New Mexico EPSCoR

RESEARCH INFRASTRUCTURE IMPROVEMENT (RII 4)
PROPOSAL DEVELOPMENT PROCESS

SCIENCE WHITE PAPER

FOR DISCUSSION
OCTOBER 21, 2011

TITLE: ENERGY, WATER, AND THE ARID SOUTHWEST: RESOURCES AND CHALLENGES

LEAD AUTHOR: BRUCE THOMSON (UNM)

New Mexico EPSCoR Program is funded in part by the National Science Foundation award #0814449 and the State of New Mexico. Any opinions, findings, conclusions, or recommendations expressed in the material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Energy, Water and the Arid Southwest:

Resources and Challenges

Bruce Thomson (Water Resources & Civil Engineering)

Introduction

The Critical Link Between Water and Energy Resources

The arid southwestern U.S. has large conventional energy resources (fossil fuels, nuclear fuel, and hydropower) and emerging energy resources (wind, solar, and biofuels). However, this region of the country is experiencing increasing demands on its water resources due to population growth, industrial development, agricultural development. Water resources are also challenged by declining quality associated with salinity increases and wastewater discharges, over allocation of existing resources, and the impacts of drought and climate change.

Some of the ways in which these constraints will become evident include:

- Lack of water for cooling of coal, nuclear, and solar thermal power plants
- Lack of water or seasonal limitations on water availability for hydropower
- Decreased efficiency of thermal power plants due to climate warming
- Water use associated with new energy generation or storage technologies
- Increased energy demand for water and wastewater treatment facilities and desalination plants
- Legal constraints on water produced as a result of energy extraction including oil production, coal bed methane dewatering, and uranium mining
- Salt management and consumptive use limits on water for biofuels and algal production
- Degraded water quality resulting from resource extraction and/or energy production
- Increased costs for water as demand increases

Research Hypothesis

Water resources including both the magnitude of the resource and its quality will constrain development of energy resources and technologies in the arid southwest. This will include extractive technologies such as development of oil, gas, and uranium resources; energy generation technologies such as hydropower and thermal processes; and storage technologies such as pumped storage. The relationship between water and energy may also impact implementation of emerging technologies that require large volumes of water such as hydrogen generation or photovoltaic cell manufacturing.

Background Information

The southwestern U.S has enormous potential for contributing to the world’s future energy needs. These include significant deposits of non-renewable resources of fossil fuels (oil, natural gas, and coal) and uranium, renewable resources (hydropower and wind energy) as well as opportunities for future renewable resources (solar thermal and photovoltaic power, and biofuels). The four corners states of AZ, CO, NM and UT are enormously rich in these resources will play an increasing role as a provider of energy and energy related products. However, it is important to recognize that there are environmental constraints associated with development of all forms of energy. These include impacts on atmospheric CO_2 levels (i.e. the carbon footprint), land resources, and water resources. In the arid southwest, the link between water and energy is especially important as water is both a limiting resource for much of this type of development, and because water resources are often the component of the environment that is most impacted by energy development activities (Solomon, 2010; Mielke et al., 2010).

Sandia National Labs provided a summary of the connections between energy sectors and water that is summarized in Table 1 (DOE, 2006). Elements of energy production and transport that currently have a major factor in the southwest are in shaded boxes. Table 2 gives an idea of the water requirements for different energy generation methods. Table 3 summarizes the energy production capacity or energy reserves in NM (DOE, 2006). The data in this last table when combined with the others illustrates the diversity of the energy-water linkages and gives an idea of the magnitude of the demand for water just in NM.

In addition to established energy technologies, it is vitally important to recognize that emerging technologies may also have a large energy demand. An important example is production of algal biofuels. Dominguez-Faus et al (2009) have discussed the water footprint of biofuels. A similar analysis should be conducted to focus on energy-water relationships in arid climates.

Table 1. Connections between energy sector and water availability & quality (adapted from DOE, 2006). Shaded cells identify energy elements & connections with existing major activity in the arid southwest.

