

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



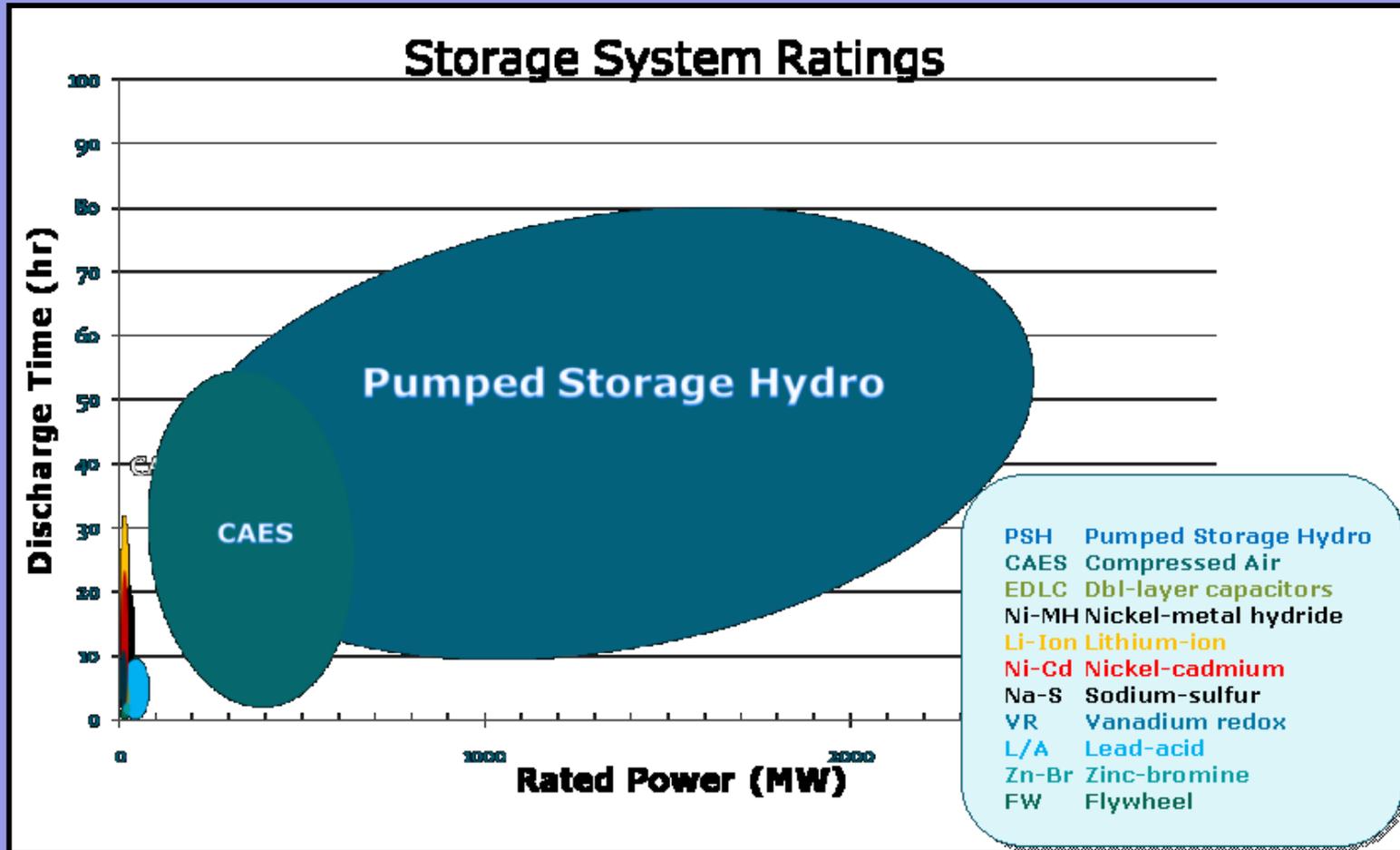
IEPR Staff Workshop
Technologies to Support Renewable Integration
(Energy Storage and Automated Demand Response)
November 16, 2010

