Wind Integration Utilizing Pumped Storage

NHA
National Hydropower Association

Northwest Power and Conservation Council

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PSE PUGET SOUND ENERGY
The Energy To Do Great Things

DTA
Devine Tarbell & Associates, Inc.
Consulting Engineers, Scientists, & Regulatory Specialists

The Challenge:
Balancing Transmission System Operations

- Maintain reliability by continuously balancing supply and demand.
- Follow the short-, medium-, and long-term changes in load with a fleet of dispatchable resources.
- Call on operating reserves when one or more units experience contingencies.

Today, an extremely sophisticated, but relatively stable environment

Courtesy of Bonneville Power Administration

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Enter Large-Scale Renewables

- A now-familiar set of market and policy drivers are resulting in a massive increase in wind generation across the United States.
- Solar, wave and tidal technologies are probably a decade behind but developing rapidly.
- A small amount of intermittent energy in a large Balancing Area has little impact on system operations, because the natural variability and uncertainty of load is greater than the natural variability and uncertainty of the energy source.

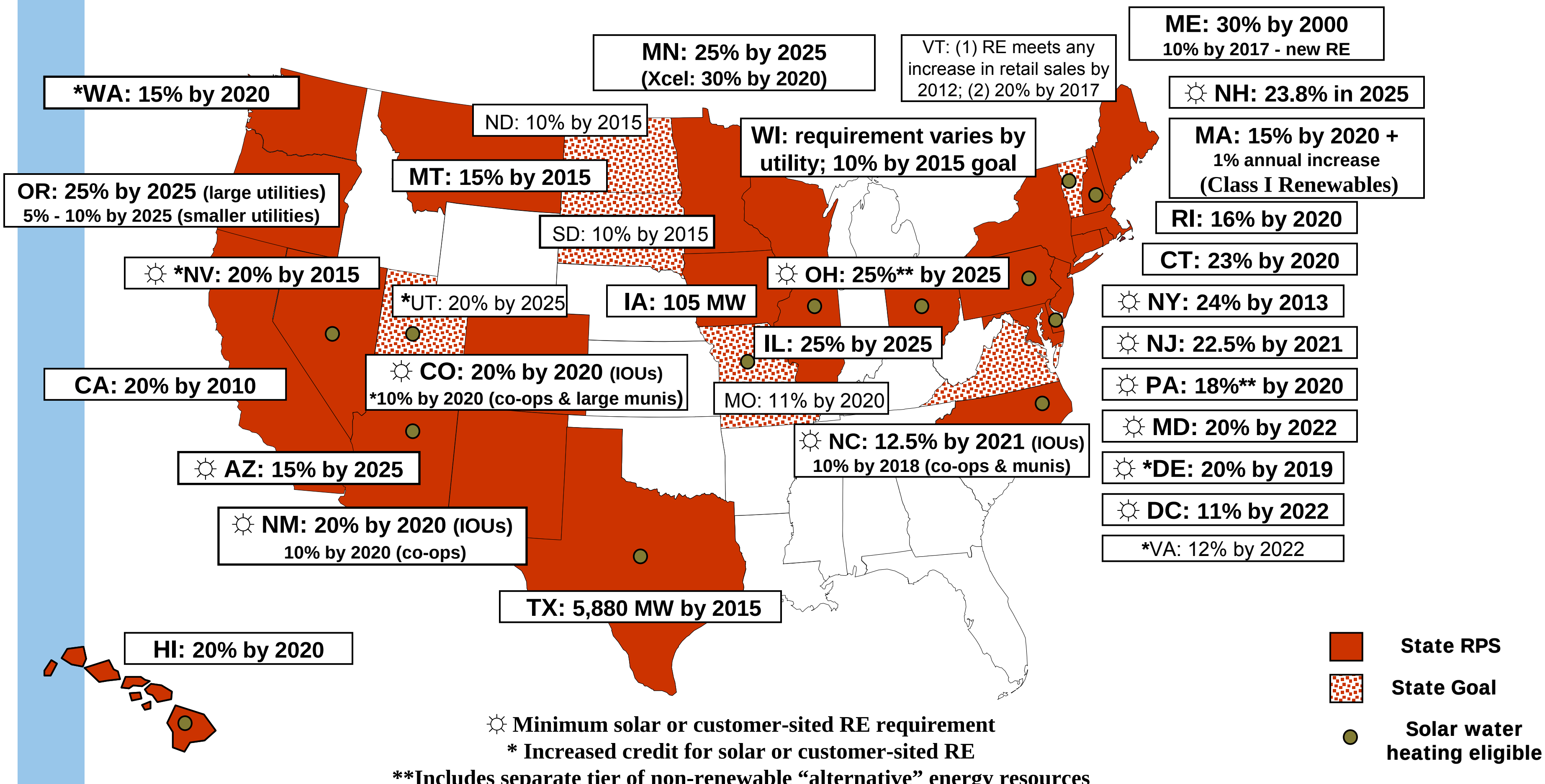
Courtesy of Bonneville Power Administration

Enter Large-Scale Renewables

- As more and more wind is added to the system, it begins to increase the overall uncertainty and variability of system operations across five different time horizons: moment-to-moment regulation, within-hour load following, next-hour, day-ahead, and seasonal.
- Each of these time horizons is of critical importance to the system operator.
- In some areas of the country, the highest winds occur during the night time period when loads are low and the value of electricity is also very low.
- This limited capacity value and mismatch between supply and demand also increases the demand for *storage*.

Courtesy of Bonneville Power Administration

Renewable Portfolio Standards



Source: www.dsireusa.org

Why Wind Energy?

- **Wind: A domestic resource without price volatility**
- **Secure, clean & renewable power technology**
- **Competitive with fossil fuels and no fuel price risk**
- **Compatible with existing land uses. Developed area <2%**
- **Reliable and accepted worldwide**
  - **Fastest growing source of electric generation in world (>25%/yr)**
  - **Fits into utility systems: >20% of electricity in Denmark from wind**
- **Local community benefits**
  - **150-200 Construction jobs & 25+ operations jobs**
  - **$600K+ annual production royalties**
  - **$1 million annual property taxes**

Wind Integration

As Renewable Portfolio Standards are advanced, grid operators have become increasingly concerned about their ability to integrate wind resources.

