WATER + ENERGY IN CHANGING CLIMATES

Managing Renewable Energy Variability with Water

Innovative Cross-Sector Solution

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Executive Summary

Agenda

- Renewables and the Smart Grid
- Energy Storage
- Water as Energy Storage?
- Water Renewables Model
- Advantages
- Challenges

- The existing electric grid cannot support the nation's goals for renewable energy without more intelligence.
- The growing complexity, energy price, and reliability issues associated with variable renewables are driving the grid to active control and energy storage.
- Wind turbines and solar plants add variability to the grid.
- To take advantage of clean, zero-cost fuel renewables (wind, solar) albeit with challenges, we need new operating models, like cross-sector solutions (Wind/Desalination).

GROWTH OF RENEWABLES AND THE SMART GRID

Growth of Renewables

- Penetration is limited by the grid's ability to accommodate variability in performance.
- Renewables are driven by new culture norms, climate change debate, consumer desire for more self-control.
- Emerging driver – zero-cost fuels for wind and solar, and some waste to energy

Renewables Growth (2004* – 2008)

Renewables Global Status Report – 2009 Update (145 countries reporting)
** Baseline – Bonn Renewables Conference 2004*

- Grid connected PV now 13GW – 600% increase
- Wind now 121GW – 250% increase
- Total from all renewables now 280GW – 75% increase
  - Includes large increase in small hydro, geothermal, & biomass generation
- Solar heating now 145 GWth – 200% increase
- Biodiesel production now 12B liters/yr – 600% increase
- Ethanol production now 67B liters/yr – 200% increase
- Annual renewables investment in new capacity now $120B/year – 400% increase

US Practical Renewables Potential

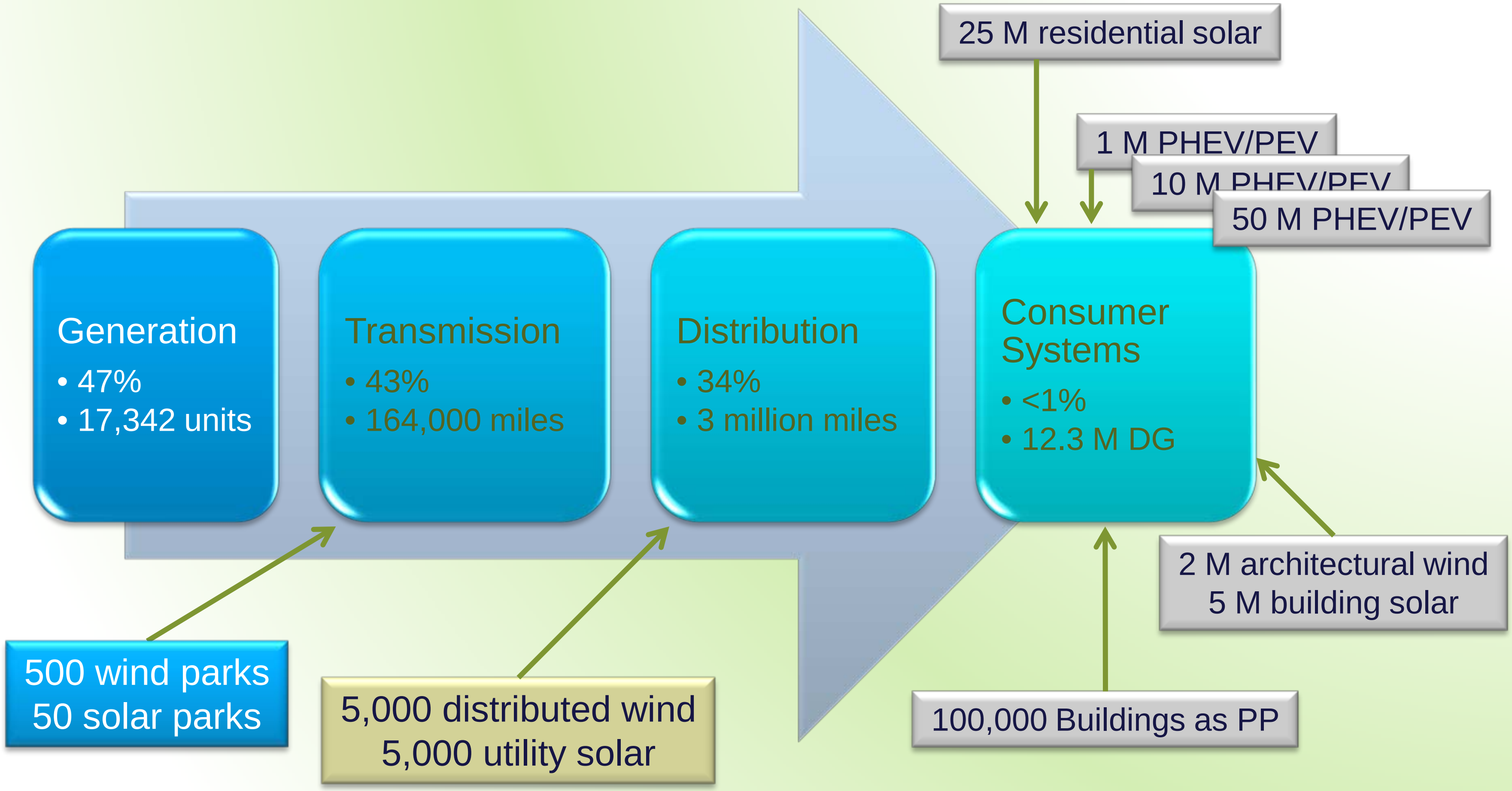
- Today's grid-connected electric capacity is 1030 GW
- Today's average daily capacity used is 475 GW
- If we include reserve margin, the US needs a daily average of 560 GW

