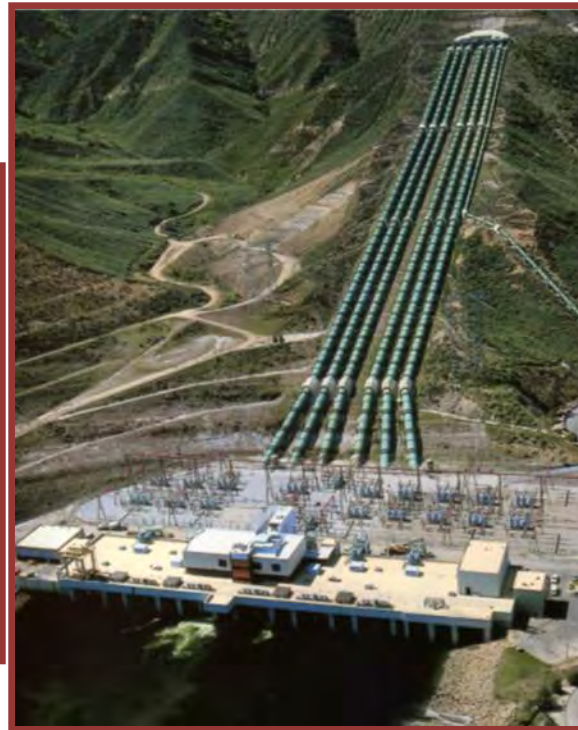


- The Use of Large Scale Pumped Hydro - Energy Storage for Grid Reliability, Renewable Integration and Renewable Load Shifting



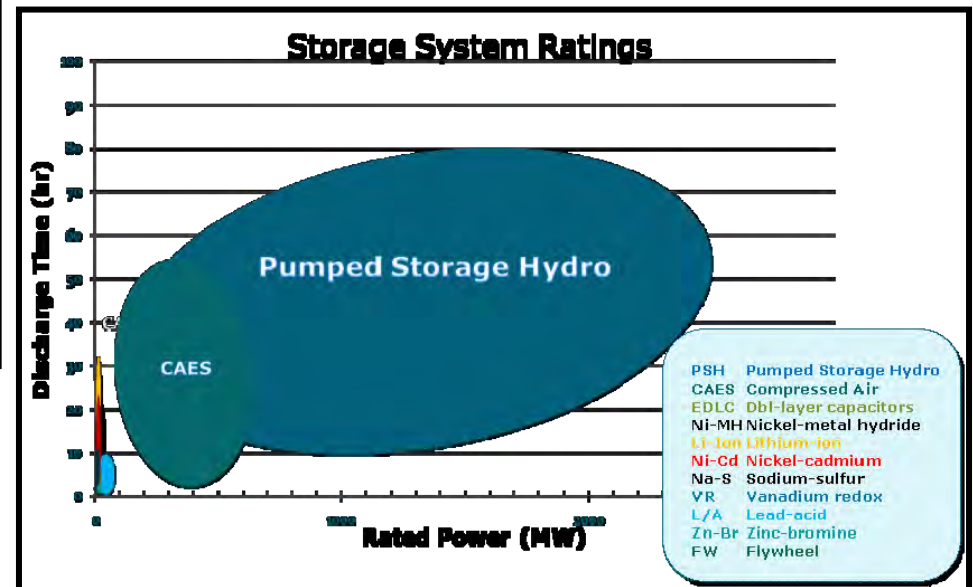
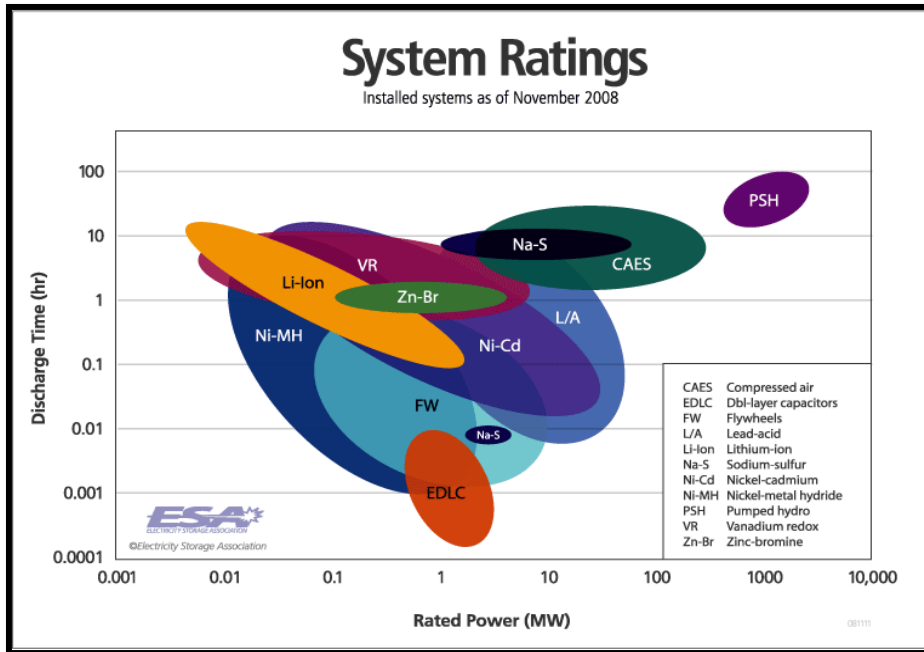
Briefing for the Electricity Energy Storage Workshop

