Renewable Energy Issues

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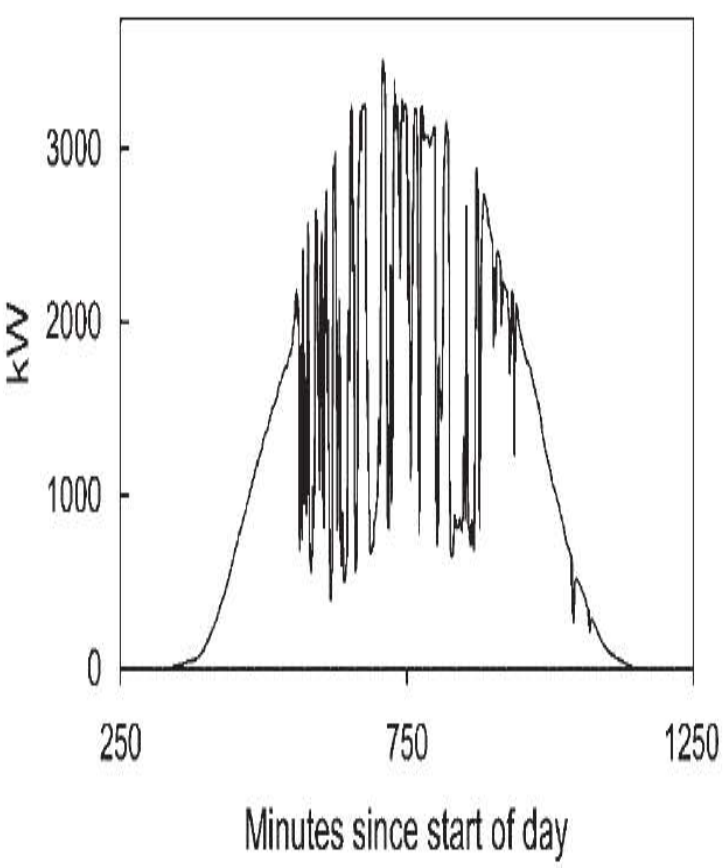
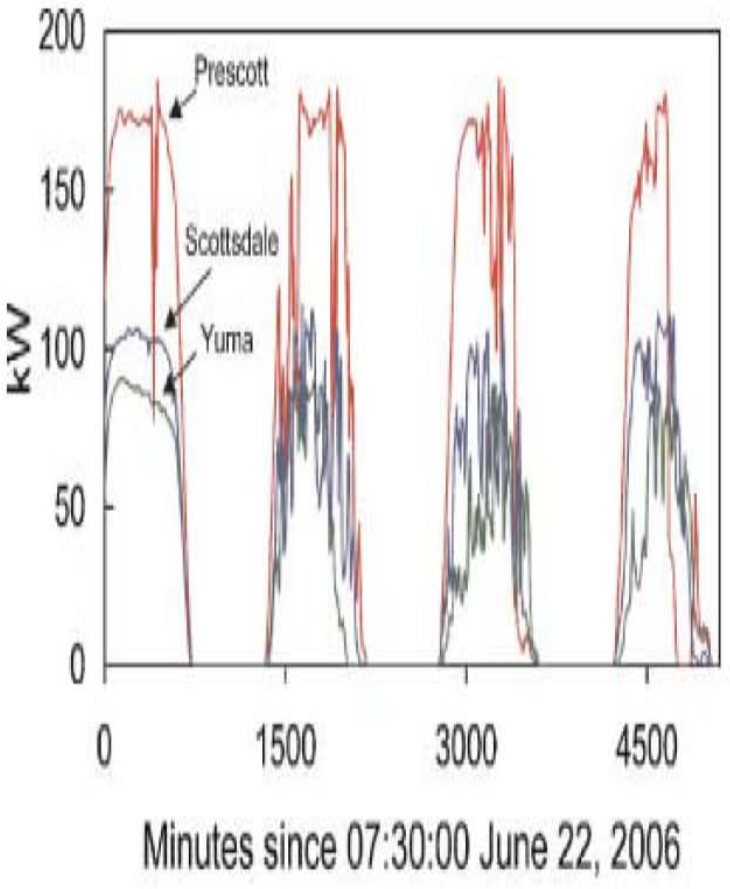
Introduction- obstacles to integration