Pumped Storage Hydropower's Role in Grid Scale Energy Storage

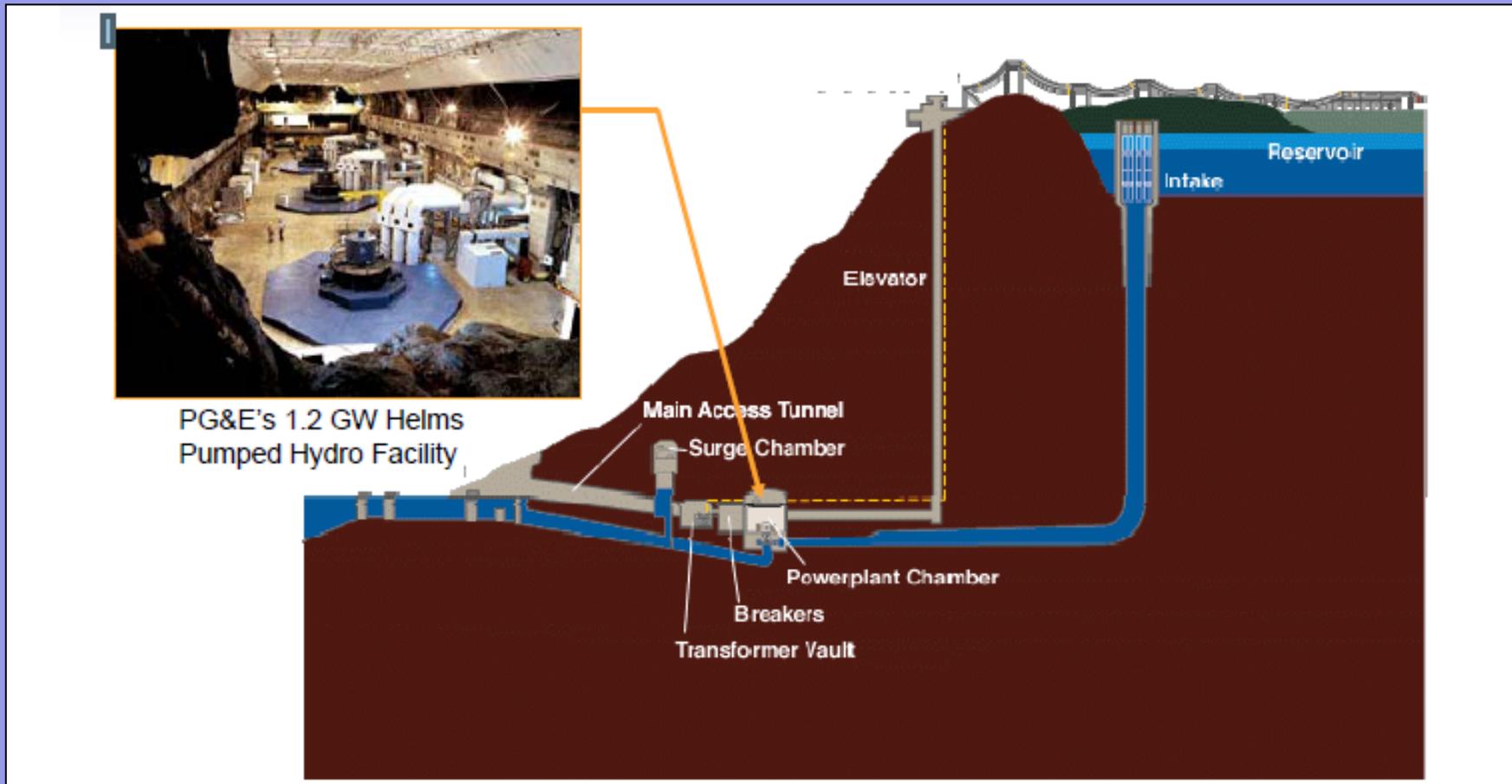
- Grid scale storage enables development of double digit levels of wind penetration.
- Europe integrates variable energy with big transmission, conventional hydro and carbon free pumped storage.
- Changing US and California market for system reserves and grid reliability services.



