



Life Cycle Water Consumption of Alternative, Low-Carbon Transportation Energy Sources

Arizona has relatively limited water resources due to its arid climate and limited surface water. Traditional forms of energy production are known to consume large volumes of water and account for approximately 20% of non-agricultural water consumption in the United States. The numbers for AZ are slightly lower, with total industrial uses of water making up around 17% of non agricultural water consumption. The Energy Information Administration has estimated that world demand for liquid fuels for transportation will grow by 50% between 2005 and 2030. If Arizona is going to meet its future energy demand, it will need to decrease harmful CO₂ emissions and limit strain on its water resources. This study provides decision makers with data to help make informed choices on which technologies are best suited to meet this challenge.

PROJECT TEAM

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PROJECT FUNDING CYCLE

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PROJECT GOALS

The goal of this project was to evaluate the life cycle water consumption of a range of low-carbon transportation energy sources.

BACKGROUND/RESEARCH METHODS

This study is part of an ongoing effort by Arizona State University and the Arizona Water Institute (AWI) to understand the important linkages between water and energy. While it is generally understood that energy is required to transport and treat water, few studies have attempted to understand the opposite link. In fact, significant quantities of water are also required in the production of various forms of energy. This study focuses on water consumption of transportation energy sources; specifically on emerging, low-carbon technologies that seek to mitigate the problems of global climate change and energy security.

These looming challenges have begun to spur the development of alternatives to our current petroleum based transportation system. However, before these alternatives are implemented on a significant scale, it is important to assess these technologies with a broad lens and ensure that they will not introduce

more problems than they will solve. A useful tool in attempting to characterize technologies is life cycle assessment (LCA). It can be used to attempt to characterize the cradle-to-grave environmental impacts of specific technological systems, in this case water consumption.

The life cycle water consumption was estimated for a range of potential low-carbon energy sources for future transportation in Arizona. The approach used was a hybrid life cycle assessment. Where data were available, major water consuming processes were evaluated on a process by process basis. The remainder of the system, including construction and maintenance, was evaluated based upon aggregated sector by sector economic input-output data from the Carnegie Mellon University EIO/LCA.net tool. The total water consumption was then calculated for the entire life cycle by combining the impacts for all major processes. For most technologies, multiple estimates were made based upon different data and assumptions. The purpose was to scope out the general range of the potential impacts on water use.

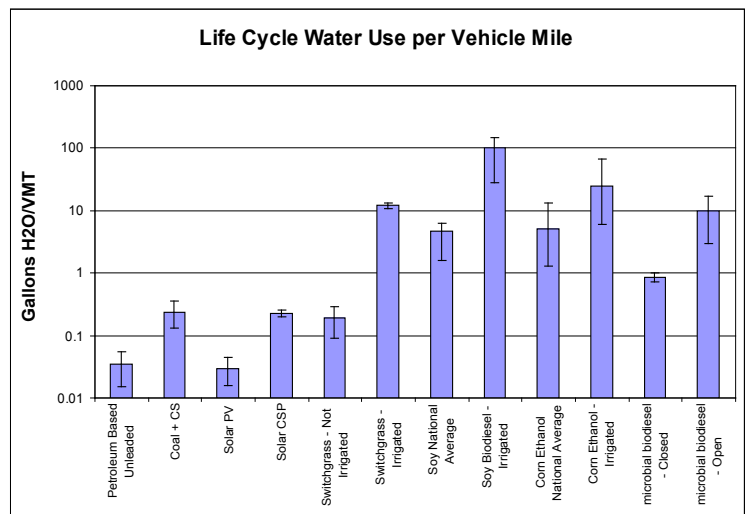


Figure 1. Summary of life cycle water consumption

A range of potential technologies were explored using this methodology, each falling into one of two main categories. The first category was biofuels, including corn ethanol, soy biodiesel, cellulosic ethanol, and microbial biodiesel. While biofuels are currently controversial, they are the only alternative fuels as yet making any significant contribution to transportation energy. The other category was electric vehicles (EV) and plug-in hybrids. These vehicles draw electricity from the grid that is stored in batteries and used to run an electric motor. While there are few EVs on the road today, they are expected to enter the market in

larger numbers over the next few years. Three low carbon electricity sources with significant potential in Arizona were evaluated including coal power tied to carbon sequestration (Coal + CS), solar photovoltaics (Solar PV), and concentrated solar power (Solar - CSP).

For the purposes of this study water consumption was defined as water evaporated from a process or discharged as wastewater. Water withdrawals that were either in continuous use or returned to the source were not included. The functional unit for the analysis was gallons of water consumed per vehicle mile traveled (VMT). This was chosen for comparison purposes to compensate for different energy densities of different fuels and different efficiencies of the vehicles that use them.

KEY STAKEHOLDER ENGAGEMENT & OUTCOMES

The life cycle water consumption for each technology is shown graphically with the error bars representing the upper and lower bound of the estimated range of water consumption (see Figure 1). In addition, data on annual vehicle travel and water demand were used to estimate how scale up of each technology would impact overall water demand in Arizona. Estimates were made assuming that either 10% or 50% of total personal transportation demand would be met by the specific technology. Results are presented in the table in terms of total acre-feet of water required and in percentage of current water demand.

CONCLUSIONS & RECOMMENDATIONS

New forms of low carbon transportation energy will be important if we, as a society, are to successfully combat global climate change. Of the technologies explored, only photovoltaic solar power appears to have as low a life cycle water impact as current petroleum based fuels. Unfortunately it is also currently one of the more expensive alternatives. In general, electrical sources of energy were found to use significantly less

water than biofuels and are not as likely to strain water supplies.

It does appear that cellulosic ethanol may be able to compete with the electrical sources as long as its feedstock is not irrigated. It is possible that some amount of cellulosic ethanol could be produced in Arizona from waste biomass. However it is not likely that a dedicated feedstock such as switchgrass can be grown efficiently in Arizona without irrigation. Importation of biofuels from other states (with substantial energy implications) may be required if these fuels are to be used to meet a significant portion of Arizona's transportation demand. Microbial biodiesel produced with feedstock grown in closed systems may be the exception. Water use is relatively low, but the technology is not fully developed and costs are currently prohibitive. Overall the results indicate that there are no silver bullet technologies and that tough decisions will have to be made between costs, carbon, and water.

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Table 1. Impact of technology scale-up on total AZ water demand

Technology	Total Acre-ft	% AZ demand	Total Acre-ft	% AZ demand
Coal +CS	3,700	0.05	18,000	0.26
Solar PV	460	0.01	2,300	0.03
Solar CSP	3,500	0.05	18,000	0.25
Switchgrass - Irrigated	20,000	2.8	1,000,000	14
Soy Biodiesel - Irrigated	2,300,000	33	12,000,000	164
Corn Ethanol - Irrigated	1,000,000	15	5,100,00	73
Microbial Biodiesel - Closed	13,000	0.19	65,000	0.93
Microbial Biodiesel - Open	160,000	2.2	780,000	11