- Wind generation can change suddenly, creating unstable grid conditions
- Wind generation often occurs during lower load periods, reducing its energy revenue
- Transmission congestion can lead to wind output curtailment or a need to upgrade transmission
- Depressed prices during high wind generation periods

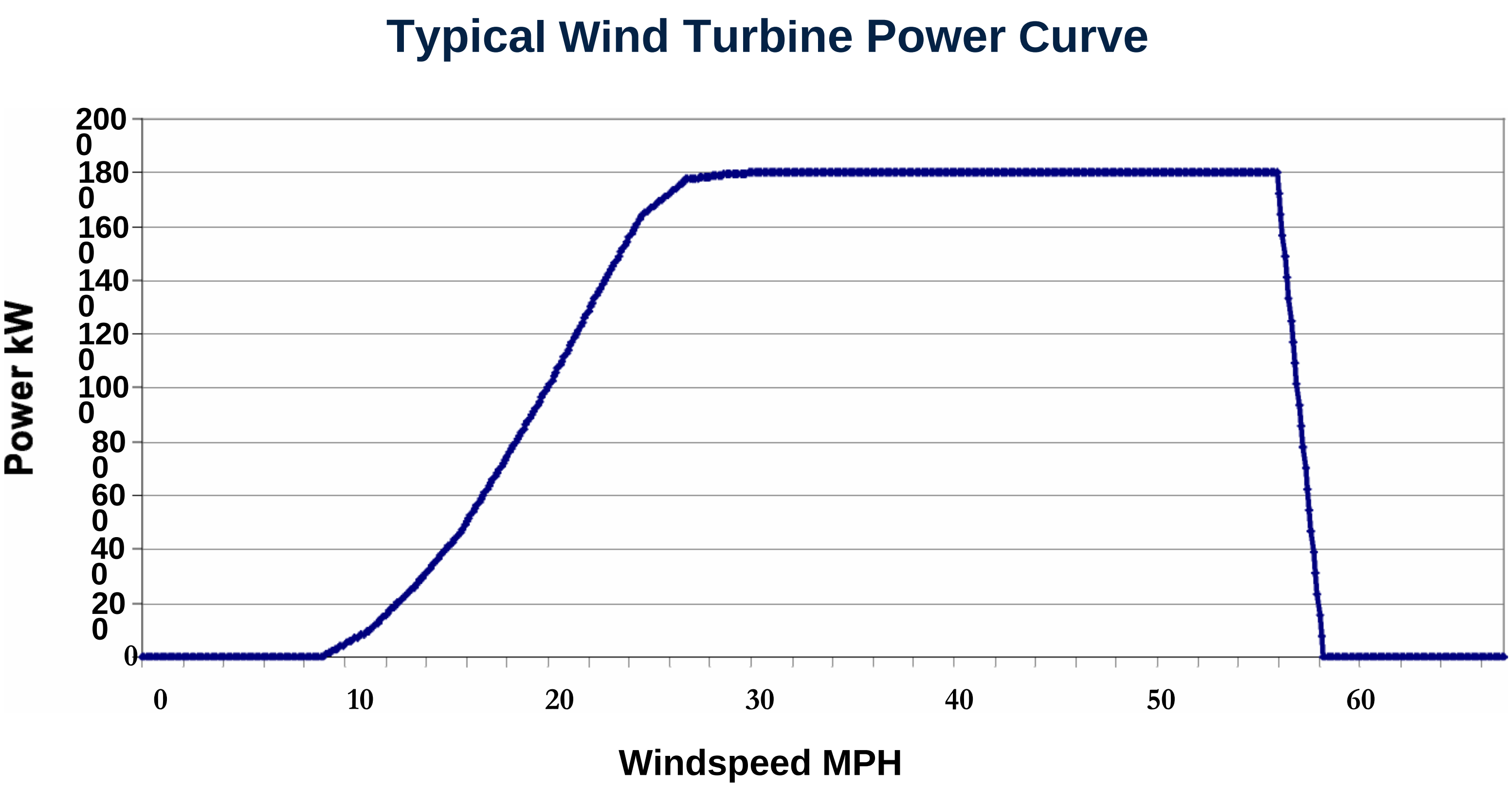
Courtesy of Bonneville Power Administration

Wind Generation Characteristics

Courtesy of Puget Sound Energy

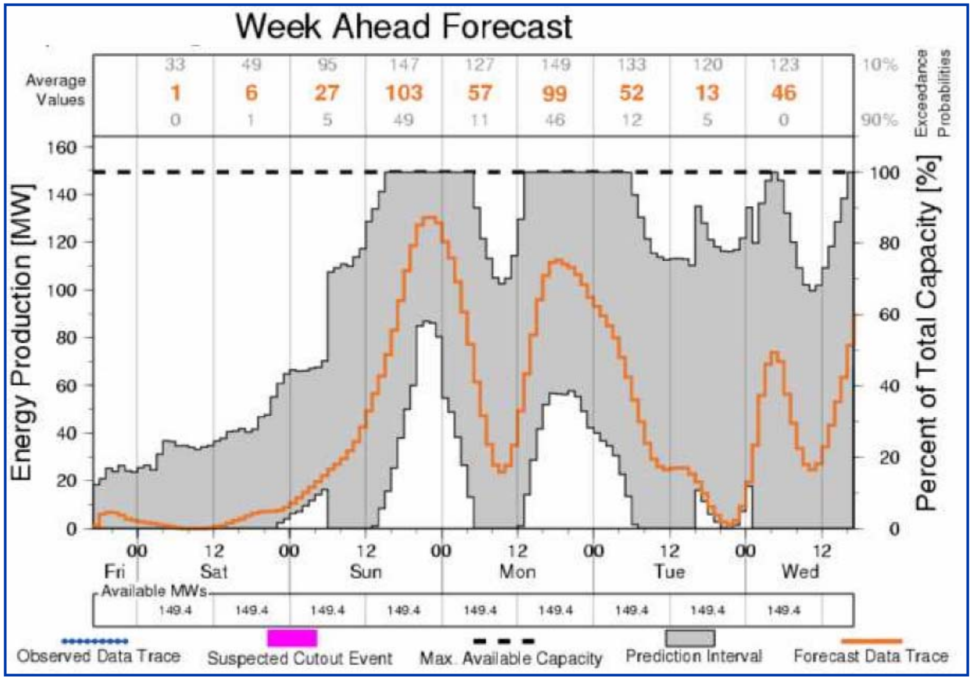
- Generates at wind speeds between 9-56 mph to produce electricity
- Nacelle and rotor turns 360° on top of tower to follow wind
- Generator produces 690 volts AC that is stepped up to 34.5 kV collection system voltage, then stepped-up to grid voltage
- Turbines connected together in strings

