THE UNIVERSITY OF TEXAS AT AUSTIN

The Nuclear Engineering Teaching Laboratory

Technology Solutions and Risk Management: Introductory Remarks

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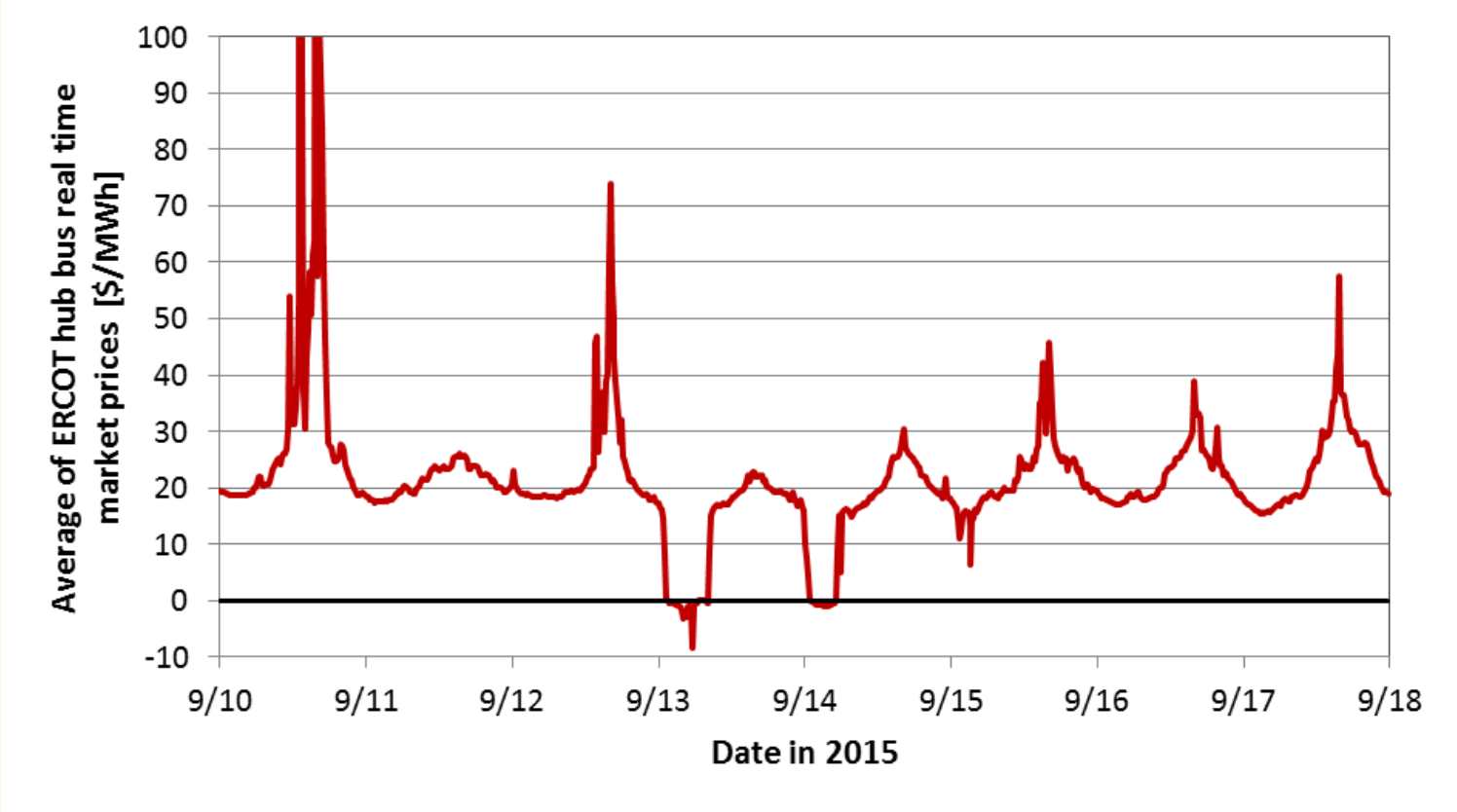
Three (of several) topics relevant to this theme

- Evolving market conditions present challenges for traditional baseload nuclear
  - How can energy storage, novel process heat applications, and hybrid technologies enable nuclear to meet the challenge?
- Small modular and advanced reactors
  - Are they ready for the market? Can they transform the role nuclear plays across the energy sector?
- Used fuel management and waste disposal
  - Boreholes may provide a disposal solution that works for any fuel cycle strategy. Is borehole disposal technology within reach?