Energy Storage Technologies

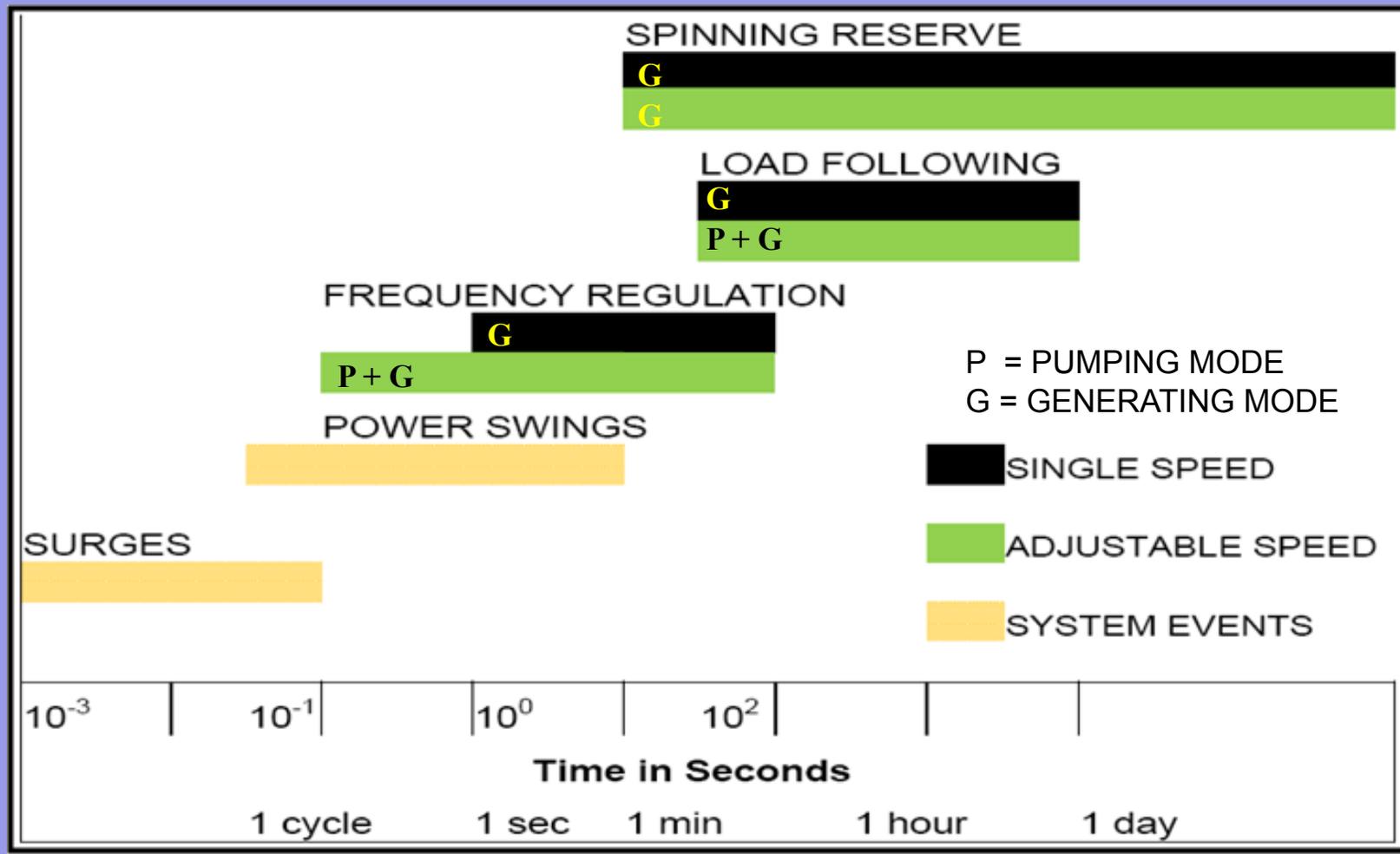


How Pumped Storage Works



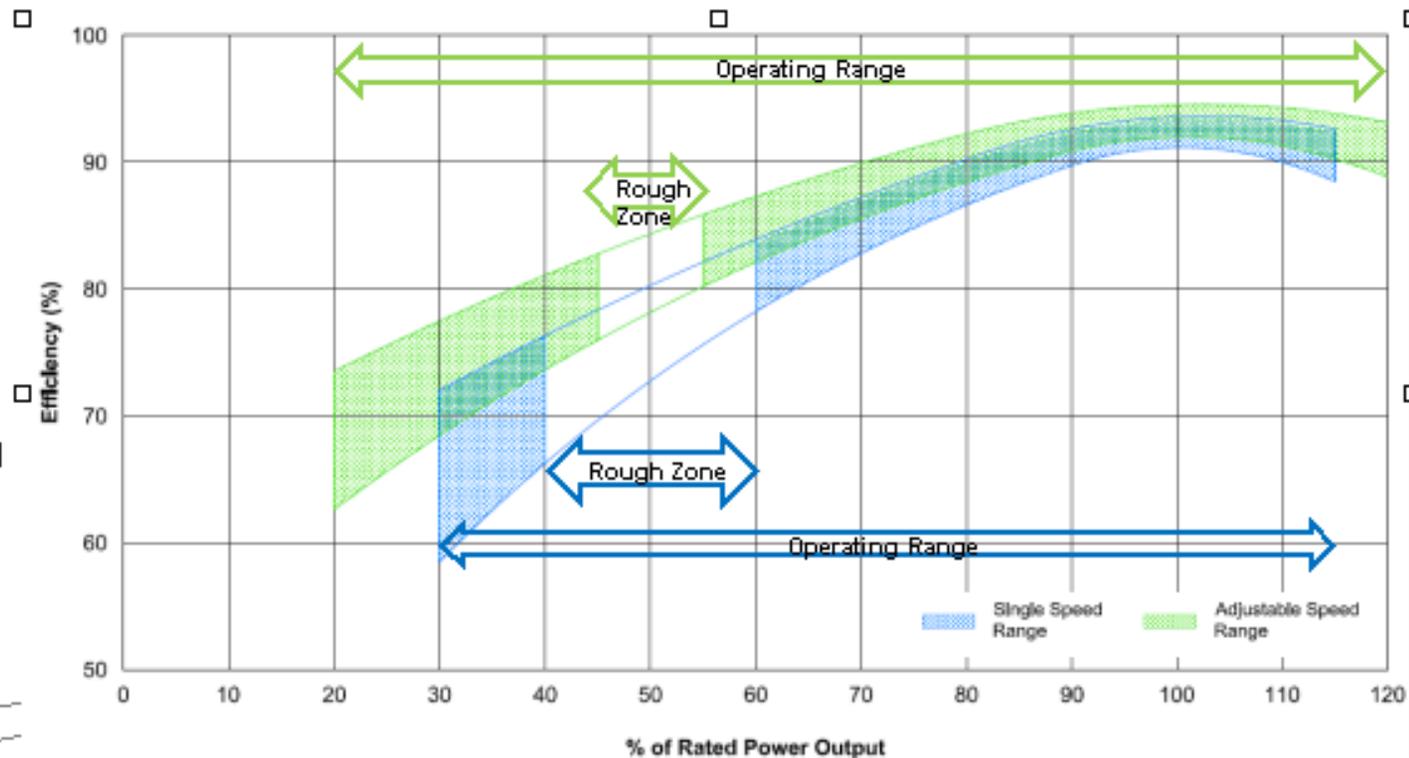
Typical Pumped Storage Project Design Scheme

Adjustable Speed Pumped Storage Fast Response Capabilities



Adjustable Speed vs Single Speed

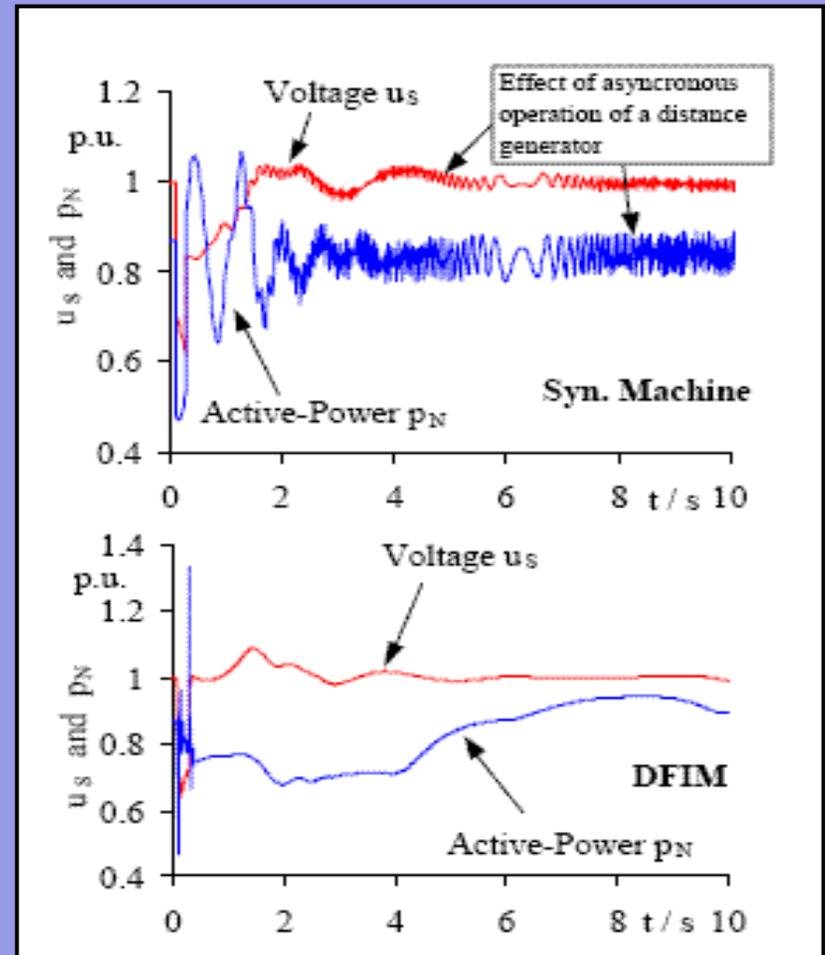
- Expanded operating range
- Higher Efficiency
- Additional Output