Wind Turbine Performance



Courtesy of Puget Sound Energy

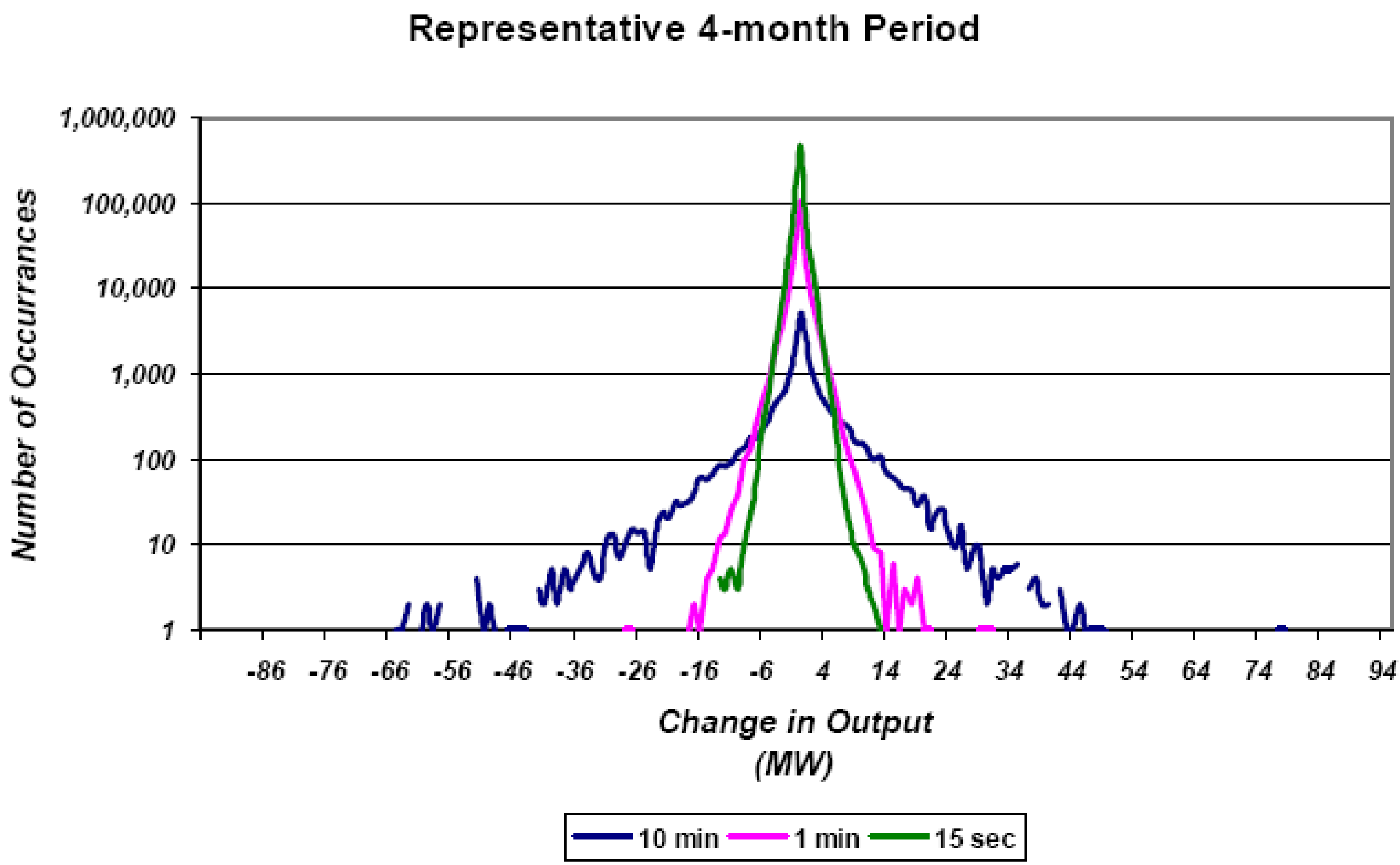
Wind Forecasting



- Trading schedule for annual, weekly, daily or hour-ahead forecasting
- Wind speed varies every hour, every minute
- Allow for no-wind, high-wind, maintenance outages, or externalities
- ~15% to 20% dispatch error