- NREL assessment of near-term practical potential by 2020 for electricity production:
  - Biomass – 130 GW
  - Geothermal – 22 GW
  - Solar – 68 GW
  - Wind – 114 GW
- Total = 334 GW

Smart Grid Revolution

- Electric consumer is more tech savvy and willing to try new approaches
- Electric rate drivers are pressing upward
- Environmental drivers are constricting the traditional electric business model
- Business as usual costs are increasing rapidly
- Delivered cost of renewables is decreasing
- Complexity and data flow of the network is increasing exponentially

From the 20th to the 21st Century



Continued increase in energy intensity

Prices increasing, in some regions faster than gasoline at the pump

Changeover to more and more digital loads

Consumer choices

Smart Grid and REN Variability

- Migration from passive to active control
- Peak demand has skewed good business sense, but renewables offer little help:
  - Wind is ~15% coincident with peak demand
  - Solar is ~70% coincident with peak demand
- Need to smooth the variability
  - Traditional: fossil generation
  - New Thought: energy storage
- Evidence of limitation without energy storage because fossil generation firming at distribution level is not satisfying (cost and emissions)

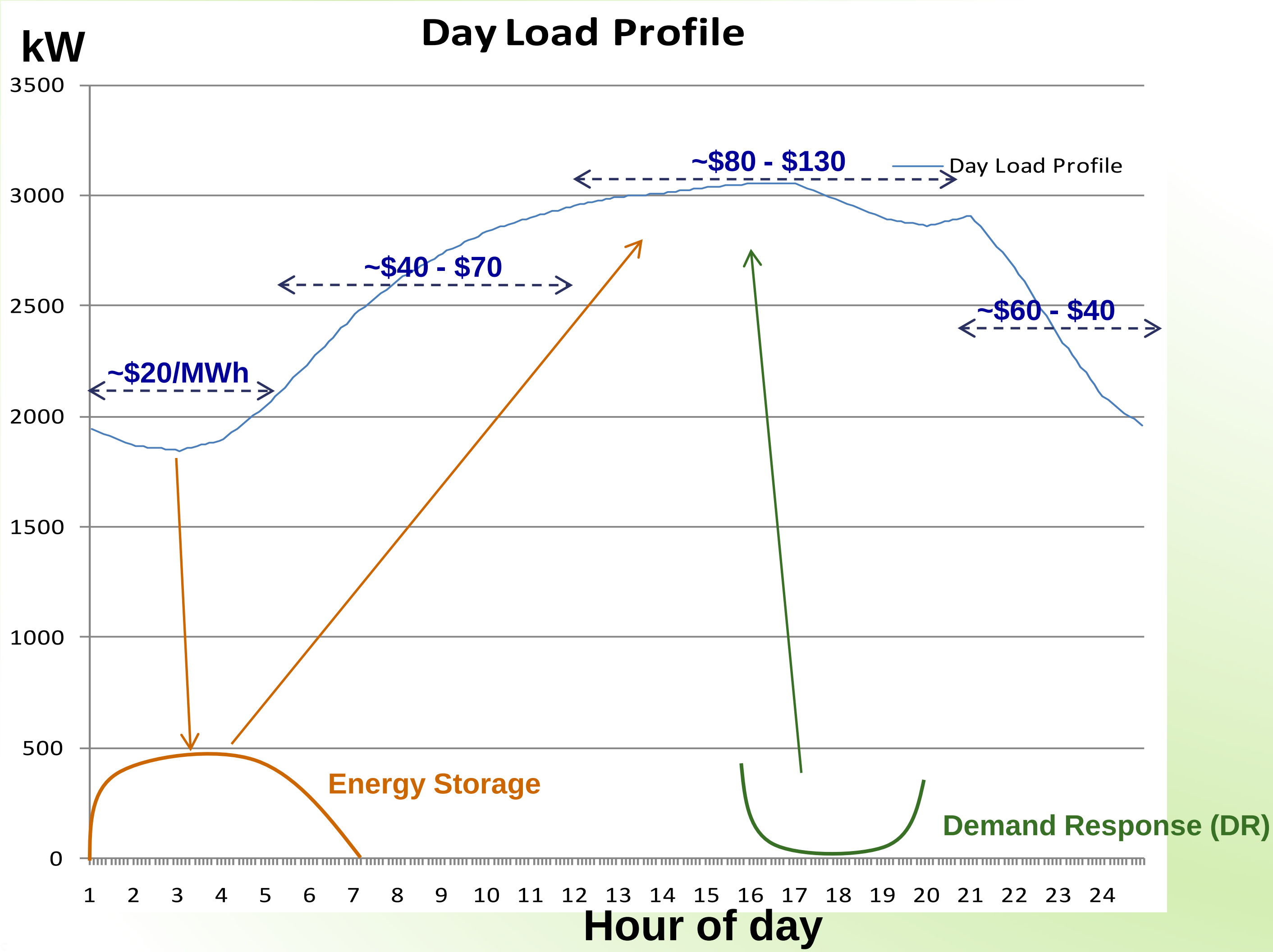
ENERGY STORAGE

Forms of Energy Storage

- Electrical energy storage
  - NaS, Li-ion, ZnBr, etc
- Thermal energy storage
  - CHP, geothermal, etc
- Physical energy storage
  - Pumped hydro, compressed air energy storage (CAES)
- A new class? "alternate production storage"
  - Biofuels production
  - Potable water production
  - Water purification

Desalination plants are traditional cogen fossil / water plants which fit the "alternate production storage" class.

