Energizing the future: Completing the energy sustainability puzzle

Energy and Water
Emerging Issues and Challenges

GWPC Salt Lake City – September 14, 2009

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Presentation Overview

- Impact of emerging water issues on current energy use and reliability
- Impact of proposed energy development and growth on national and regional water resource requirements
- Growing national and international energy and water trends, interests, and challenges

Background info @ www.sandia.gov/energy-water
Energy and Water are Interdependent

Water for Energy and Energy for Water

**Energy and power production** require water:
- Thermoelectric cooling
- Hydropower
- Energy minerals extraction/mining
- Fuel Production (fossil fuels, H₂, biofuels)
- Emission control

**Water production, processing, distribution, and end-use** require energy:
- Pumping
- Conveyance and Transport
- Treatment
- Use conditioning
- Surface and Ground water
Water Consumption by Sector

U.S. Freshwater Consumption, 100 Bgal/day

- Irrigation: 80.6%
- Livestock: 3.3%
- Domestic: 7.1%
- Commercial: 1.2%
- Thermoelectric: 3.3%
- Industrial: 3.3%
- Mining: 1.2%

[USGS, 1998]

Energy uses 27 percent of all non-agricultural fresh water
Growing Limitations on Fresh Surface and Ground Water Availability

- Little increase in surface water storage capacity since 1980
- Concerns over climate impacts on surface water supplies

Many major ground water aquifers seeing reductions in water quality and yield

(Shannon 2007)
Most State Water Managers Expect Shortages Over The Next Decade Under Average Conditions

Source: GAO 2003
Water Availability Is Already Impacting New Energy Development

- Recent energy facility permitting issues due to water availability
LAKE NORMAN, N.C. - Nuclear reactors across the Southeast could be forced to throttle back or temporarily shut down later this year because drought is drying up the rivers and lakes that supply power plants with the awesome amounts of cooling water they need to operate.
Water Quality Issues are Impacting Energy Development

- **Produced water management**
  - CBM, gas shales, mine water

- **Waste water management**
  - Oil shale, biofuels processing

![Map of Oil and Natural Gas Production in the United States](image)

Oil and Gas Produced Water
Gas Shale development could be extensive and impact water availability and quality

- Water is used in drilling, completion, and fracturing
- Up to 3 million gallons of water is needed per well
- Water recovery can be 20% to 70%
- Recovered water quality varies – from 10,000 ppm TDS to 100,000 ppm TDS
- Recovered water is commonly injected into deep wells
## Water Use and Consumption for Electric Power Generation

<table>
<thead>
<tr>
<th>Plant-type</th>
<th>Cooling Process</th>
<th>Water Use Intensity (gal/MWh&lt;sub&gt;e&lt;/sub&gt;)</th>
<th>Water Use Intensity (gal/MWh&lt;sub&gt;e&lt;/sub&gt;)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Steam Condensing</td>
<td>Other Uses</td>
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<tr>
<td></td>
<td></td>
<td>Withdrawal</td>
<td>Consumption</td>
</tr>
<tr>
<td>Fossil/ biomass steam turbine</td>
<td>Open-loop</td>
<td>20,000–50,000</td>
<td>~200-300</td>
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<td></td>
<td>Closed-loop</td>
<td>300–600</td>
<td>300–480</td>
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<td></td>
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<td>~30</td>
<td></td>
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<tr>
<td>Nuclear steam turbine</td>
<td>Open-loop</td>
<td>25,000–60,000</td>
<td>~400</td>
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<td></td>
<td>Closed-loop</td>
<td>500–1,100</td>
<td>400–720</td>
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<td></td>
<td></td>
<td>~30</td>
<td></td>
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<tr>
<td>Natural Gas Combined-Cycle</td>
<td>Open-loop</td>
<td>7,500–20,000</td>
<td>100</td>
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<td></td>
<td>Closed-loop</td>
<td>230</td>
<td>180</td>
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<td>7–10</td>
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<tr>
<td>Integrated Gasification Combined-Cycle</td>
<td>Closed-loop</td>
<td>200</td>
<td>180</td>
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<td></td>
<td></td>
<td>150</td>
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<tr>
<td>Carbon sequestration for fossil energy generation</td>
<td></td>
<td>~25% increase in water withdrawal and consumption</td>
<td></td>
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<tr>
<td>Geothermal Steam</td>
<td>Closed-loop</td>
<td>2000</td>
<td>1350</td>
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<td></td>
<td></td>
<td>50</td>
<td></td>
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<tr>
<td>Concentrating Solar</td>
<td>Closed-loop</td>
<td>750</td>
<td>740</td>
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<td></td>
<td></td>
<td>10</td>
<td></td>
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<tr>
<td>Wind and Solar Photovoltaic</td>
<td>Closed-loop</td>
<td>N/A</td>
<td>0</td>
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<td></td>
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<td>1-2</td>
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</tbody>
</table>
Water Demands for Future Electric Power Development

- Water demands could almost triple from 1995 consumption for projected mix of plants and cooling.
- Carbon emission requirements will increase water consumption by an additional 1-2 Bgal/day.
Regional Variations in Water Laws and Nuclear Reactor Applications

- Appropriation States
- Hybrid States
- Riparian States
Regional Growth in Thermoelectric Power Generation

Projected Thermoelectric Increases
(Capacity in 2025 vs 1995)