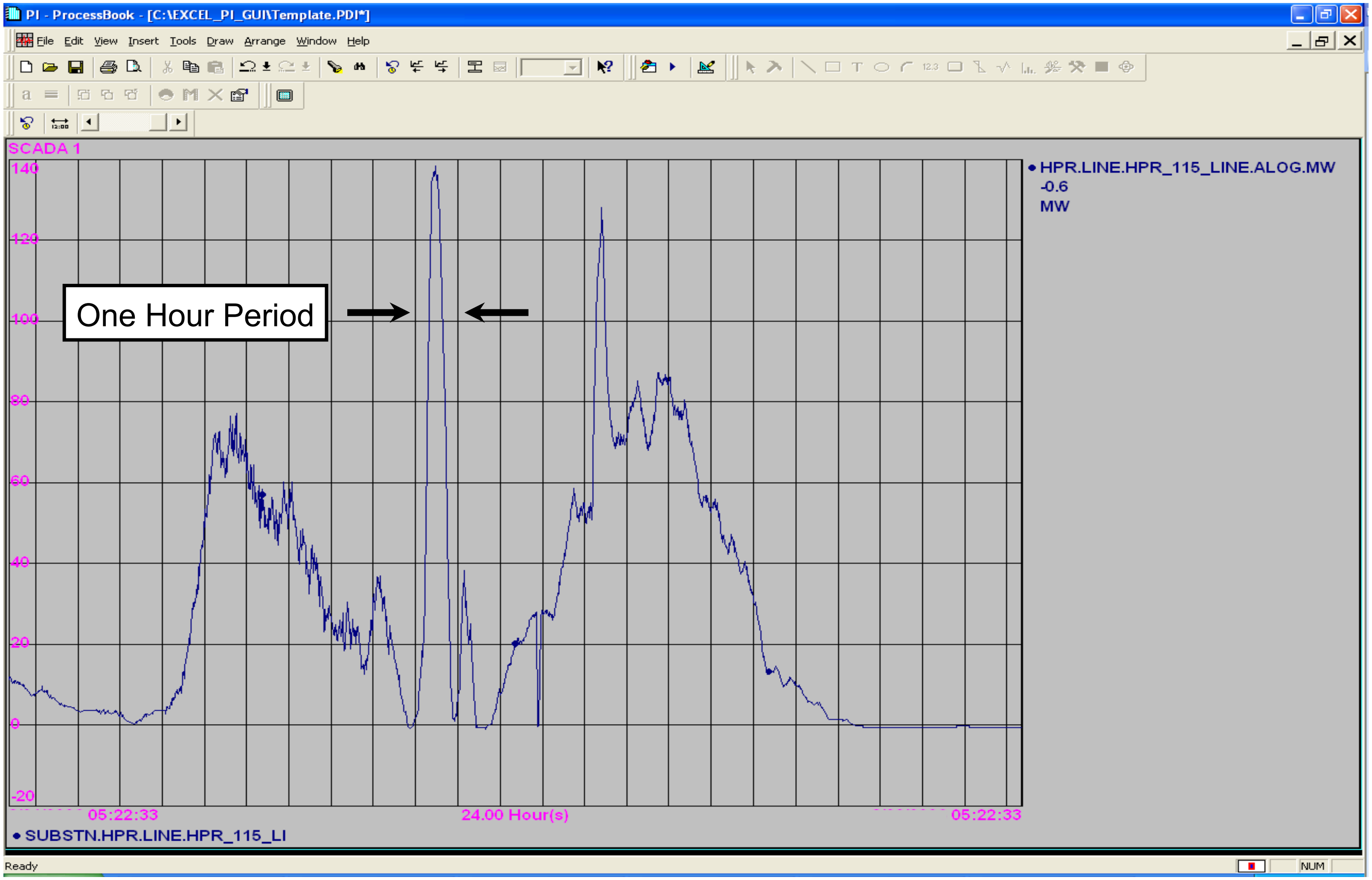
Courtesy of Puget Sound Energy

Wind Variability Example



Courtesy of Puget Sound Energy

Wind Variability Extreme



Courtesy of Puget Sound Energy

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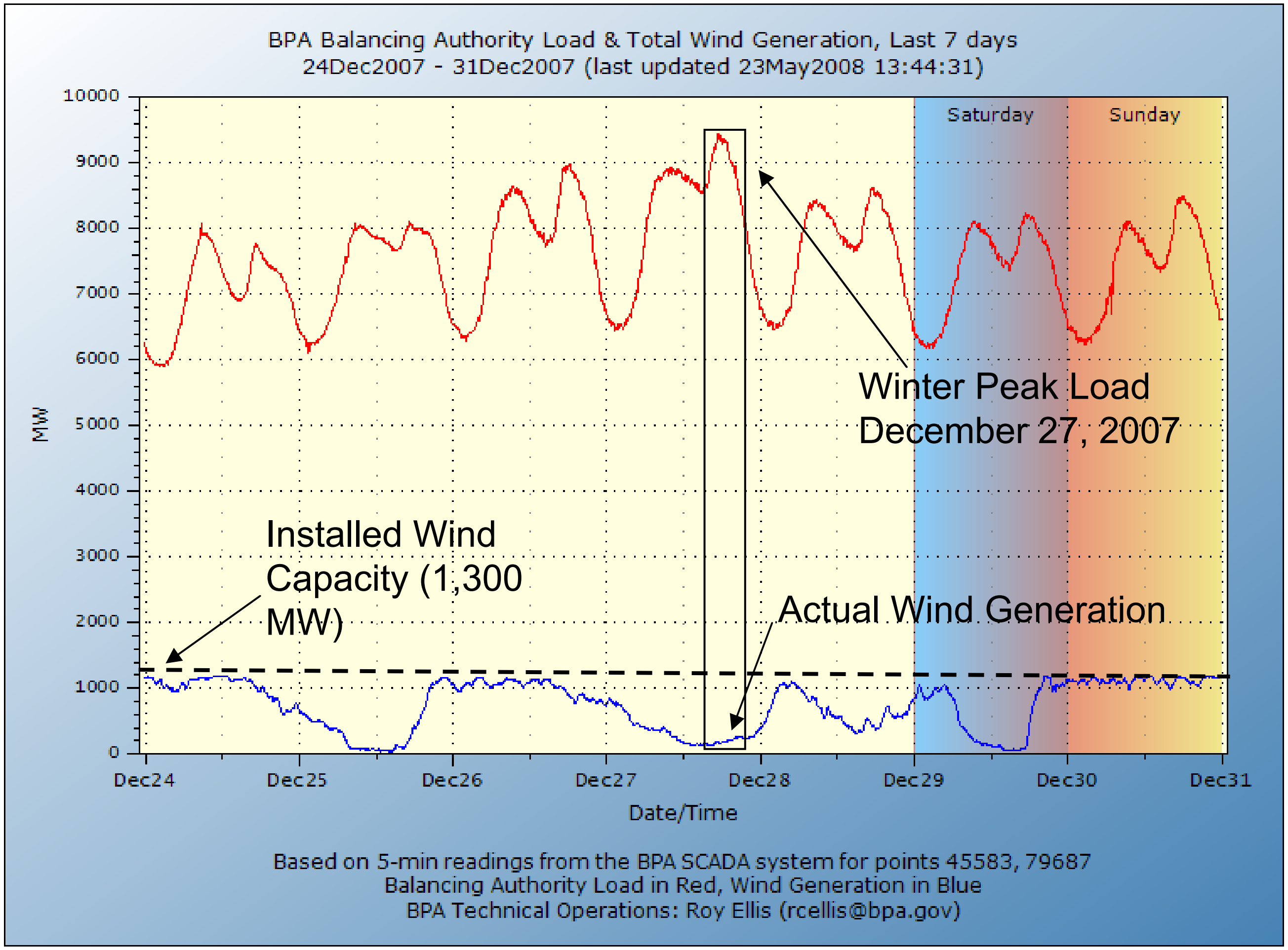
Load and Wind on BPA System

December 24-31, 2007 (Total Installed Wind of 1,300 MW)



Courtesy of Bonneville Power Administration

Wind Needs a Dance Partner

Wind is the celebrity of renewable energy.

It's well known and popular, but it generates energy intermittently.

Wind needs a professional dance partner for balance and control.

(Wind can be more than just a pretty face.)

Pumped Storage is the Best Partner

Hydro Pumped Storage Balances Wind Power, Turning *Celebrity* into *Reliability*.

Pumped Storage

Pumped Storage can address all these concerns

- Rapid response to offset wind generation variability
- Store wind energy during lower value periods
- Prevent wind curtailment and avoid new transmission investments
- “Shape” prices by optimizing schedules of wind output and storage

But it comes at a cost

- Capital and operating costs of the combined wind/PS complex
- Energy losses related to storage

Courtesy of Bonneville Power Administration

Hydroelectric Pumped Storage

- What is it?