Adjustable Speed Energy Storage Solutions

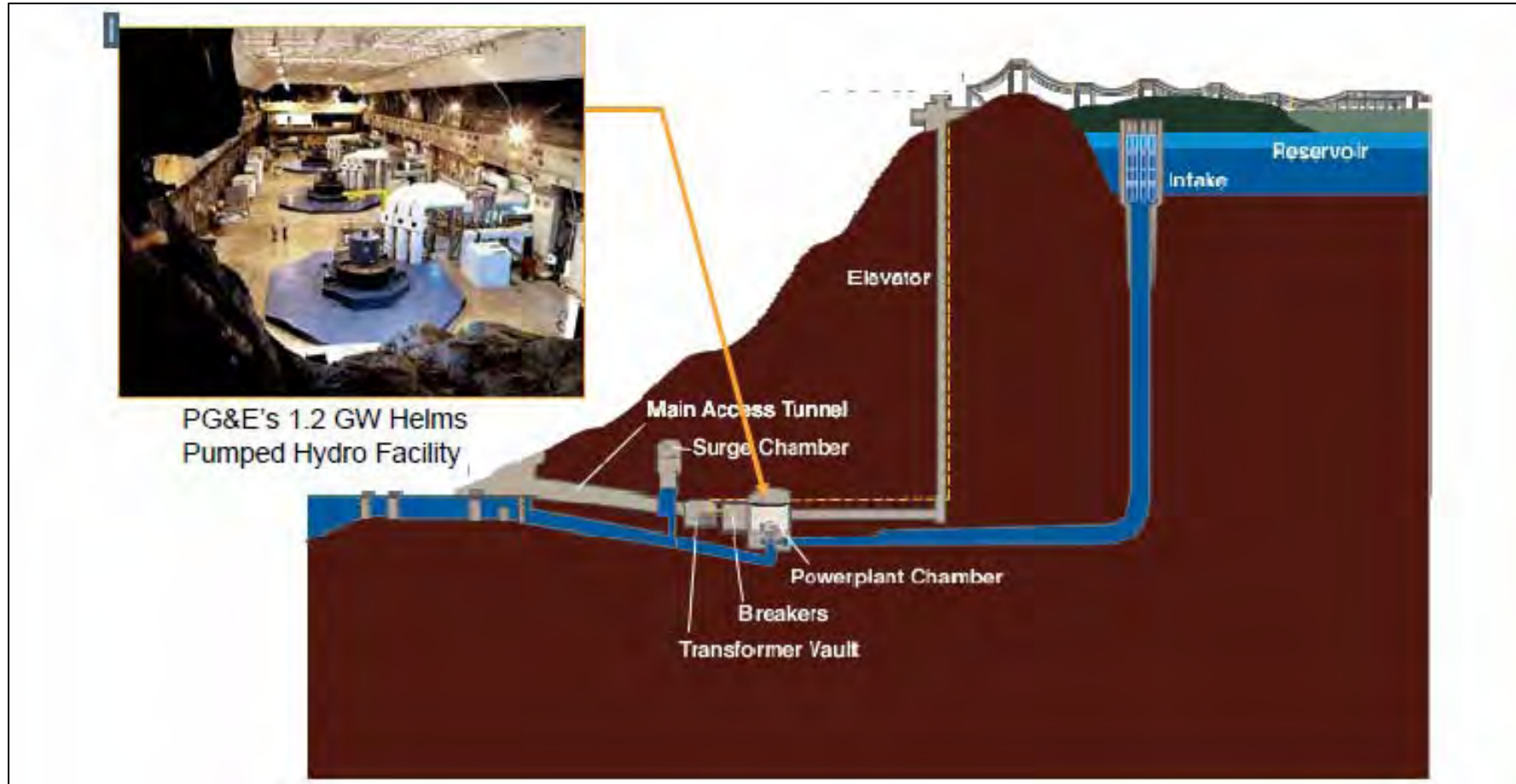
- **Grid scale storage enables development of double digit levels of wind penetration.**
- **Europe integrates variable energy with big transmission, conventional hydro and carbon free pumped storage.**
- **Changing US market for system reserves and grid reliability services.**



