Energy and Water in the Western and Texas Interconnects

Vincent Tidwell
Sandia National Laboratories
Albuquerque, New Mexico

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Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
Estimated Freshwater Withdrawals by Sector: 349 BGD

- Thermoelectric: 40%
- Irrigation: 38%
- Public Supply: 14%
- Industrial: 6%
- Livestock: 2%

49% of total daily water withdrawals

Source: USGS 2005
U.S. Freshwater Consumption: 100 BGD

Source: Solley et al., 1998
Water for Energy

Energy for Water

Energy and power production requires water
- Thermoelectric Cooling
- Energy Minerals Extraction/Mining
- Fuel Processing (fossil fuels, $H_2$, biofuels)
- Emission Control

Water production, processing, distribution, and end-use requires energy
- Pumping
- Conveyance
- Treatment
- Distribution
  - Use Conditioning
Energy and Water Tomorrow

Projected Population Growth

US Census Bureau Data

- 2002: 286 M
- 2050: 404 M
- 2100: 571 M

nearly double

70 million more people by 2030

Projected Growth in Electric Power Generation

Electricity Consumption (billion kWh)

Source: EIA 2004

Projected Growth in non-Ag Water Consumption

Non-Agricultural Water Consumption (Billion Gallons per Day)

Source: EIA 2004
Thermoelectric Water Consumption in the Continental United States: 2005
Total Water Consumption in the United States: 2005
Projected Increase in Non-Thermoelectric Water Consumption 2004-2030
Energy and Water in the Western and Texas Interconnects

- Develop an integrated Energy-Water Decision Support System (DSS) that will enable planners to analyze the potential implications of water stress for transmission and resource planning.

- Pursue the formulation and development of the Energy-Water DSS through a strongly collaborative process between Western Electricity Coordinating Council, Electric Reliability Council of Texas, Western Governors’ Association, and Western States Water Council.

- Exercise the Energy-Water DSS to investigate water transmission planning scenarios.
Project Partners

- Sandia National Laboratories
  - Vincent Tidwell
  - Len Malczynski
  - Peter Kobos
- Argonne National Laboratory
  - John Gasper
  - John Veil
  - Tom Veselka
- Electric Power Research Institute
  - Robert Goldstein
- National Renewable Energy Laboratory
  - Jordan Macknick
  - Robin Newmark
  - Daniel Inman
  - Kathleen Hallett
- Idaho National Laboratory
  - Gerald Sehlke
  - Randy Lee
- Pacific Northwest National Laboratory
  - Mark Wigmosta
  - Richard Skaggs
  - Ruby Leung
- University of Texas
  - Michael Webber
  - Carey King
Model Overview

- Model Objectives:
  - Develop a general framework for "what if" policy analysis,
  - Adopt a national view while allowing regional analysis, and
  - Provide interactive environment for stakeholder/decision maker engagement

Results By Watershed

Results By State or County

Change in Water Use

<table>
<thead>
<tr>
<th>Year</th>
<th>Municipal</th>
<th>Industry</th>
<th>Thermoelectric</th>
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<td>12,500</td>
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<tr>
<td>1/1/2029</td>
<td>15,000</td>
<td>30,000</td>
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</table>

Change in Water Consumption

<table>
<thead>
<tr>
<th>Year</th>
<th>Municipal</th>
<th>Industry</th>
<th>Thermoelectric</th>
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<tbody>
<tr>
<td>1/1/2004</td>
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<td>1/1/2014</td>
<td>1,000</td>
<td>2,000</td>
<td>1,000</td>
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<tr>
<td>1/1/2019</td>
<td>1,500</td>
<td>3,000</td>
<td>1,500</td>
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<tr>
<td>1/1/2024</td>
<td>2,000</td>
<td>4,000</td>
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<tr>
<td>1/1/2029</td>
<td>2,500</td>
<td>5,000</td>
<td>2,500</td>
</tr>
</tbody>
</table>
Thermoelectric Water Use Calculator

- Water Withdrawal and Consumption by Power Plant
  - Current and
  - Future Fleet
- Potential Policy Changes
  - Open Loop Cooling
  - Carbon Capture and Sequestration
Thermoelectric Water Use Calculator