Energy Element	Connection to Water Quantity	Connection to Water Quality	Energy Element	Connection to Water Quantity	Connection to Water Quality
Energy Extraction & Production			**Refining & Processing**		
Oil & Gas Exploration	Water for drilling, completion & fracturing	Impact on shallow groundwater quality	Traditional Oil & Gas Refining	Water needed to refine oil & gas	End use can impact water quality
Oil & Gas Production	Large volumes of produced, impaired water	Produced water can impact surface & ground water	Biofuels & Ethanol	Water for growing & refining	Refinery wastewater treatment
Coal & Uranium Mining	Mining operations can generate large quantities of water	Tailings & drainage can impact surface & ground water	Synfuels & Hydrogen	Water for synthesis or steam refining	Wastewater treatment
Electric Power Generation			**Energy Transportation & Storage**		
Thermoelectric (fossil, biomass, nuclear, solar)	Surface & ground water for cooling & scrubbing	Thermal & air emissions impact surface waters & ecology	Energy Pipelines	Water for hydrostatic testing	Wastewater requires treatment
Hydroelectric	Water lost to evaporation	Cam impact water temperatures, quality, ecology	Coal Slurry Pipelines	Water for slurry transport, water not returned	Final water is poor quality, requires treatment
Solar PV & Wind	None during operation; minimal water use for panel & blade washing		Barge transport of Energy	River flows & stages impact fuel delivery	Spills or accidents can impact water quality
			Oil & Gas Storage Caverns	Slurry mining of caverns requires large quantities of water	Slurry disposal impacts water quality & ecology

Table 2. Water requirements for energy production by different processes (DOE, 2006).

Process	L/MWh
Petroleum extraction	10-40
Oil refining	80-150
Oil shale surface retort	170-681
NGCC[a] power plant, closed loop cooling	230-30,300
Coal IGCC[b]	~900
Nuclear power plant, closed loop cooling	~950
Geothermal power plant, closed loop tower	1,900-4,200
EOR[c]	~7,600
NGCC, open loop cooling	28,400 – 75,700
Nuclear power plant, open loop cooling	94,600 – 227,100
Corn ethanol irrigation	2,270,000 – 8,670,000
Soybean biodiesel irrigation	13,900,00 – 27,900,000

Notes:
[a]Natural gas combined cycle
[b]Integrated gasification combined-cycle
[c]Enhanced oil recovery

Table 3. Major energy production capacity or energy reserves by various energy sectors in NM.

Sector	Production
Hydropower capacity	80.6 MW
Coal Fired Electric Generation Capacity	4,150 MW
Gas Turbine Electric Generation Capacity	3,380 MW
Geothermal Capacity	10 MW
Natural Gas Reserves (2009)	1.4×10^{12} ft^3
Oil Production	67 Mbbl/yr
Refining Capacity	96,500 bbl/d
Wind Energy Capacity	497 MW
Uranium Reserves (@ $100/lb)	390 M lbs U_3O_8

Clarens et al. (2010) have compared the land, energy, green house gas, water, and phosphate (PO_4^{3-}) life cycle burdens for production of energy among algae, corn, canola, and switchgrass. They show that while algae roughly one-third the land requirement of corn, it requires 30 times more water. It is important to note that their analysis was for energy production in Virginia. Evaporative losses in NM would be expected to be much greater due to the arid climate. Another challenge is waste management associated with algal biofuels production. For example, Thomson and Howe (2011) have done analyses which show that there are substantial challenges associated with salinity management and especially salt brine disposal associated with algal production in arid climates that have not been considered to date.

Table 4 Five Life Cycle Burdens for Production of One Functional Unit of Energy (317 GJ) Algae, Corn, Canola, and Switchgrass in Virginia (Clarens et al., 2010).

	Land (ha)	Energy (MJ) $x10^{-4}$	GHG (kg CO_2) $x10^4$	Water (m^3)	Eutrophication (kg PO_4 equiv.)
algae	0.4±0.05	30±6.6	1.8±0.58	12±2.4	3.3±0.86
corn	1.3±0.3	3.8±0.35	-2.6±0.09	0.82±0.19	26±5.4
canola	2.0±0.2	7.0±0.83	-1.6±0.10	1.0±0.14	28±5.8
switchgrass	1.7±0.4	2.9±0.27	-2.4±0.18	0.57±0.21	6.1±1.7

Project Objectives

This project will establish an integrated collaborative investigation to quantify technical, economic, and policy relationships between water and energy development in the arid southwest to include:

- Development of energy resources including fossil fuels (coal, oil, & gas) and nuclear fuels (uranium)
- Energy production by thermal electric generation using fossil fuels, nuclear fuels, and solar thermal sources and hydroelectric power generation, as well as alternative production methods such as wind, geothermal, photovoltaic generation and other methods
- Waste management and disposal of residuals from energy production and generation including wastes from mining and drilling operations, wastes from processing operations (i.e. refining and milling wastes), wastes from emission controls, and residuals from energy generation and transmission facilities.
- Identify emerging energy production technologies that may impact water resources.
- Identify energy relationships with water including agricultural use, municipal & industrial use, water/wastewater treatment & conditioning.
- Establish collaboration with national labs, federal & state agencies, and the energy industry to develop framework for developing proposal to create national research center for investigation of the technical, economic and environmental connections between energy and water.