Energy Storage Technologies



How Pumped Storage Works

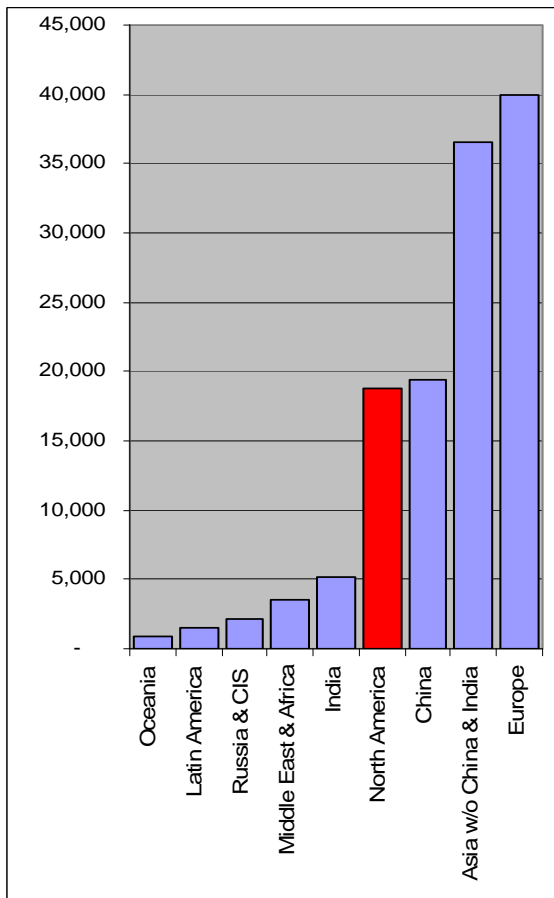


Typical Pumped Storage Project Design Scheme

Snapshot of Pumped Storage Globally

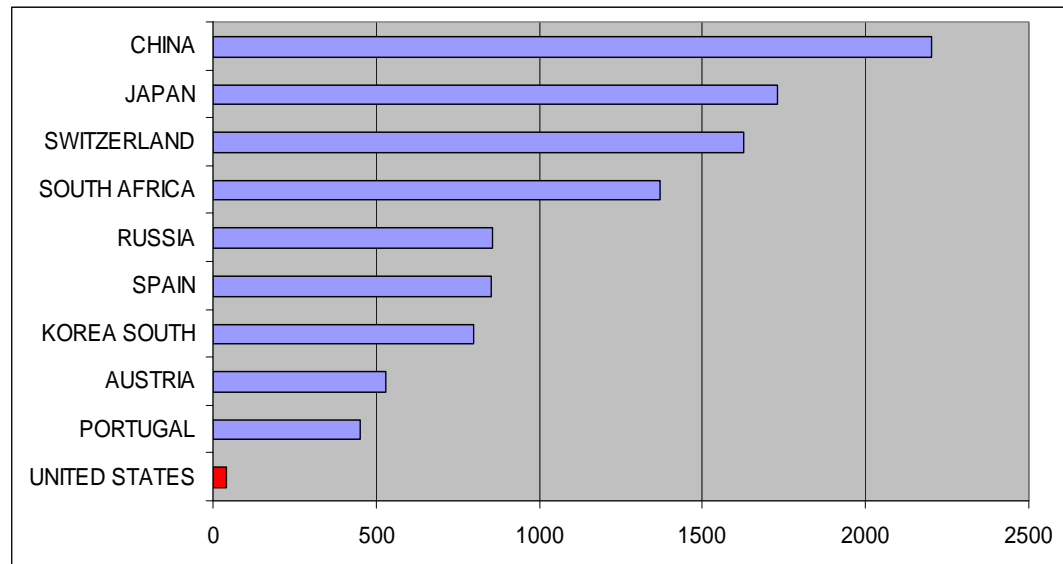
Pump Storage Units in Operation (MW) by Country/Continent

- 127,961MW Worldwide
- Totaling 922 PS Units



Pumped Storage Projects Under Construction (MW)

- 10,453 MW Worldwide
- Totaling 45 PS Units



Pumped Storage Trends in Europe

- **Most economical means of Energy Storage**
 - **A fundamental grid component**
- **Provides balancing, reserves and grid stability for new interconnected ISOs**
- **Proven reliable technology with 50 to 100 year design life**
- **Large increase in Wind Energy to 8% of Energy (53GW) – with selected regions > 20% penetration**
- **Adjustable/Variable speed focus new and re-optimization of existing plants**
- **European approach toward pumped storage is spreading globally**