Evolving market conditions: ERCOT, September 13-20, 2015

- For several hours on September 13 and 14, 2015, the average ERCOT hub bus real time market electricity price was negative:



Immediate cause: exceptionally high wind output on September 13 and 14

- Wind output at times exceeded 70% of installed capacity;
- on the evening of September 12, output jumped by nearly 8,000 MW in just a couple of hours.

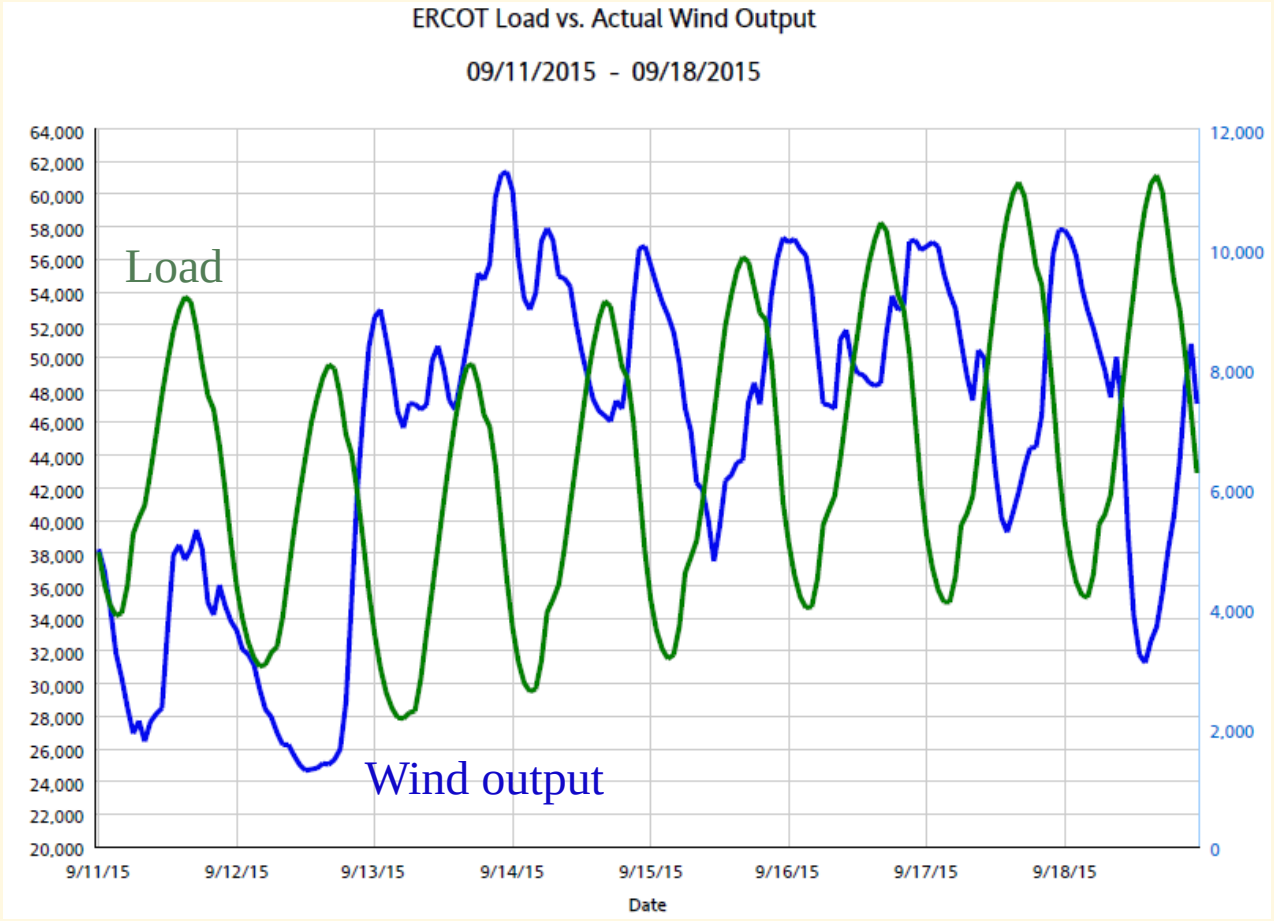
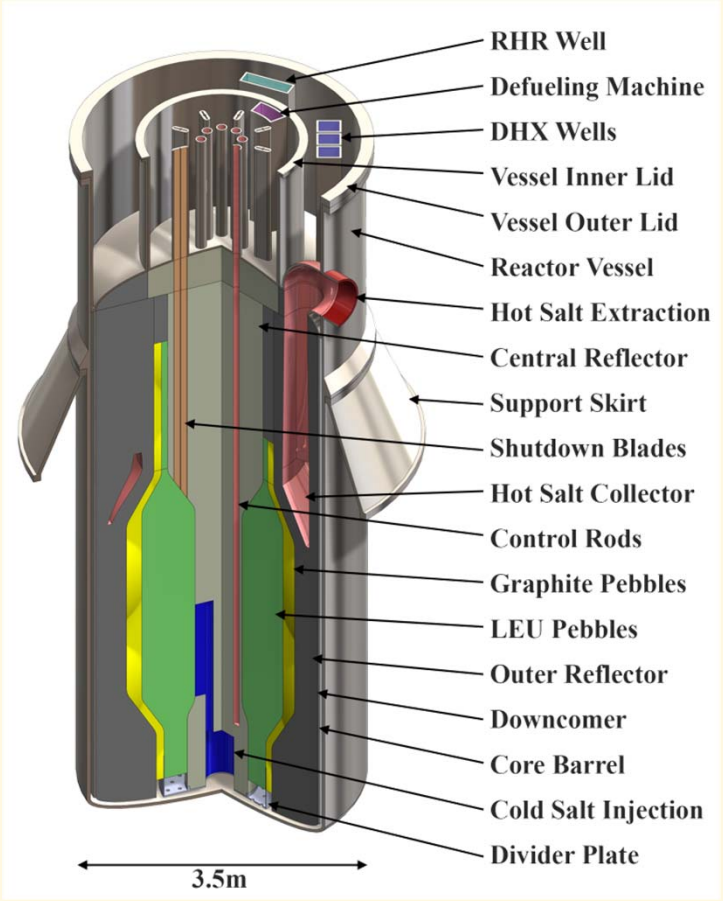


