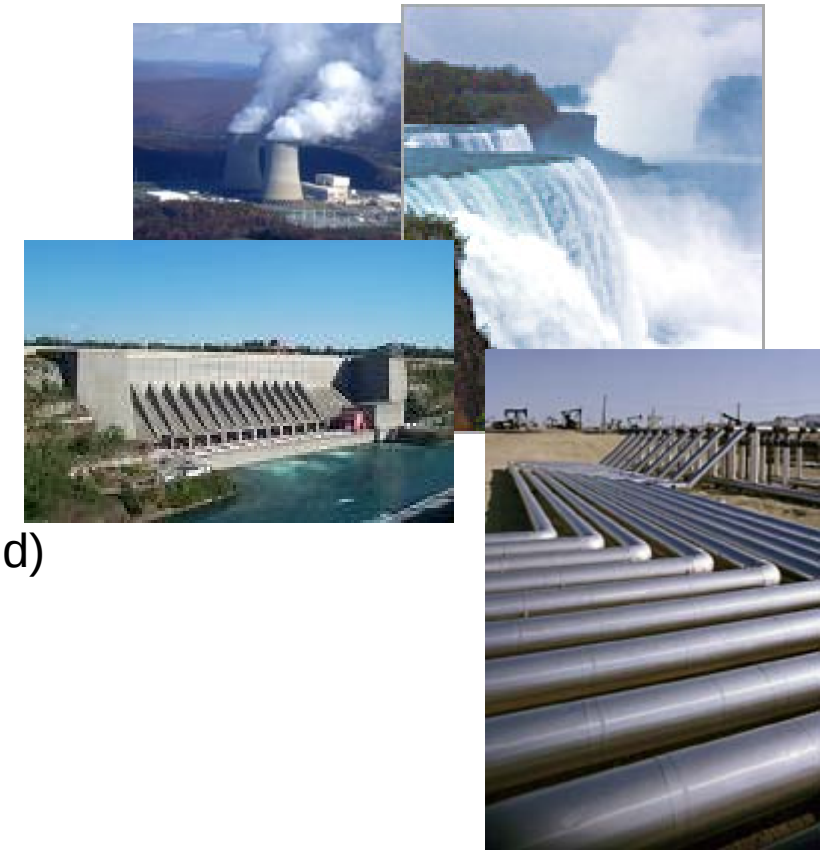
- Markets
  - Real Time
  - Day Ahead
  - Demand Response
  - Balancing Area Cooperation
- Flexible Generation
  - Gas turbines
  - Hydro Units
- Existing Energy Storage
  - Hydro Impoundments
  - Pumped Hydro
  - Gas Storage (Pipeline/Underground)
- Wind Curtailment
- Load Curtailment
- New Energy Storage