  An efficient means to store energy when the demand for power is low and to generate power with the stored energy when the demand is high.

- How does it work?

  Water is stored in two reservoirs, upper and lower. During periods of low power demand, water is pumped from the lower lake to the upper lake. During high demand periods, water from the upper reservoir is passed through turbines to generate power.

More importantly: Pumped Storage really is a System Operations tool

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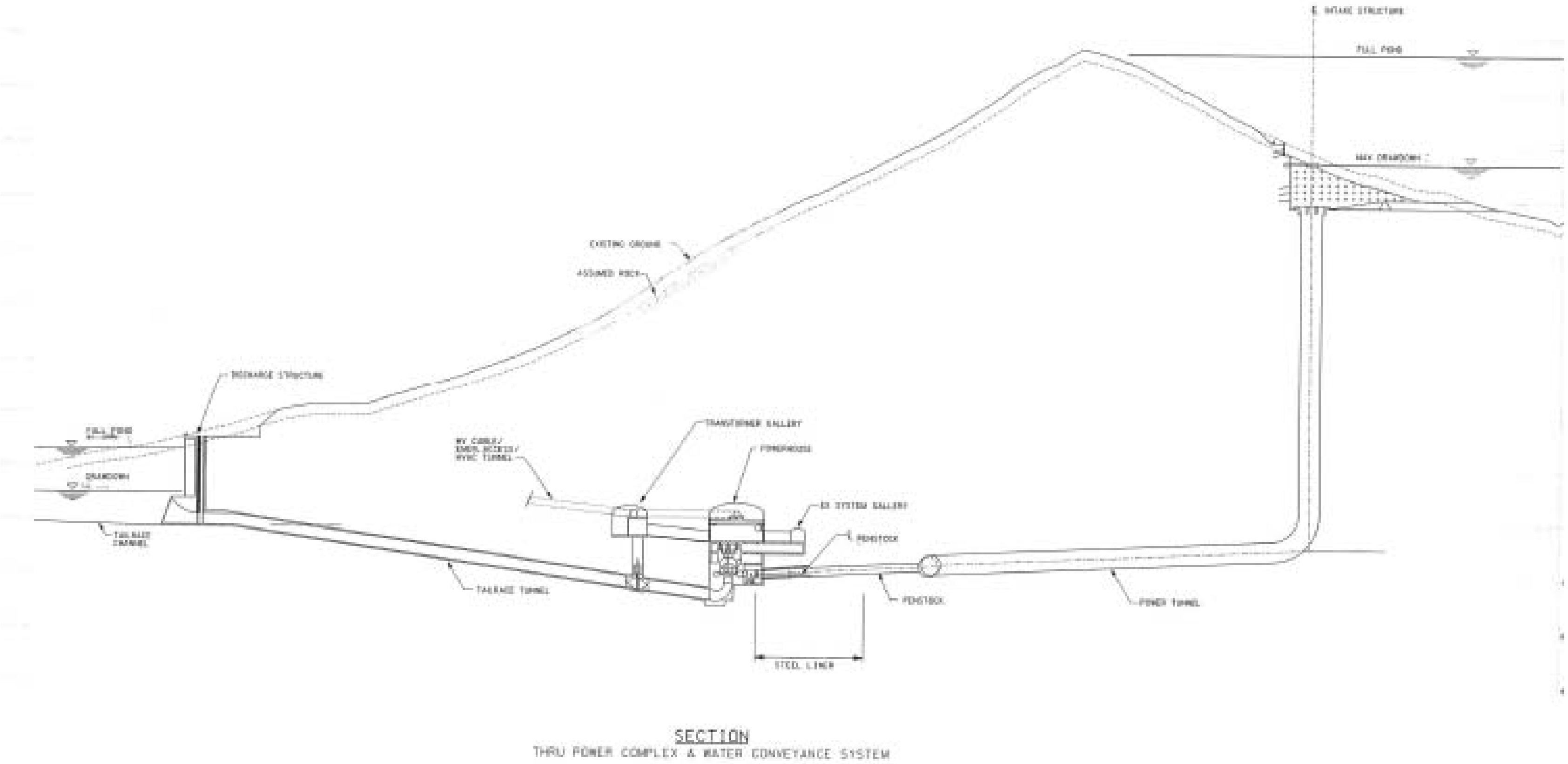
Pumped Storage as an Energy Resource



Typical Underground Pumped Storage Facility

Role of Pumped Storage in the Power Market

- Provides peaking capacity and fast response to peak electric grid demands each day
- Increases the efficiency of existing power plants and transmission facilities
- Is the preferred supplier of ancillary services to provide grid stability
- Improves the reliability of electricity supply
- Reduces the need for additional transmission assets – ACE control
- Allows for better integration of renewables into the system

Dynamic Benefits of Pumped Storage

- Spinning Reserve

  Restoration is needed in 60 (WECC) or 90 (NERC) minutes. Pumped storage is a good source of dependable spinning reserve.

- Frequency Regulation

  Pumped storage is a reliable source of frequency regulation support (which has a tighter regulatory requirement than spinning reserve; not as constrained as conventional hydro stations.)

  - Pumped Storage can facilitate wind energy's high ramping rates

Dynamic Benefits of Pumped Storage

- Improved Unit Commitment

  Reduces the number of thermal/CT unit starts. Provides peak shaving. Impact is dependent upon load shape.

- Voltage/PF Support/Correction

  Can be used to provide large VAR/voltage compensation as desired at relatively low costs.

- Dependable Capacity

  Refers to the amount of capacity a hydro project can reliably contribute to meet demand. Pumped storage provides dependable capacity and can provide the "firming" component for wind and solar.

Dynamic Benefits of Pumped Storage

- Reduced System Minimum Loading

  Many base load generation units run below minimum load. Inefficient base unit operation at minimum load and can lead to voltage/frequency problems. Pumped storage can be used to improve minimum loading and allow more efficient base unit operation.

- Load Following

  Faster response than any other technology; can go from a load to a generation source in a matter of minutes. Less wear on thermal units. Allows overall generation system to operate more efficiently.

- Improved utilization of wind generation at night
- Balances wind generation in terms of negative load

Pumped Storage as an Energy Resource

A Practical Example

Pumped Storage as an Energy Resource

- System Capacity

Coal	7,700 MW
Nuclear	7,050 MW
Combustion Turbines (sc)	2,000 MW
Conventional Hydro	1,000 MW
Pumped Storage	
• Plant 1	610 MW
• Plant 2	1,065 MW
• **Total**	**19,425 MW**

Pumped Storage as an Energy Resource

- System Load

Maximum Demand	17,000 MW
Minimum Load (approx.)	7,000 MW
Average Daily Swing	4,000 – 6,000 MW

Pumped Storage as an Energy Resource

- Generation Supply

Base Load ……………………..Large Thermal/Nuclear Units

Seasonal Peak Load …………...Combustion Turbines

Load Following/Daily Peak …..Conventional Hydro/Pumped Storage

Wind & Solar --- Where does it fit above?