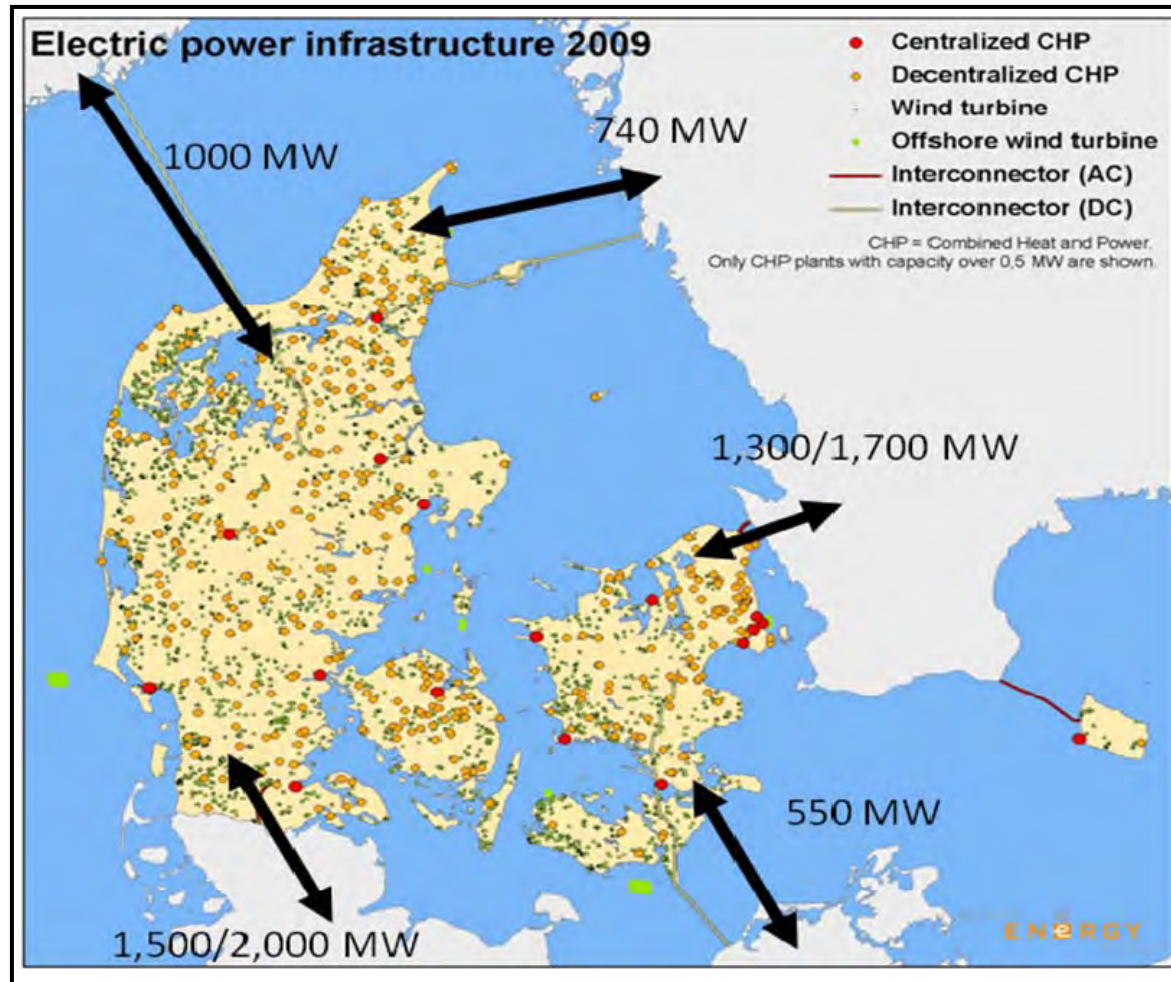


Denmark & Grid Reliability

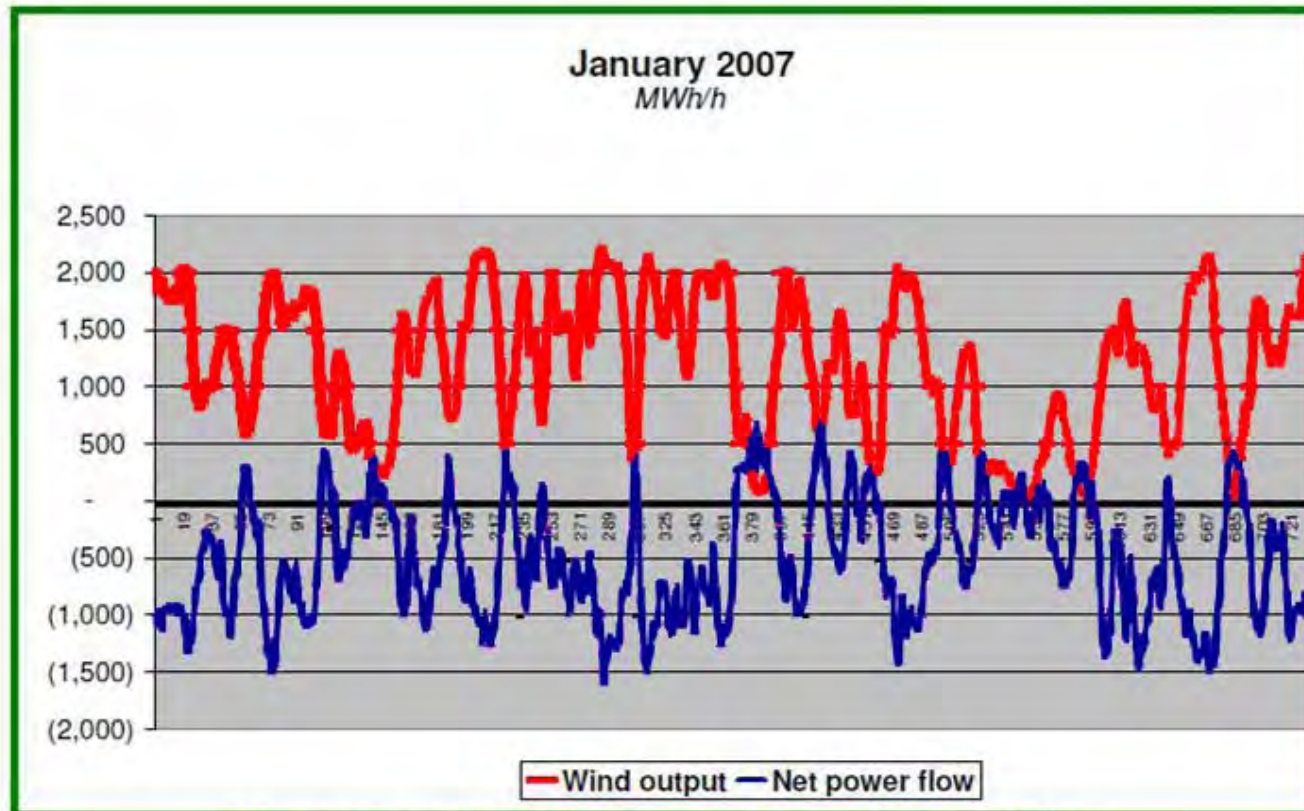
- **30% wind penetration in the generation mix**
- **No native load balancing**
- **Balancing services provided via interconnects**
 - **Strong interconnections with Norway , Sweden and Germany**
 - **Utilizes energy storage and flexible energy options in neighboring balancing areas**
 - **Excess wind is exported and stored in Norwegian hydropower reservoirs**



