



Emergence or Emergency? Things that May Shape the Power System

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This is meant to be thought-provoking

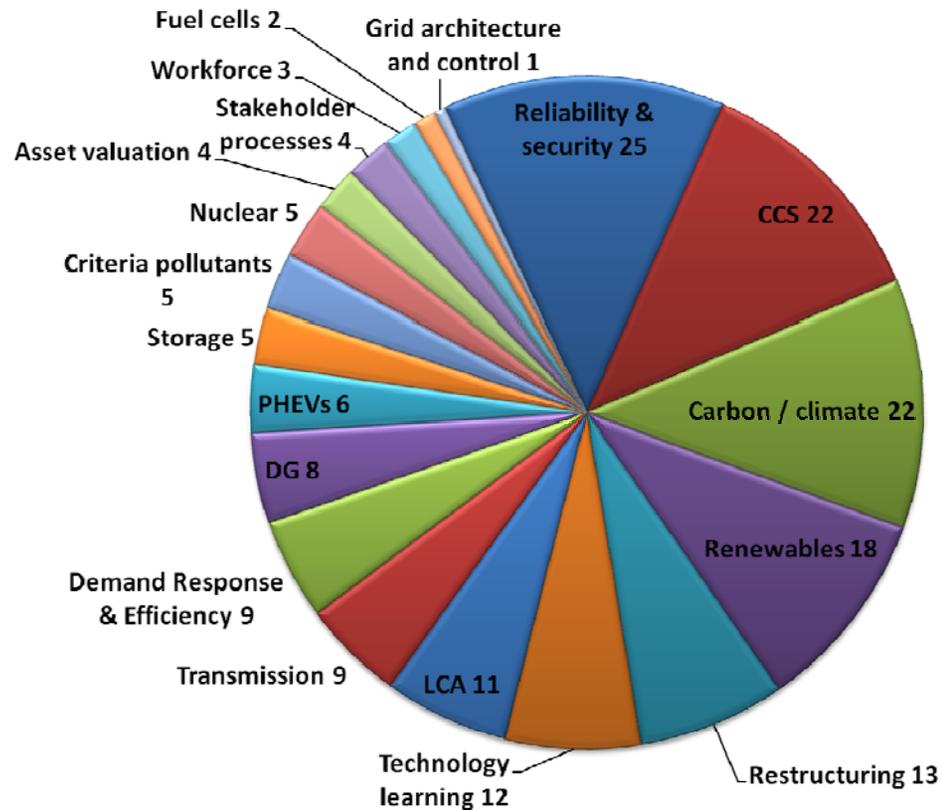
- I've spent the past 8 years as the executive director of the largest interdisciplinary group in the world studying the problems of the electric power industry, the Carnegie Mellon Electricity Industry Center.
- 22 Faculty, 29 Ph.D. Students, and 2 post-doctoral fellows.
- 21 PhDs granted.
- 195 peer-reviewed publications (as of October 2010).
- Our faculty have served as the
 - Chair of EPA's Science Advisory Board
 - President of the Society for Risk Analysis
 - DHS advisory board
 - EPRI Board, and chair of EPRI's Advisory Council
 - Chair of 5 National Academy panels on energy





Our approach...

...is conducting systems studies that combine engineering, economics and regulatory and other analysis.





We work very closely with real-world organizations

30 companies as well as:

So, what thoughts has this caused me to have?