Energy Storage and Grid Economics

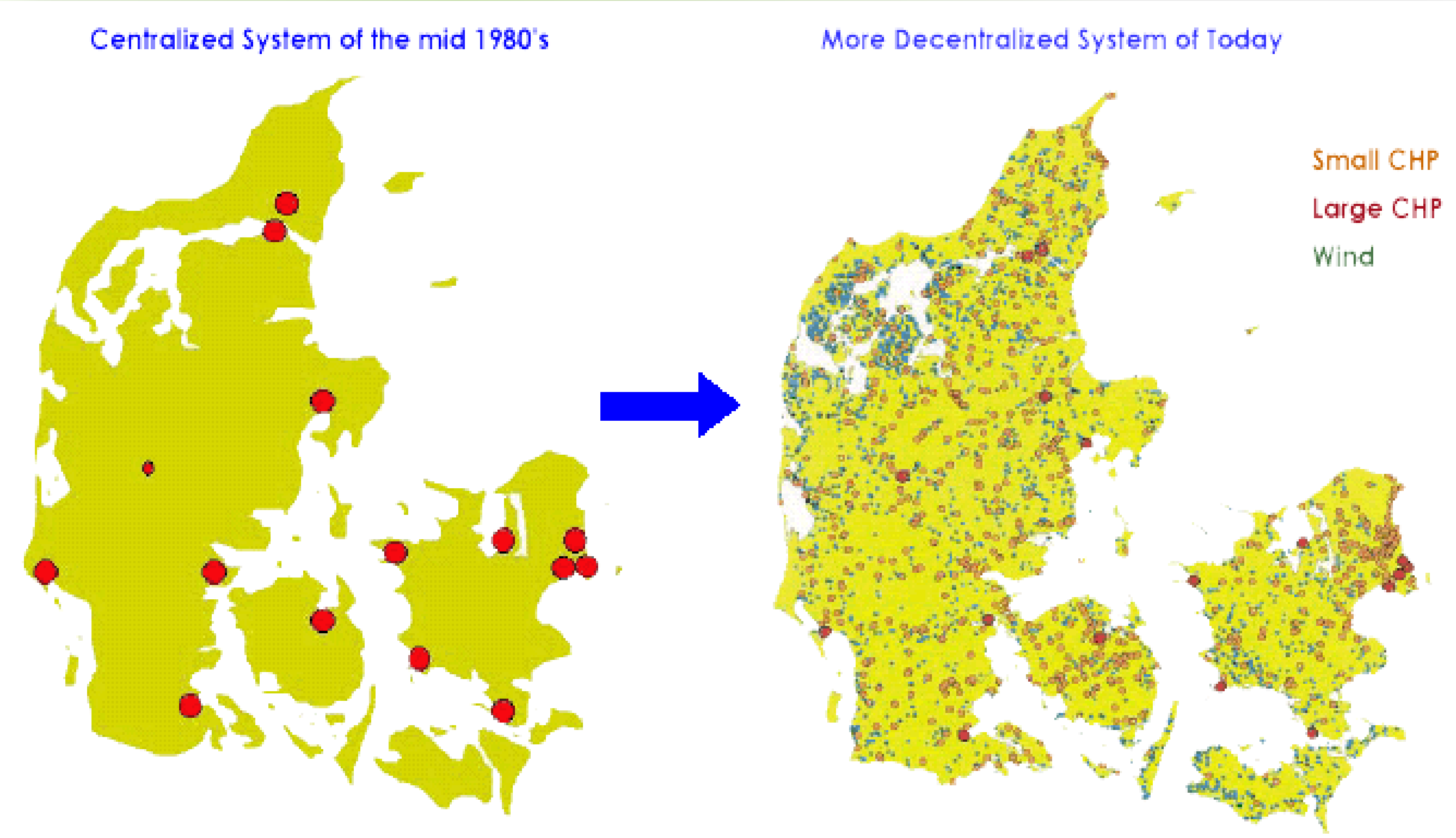


WATER AS ENERGY STORAGE?

