Decision Support for Integrated Water-Energy Planning

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Project Impetus

- Energy-Water Roadmap findings:
  - Reduce fresh water consumption in electric power generation
  - Improved water efficiency in alternative fuels production
  - Treatment and use of non-traditional water for energy development
  - Integrated energy and water resource planning and management
Multiple Complex Interacting Systems
Complex Coordination

Water Managers
- Flood/Drought
- Residential/Commercial
- Industrial
- Agriculture
- Environment
- Energy

Regulators
- Air Quality
- Water Quality
- Instream Flows
- Water Rights
- Energy Reliability

Public
- Social/Cultural Values
- Environmental Concerns
- Equity

Energy Providers
- Peak/Base
- Generation Type
- Location
- Capacity
- Cost
We employ **System Dynamics**, which provides a formal framework for managing multiple interacting subsystems, each of which vary in time.

With system dynamics we are able to quantify feedback, time delays, and coupling between subsystem components.

Focus is on **Dynamic Complexity** rather than **Detail Complexity**!
System Dynamics: Interactive Modeling

- Broadly accessible
  - PC based
  - User friendly interfaces
  - Computations in seconds to minutes
- Provides interactive environment for scenario testing
Model Objective

- Develop a decision support framework for integrated energy-water planning and management that targets the needs of energy and water producers, resource managers, regulators, and decision makers at the federal, state and local levels. Direct “what-if” analysis and scenario exploration around coupled energy-water issues:
  - Electrical power generation portfolio,
  - Cooling options for thermoelectric power,
  - Power/Water conservation,
  - Spatial trends in power and water demand, and
  - Competition between electrical power generation and other water demand sectors.
• Political boundaries (gray lines),
• Electric power grid (yellow lines), and
• Watershed boundaries (orange shaded region).
Water and Electricity Demand

- Water and electricity demand are based on changes in:
  - Population,
  - Gross state product
- Calculations are made at the county level
Power Generation Analysis

- Simulated at the power plant level with 4841 individual plants modeled.
- Plants distinguished by:
  - Fuel type,
  - Utility vs. non-utility,
  - Boiler type,
  - Build date,
  - Installed capacity,
  - Geographic location,
  - Annual power output,
  - Cooling type.
- Water use data based on eGRID reports and rectification with USGS county-level thermoelectric water use data base.
Power Plant Retirement

Replacement

Power Plant Replacement Module (PPRM): Coal-Fired Power Plants in the U.S.

- Plants in operation: 3,500 MW
- Decommissioned: 2,000 MW
- Replacement: 1,500 MW
- New: 2,000 MW

% Change over time: 6-8%
Water Use Analysis

- Water use data taken from U.S. Geological Survey’s “Water Use in the United States”
- Data were collected at five year intervals from 1985-1995
- Data are available at the national, state, county and watershed levels
- For purposes of analysis data are disaggregated by:
  - Sector {municipal, industrial, thermoelectric, mining, livestock, and agriculture}
  - Source {groundwater, surface water, other}
Water Use Analysis

- Future water use projections based on historical trends
- Trends analyzed through simple linear regression over the available 10 years of data
- Trends explored in terms of:
  - Direct water use
  - Per capita use
  - Economic intensity
- Change limited to ±20% of 1995 base value
Dynamic Supply Indicators

- There has been NO national census for water supply like water use
- As such, will rely on water supply indicators that are dynamically linked to the water use model
  - Surface water supply index
  - Drought flow index
  - Groundwater supply index
Baseline Scenario: National

- Increase power plant capacity based on EIA projections (~35% in 27 years)
- New plants have same fuel/cooling type distribution as current
Baseline Scenario: National

- Under this scenario growth in thermoelectric water use outpaces all other water sectors
- New consumptive use is very modest
Baseline Scenario: National

- Roughly one-half of new water demands will target surface water supplies

![Diagram of Change in Water Use by Supply]

- Change in GW Use
- Change in SW Use
- Change in Non Potable Use

Change in Water Use by Supply

Jan 01, 2004 to Jan 01, 2029

Million gallons/day
Baseline Scenario: National

- Steady growth in electricity demand for primary and waste water processing
Baseline Scenario: NERC Region

Installed Electrical Capacity (Megawatts, MW) for the U.S. North American Reliability Council (NERC) regions.
Baseline Scenario: NERC Region

New Water Demand for the U.S. North American Reliability Council (NERC) regions.