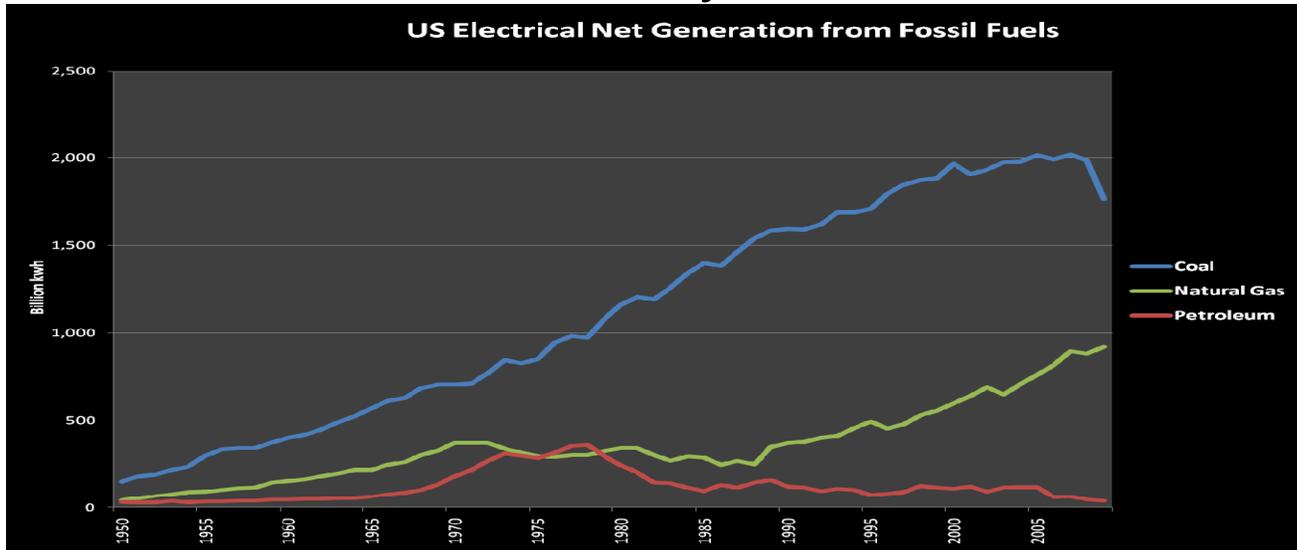
What we are seeing at the moment

- Must-run wind is undercutting the economics of baseload, and shoulder plants.
 - There are pressures for capacity payments.
- The recession has deferred utility interest in DR and EE
 - But state mandates are providing some very interesting experiments. For example, \$1.25/kWh peak in PEPCO.

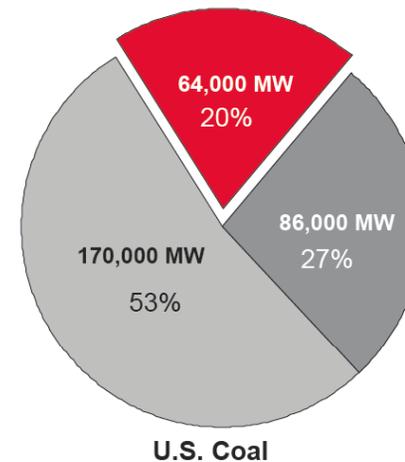
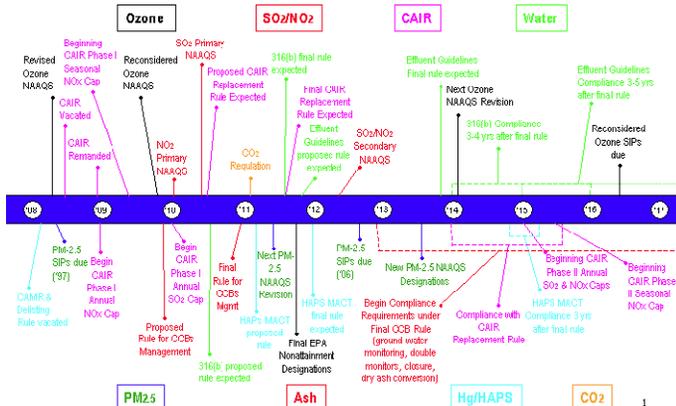


What we are seeing at the moment

- Coal has taken essentially all of the demand downturn



- Coal units are endangered



Source: Nick Akins, AEP

“Fully-Exposed”	“Partially-Exposed”	“Least-Exposed”
Probable retirement	Evaluating potential retirement	Not likely to be retired



Retirement of 64-150 GW of coal

- How much AGC will retire?
- Will retirements affect the inertia of the system?
- What operations changes will be required?
- Gas will buffer wind at most time scales more easily than coal, but new closed-loop control systems are likely to be required in high-wind areas.
- Very likely to increase rate volatility.