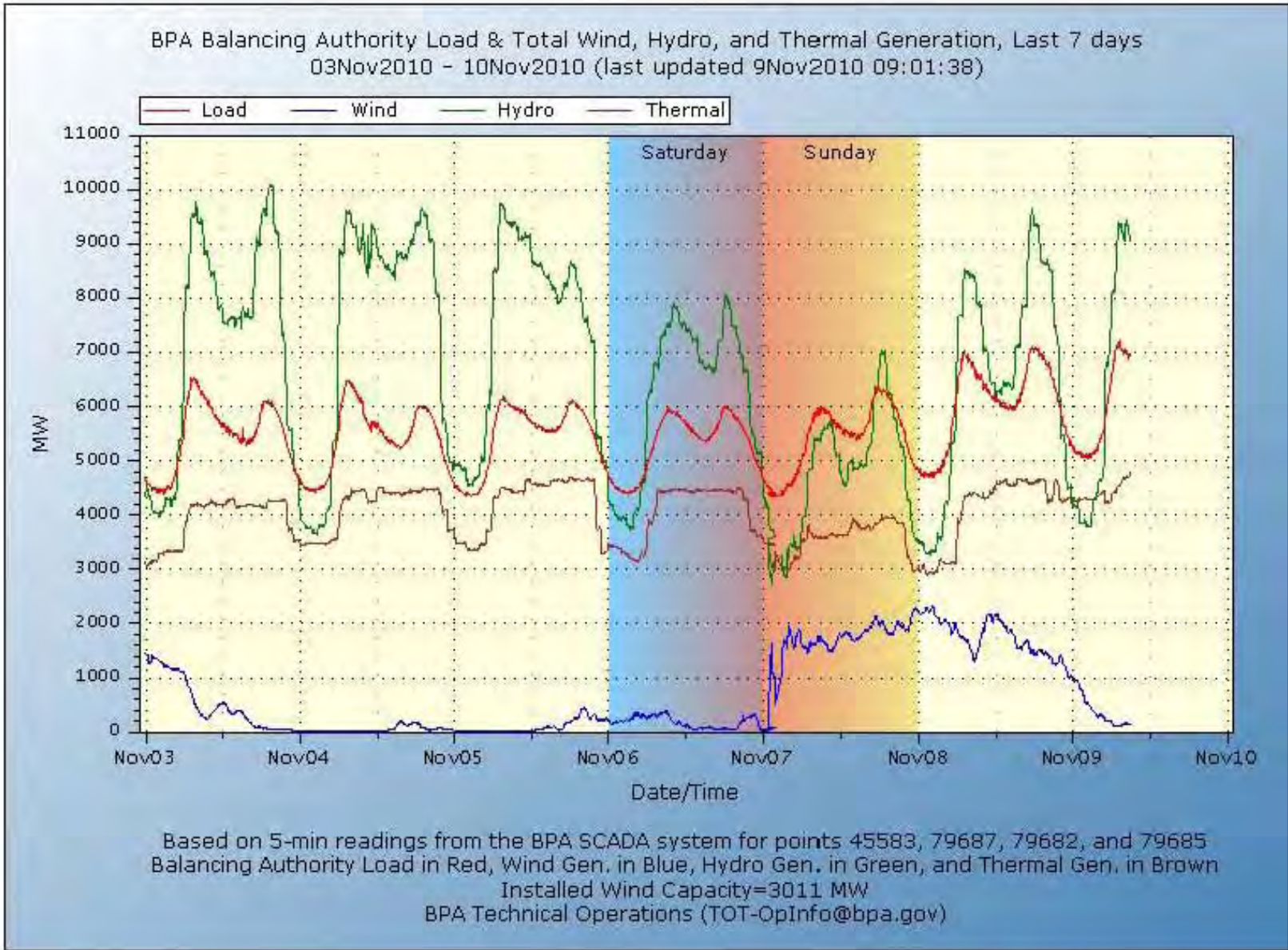
Power Balance in Denmark 2008