Actual Ex:
A 395 MVA PSH unit with ASH capability expands its operating range from 140 MW to 204 MW

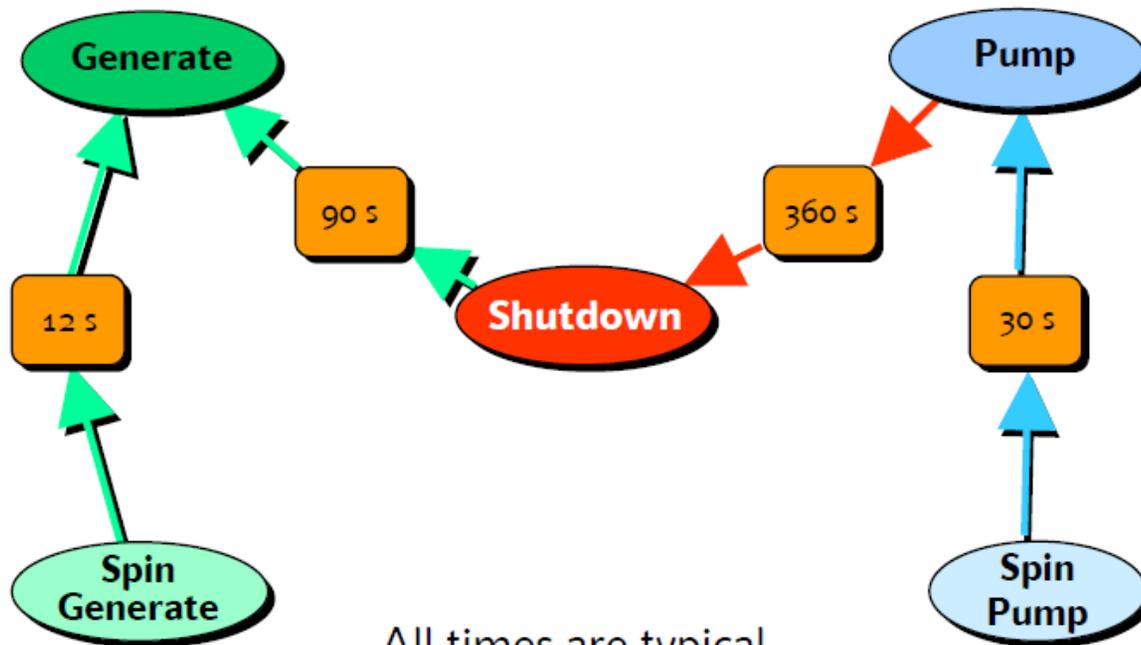
Adjustable Speed Pumped Storage is a 'fly wheel'

- Utilize angular momentum stored in spinning rotor mass.
- Rapid change of rotor speed
- ≈ 150 Milli Seconds
- Change speed and energy stored in rotating inertia: $\omega M = \omega S \pm \omega R$
- Control bulk power system power and frequency variations.



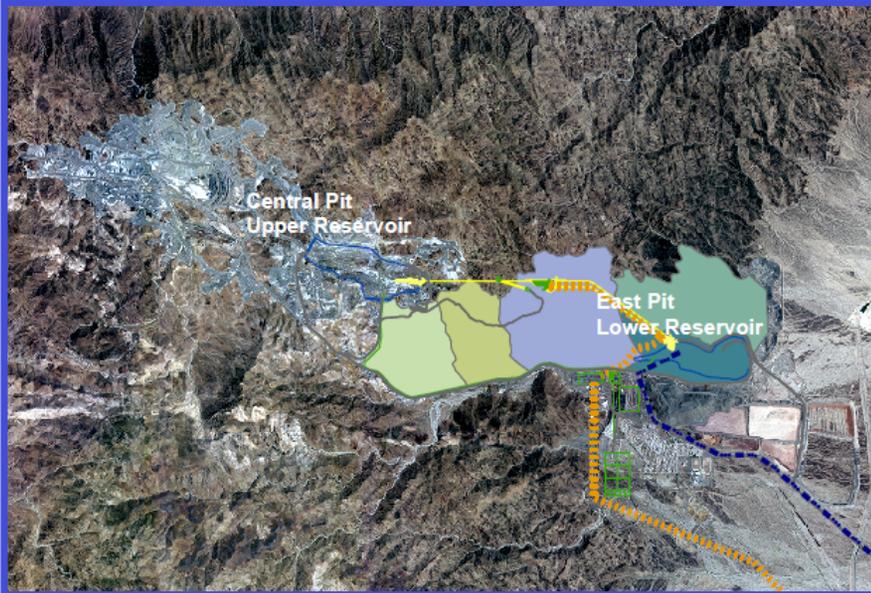
- Pump-Generating Turbine Capabilities - Turn Around Times (Pump to Generate)

Dinorwig mode times change (seconds)