Whew – it's a good thing \$12 Natural Gas is a thing of the past

The New York Times

March 21, 2009

Natural Gas, Suddenly Abundant, Is Cheaper

NATURAL GAS IS ABUNDANT

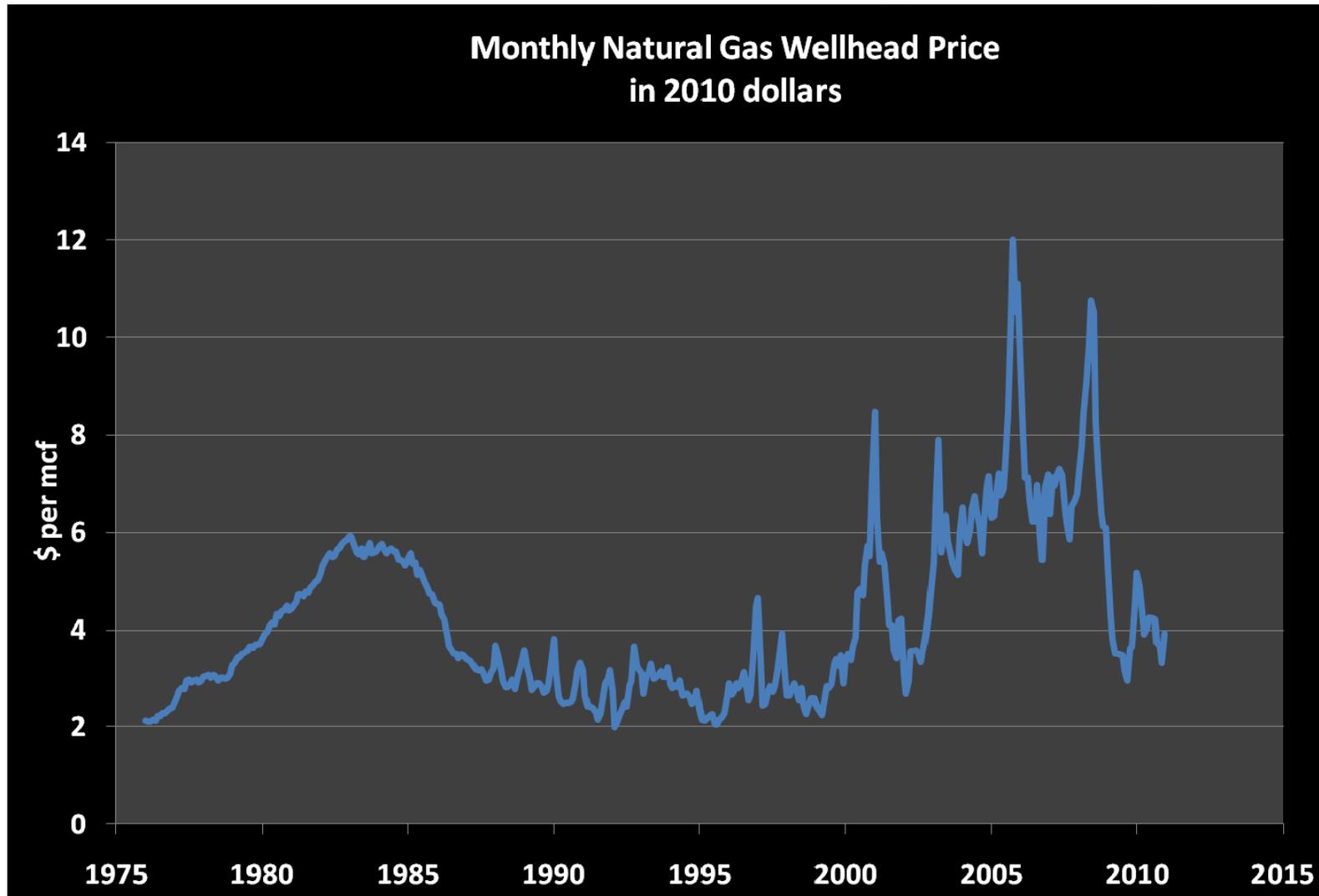
Vast new natural gas resources are being discovered across North America. In the past five years, shale reservoirs have revealed natural gas deposits that doubled previous estimated U.S. gas reserves - giving us close to a 200-year supply. And as large reserves are developed that previously weren't possible to produce, that supply is growing. It's vital because many experts agree that global oil production has peaked, even as demand is still rising. Because of its growing abundance, domestic natural gas will play a major role in meeting our 21st-century energy needs.

