Energy Sector Vulnerability to Climate Change: Adaptation Options to Increase Resilience

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Energy and Adaptation: some recent efforts

First **U.S. National Assessment of Possible Consequences of Climate Variability of Change, 1997-2000**, considered “sectors”: agriculture, coastal areas and resources, forests, health, and water. Energy focus was on mitigation, not impacts or adaptation.

**U.S. Climate Change Science Program’s CCSP Synthesis & Assessment Product 4.5:** How might climate change directly or indirectly affect U.S. energy production, supply and consumption?

**2013 National Climate Assessment** (in process) specifically addresses impacts, energy supply and use, vulnerabilities, interfaces, mitigation and adaptation.

The **U.S. Department of Energy** is conducting an assessment of vulnerabilities of the U.S. energy sector to climate change and extreme weather. Emphasizing peer reviewed research, it seeks to quantify vulnerabilities and identify specific knowledge or technology gaps. It draws upon a July 2012 workshop, “Climate Change and Extreme Weather Vulnerability Assessment of the US Energy Sector”, hosted by the Atlantic Council and sponsored by DOE to solicit industry input.
The DOE effort focuses on the implications of climate change projections on specific elements of the energy system.

**Climate Change**
- Increasing temperature
- Limited water availability
- Sea level rise
- Increasing frequency and intensity of storms and flooding

**Energy Sector Impacts**
- Oil and gas exploration and production
- Fuel transport
- Thermoelectric power
- Hydropower
- Wind energy
- Solar energy
- Bioenergy
- Electric grid
- Electricity demand

Photo by Warren Gretz, NREL 07317
Photo by NREL 19498
Vulnerabilities occur across many dimensions; Stakeholder perspectives drive priorities*

- Chronic or gradual vs. extreme events
- Single unit vs. corporate perspective
- Local vs. regional or national
- Supply constraints vs. demand projections

- Complex regulatory regimes are in place
  - What is vulnerable?
  - definition of a 100 yr flood plain
  - what are appropriate rebuild standards?

- Energy system damages extend beyond physical systems into social impacts

- Who pays?
  - Currently, uncompensated costs are often covered by society (not the energy sector or insurance industry)

- Our increased dependence on electricity (e.g. today’s digital economy) is at odds with increased vulnerabilities to extreme weather and climate change

* Insights from July workshop
There is a disconnect between scales and timeframes of current scientific estimates and those needed by decision makers.*

In prioritizing vulnerabilities, considerations include the probability and frequency of events, the timeframe, the costs associated with it (direct, indirect, and societal).

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An example: Water for thermoelectric power cooling

- Thermoelectric power generation is the largest user of freshwater in the United States, withdrawing over 140,000 million gallons per day (MGD), accounting for 49% of total water use.  
  
  Source: Kenny et al, 2009

Power plants equipped with once-through cooling systems accounted for 92% of water withdrawals for thermoelectric power. Plants equipped with recirculating systems withdrew the remaining 8%.

Source: Macknick et al., 2011
Example: Water for thermoelectric power cooling

Consumptive fresh water use by thermoelectric power plants mapped at the 6-digit HUC level (this study). Total estimated at 4,868 MGD.
Example: Water for thermoelectric power cooling

Consider retrofitting current power plants for zero freshwater use: using non-potable water (brackish groundwater or municipal waste water) or converting to a dry cooling system.

Consumptive fresh water use by thermoelectric power plants mapped at the 6-digit HUC level (this study). Total estimated at 4,868 MGD.
Transitioning to zero freshwater withdrawal for thermoelectric generation: a scoping level analysis*

Retrofits considered: *average difficulty, according to EPA guidelines*
- Recirculating cooling (first step for once-through cooling systems)
- Dry cooling
- Municipal waste water
- Brackish groundwater

Costs:
- Capital
- Operating and Maintenance (O&M) costs
- Capture (e.g., conveyance costs for waste water, drilling and pumping costs for brackish groundwater)
- Treatment
- Parasitic energy losses

Availability:
- Municipal waste water: within 50 miles
- Brackish water: <2500 ft deep, salinities >10,000 TDS

* NOTE: not taking into consideration site-specific constraints such as land availability, local regulations, technology vintage
Transitioning to zero freshwater withdrawal for thermoelectric generation: retrofit options and $\Delta$LCOE*

For each of 1178 power plants using freshwater in a steam cycle:

Retrofit cost: once-through to recirculating cooling
Determine availability of brackish and waste water
Cost to convert each power plant:
  - waste water
  - brackish water
  - dry cooling
Select least cost alternative
Calculate reduction in water demand
Aggregate results at the HUC-6 level

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<th>Technology</th>
<th>Average capital cost</th>
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<td>Waste water</td>
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<td>Brackish water</td>
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<td>Dry cooling</td>
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</table>

Sources: 1. EIA 2010; figures from DOE

*\Delta$LCOE=Change in Levelized Cost of Electricity
Transitioning to Zero Freshwater Withdrawal for Thermoelectric Generation: ΔLCOE associated with retrofit

Note: ΔLCOEs tend to be lower in the West, Texas Gulf Coast and south Florida, which are areas prone to drought stress

<table>
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<th>Number of plants</th>
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<tr>
<td>Brackish water</td>
<td>109</td>
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<tr>
<td>Dry cooling</td>
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</table>

Preliminary results

With wholesale cost of electricity about $40/MWh*, many retrofits could be accomplished at levels that would add less than 10% to current power plant generation expenses.

*average 2012 wholesale cost over 3 US trading hub regions

Source: DOE
Transitioning to zero freshwater withdrawal for thermoelectric generation: potential water savings

Applying a simple metric to identify regions susceptible to drought stress where the consumptive use of water approaches 70% of the physical supply (see Tidwell et al., 2012 for details), we find that retrofitting power plants in drought-vulnerable watersheds could save 847 MGD or about 17% of all thermoelectric consumption.

ΔLCOEs for such retrofits are generally below $5/MWh.
Such an investment will be viewed differently based on the stakeholder’s perspective.

Planning and risk assessment scale and timeframe:

- **Single unit**: Plant manager
- **Multiple plants**: Utility
- **Competing uses**: Regional resource manager
- **Competing uses**: National policy maker

They all could benefit from higher resolution in the fundamental scientific inputs and projections.

Average capital costs range from $4.8M to $120M, depending on the technology.

Opportunity to “free up” some freshwater resources.

Average ΔLCOE to retrofit all 1178 U.S. plants is $6.3-$8.9/MWh* with a range from $0.3 - $900/MWh. *discount rates of 3% and 10%, respectively.