Figure: ERCOT Wind Integration Report, September 18, 2015.

Technologies enabling nuclear to play a key role in a low-carbon grid

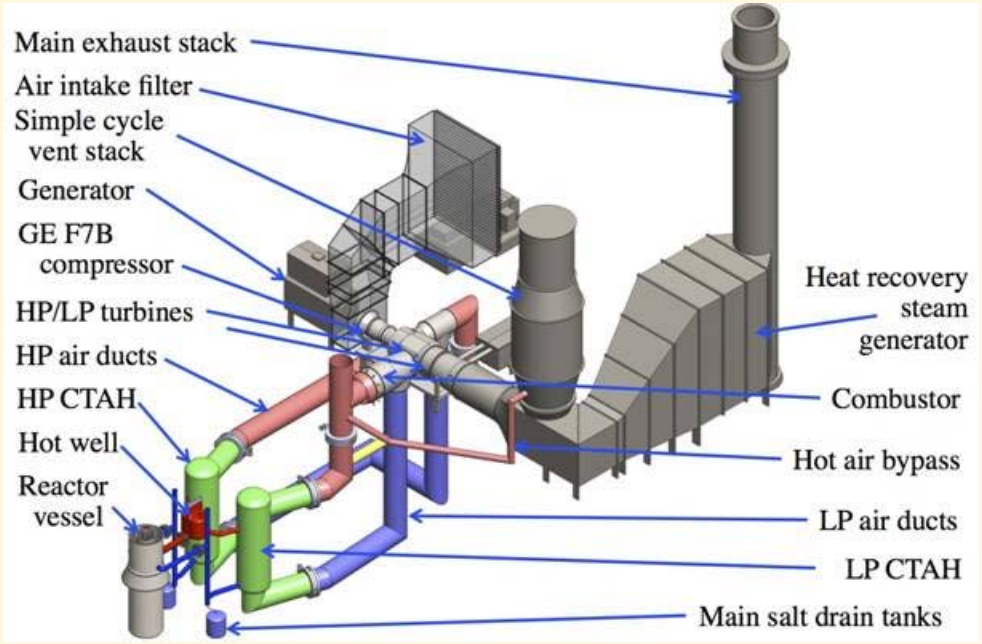
- Nuclear, wind and solar feature high capital and low operating costs:
  - economics requires that these generators be fully utilized.
- How can a combination of nuclear and renewables match the demand profile? Technologies to consider include:
  - electricity storage,
  - At-reactor thermal energy storage,
  - Production of alternate energy carriers, e.g.:
    - nuclear (electricity + heat) / renewable (electricity) hydrogen production via high-temperature electrolysis; underground storage of hydrogen,
  - Nuclear-fossil hybrids, e.g.:
    - High-temperature reactor coupled with gas turbine to run a high-efficiency (66%) topping cycle.