"The assessments and estimates on natural gas supply are very impressive



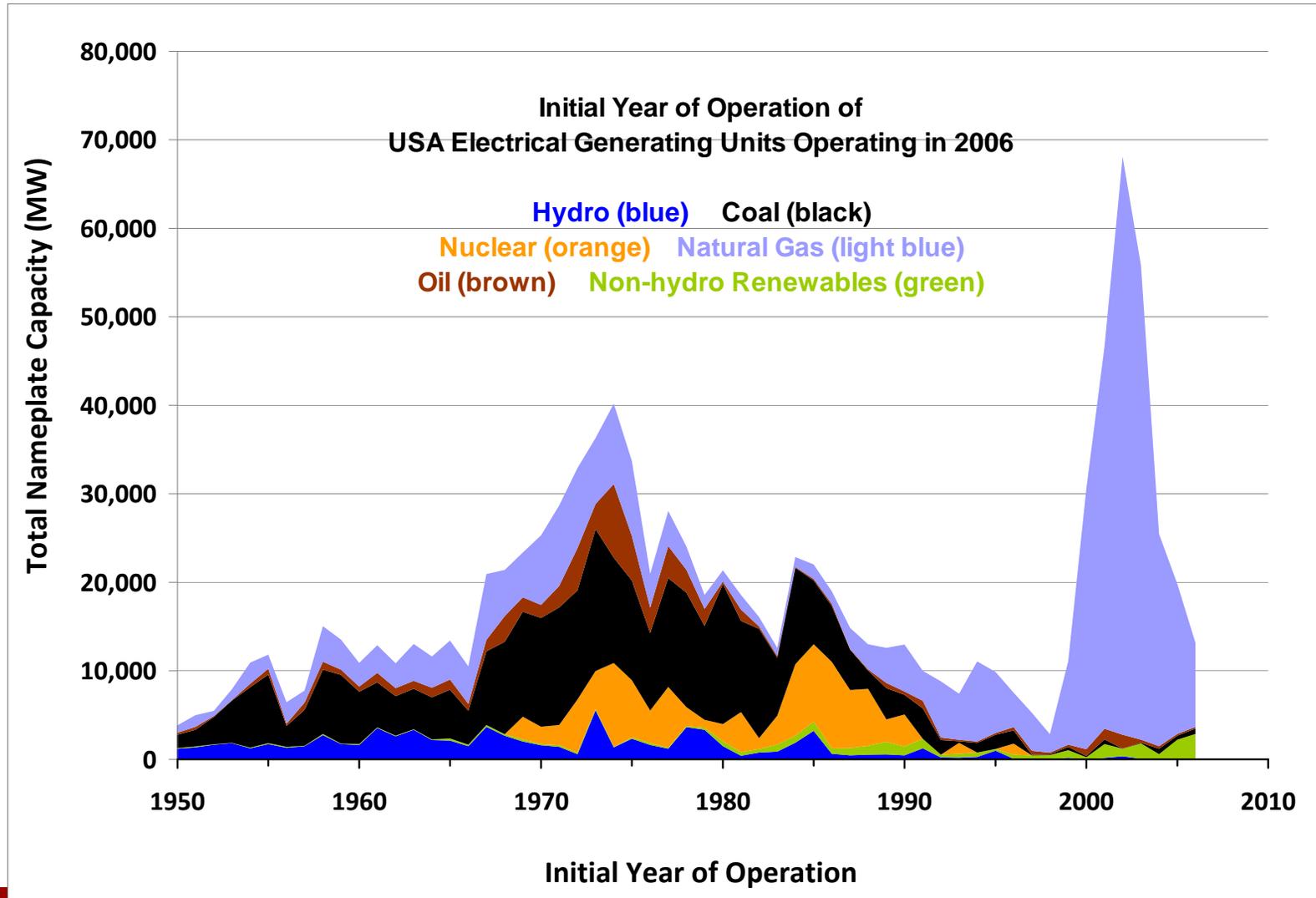


Whew – it's a good thing \$12 Natural Gas is a thing of the past





Whew – it's a good thing \$12 Natural Gas is a thing of the past





If gas stays at \$4

- That's pretty much all we'll build, except for RPS
- Look for more NGCT, instead of NGCC
 - If gas is on the margin, owners of coal and nuclear will want the LMP to be as high as possible, so will opt for worse heat rate
- Advanced generation will be economically improbable
 - NGCC **5 cents per kWh** (7000 heat rate, \$1000/kW, 75% capacity factor, 10% capital charge rate, 20 years)
 - NGCT **6.5 cents per kWh**





If gas stays at \$4

- Wind
 - The PTC (2.2 ¢/kWh) is probably unsustainable at large scale wind
 - \$1.5B in 2009 at 1.8% wind; \$17B at 20% wind = NASA.
 - Accelerated depreciation adds even more tax expenditures.
 - Spain reduced their wind subsidy when wind reached 12%.
 - To compete with NGCT, wind with a 40% capacity factor would need to have to have a capital cost of \$1600/kW or below with no PTC. That is plausible (capital costs are now \$1800, and capacity factors are in the mid-30s for many sites).
 - Wind with a 30% capacity factor would need to cost \$1100/kW
 - BUT – that assumes transmission and variability costs are not counted. Big fight brewing.
- The best solar PV (CdTe in the desert): ~17 ¢/kWh
- Solar thermal is more expensive (and getting higher)
- Enhanced geothermal probably 10-15 ¢/kWh