Water Demand by NERC Region

NERC regions

ASCC
ERCOT
FRCC
HICC
MRO
NPCC
RFC
SERC
SPP
WECC

0
30,000
60,000
90,000

MGD

Current
Reference

New Thermoelectric Water Demand Compared to All Other Water Demands

NERC regions

ASCC
ERCOT
FRCC
HICC
MRO
NPCC
RFC
SERC
SPP
WECC

0
5,000
10,000
15,000
20,000

million gallon/da

Thermoelectric
All Other Demand

Home
Energy by NERC
GDP Controls
Population Cont.
Energy Controls
Water Controls

Sandia National Laboratories
Baseline Scenario: County

- Change in population 2004-2030
- Dark blue is an increase of 1 million people
Baseline Scenario: County

- Change in electricity demand 2004-2030
- Dark blue is an increase of 2500 MW
Baseline Scenario: County

- Ratio of electricity production to demand in 2030
- Dark blue corresponds to a ratio of 35
- Includes “siting” of new plants
Baseline Scenario: County

- Water use by irrigated agriculture in 2004
- Dark blue corresponds to 300 MGD
Baseline Scenario: County

- Change in total water use 2004-2030
- Dark blue is an increase of 400 MGD
Cooling Tower Scenario: National

- Significantly reduces new water use
- Also, almost doubles water consumption
Cooling Tower Scenario: NERC

New Water Demand for the U.S. North American Reliability Council (NERC) regions.

Water Demand by NERC Region

- ASCC
- ERCOT
- FRCC
- HICC
- MRO
- NPCC
- RFC
- SERC
- SPP
- WECC

Current

Reference

NERC regions

New Thermoelectric Water Demand Compared to All Other Water Demands

- ASCC
- ERCOT
- FRCC
- HICC
- MRO
- NPCC
- RFC
- SERC
- SPP
- WECC

Thermoelectric

All Other Demand

NERC regions

Energy by NERC

Energy Controls

GDP Controls

Population Cont.
Cooling Tower Scenario: County Total Change in Water Use

Dark blue is an increase of 400 MGD
Decommissioning Scenario: National

- Here we also replace decommissioned plants with cooling towers.
- Total water use decreases.
- Water consumption by thermoelectric production increases yet again.

Change in Water Use

<table>
<thead>
<tr>
<th>Jan 01, 2004</th>
<th>Jan 01, 2009</th>
<th>Jan 01, 2014</th>
<th>Jan 01, 2019</th>
<th>Jan 01, 2024</th>
<th>Jan 01, 2029</th>
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<tr>
<td>-10,000</td>
<td>0</td>
<td>10,000</td>
<td>20,000</td>
<td>30,000</td>
<td>40,000</td>
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Change in Water Consumption

<table>
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<tr>
<th>Jan 01, 2004</th>
<th>Jan 01, 2014</th>
<th>Jan 01, 2024</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>500</td>
<td>1,000</td>
</tr>
</tbody>
</table>

Municipal
Industry
Thermoelectric
*Municipal
*Industry
*Thermoelectric

Energy for Water

GDP Controls
Population Cont.
Water Availability

• Ratio of mean surface water flow to demand

• Scale
  – White <3
  – Lt. Blue <10
  – Dk. Blue >10
Water Availability

• Ratio of 5th percentile of surface water flow to demand
• Scale
  – White <3
  – Lt. Blue <10
  – Dk. Blue >10
Water Availability

- Ratio of mean base flow (measure of sustainable groundwater recharge) to demand
- Scale
  - White <3
  - Lt. Blue <10
  - Dk. Blue >10
Water Availability

- Work in progress
- Identify counties that meet key siting criteria
  - Water availability
  - Proximity to demand
  - Transmission capacity
  - Etc.
Water Competition

• Other water use scaled to power plant demand

• Scale
  – White =1
  – Lt. Blue =10
  – Dk. Blue >10

• Average plant size of 3.6 MGD
Regional Analysis

Willamette River Basin
TEMPERATURE IMPACT MODEL

Fish Thresholds
Mckenzie River
Temperature
Blue River Reservoir
Cougar Reservoir

Power Generation
Calibration

CURRENT SIMULATION VS. BASE CASE

DIFFERENCE FROM BASE CASE

CLICK the "PLAY" button at the top-left of the screen to RUN the model. CLICK the "BACK" button to return to the watershed screen.

View the results by going to the results page for that watershed or viewing the summary page for the entire basin.