Concept

- Remember – primary goal is to "firm up" variable renewables
- Concept:
  - Use non-coincident excess wind / solar for water production
  - Use renewables as an alternate energy resource for water production
  - As electrical output varies, vary water production

Similar to Denmark Hybrid Wind/CHP



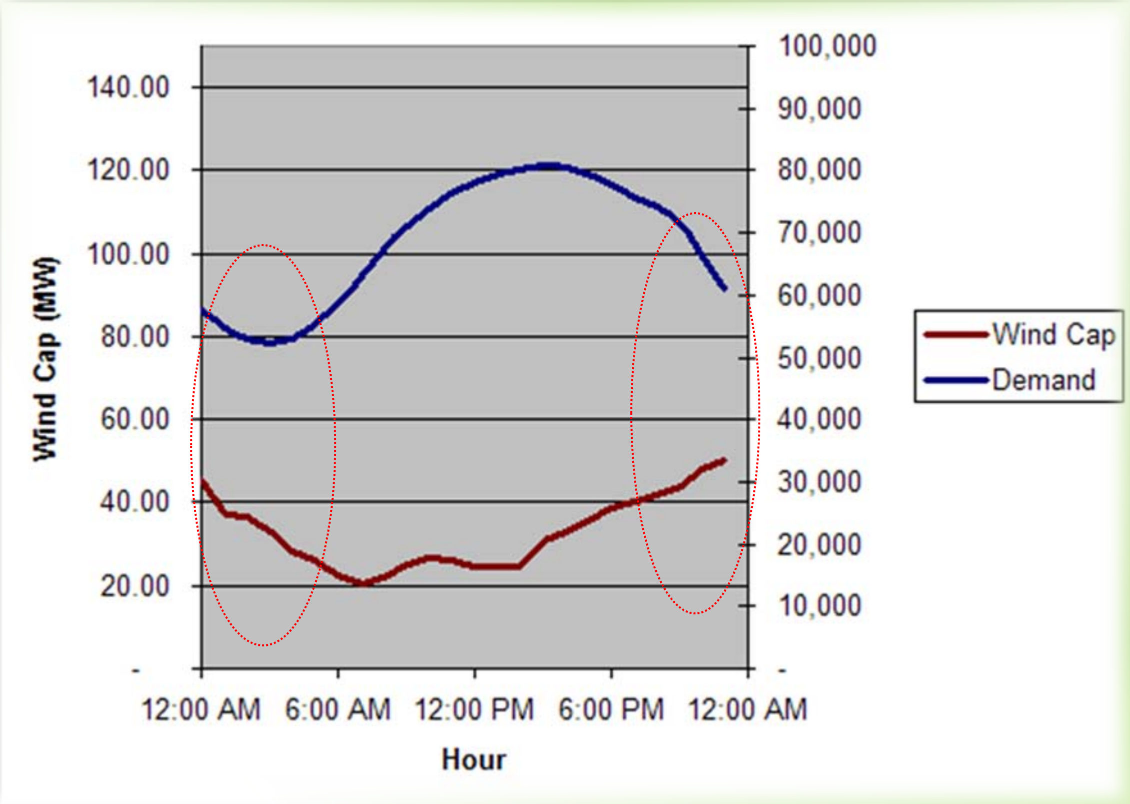
Source: Danish Energy Center

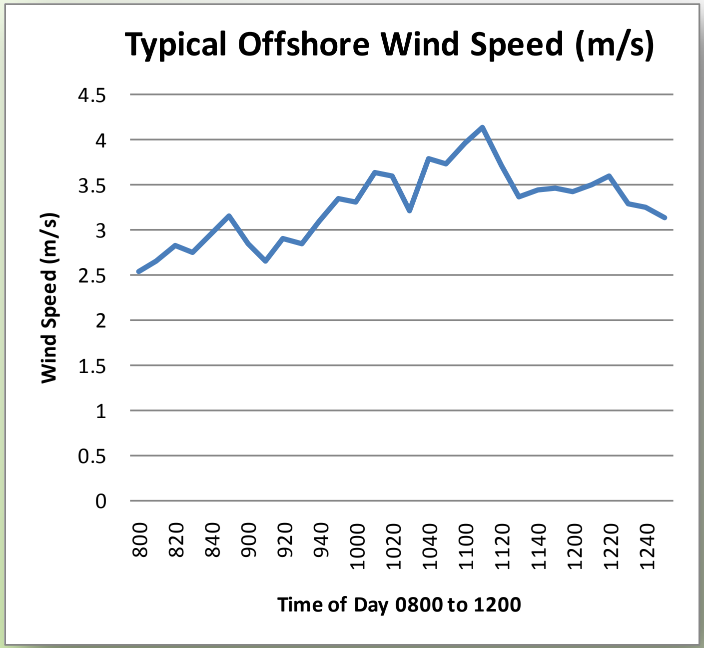
How Would It Work?

Offshore wind is most stable and has highest performance.

Wind Coincidence with Load

Often wind power is best when it is needed least.





Wind is variable.

Source: "The Coincidence of Wind", Pterra Consulting, May 2009

“Firming” the Wind

- The industry typically considers 10 – 30% combustion turbine (CT) capacity must be added to wind turbines to make it firm
- NREL report: Base Case – Cash leveraged levelized cost of energy (LCOE) from wind turbines (34% capacity factor) = $58/MWh
- A 20% capacity addition of CT to a wind farm would add roughly $11.6/MWh to the LCOE
- A desalination plant that accommodates the offshore wind farm variability to qualify as a firm resource is worth $11.6/MWh.
- For a 48MW wind park supporting a 40 GL/yr desal plant this represents $1.6M savings/year, or $32.4M over 20 years.

Energy Use for Desalination

- Typical energy usage from actual plants range from 2.9 to 5 kWh/m^3, or 0.0110 to 0.0156 kWh/gallon
- A 40 gigaliter (GL)/year plan would require:
  - $40 \times 10^6 m^3 \times 3.5\ kWh/m^3$ => 140,000 MWh/yr
  - assuming 6,000 hrs/yr of operation, this desalination plant would need a 23.3 MWe power source
- Offshore Wind Farm for 140,000 MWh/yr