If gas stays at \$4

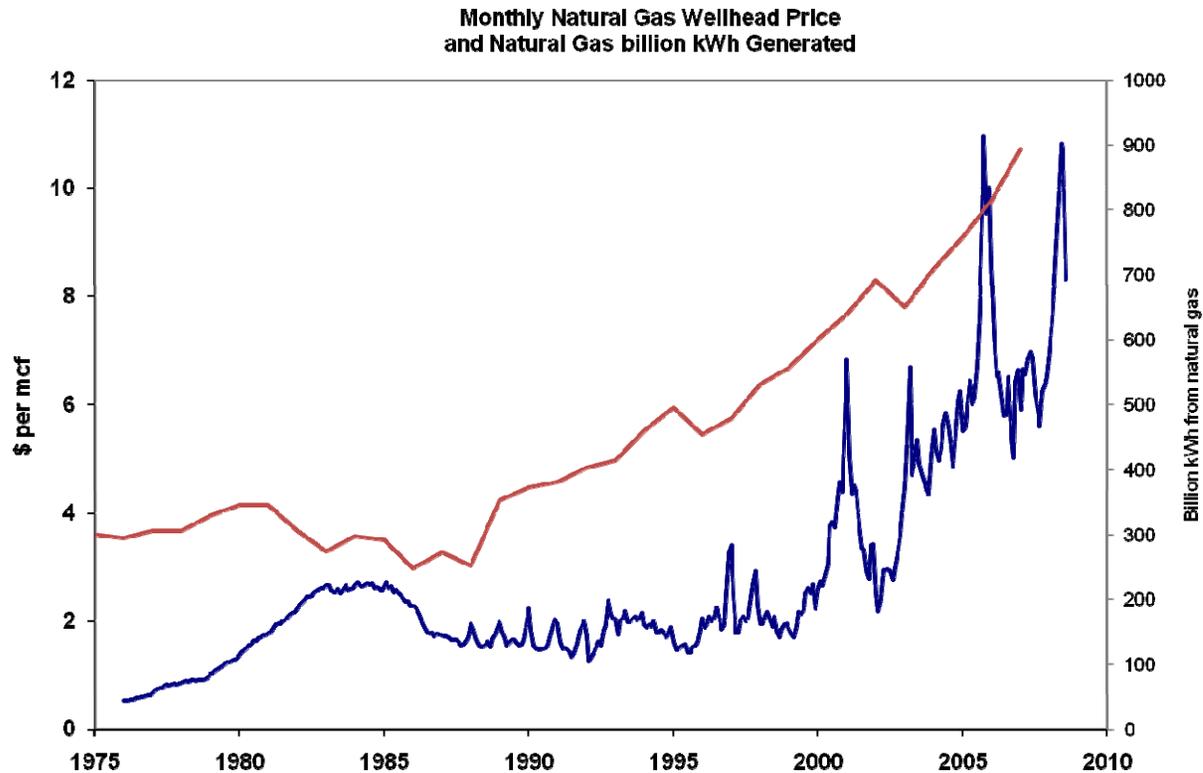
- RPS constraints will begin to bind...
 - ...and there will be a big fight about transmission and variability costs. Wind+Gas+Transmission = \$\$\$
 - ...some states may see pressure to abandon RPS.
- State RPS solar set-asides have already come under pressure.
- CHP and perhaps microgrids may become economic. There are new tri-gen technologies that may make maintenance quite reasonable. Will the real frontier in DG be microturbines, instead of a million solar rooftops?





But...

1. The surest way to tell you are in an unsustainable boom is if the practitioners think it will last forever. - Jay Apt, 2008
2. The surest route to \$8 gas is to plan on \$5 gas. - Jen Snyder, WoodMackenzie, 2010





What about externalities?

- Water is a big part of the likely uneconomical coal units.
- The administration indicated a shift from a national RPS to a national CPS in the State of the Union address, so performance standards rather than caps may be the basis for post-2012 discussions.
- A shift from discussion of “**low carbon**” to “**secure, lower carbon**” in the USA?
 - Natural gas, electric cars, CNG vehicles, lower RPS in some states.





After the great recession

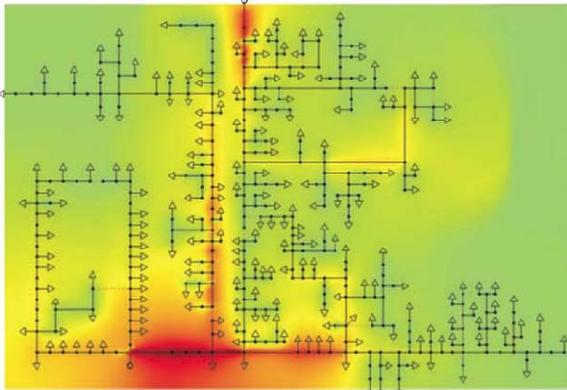
- Pressure on reserve margins in some regions, especially with the coming coal retirements.
- Perhaps an honest comparison of prices
 - China: 8.5 to 10 ¢/kWh industrial price (cost is likely higher)
 - China natural gas is \$12-16/mmBTU; \$13 in SW Asia.
- Perhaps a discussion on building energy use
 - A 10% reduction is equivalent to all USA non-hydro renewables.
- Distribution system transformer EE standards started this year. Will other systems standards follow?
- A continued discussion of where regulatory authority should end and markets begin, and perhaps of what is required to make a free market a competitive market.