Cooling Options

Once-Through Cooling

Condenser

Steam

Condensate

Condensate

20,000-50,000 gal/MWh

River

~300 gal/MWh

Increased River Evaporation

Closed-Loop (Evaporative) Cooling

Condenser

Steam

Condensate

Pump

Water Vapor

Cooling Tower

~480 gal/MWh

Freshwater Supply
500-600 gal/MWh

Blowdown

Dry-Cooled Power Plant
# Thermoelectric Water Use Calculator

## Plant Type Options

<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>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Steam Condensing&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Withdrawal</td>
<td>Consumption</td>
</tr>
<tr>
<td>Fossil/ biomass steam turbine&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Open-loop</td>
<td>20,000–50,000</td>
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<tr>
<td></td>
<td>Closed-loop</td>
<td>300–600</td>
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<tr>
<td></td>
<td>Dry</td>
<td>0</td>
</tr>
<tr>
<td>Nuclear steam turbine&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Open-loop</td>
<td>25,000–60,000</td>
</tr>
<tr>
<td></td>
<td>Closed-loop</td>
<td>500–1,100</td>
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<tr>
<td></td>
<td>Dry</td>
<td>0</td>
</tr>
<tr>
<td>Natural Gas Combined-Cycle&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Open-loop</td>
<td>7,500–20,000</td>
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<tr>
<td></td>
<td>Closed-loop</td>
<td>~230</td>
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<tr>
<td></td>
<td>Dry</td>
<td>0</td>
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<tr>
<td>Coal Integrated Gasification Combined-Cycle&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Closed-loop</td>
<td>200</td>
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<tr>
<td></td>
<td>Dry</td>
<td>0</td>
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<tr>
<td>Geothermal Steam&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Closed-loop</td>
<td>2000</td>
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<tr>
<td>Concentrating Solar&lt;sup&gt;g,h&lt;/sup&gt;</td>
<td>Closed-loop</td>
<td>900</td>
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<tr>
<td></td>
<td>Dry</td>
<td>10</td>
</tr>
<tr>
<td>Wind and Solar Photovoltaics&lt;sup&gt;i&lt;/sup&gt;</td>
<td>N/A</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>a</sup>Carbon sequestration for fossil energy generation

Fossil or biomass<sup>k</sup> | All | ~90% increase in water withdrawal and consumption
- Current mix has the highest water use, 236.1 BGD in 2030 and lowest water consumption, 4.3 BGD.
- Recirculating cooling towers in all new construction and recommissioned plants have the lowest water use, 184.8 BGD but highest consumption, 5.0 BGD.
Thermoelectric Water Use Calculator
Water Demand Projection Model

- Updating Water Demand Model
- Biofuel Water Use
- Water Use for Energy Extraction
Water Demand Projection Model

Projected Increase in Groundwater Pumping for Non-Thermoelectric Use: 2004-2030
Water Demand Projection Model

Projected Increase in Non-Thermoelectric Water Consumption 2004-2030
No land use change for residues equals 2006 corn ethanol acreage.

37 M acres cropland as pasture and idle cropland.

37 M acres non-grazed forest land.

2030 land use.
Water Demand Projection Model

Biofuel Water Consumption: 2030

Represents 5.6% of total United States consumption, up from 3.7% in 2007
Water Demand Projection Model

Biofuel Water Demands for Irrigation: 2030
### Water Demand Projection Model

**Water Use and Consumption for Several Transportation Fuel Alternatives**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Process</th>
<th>Process Water Use Intensity (gal water/gal fuel)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Process Water Use</td>
</tr>
<tr>
<td>Crude oil(^a)</td>
<td>Oil and gas refining</td>
<td>2</td>
</tr>
<tr>
<td>Coal-to-liquids(^b)</td>
<td>Liquefaction and refining</td>
<td>10-15</td>
</tr>
<tr>
<td>Oil shale(^c)</td>
<td>Ex situ retort</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td>In situ retort</td>
<td>3</td>
</tr>
<tr>
<td>Hydrogen(^d)</td>
<td>Natural gas steam reforming</td>
<td>6-10</td>
</tr>
<tr>
<td></td>
<td>Solar or wind electrolysis</td>
<td>3</td>
</tr>
</tbody>
</table>
Water Demand Projection Model