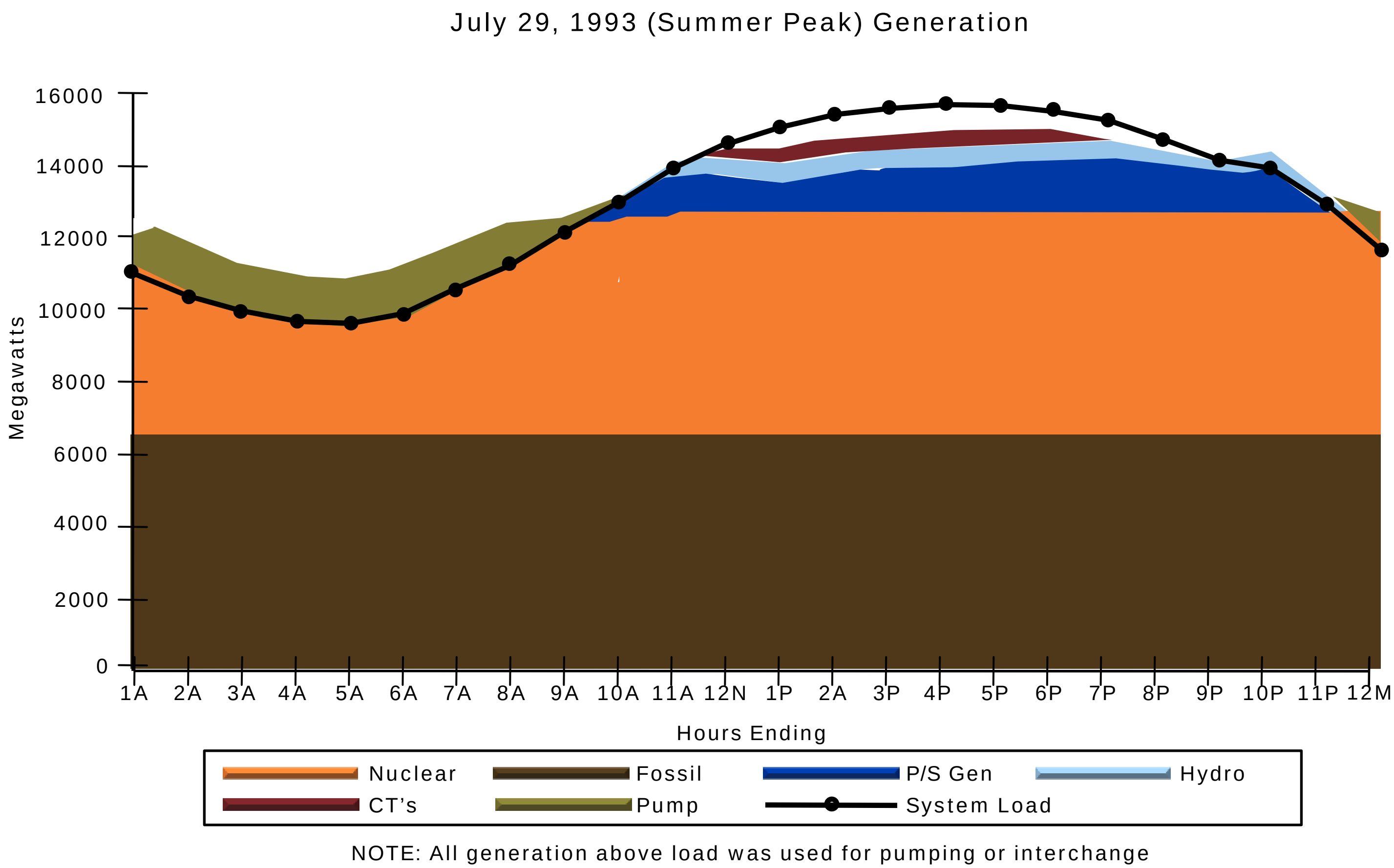
Pumped Storage as an Energy Resource

- Pumped Storage Operations
  - Spring/Fall

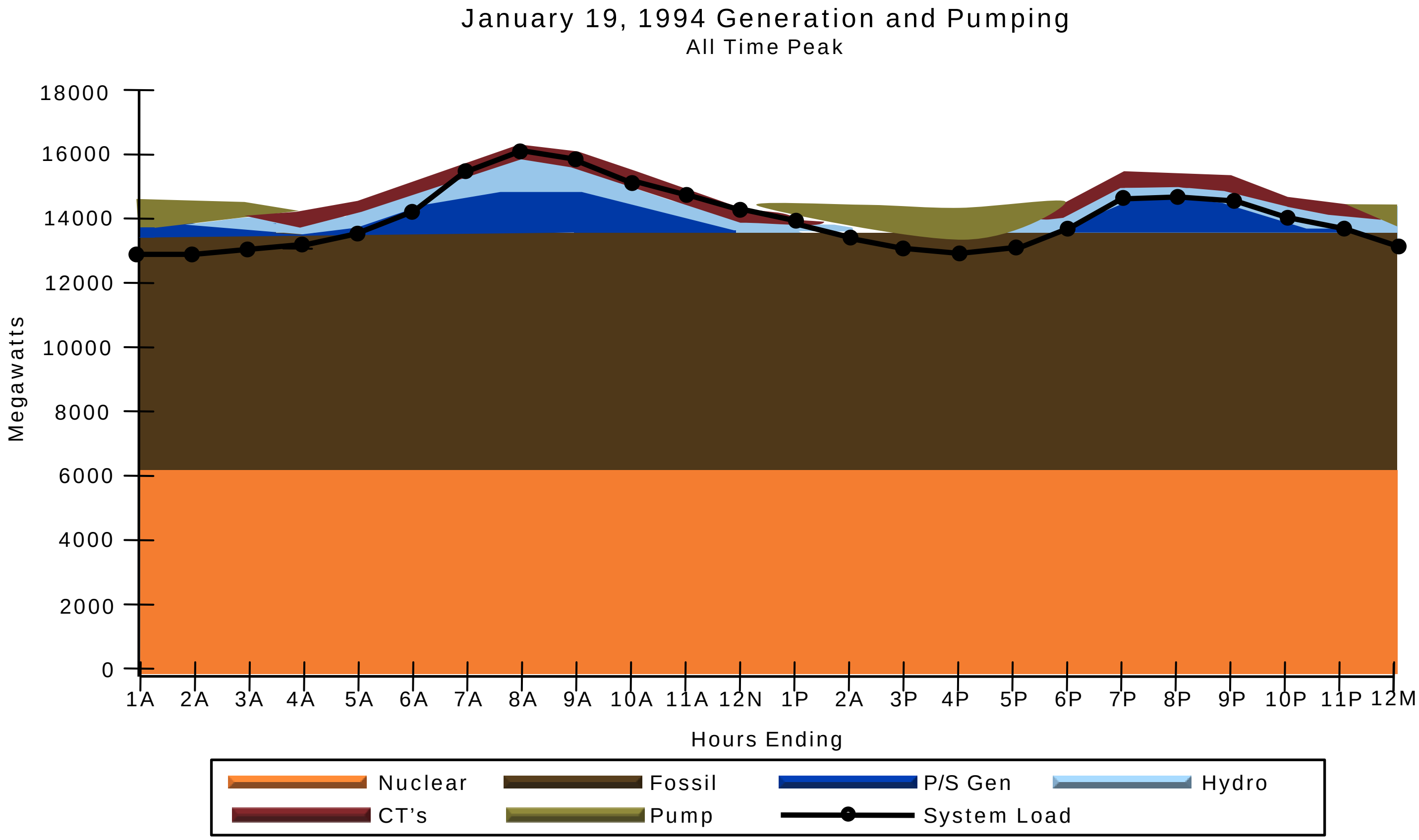
    Vital to meet light demand / minimum load problems
    - Pumping ability is critical
    - Minimizes unit commitment requirements
  - Winter/Summer