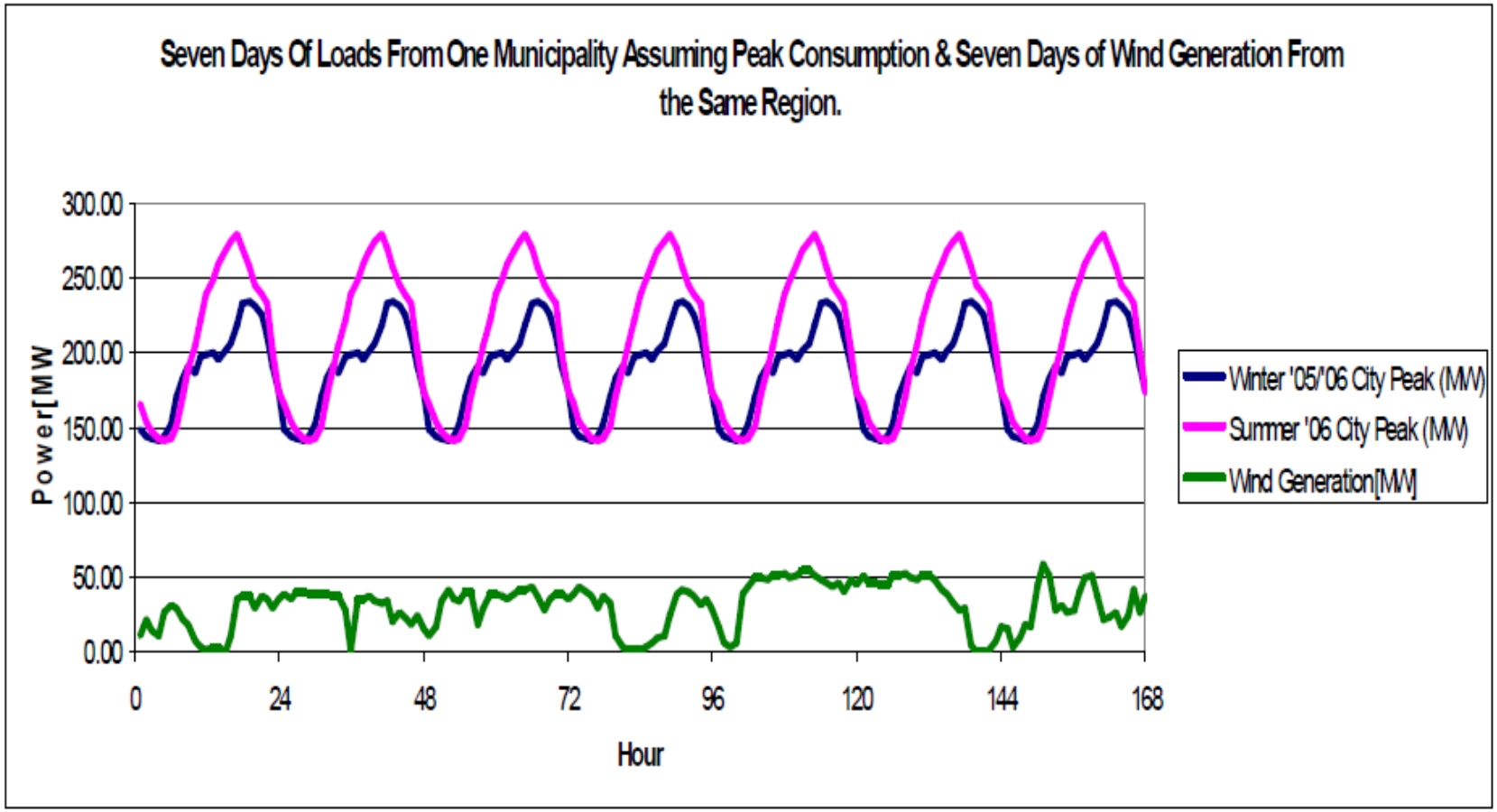
1. The Variability of Wind, Solar and Hydroelectric Power and Mismatch to the loads
2. The Integration and Control of a Large Number of Distributed Sources in to the Grid
3. Security and Privacy
4. Safety