Advanced reactor technologies: Fluoride high temperature reactor (FHR)



Pebble bed FHR:

- Online refueling
- High outlet temperature (600 – 700 C)
- No fuel failure even under beyond design basis accident



FHR with nuclear-air combined cycle plant:

- Provides a peaking capability, enabled by advances in gas turbine technology
- Precedent from 1970s: PWR steam sent to oil-fired superheat for high-efficiency conversion of oil to electricity

Illustrations courtesy of C. Forsberg, MIT

Deep borehole disposal in crystalline rock can isolate waste for millions of years

- Minimal reliance on engineered barriers due to
  - isolation from near-surface groundwater flows,
  - long transport length through low porosity/permeability rock,
  - Chemically reducing environment limiting mobility.
- Some 800 boreholes could dispose used fuel from all existing reactors

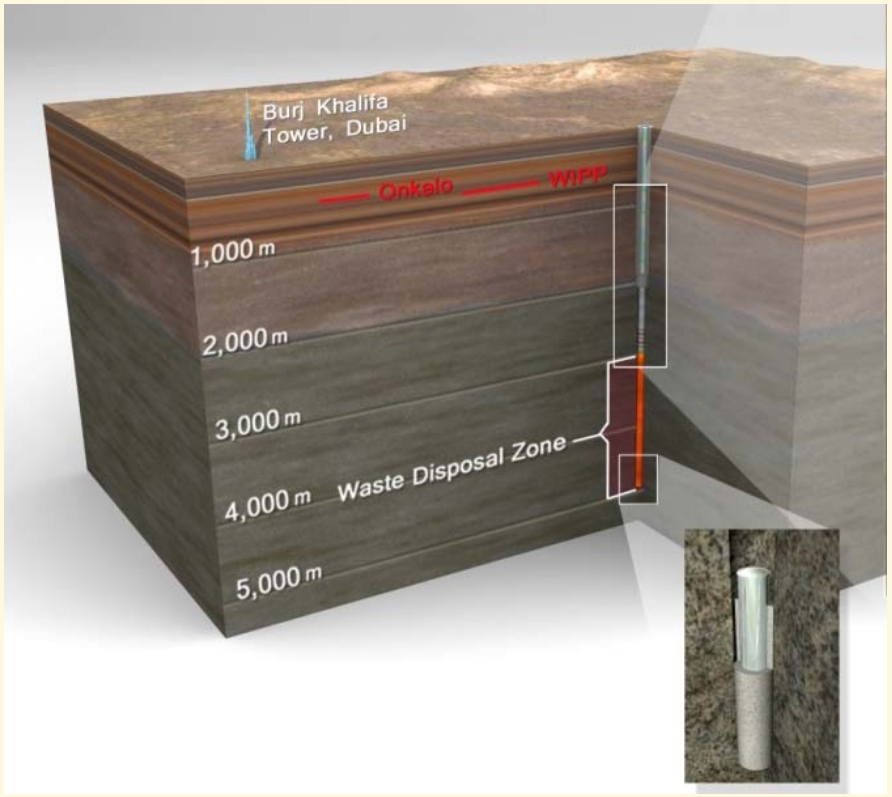


Figure. Waste is disposed at depths of 3-5 km in 0.5-0.75 m diameter boreholes.

Source: G. Freeze, "Deep Borehole Disposal Performance Assessment," SAND2015-10776C, December 2015.

Deep boreholes and the importance of a feasible disposal option to the nuclear industry

- Boreholes for waste disposal require modest progress beyond current capabilities (figure).
- The absence of a demonstrated waste disposal alternative represents a risk on several levels:
  - public acceptance, cost, licensing…
- Large excavated repositories like Yucca Mountain are one-off projects for which confidence-building demonstrations aren't feasible
  - proving the viability of borehole disposal may substantially reduce perceived risk.

			Internal Clearance of Bore (Diameter)						
			Small		Medium		Large		Very Large
			< 0.1 m	0.1 m *(4 in)*	0.3 m *(12 in)*	0.5 m *(20 in)*	0.75 m *(30 in)*	1.0 m *(39 in)*	> 1 m
Depth (km)	Shallow	0.5 - 1							A
	Medium	2							
		3							
	Deep	4				B	E		
		5				D	F		
	Very Deep +	6 - 12		C					

Green: mature, industrially implemented application
Yellow: feasible application (modest uncertainty)
Red: beyond current technology (larger uncertainty)

A – C: achieved boreholes
D – F: region of interest for radioactive waste disposal

Source: A. Sowder, R. McCullum, and V. Kindfuller, "Why Demonstration of a Deep Borehole Concept Matters to the Nuclear Industry," Proc. IHLWRM'15, Charleston, SC, April 2015.