Examples of Studies That Might Be Conducted in this Project

<u>Develop relationships between extraction technologies and water resources:</u> This study would consider the quantity of water produced during extraction of different types of energy materials including oil, gas, and uranium. In addition to the quantity of water produced, an equally important component of the research would be the quality of this water and the potential for conservation, reuse, and recovery of the water. The study would necessarily involve consideration of the legal, economic, and cultural impacts of water production.

<u>Investigation of water resource and water quality demands associated with algal biofuels production:</u> Evaporative losses associated with growth of algae present two challenges. First, is the loss of water. Development of an algal biofuels industry in the arid southwest must determine if sufficient water is available and what the sources might be. The second challenge is

salt management. Evaporative losses of water result in increasing salinity which, if not checked, will exceed the limits in which algae can grow. There is a need for fundamental investigations into the salt tolerance of high lipid producing organisms as well as development of technologies and management techniques for brine produced by the algae ponds.

Development of innovative strategies for water reuse by energy production technologies: As shown in Table 2 thermal power generation requires large amounts of water which is used primarily for cooling. There is a need for technologies which can substitute high quality fresh water with low quality water for these applications. This would require development of technologies in water & wastewater treatment, heat transfer and cooling, and material science and corrosion control.

Other ideas?

References

Brister, L., Price, L.G. editors (2002). New Mexico's Energy, Present and Future: Policy, Production, Economics, and Environment, B.S. Brister & L. Greer Price (eds.), New Mexico Bureau of Geology and Mineral Resources, Decision-Makers Field Conference, 2002, San Juan Basin, NMBGMR, Socorro, NM, 156 p.

Clarens, A.F., Resurreccion, E.P., White, M.A., Colosi, L.M. (2010). Environmental Life Cycle Comparison of Algae to Other Bioenergy Feedstocks, Envi. Sc. Technol., vol. 44, pp. 1813-1819.

Department of Energy (DOE) (2006). Energy Demands on Water Resources, Report to Congress, Interdependency of Energy and Water, 80 p. (http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf)

Dominguez-Faus, R., Powers, S.E., Burken, J.G., Alvarez, P.J. (2009). The Water Footprint of Biofuels: A Drink or Drive Issue?, Envi. Sc. Technol., vol. 43, pp. 3005-3010.

Electric Power Research Institute (EPRI, 2002a). Water and Sustainability (Volume 3): U.S. Water Consumption for Power Production - The Next Half Century, Topical Report, May 2002, Report No. 1006786.

Hightower, M. Pierce, S.A. (2008), The energy challenge, Nature **452**, pp. 285–286 (20 March 2008).

Mielke, E., Anadon, L.D., Narayanamurti, V. (2010). "Water Consumption of Energy Resource Extraction, Processing, and Conversion: A review of the literature for estimates of water intensity of energy-resource extraction, processing to fuels, and conversion to electricity," Discussion Paper 2010-15, Energy Technology Innovation Policy research group, Belfer Center for Science and International Affairs, Harvard Kennedy School ,http://belfercenter.ksg.harvard.edu/publication/20479/water_consumption_of_energy_resource_extraction_processing_and_conversion.html?breadcrumb=%2Fproject%2F10%2Fenergy_technology_innovation_policy

National Energy Technology Laboratory (NETL) (2007). Freshwater Needs to Meet Future Thermoelectric Generation Requirements. Retrieved December 16, 2010 from: 〈http://www.netl.doe.gov/technologies/coallpower/ewr/pubs/2007%20Water%20Needs%20Analysis%20-%20Final%20REVISED%205-8-08.pdf〉.

Rice, C.A., Nuccio, V. (2000). Water Produced with Coal Bed Methane, USGS Fact Sheet FS-156-00, 2 p.

San Juan Basin Regional Uranium Study (SJBRUS) (1980). Uranium development in the San Juan Basin region : a report on environmental issues, prepared by San Juan Basin Regional Uranium Study, Office of Trust Responsibilities, Bureau of Indian Affairs, lead agency, Albuquerque, NM, 548 p.

Solomon, S. (2010). Water: The Epic Struggle for Wealth, Power, and Civilization, Harper Pubs., 608 p.

Thomson, B.M., Heggen, R.J. (1983). "Uranium and water: Managing common resources," Chemtech, vol. 13, no. 5, pp. 294-299.

Veil, J.A., Quinn, J.J. (2002). Water Issues Associated with Heavy Oil Production, ANL/EVS/R-08/4 (http://www.evs.anl.gov/pub/doc/ANL_EVS_2321_heavyoilreport.pdf) Argonne national Laboratory, Oak Ridge, TN, 64 p.