    Rapidly changing load conditions
    - 2000 MW per hour

Summer Grid Profile

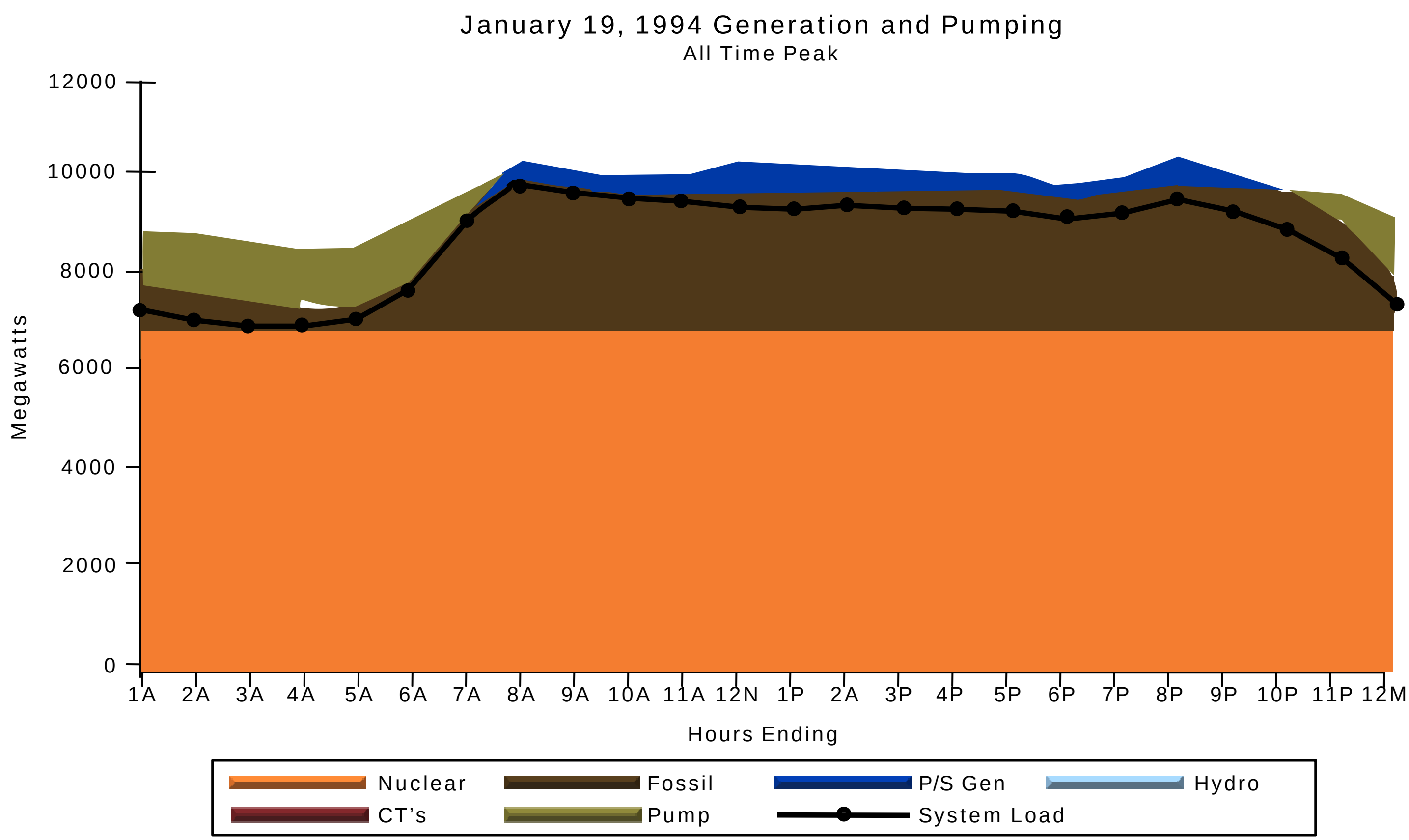


Winter Grid Profile



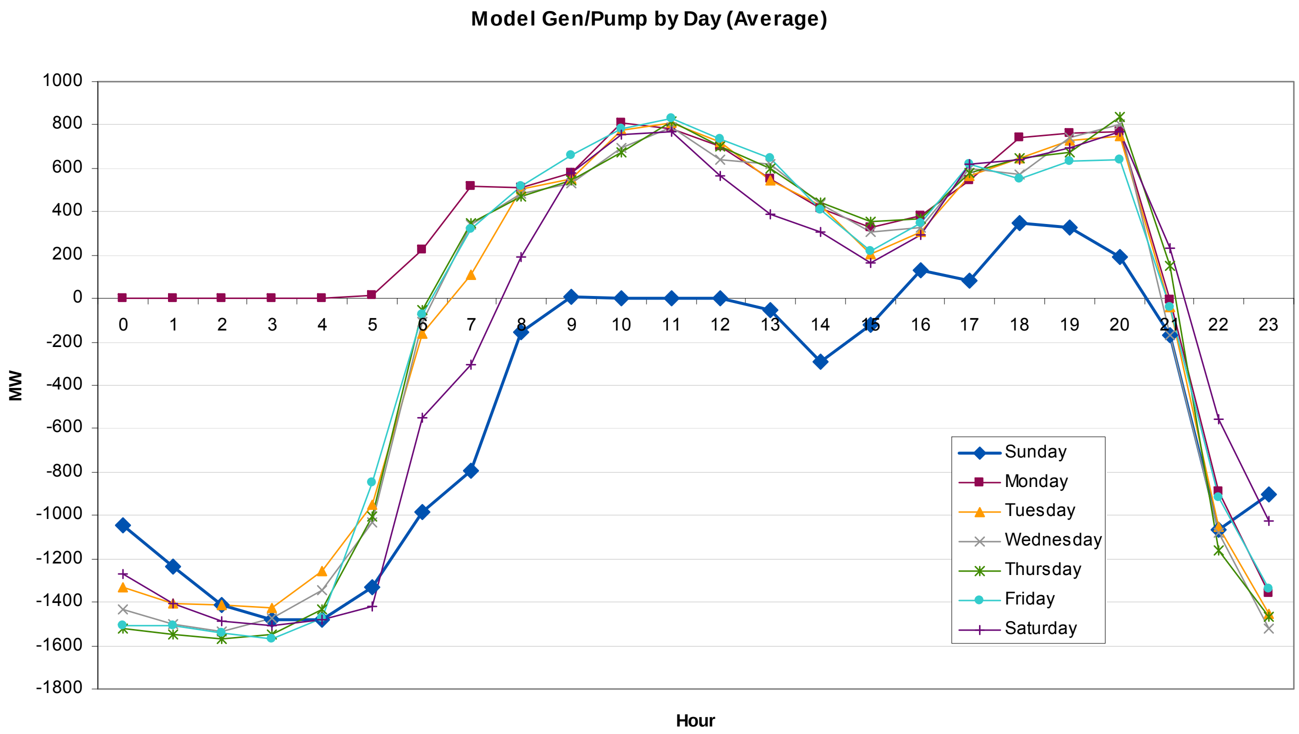
NOTE: All generation above load was used for pumping or interchange

Fall / Spring Grid Profile



Daily Operations
Are More Complicated

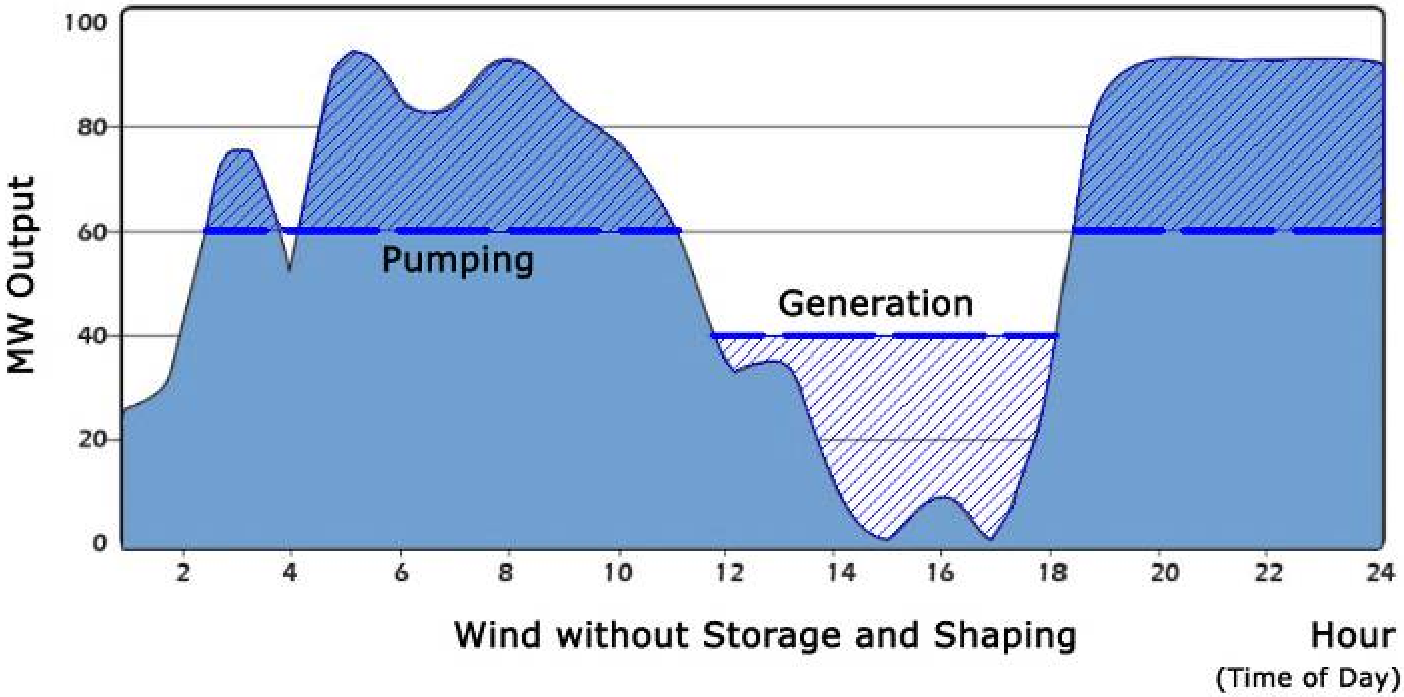
Market depth, transmission limitations and native load obligations can all complicate PS operations.



Courtesy of Ventyx

Integrating Wind with Pumped Storage

Shaping Wind Variability



Possible Variability Solutions

- Policy
  - Control Area pooling to share load-following & reserve capabilities
  - Schedule energy trading with smaller blocks and shorter durations
  - Production tax incentives for additional Hydro development
  - Investment tax incentives for Pumped Storage
  - NHA working with AWEA on national solutions

Possible Variability Solutions, cont.

- Operational
  - Improved wind forecasting accuracy
  - Automatic generation control on appropriate hydro & thermal units
  - Enhance turn-down of existing non-hydro generating units (gas or coal-fired)
  - Add generation projects having Load Following flexibility
- Storage
  - Deploy energy storage systems