All times are typical

Benefits of Closed Loop Pumped Storage System

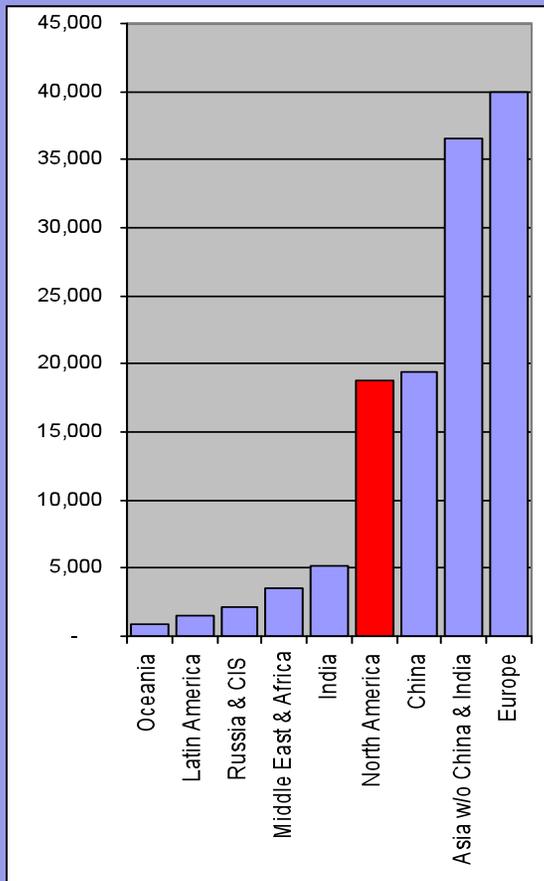


- Self contained “off-stream” water system
- No need for new dams on main stem rivers
- Uses existing infrastructure
- Minimizes environmental impacts (shorter permitting time)

Snapshot of Pumped Storage Globally

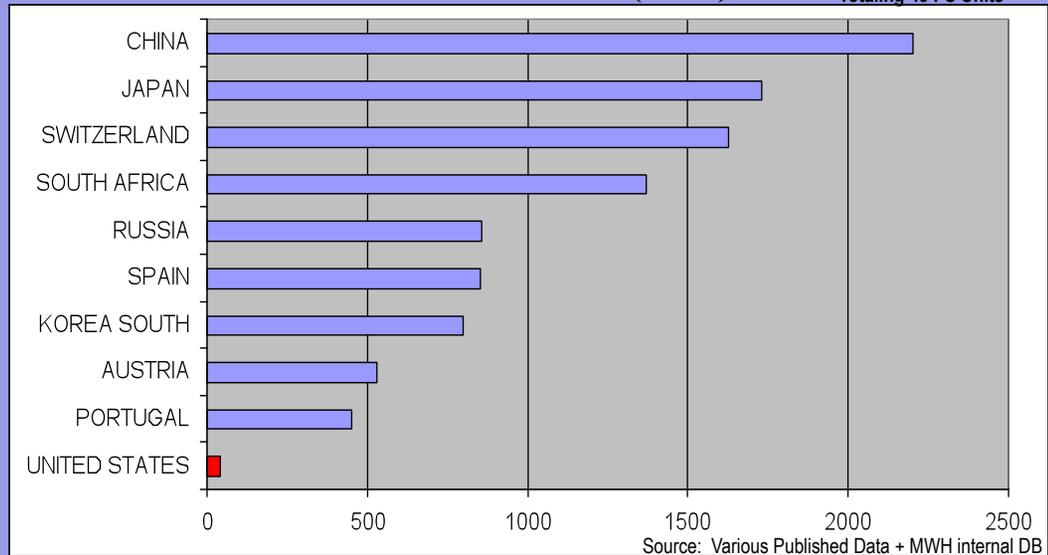
Pump Storage Units in Operation (MW) by Country/Continent

- 127,961MW Worldwide
- Totalling 922 PS Units



Pumped Storage Projects Under Construction (MW)