  - Design capacity x capacity factor x hrs/yr = 140,000 MWh/yr
  - Capacity = 140,000 MWh/yr / (34% x 8760 hrs/yr) = 47.0 MW
  - This would be a 16 x 3 MW wind farm
- Onshore Solar Park for 140,000 MWh/yr
  - Capacity factor (18%) => 88.8 MW
  - This would be a 327,830 m^2 (573m x 573m) PV array

Consider a Wind / Desalination Plant

- 40 GL/yr => 16 x 3 MW wind farm
- LCOE from wind turbines (34% capacity factor) = $58/MWh
- A Florida desalination plant powered by fossil energy:
  - Published rate: $0.0025/gallon
  - Wholesale standard offer price for power: $0.065/kWh
  - Fossil energy for desalination: 0.013 kWh/gallon
  - Fossil energy cost for desalination: $0.000845/gal, 33.8% of the rate
  - With CO_2 Mgmt (add $0.03/kWh): $0.001235/gal, 49.4% of the rate
- From wind farm
  - Wind energy cost for desalination: $0.000754/gal, 30.2% of the rate
- This downward price pressure on cost of water should incentivize hybrid wind/desalination plants

ADVANTAGES & CHALLENGES

Advantages

- Increased firm power from renewables where most needed – coastal regions
- Use inherent flexibility in water production to accommodate renewables variability
- Lesser cost of water from desalination
- Flatter cost of water production long-term
- Most cost effective match at water's edge, which matches energy / water load

Challenges

- Traditional financing, permitting, and regulations would require education on the concept
- Current technology based on working fluid heating in the reverse osmosis (RO) process
  - Wind doesn't generate heat in electricity production
  - Solar can or cannot depending on technology
- Solar capital cost