Solar Variability- Examples

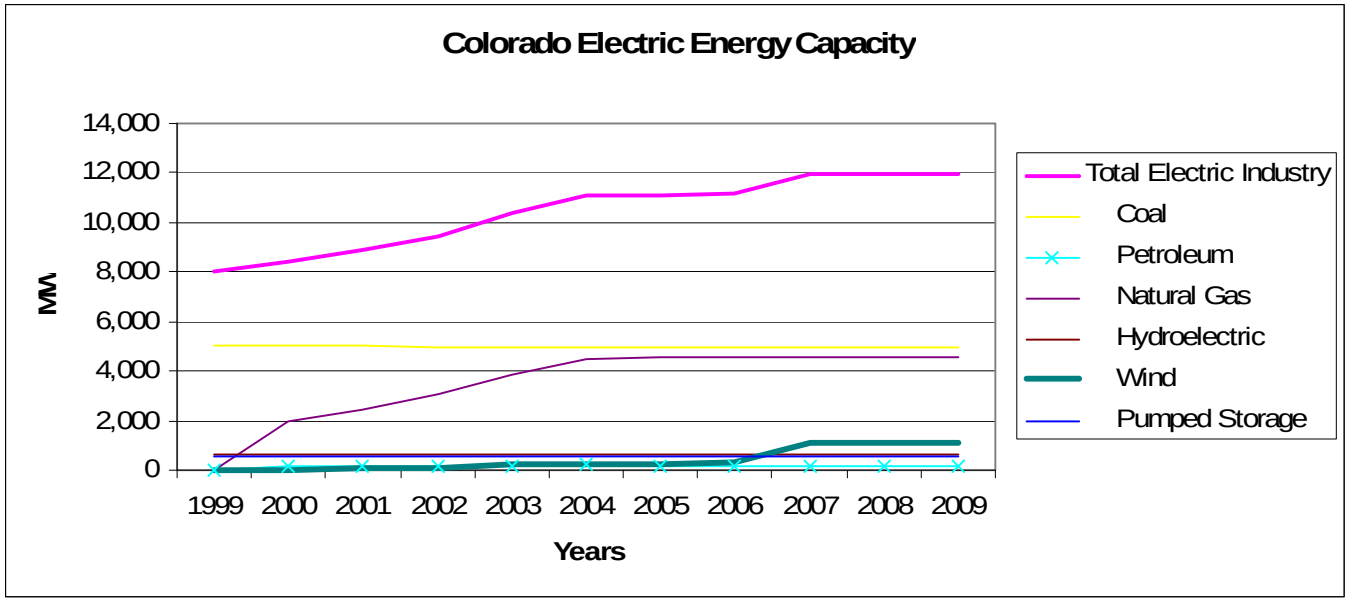


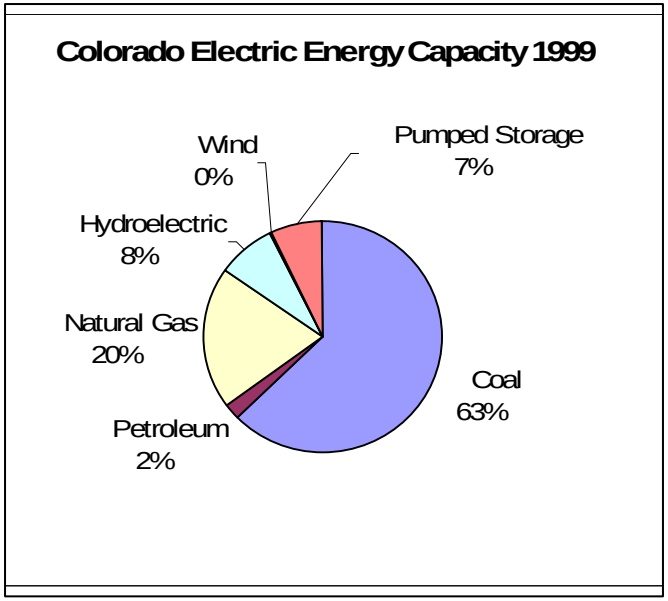


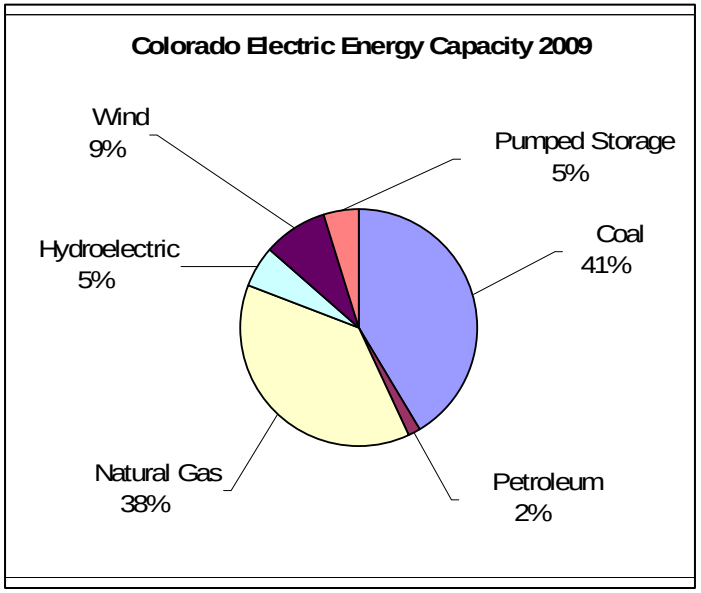
Wind & Load Variability Example



Integrating wind into the Colorado Electric Grid

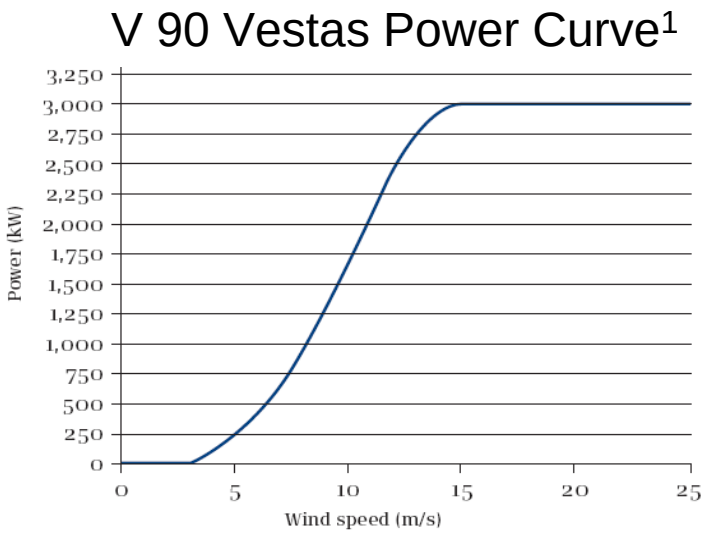




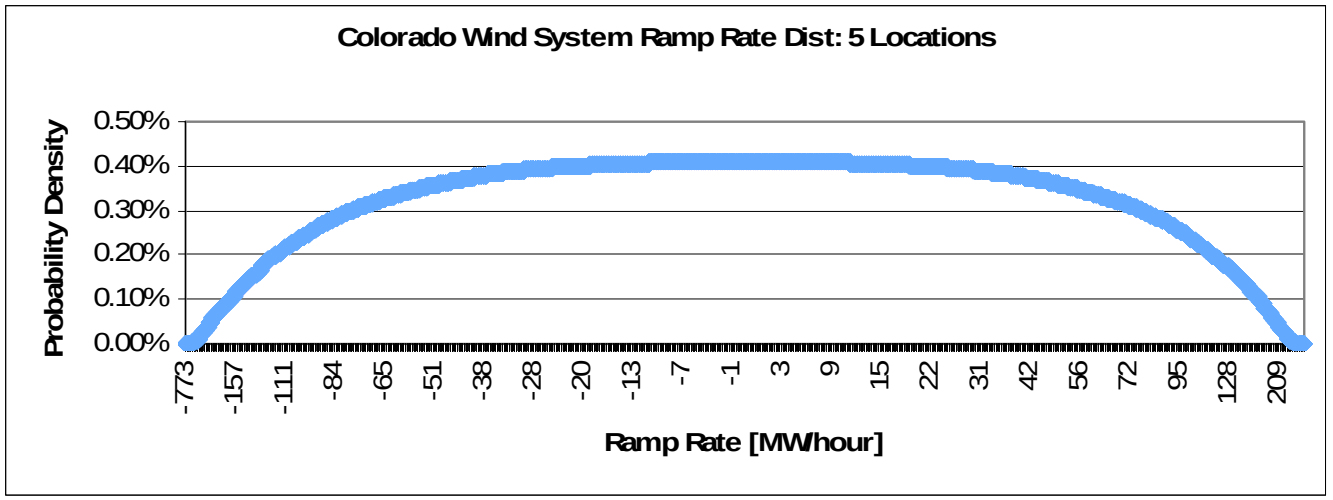


Source EIA through 2006- Data extrapolation + AWEA to 2009

Colorado Wind Energy Variability:
Current System



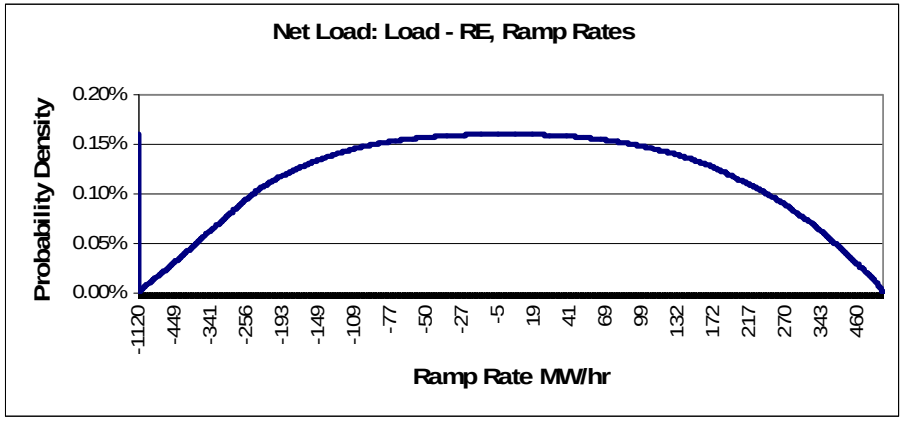
Current Colorado System	
Mean	0.05
Standard Error	1.04
Standard Deviation	97.43
Sample Variance	9,491.87
Range	1,545.98
Minimum	-772.78
Maximum	773.20



1. *V 90 Vestas Power curve available online: www.vestas.com*

Matching Fossil Resources to the Net Load

Generation Resource Type	Rated Capacity [MW]	Ramp Up [MW/hr]	Ramp Down [MW/hr]
Coal sub-total[ii]	*2834*	*322.58*	*-630.27*
Gas sub-total	*775*	*37.70*	*-65.75*
Ramp per (MW/hr)/MW avg.	**NA**	**.0998**	**-.1926**
Total	**3609**	**360.28**	**-695.02**
Extrapolated Total	**7,884 MW**	**786.82**	**-1,518.30**