- 10,453 MW Worldwide
- Totalling 45 PS Units



Source: Various Published Data + MWH internal DB

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

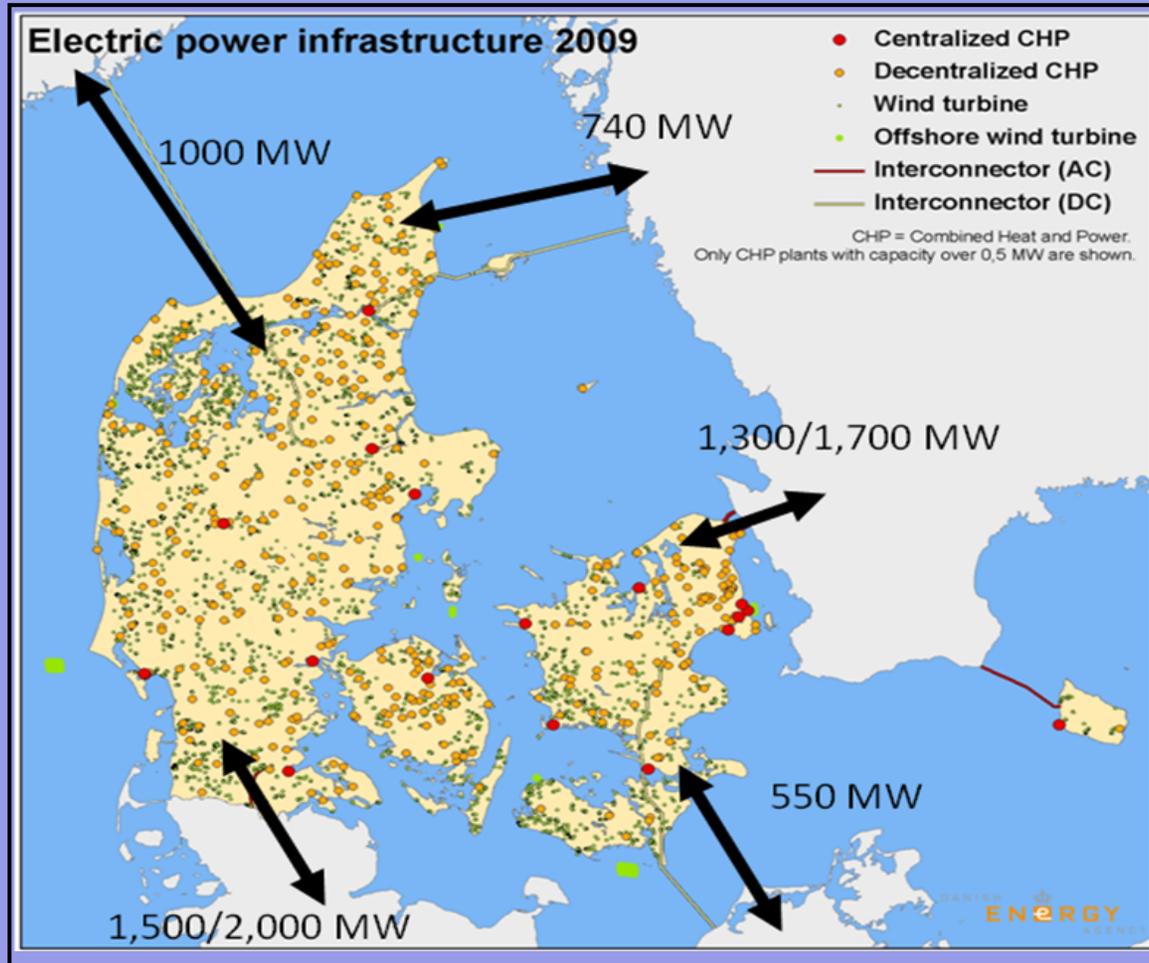


Denmark & Grid Reliability

- 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