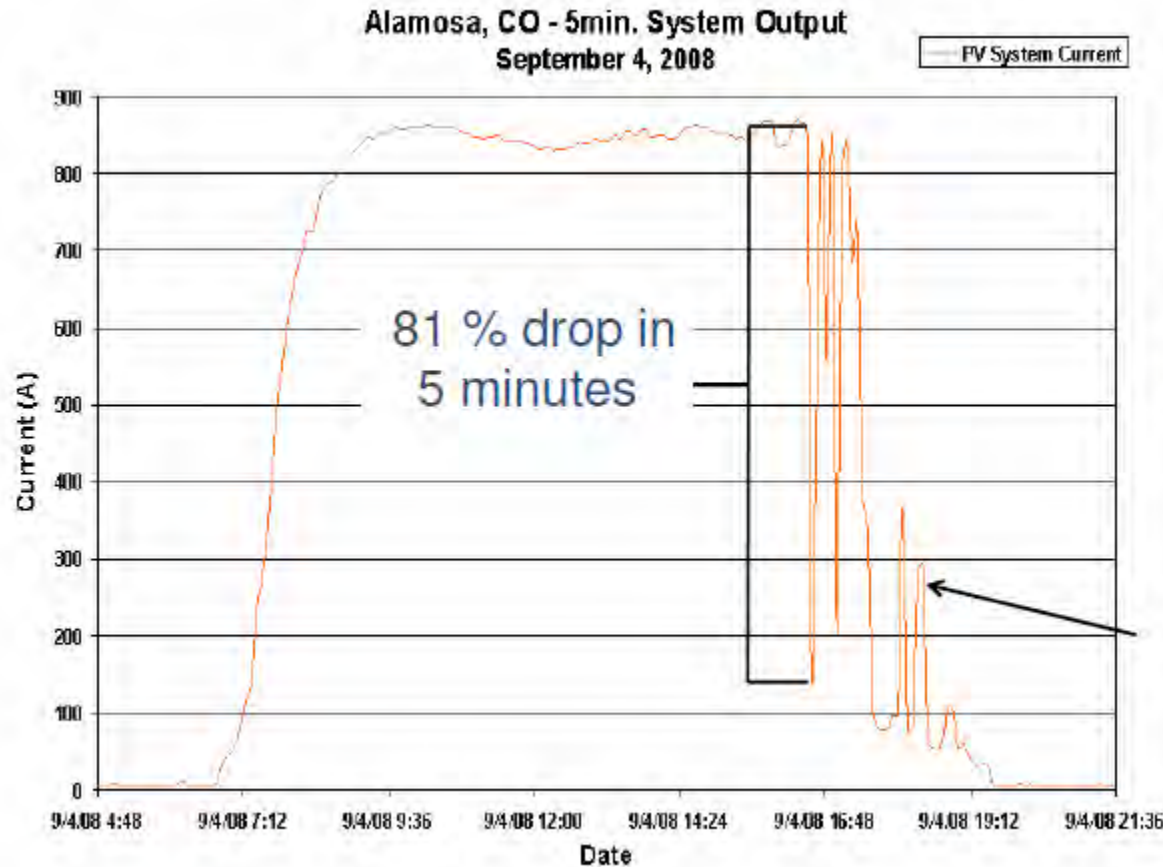
Western Denmark Wind Output and Net Electricity Flows