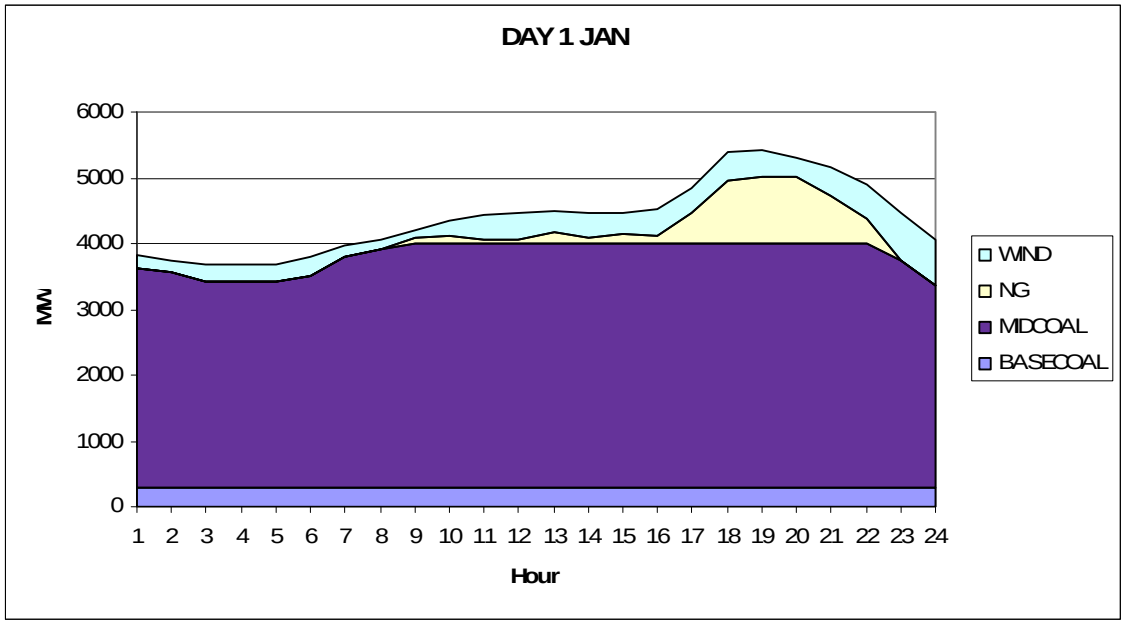


Ramp Rate MW/hr	Number of Ramp Events	% of the year
-1000	1	0.01%
-900	2	0.02%
-800	2	0.02%
-700	26	0.30%
-600	72	0.82%
-500	178	2.03%
-400	317	3.62%
-300	434	4.95%
-200	603	6.88%
-100	1010	11.53%
0	1666	19.02%
100	1632	18.63%
200	1083	12.36%
300	769	8.78%
400	472	5.39%
500	284	3.24%
600	146	1.67%
700	44	0.50%
800	**13**	**0.15%**
900	**5**	**0.06%**
1000	**1**	**0.01%**