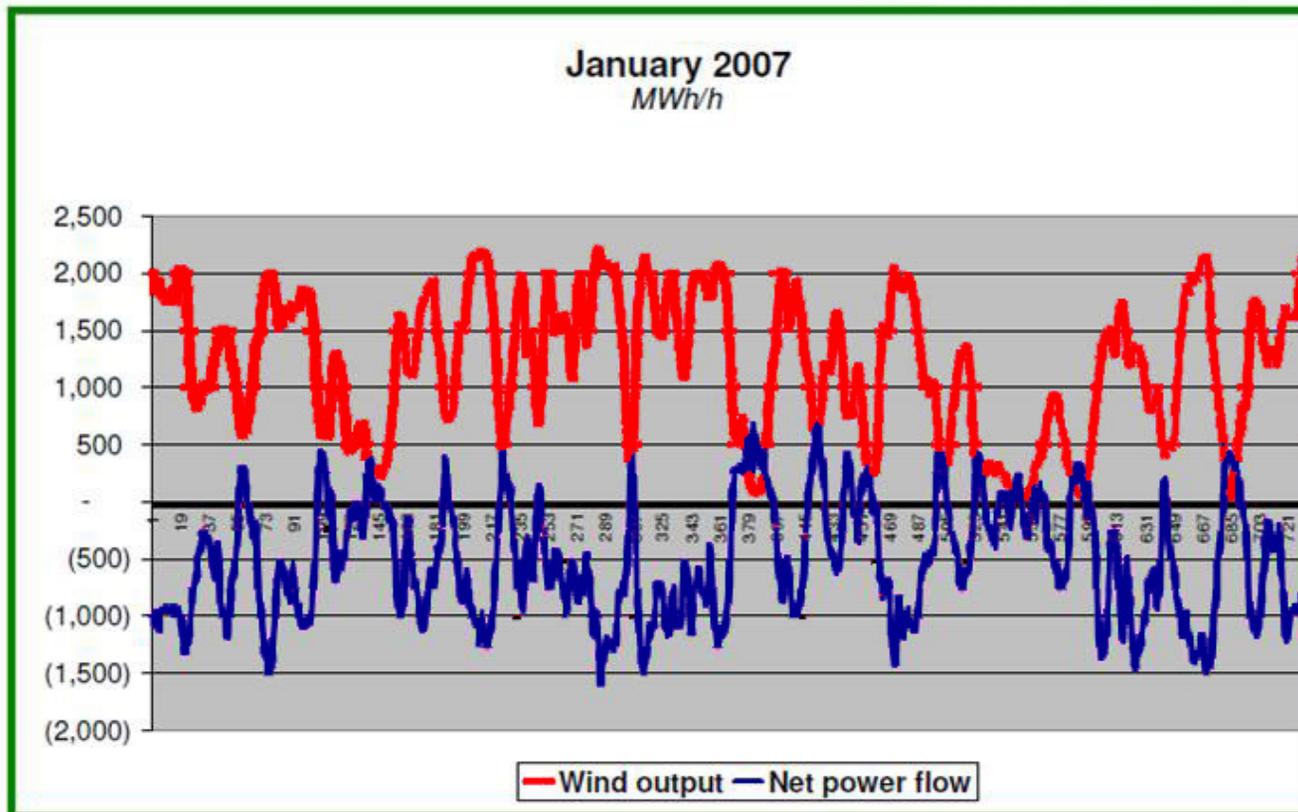


Power Balance in Denmark 2008



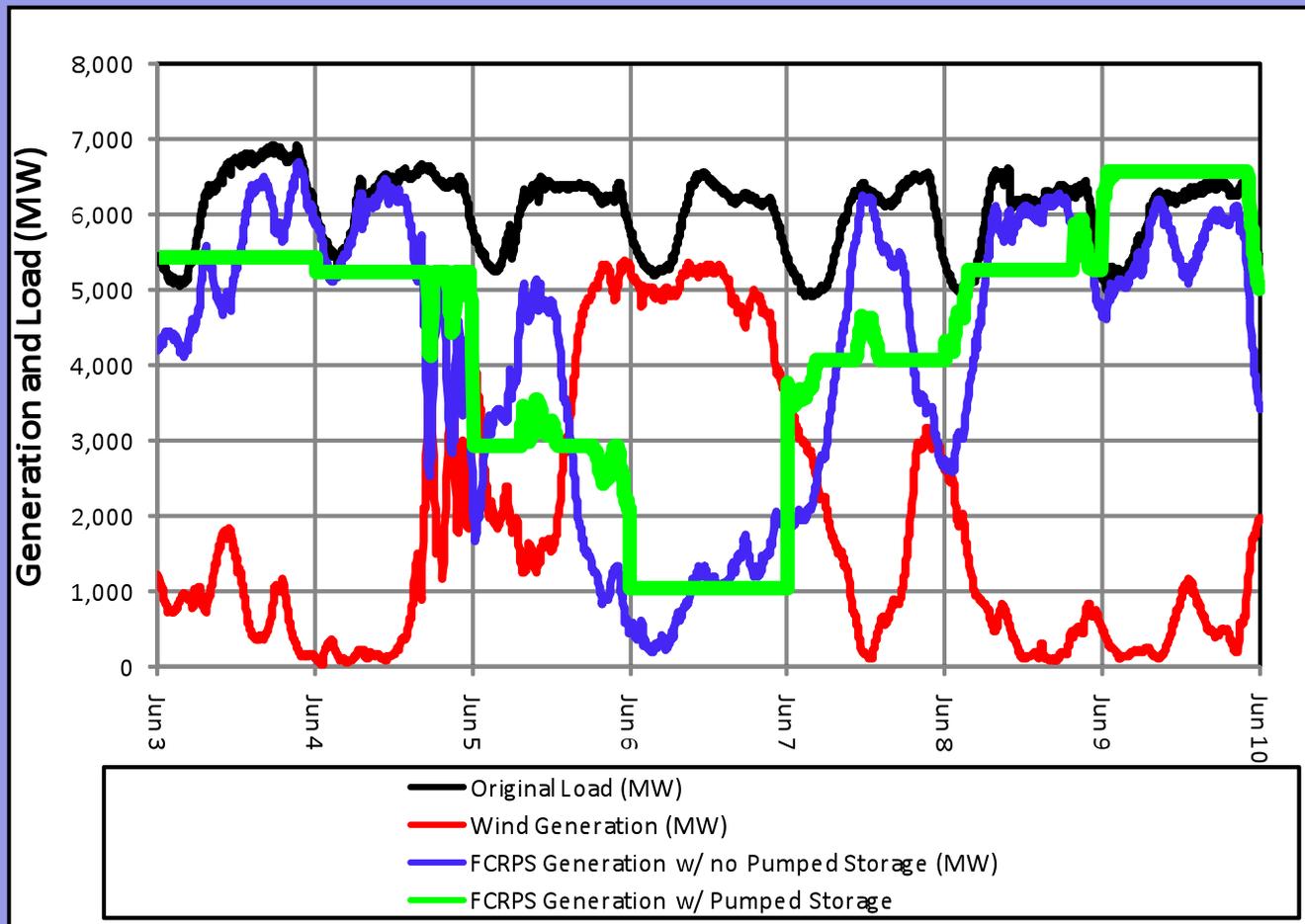
Source: Energinet.dk

Western Denmark Wind Output and Net Electricity Flows



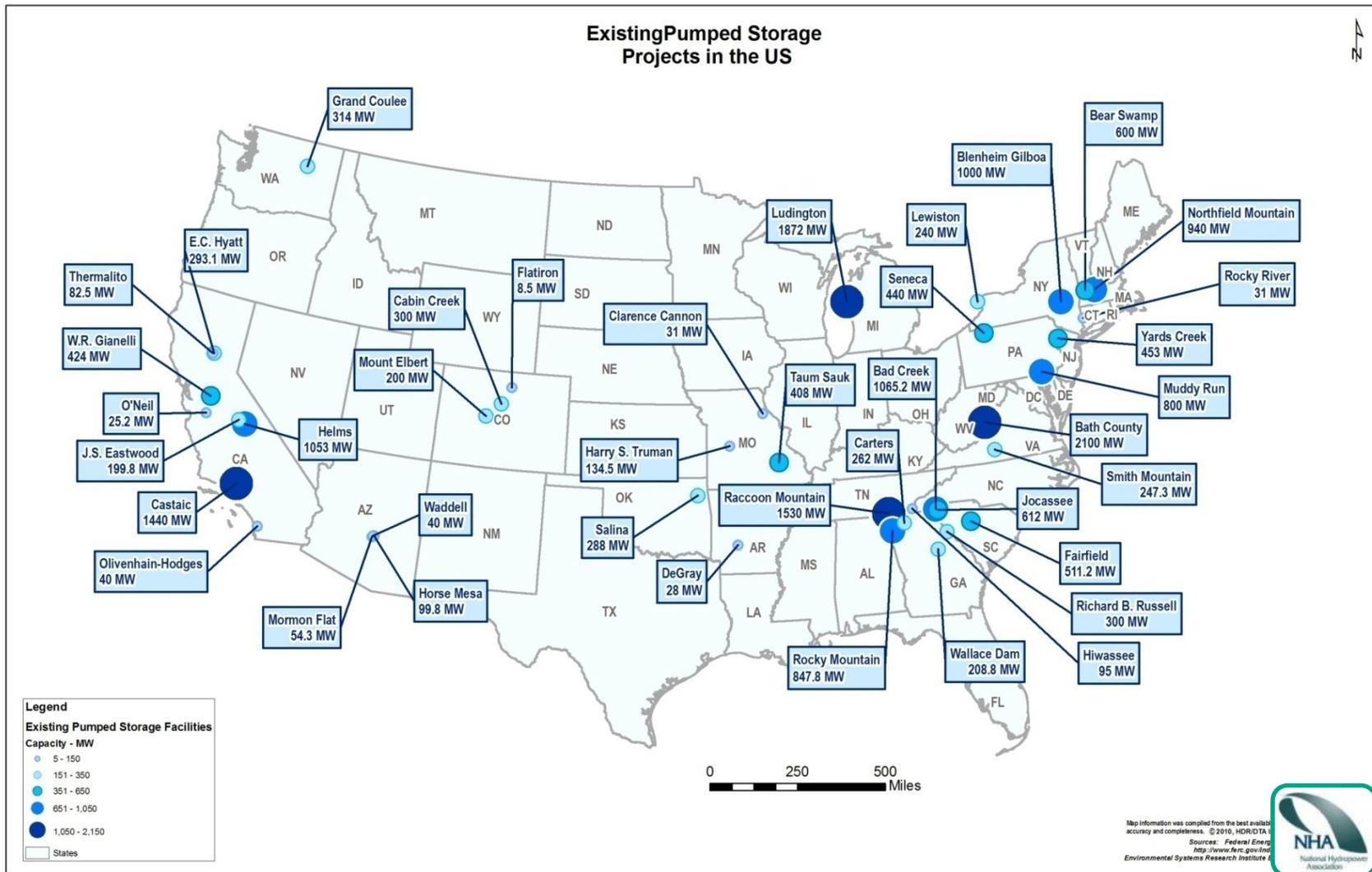
Source: *Energinet.dk* (Denmark's system operator)