Source: Energinet.dk (Denmark's system operator)



Solar Energy Sources Are Highly Variable

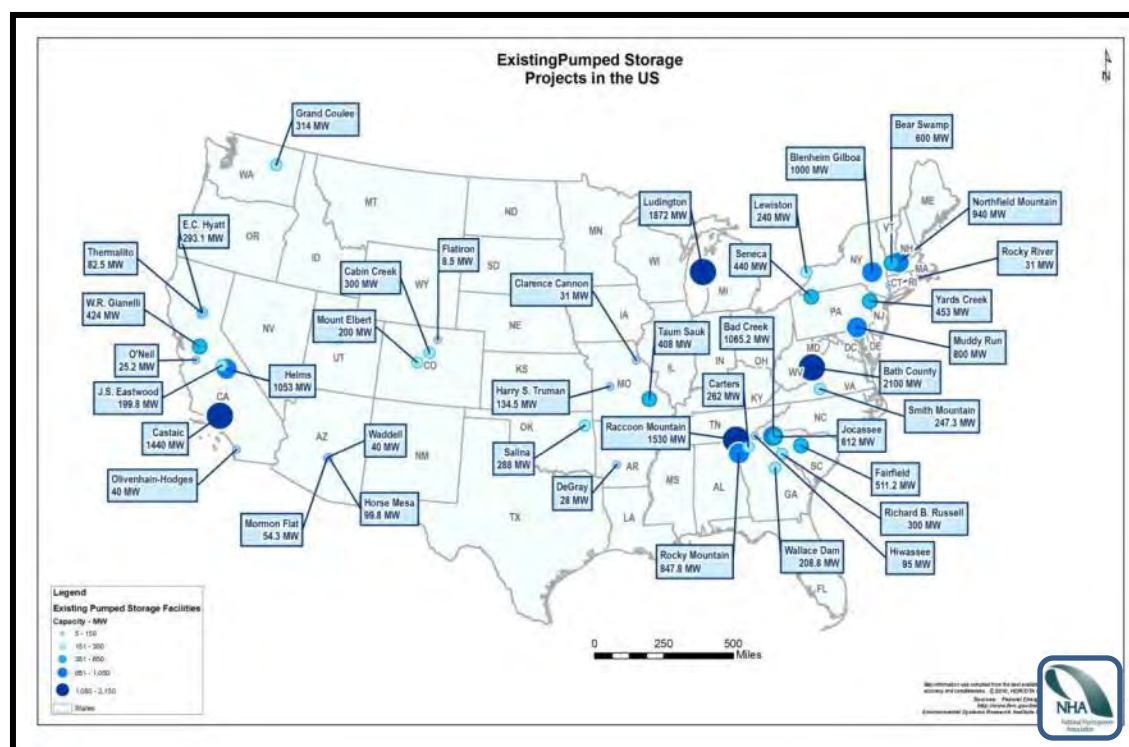


Output from an 8MW solar PV panel in Colorado on 9/4/08

High variability due to clouds

Courtesy: Secretary Steven Chu, USDOE, GridWeek, 09/21/2009

Pumped Storage Is a Proven Technology Large and Small



Benefits of Pump Storage:

- Not a New Concept
- Proven Technology
- Minimizes Environmental Impact
- Only technology capable of providing utility size storage

Summary of Pumped Storage Hydro

- **Per KEMA and NERC Reports, the U.S. grid needs additional energy storage for renewable integration and grid reliability**
- **Adjustable speed pump-generating turbines increase flexibility and operating efficiencies**
- **Pumped Storage currently utilized in Europe to integrate renewable resources, primarily wind**
- **Western Interconnect has several pumped storage projects in the development phase that could help meet the Region's utility-scale storage capacity needs.**

Sources of Additional information

<http://www.energy.ca.gov/2010publications/CEC-500-2010-010/CEC-500-2010-010.PDF>

<http://www.nerc.com/files/2010%20LTRA.pdf>

http://www.nerc.com/docs/pc/ivgtf/IVGTF_Task_1_5_Final.pdf

http://www.nerc.com/docs/pc/ivgtf/IVGTF_Task_1_4_Final.pdf

Thank You

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