Integrating wind into the Colorado Electric Grid

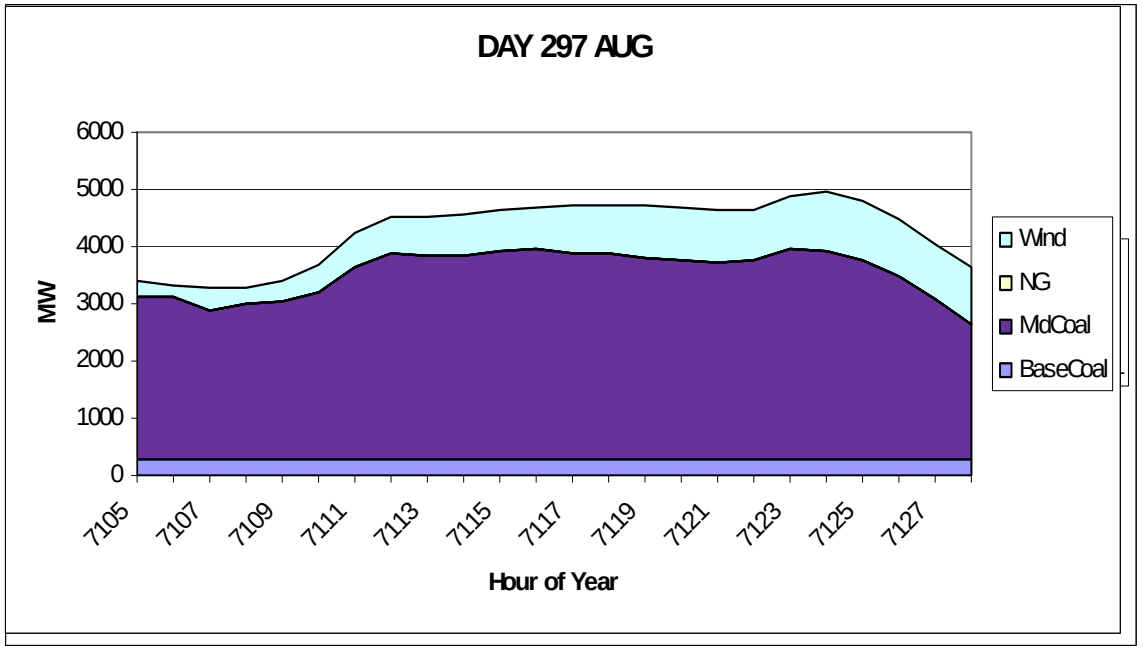
Fairly easy Integration

50% of the year



Very challenging Integration

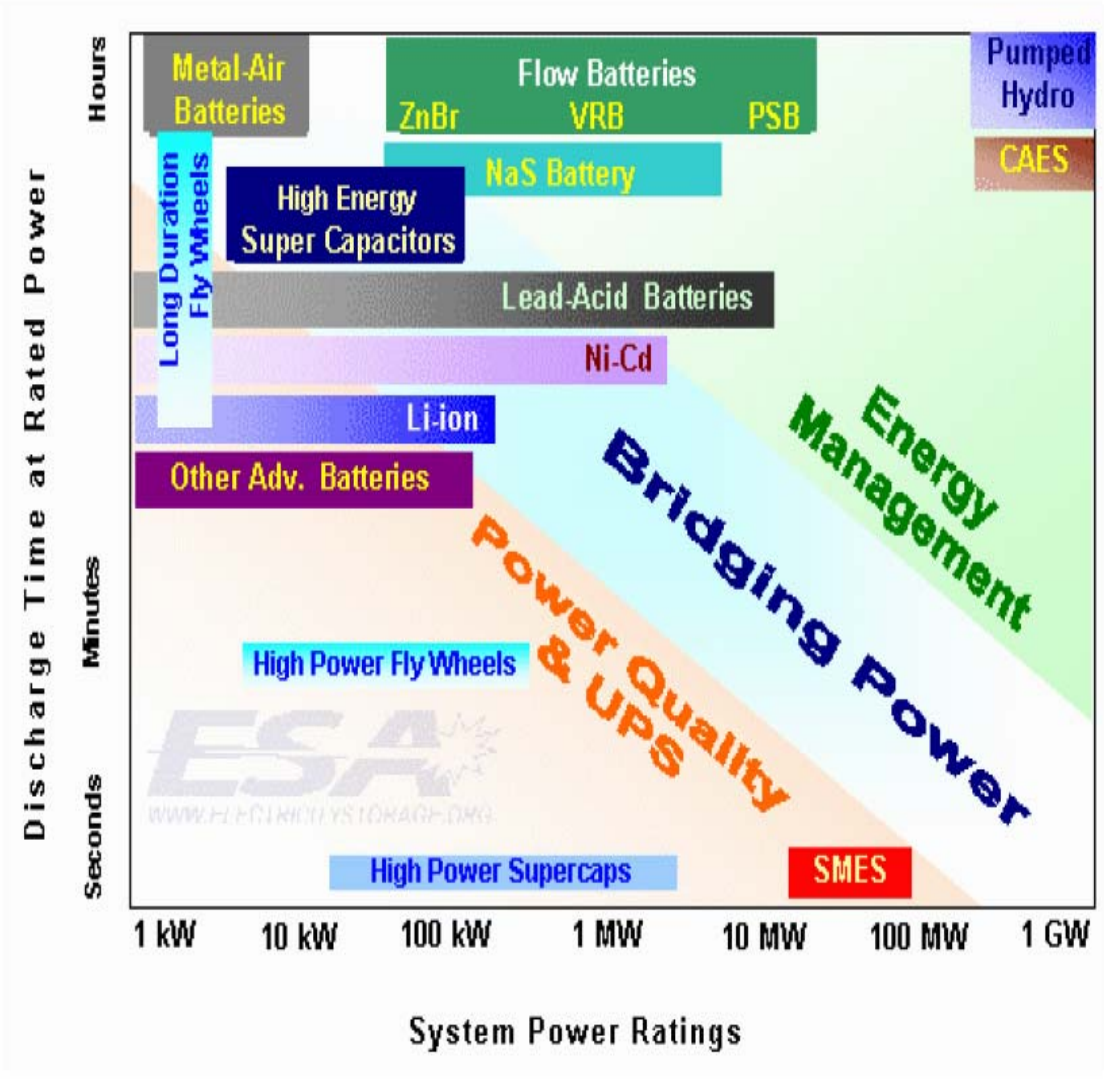
Less then 10% of the year



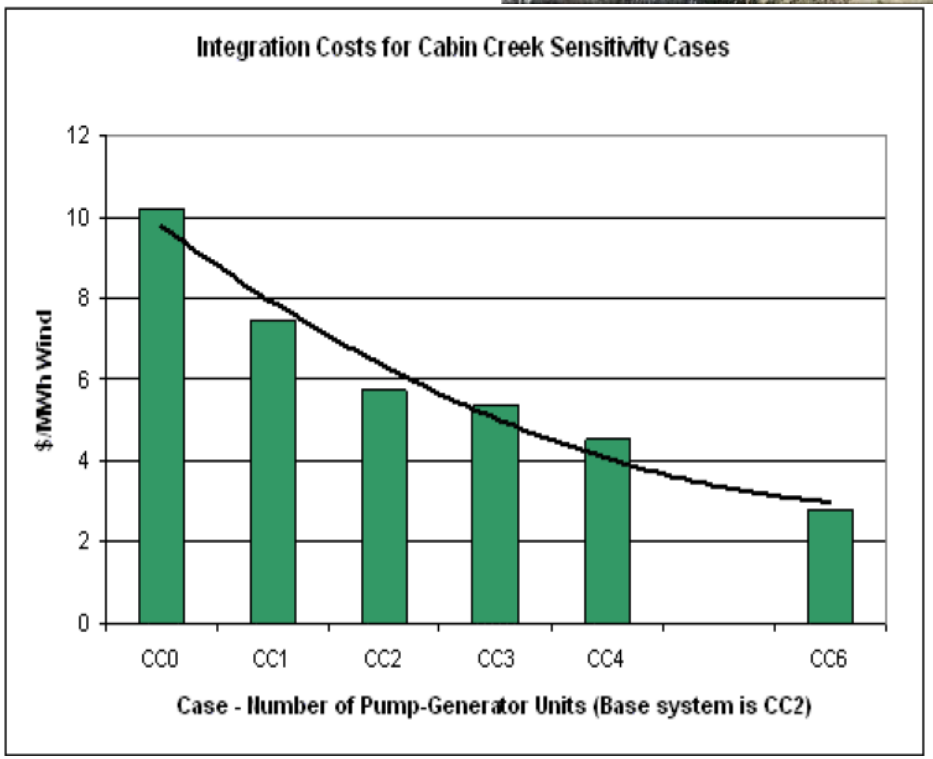
Approaches to Solving the Variability Issues.

1. At low penetration grid spinning reserves.
2. Gas fired generators
3. Storage
   A. Batteries, supercapacitors, fly wheels,
   B. Pumped Hydroelectric systems, CAES
4. Demand Response
5. Biomass, geothermal,

Energy Storage Systems



Pumped Hydro Storage in Colorado



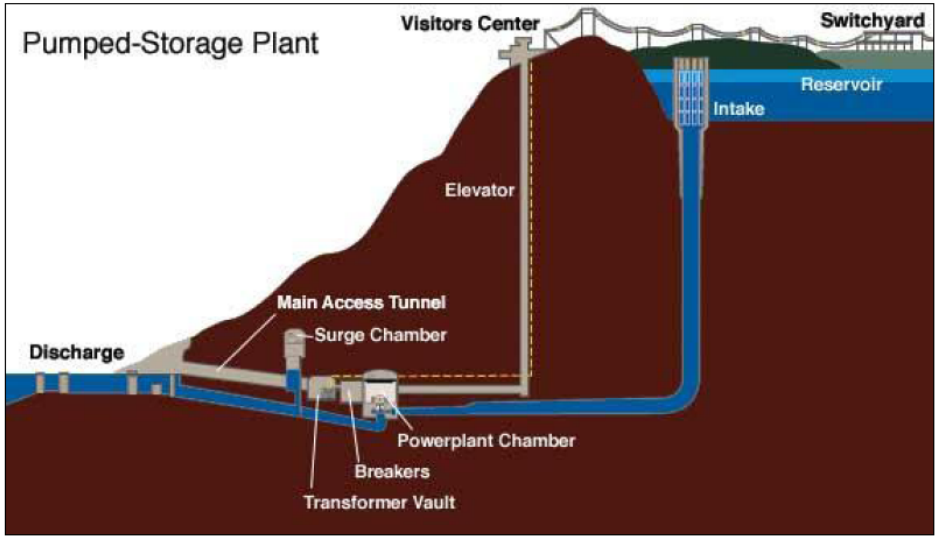
Case Name	Wind Integration Cost ($/MWh) ($5/MMBtu gas)
ase Case CC2 - 2 Cabin Creek Units	**$5.75**
:C0 - No Cabin Creek Units	$10.19
:C1 - 1 Cabin Creek Unit	$7.49
:C3 - 3 Cabin Creek Units	$5.34
:C4 - 4 Cabin Creek Units	$4.55
:C4 - 6 Cabin Creek Units	$2.78

Wind Integration Study for Public Service of Colorado Addendum Detailed Analysis of 20% Wind Penetration

http://www.xcelenergy.com/SiteCollectionDocuments/docs/CRPWindIntegrationStudy.pdf

Pumped hydroelectric installation at Raccoon Mt

(TVA).



- Construction at Raccoon Mountain 1970-1978.
- The reservoir at the top of the mountain has 528 acres of water surface.
- Once the upper reservoir is full, the pumped-storage plant can provide 22 hours of continuous power generation.
- Generating capacity of Raccoon Mountain is 1,600 MW