Historic BPA Load – Managing Reliability & Wind Integration with Pumped Storage

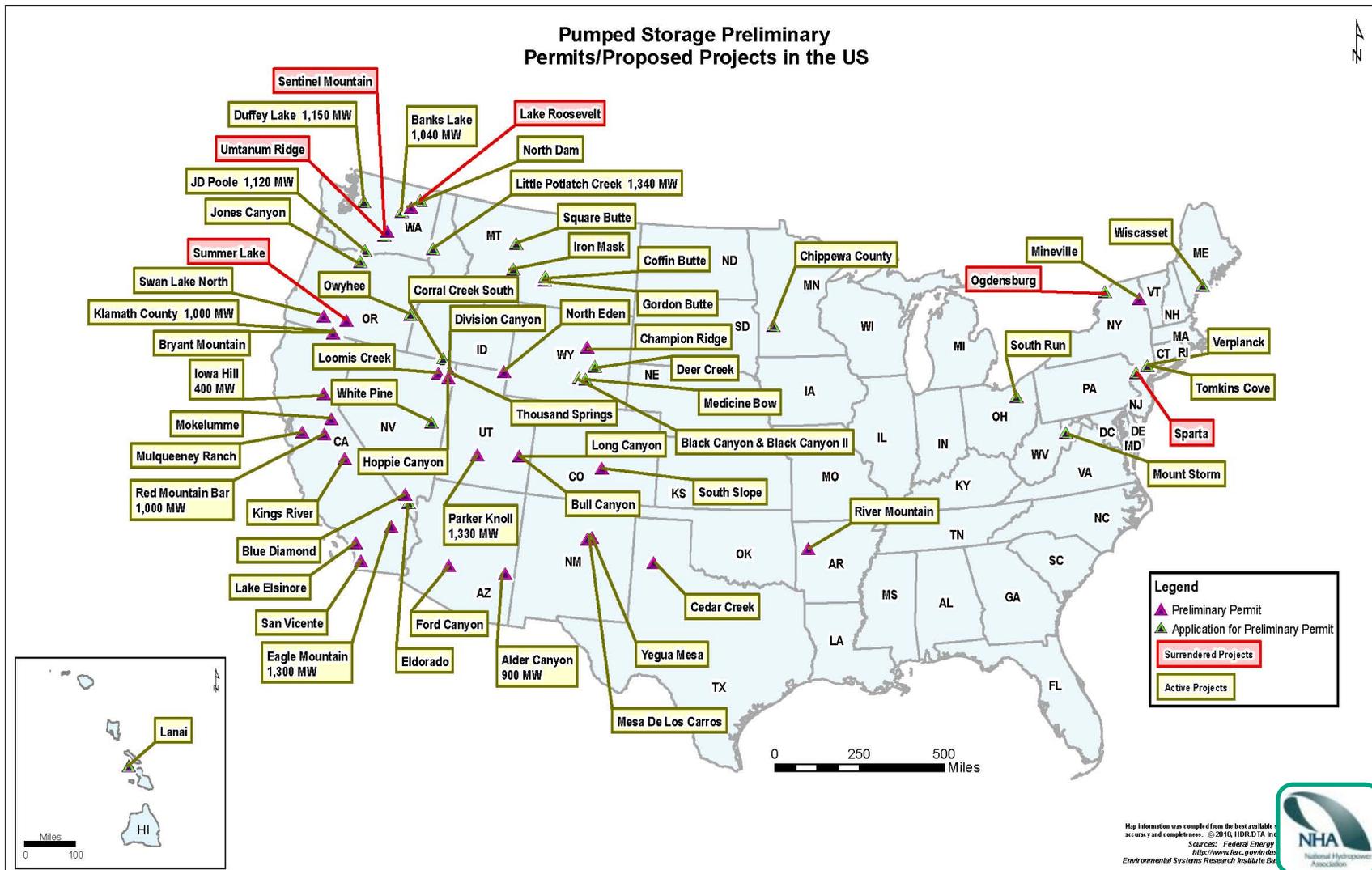


Simulated Approximately 6,250 MW Projected Wind Interconnection and FCRPS Re-Dispatch due to Pumped Storage

Existing Pumped Storage Hydro Plants



Proposed Pumped Storage Hydro Projects



Map information was compiled from the best available accuracy and completeness. © 2010, HDR/ETA Inc.
 Sources: Federal Energy
<http://www.ferc.gov/energy>
 Environmental Systems Research Institute, Inc.



Pumped Storage in California

- 25% of the Nation's operating pumped storage units
- 8 proposed projects 6,330 MW
 - Currently in the FERC permitting/licensing process
- P-S meets goals of AB-32:
 - Peaking capability without air quality impacts (emission free)



Summary of Pumped Storage Hydro

- Per KEMA and NERC Reports, California 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
- California has several pumped storage projects in the development phase that could help meet CA'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

Contact Information

Dr. Douglas Divine, CEO
Eagle Crest Energy
ddivine@eaglecrestenergy.com
(832) 526-2359

Donald Erpenbeck
Senior Vice President
MWH Global
Donald.Erpenbeck@mwhglobal.com
(414) 615-1968

Rick Miller
Senior Vice President
HDR|DTA
Rick.Miller@hdrinc.com
(704) 342-7379