Water for Fuels Extraction

- 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 Availability Model

• Expand Water Availability Model

• Non-Potable Resources

• Water Institutions Tool

Groundwater Overdraft

Source: Shannon 2006
Water Demand Projection Model

Physical Water Supply

- Utilize historical stream gauging data from the USGS (cumulative distributions)
- Available surface water flow is estimated from mean stream flow.
- 5% percentile flows are used to estimate yearly low flow conditions.
- Base flow is used as measure of sustainable groundwater recharge.
- Future flows are reduced by upstream consumptive use.
Water Demand Projection Model

Non-Potable Water Resources

Brackish Ground Water Aquifers

Produced Water Resources
Water Demand Projection Model

**Power Requirements For Treatment**

- Desal growing at 10% per year, waste water reuse at 15% per year
- Non-traditional water use is energy intensive
Institutional Controls on Water Availability

**Colorado Water Rights**

**Institutional Structure**

- Surface Water & Tributary (SW)
  - Absolute Water Rights (SWR) (water rights)
  - Conditional Water Rights (CWR) (future water)

- Ag and Muni Conservation – if a municipality consumes, it cannot use that conserved water without any further approval (assuming decrees are correct, and properly defined service area). Farmer who reduces CI cannot apply that conserved water on other land or sell it unless going through a change in use, because the WRI is associated with an area of farmed land.

- South Platte, Arkansas, and Rio Grande are always appropriated

**NEXT STEPS**

- CEQA
  - 404 (WQ) and discharge permit
  - 401 construction /operation permit
- NEPA
  - 515 required (3-5 years)
- ESA
  - 1 year
- Counties
  - DOB (2-6 months)
  - Permits
  - 3141 Regs allow for stg, construction, ag, urban transfer
  - BLM or FS
  - Special use permit required
Identify and assess environmental risk from water use and climate change

ECM will include two modules:

- Environmental Risk Tool – develops and applies risk weighting factors to study areas based on presence of environmental resources, resource regulatory status, resource sensitivity to water and change in water availability.
- GIS Risk Visualization Tool – interactive GIS that spatially displays results from Environmental Risk Tool

ECM utilizes data from Water Demand, Water Availability and Climate Change Models,

ECM interfaces with DSS to facilitate scenario analysis

Water Demand Projection Model

Ratio of Mean Stream Flow to Environmental Flow Requirements: 2004

Mean Flow
Env. Flow

<1

1-1.25

>1.25
Scenario Analysis

Note – The small boxes represent opportunities for stakeholders to be directly involved in planning processes.

TEPPC Workgroup activities are open to all and decisions are made by consensus. It is at these meetings where many of the details of the planning process are decided.
Scenario Analysis

Ratio of Sustainable Recharge to Groundwater Pumping: 2004

[Map showing the ratio of sustainable recharge to groundwater pumping across the United States, with different shades indicating the ratio: 1-2, 2-10, >10.]
Scenario Analysis

Future thermoelectric consumption in watersheds prone to groundwater stress

- 77 MGD consumption at risk
Scenario Analysis

Ratio of Mean Stream Flow to Total Water Consumption: 2004

Supply Consumption

- 1-2
- 2-10
- >10
Scenario Analysis

Future thermoelectric consumption in watersheds prone to surface water stress

- 180 MGD consumption at risk
Scenario Analysis

Ratio of 5th Percentile Stream Flow (Low Flow) to Total Water Consumption: 2004
Scenario Analysis

Future thermoelectric consumption in watersheds prone to low flow stress

- 1316 MGD consumption at risk
Contact: Vincent Tidwell
Sandia National Laboratories
PO Box 5800; MS 0735
Albuquerque, NM 87185
(505) 844-6025
vctidwe@sandia.gov

More Information at:
www.sandia.gov/mission/energy/arra/energy-water.html