Flexibility Supply Curve

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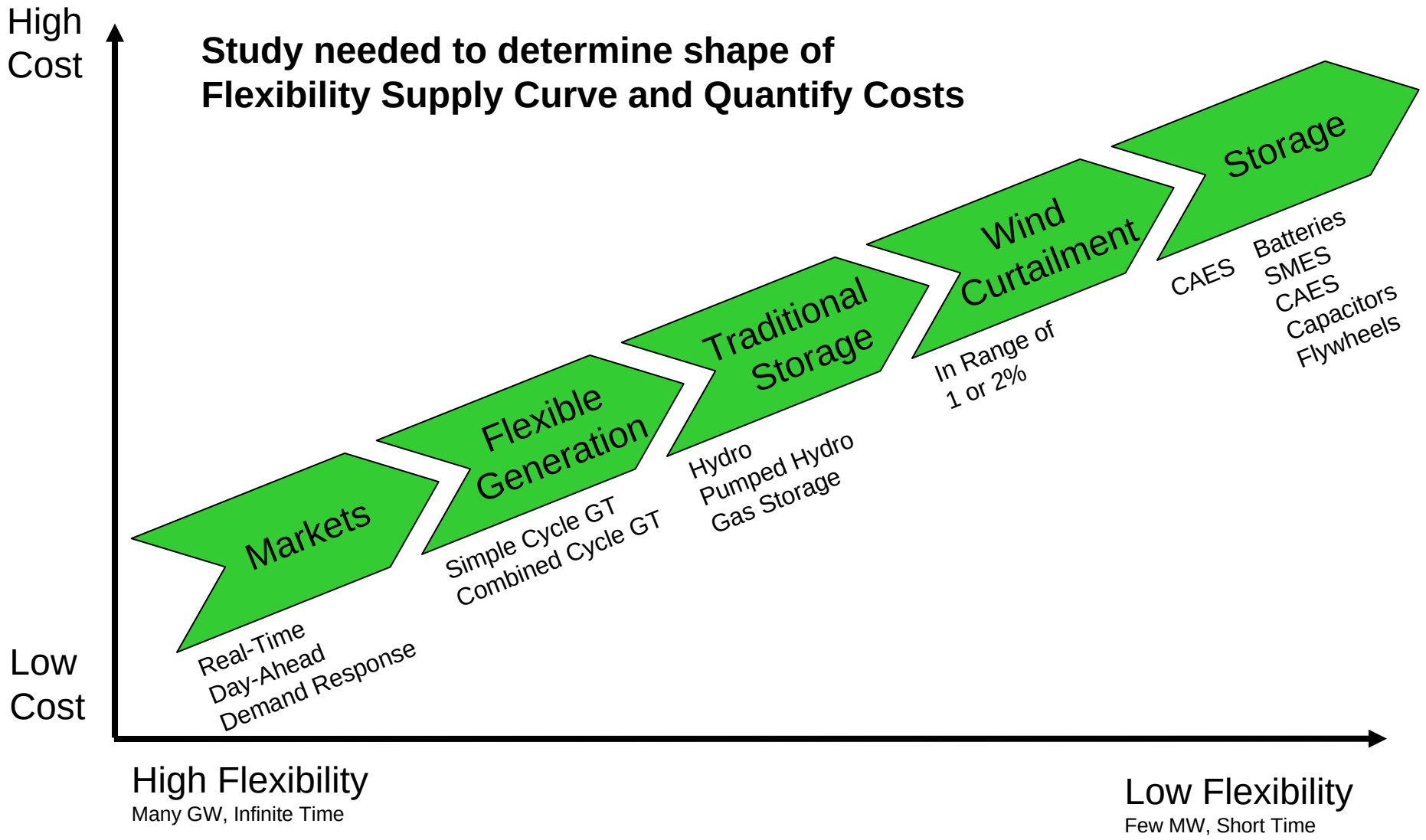

Storage Questions

- Should storage be linked to a specific Wind Site or is it a Network tool?
- Does storage have to be renewable?
- Should storage be located near the generation or near the load?
  - Assuming sufficient transmission, it can be located anywhere
- What are the possible applications of storage (response time & duration)?

What have Studies Concluded?

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- Due to inherent system variability, storage can contribute to system flexibility regardless of the role of Renewable Energy
- No Study or Report shows that new storage is needed to achieve 20% energy production from wind energy
- Experience from Europe shows that an electric system can be operated with 20% wind without added storage requirements

Utility Perspective on Wind Integration Costs

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Bonneville Power Administration - filing a Wind Integration-Within-Hour Balancing Service Rate with FERC. The rate equates to **$2.70 per megawatt-hour** for balancing wind variability within the BPA Balancing Authority Area with wind at a penetration level of 8.7% of their electricity production.

Paul Bonavia, President of Xcel Energy, one of the nation's largest electric utility companies:

"Our studies and experiences show that wind energy integrates effectively and reliably into our power systems with regional market operations to mitigate the impact of wind variability. In these cases even with 25 percent of the electricity on our system from wind we forecast cost for operating system reserves of approximately **$5 per megawatt-hour**, or roughly 10 percent of the cost of the wind energy."

Even at 25% penetration, New Storage would have to compete with the cost of existing system flexibility. In this case, ½ cent per kwh.

Possible Applications of Storage

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- Peak/Off-peak price arbitrage
- Short term stability
- Ancillary Services (Regulation)
- Improved Power Quality
- Ramp Rate reduction
- Defer T&D upgrades

Currently achieved through system flexibility

Storage Technologies

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- Natural gas in the ground and pipelines
- Hydro impoundments & pumped Storage
- Batteries (Stationary and PHEV)
- Compressed air (CAES)
- Thermal
- Capacitors
- Flywheels

A wide variety of applications, efficiencies, costs, charge & discharge rates, energy density, locational constraints, etc must be considered.

Storage is selected based on economics

Conclusions

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Storage benefits the system without renewables and renewables benefit the system without storage…

…It's all about managing

Variability with Flexibility.

Storage is one piece of this puzzle