To what extent will prices be used as engineering controls?

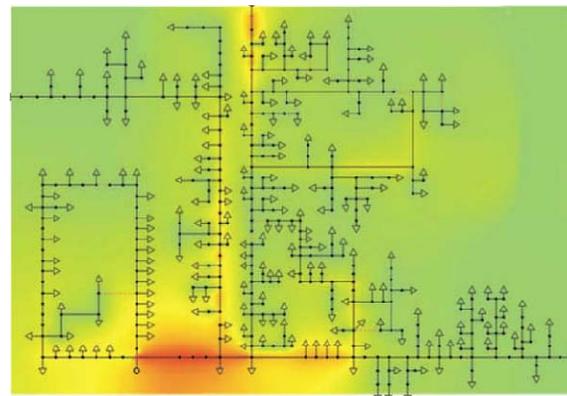
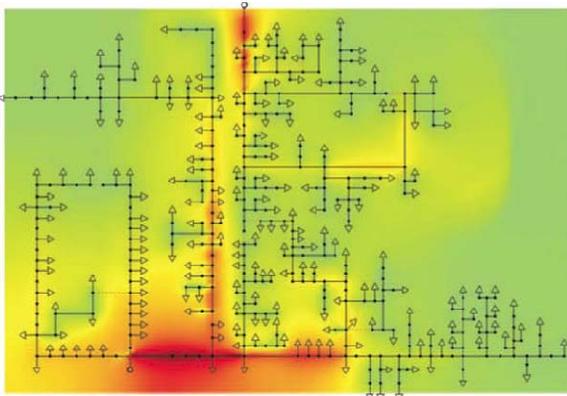
- Suppose we have 50% electric vehicles.
- Without price signals, we all plug in when we get home.



Source:

Lopes et al.: Integration of Electric Vehicles in the Electric Power System, Proceedings of the IEEE 99(1), January 2011

- With a price drop at midnight, we all plug in then!



Needed:
staggered plug-in.





Storage

- Pumped hydro is now 22 GW (2.2% of total capacity).
- The resource estimates for potential hydro are very old.
- Modern control of run-of-river hydro appears promising.
- Utility-scale battery prospects at economic costs are quite good – some of the best current R&D.
 - Example: Aquion Energy's ambient-temperature battery
 - Anode is activated carbon
 - Cathode is NaMnO_2
 - Electrolyte is Na_2SO_4 in water
 - Rapid cycling shows at least 5000 cycles with no fade to 100% DoD, 95 % round-trip efficiency
 - Looks like \$200/kWh is feasible





Smart Grid

- Smart Meters, as they are being implemented, do not solve any problem for the consumer, hence the resistance.
- Regulators are getting testy, and asking to see quantifiable benefits.
- No one is taking cyber security seriously.
 - With \$400 Billion up for grabs, there will be sophisticated attacks.
 - Voting machines were thought by industry to be ok too...
 - Not even a good discussion of the architecture for survivability
- There is a big untapped opportunity in dynamic control of stability-limited transmission lines to increase capacity.
- Some promising work on lower-cost small FACTS has been done at Georgia Tech and other places.





Summary

- We will (again) build a great deal of natural gas.
- If gas price stays low: perhaps more DG/CHP, not much else.
- The prospects for GHG control in the USA probably lie with CPS.
- Wind will continue to increase, and is already over 10% in some limited areas in the USA. Capacity payments & transmission fights.
 - Stability issues may increase as coal units are retired
 - Natural gas units may need new wind-following control
 - Storage (hydro and batteries) may increase
- There will be pressure on states to roll back RPS.
- Any work that relaxes transmission stability limits would be valuable.
- Lower-cost FACTS?
- Design for resiliency against cyber attacks will be ignored.
- Demand response may get interesting.
- Standards vs. Price Signals vs. Direct Control?





Thank you.

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