- Most growth in regions that are already water stressed
- Most new plants expected to use evaporative cooling because of EPA 316 A & B requirements

Source: NETL, 2004
<table>
<thead>
<tr>
<th>Fuel Type and Process</th>
<th>Relationship to Water Quantity</th>
<th>Relationship to Water Quality</th>
<th>Water Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Oil &amp; Gas</td>
<td>Water needed to extract and refine, Water produced from extraction</td>
<td>Produced water generated from extraction; Wastewater generated from processing;</td>
<td>7 – 20</td>
</tr>
<tr>
<td>- Oil Refining</td>
<td></td>
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<tr>
<td>- NG extraction/Processing</td>
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<tr>
<td>Biofuels</td>
<td>Water needed for growing feedstock and for fuel processing;</td>
<td>Wastewater generated from processing; Agricultural irrigation runoff and infiltration contaminated with fertilizer, herbicide, and pesticide compounds</td>
<td>12 – 160</td>
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<tr>
<td>- Grain Ethanol Processing</td>
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<td>- Corn Irrigation for EtOH</td>
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<td>- Biodiesel Processing</td>
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<tr>
<td>- Soy Irrigation for Biodiesel</td>
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<tr>
<td>- Lignocellulosic Ethanol and other synthesized Biomass to Liquid (BTL) fuels</td>
<td>Water for processing; Energy crop impacts on hydrologic flows</td>
<td>Wastewater generated; Water quality benefits of perennial energy crops</td>
<td>24 – 150 (\text{gal/MMBTU}) (ethanol)</td>
</tr>
<tr>
<td>Oil Shale</td>
<td>Water needed to Extract / Refine</td>
<td>Wastewater generated; In-situ impact uncertain; Surface leachate runoff</td>
<td>1 – 9 (\text{gal/MMBTU})</td>
</tr>
<tr>
<td>- In situ retort</td>
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<tr>
<td>- Ex situ retort</td>
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<tr>
<td>Oil Sands</td>
<td>Water needed to Extract / Refine</td>
<td>Wastewater generated; Leachate runoff</td>
<td>20 – 50 (\text{gal/MMBTU})</td>
</tr>
<tr>
<td>Synthetic Fuels</td>
<td>Water needed for synthesis and/or steam reforming of natural gas (NG)</td>
<td>Wastewater generated from coal mining and CTL processing</td>
<td>35 – 70 (\text{gal/MMBTU})</td>
</tr>
<tr>
<td>- Coal to Liquid (CTL)</td>
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<tr>
<td>- Hydrogen RE Electrolysis</td>
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<tr>
<td>- Hydrogen (NG Reforming)</td>
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</tbody>
</table>

\(\uparrow\) Ranges of water use per unit energy largely based on data taken from the Energy-Water Report to Congress (DOE, 2007)
\(\downarrow\) Conservative estimates of water use intensity for irrigated feedstock production based on per-acre crop water demand and fuel yield
\(\uparrow\) Estimates based on unvalidated projections for commercial processing; \(\downarrow\) Assuming rain-fed biomass feedstock production
Emerging Water Demands for Alternative Fuels Development

- Irrigation of even small percentage of biofuel acreage could increase water consumption by an additional 3-5 Bgal/day.
Biomass and Water Use Impacts Will be Regional
Oil Shale development will be regional and impact water availability and quality

- Reserves are in areas of limited water resources
- Water needed for retorting, steam flushing, and cooling up to 3 gallons per gallon of fuel
- Concerns over in situ migration of retort by-products and impact on ground water quality
Growing Use of Non-traditional Water Resources

- Desal growing at 10% per year, waste water reuse at 15% per year
- Reuse not accounted for in USGS assessments
- Non-traditional water use is energy intensive
US Energy Sustainability

A critical piece is missing

1. Renewable & Alternative Sources
2. Infrastructure Upgrades
3. Increased Fuel Supply
4. Energy Efficiency
5. Environmental Impact

[Images of renewable energy sources, power plants, and a cityscape]
Energy and Water Issues and Challenges are becoming an International Concern

• State and national water and energy groups
  – Research and regulatory groups considering future energy and water needs

• Increased media interest
  – NATURE, ECONOMIST, FORTUNE
  – Technical magazines and journals

• National Academy of Sciences interest in energy debate and interdependencies research

• Growing international concerns and interest
  – Europe, Australia, Asia, Canada
2003 Heat Wave Impact on French Electric Power Generation

- Loss of 7 to 15% of nuclear generation capacity for 5 weeks
- Loss of 20% of hydro generation capacity
- Large-scale load shedding and shut off transmission to Italy
- Sharp increase of spot-market prices: 1000 to 1500 $ / MWh for most critical days

Normal conditions in August

Bort-les-Orgues Réservoir

August 27, 2003
Summary of Major National Needs and Issues from Energy Water Workshops

Better resources planning and management
  • Improved water supply and demand characterization, monitoring, and modeling
  • Integrated regional energy and water resource planning and decision support tools
  • Framework for incorporating infrastructure, regulatory, and policy considerations for improved energy/water efficiency planning

Improved water and energy use efficiency
  • Improved water efficiency in thermoelectric power generation
  • Improved biofuels/biomass water use efficiency
  • Reduced water intensity for emerging energy resources

Development of alternative water resources and supplies
  • Non-traditional and oil and gas produced water use and reuse
  • Improved energy efficiency for non-traditional water treatment and use

www.sandia.gov/energy-water