Compressed Air Storage

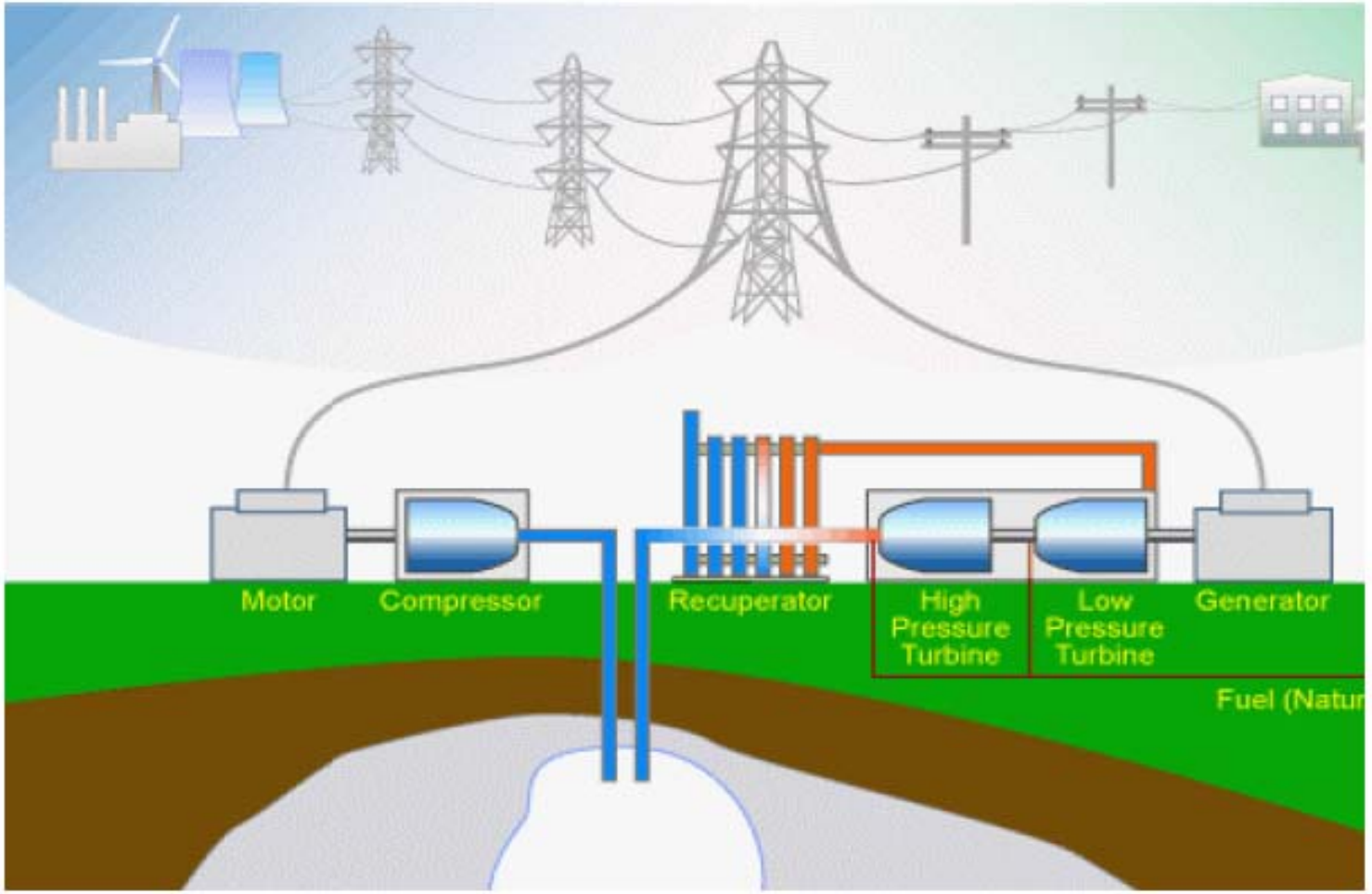


Figure 2: Generic diagram of CAES operation [16]

Cost of Increasing Wind Energy Penetration

Table 2-1: Gas Cost Impact of wind penetrations with and without storage on Xcel's electric grid

Wind Penetration	10%	15%
$/MWH Gas Impact No Storage Benefits	$2.17	$2.52
$/MWH Gas Impact with storage benefits	$1.26	$1.45

Table 2-2: Cost impact of increasing wind penetration on Xcel's electric grid

Wind Penetration	Electric Production Cost Impact	Gas Supply System Impact	Total
10%	$2.25	$1.26	$3.51/MWH
15%	$3.32	$1.45	$4.77/MWH
20%	$7.47	$2.10	$9.57/MWH

Control Problems

1. Voltage Control
2. Frequency Control
3. Two Way Power Flow
4. Generation of Harmonics
5. Setting up a Communications for a Smart Grid.
6. Security of the Controls.

Smart Grids

1. Smart Meters Issues
   - More than 50 manufactures
   - The communications systems are not compatible.
   - Need for Standard Interfaces
2. Multiple communications systems
3. Public, Wireless, Wire-line, Optical Fiber
4. Private, Broadband Over the Power Lines, Optical Fiber

Security Issues

1. You do not want an enemy or a hacker to shut down the power.
2. You need to control access to individuals power use data.
3. You need to locate faults and Isolate regions from many new distributed sources.

Safety Questions Not Asked

1. If we go to many solar photovoltaic roof top system, what will the accident rate be for falling off ladders so clean the snow off fixing inverters, batteries, etc?
2. How will this compare with the present system with a relatively few electrical workers and large centralized generators?