Every Drop Counts

Valuing the Water Used to Generate Electricity

WESTERN RESOURCE
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Every Drop Counts

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Western Resource Advocates' mission is to protect the West's land, air, and water.

Our lawyers, scientists, and economists:

1) advance clean energy to reduce pollution and global climate change;
2) promote urban water conservation and river restoration; and
3) defend special public lands from energy development.

We collaborate with other conservation groups, hunters and fishermen, ranchers, American Indians, and others to ensure a sustainable future for the West.

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Executive Summary

Water has tremendous value—people, crops, industry, and the environment all rely on this limited resource. In the arid and semi-arid West, the value of water is even more pronounced, rising precipitously in times of drought and scarcity. Climate change models project increased rates of evapotranspiration throughout the West, more severe droughts, and reduced runoff in the Colorado River. Accordingly, the value of water in the Southwest will continue to rise.

In 2005, power plants in six states—Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming—consumed an estimated 395,000 acre-feet (AF) of water. These plants impact our region's rivers and aquifers, and tie up water that could meet growing urban, agricultural, or environmental needs.

FIGURE ES 1 THE VALUE OF WATER IN THE WEST

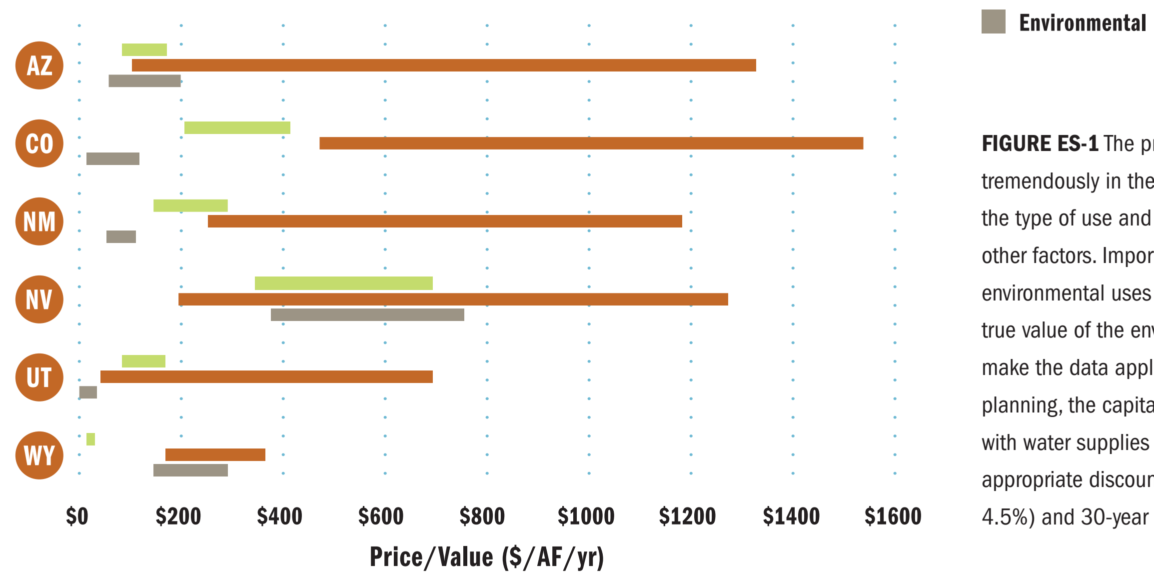


FIGURE ES-1 The price of water varies tremendously in the West, depending on the type of use and the location, among other factors. Importantly, prices paid for environmental uses often understate the true value of the environmental benefit. To make the data applicable to electric utility planning, the capital costs associated with water supplies are annualized using appropriate discount rates (typically around 4.5%) and 30-year periods.

Electric utilities' choices can have vastly different impacts on water resources.

Electric utilities' choices can have vastly different impacts on water resources. A wet-cooled coal plant, for example, typically uses three times as much water as a combined-cycle gas plant; wind turbines, solar photovoltaic panels, and energy efficiency use no water; and employing dry cooling in a thermoelectric power plant can reduce water use by 90%. Yet most electric utilities and regulators do not adequately consider water in their future resource plans. Electric utilities typically appropriate or purchase water rights for new thermoelectric power plants, but the cost of these water rights does not reflect the opportunity cost of water use over the life of the power plant—40 to 50 years or longer.

While the value of water is highly varied, it is not zero. This report attempts to develop a range of values of water for use in electric resource planning. Western Resource Advocates (WRA) analyzed the prices paid for water by the three different sectors that compete with power plants: municipal, agricultural, and environmental (Figure ES 1). In addition, we assessed the authority of regulators in the six states to consider water in evaluating utilities' electric resource plans. We found that, across the region, the degree to which water influences regulators' and utilities' electric resource planning decisions varies significantly.

Municipal Values

Cities have—by far—the highest willingness (and ability) to pay for water. WRA analyzed market-based transfers, municipal "tap" fees, and the cost of new water supply projects to identify the cost of water for municipalities. The values vary considerably between data sources, but the trends are consistent: Coloradans, particularly along the Front Range, have the most expensive water, and residents in Wyoming and Utah—where water is generally less (economically) scarce—have the cheapest water (Figure ES 1). Of note, the cost of water is notably different from the *value* of water. The cost, or price, likely forms the lower bound of the value of water, particularly for cities.

Future trends of municipal water values are important. In Colorado, water prices rose precipitously in the early 2000s, as urban populations swelled along Colorado's Front Range and severe drought impacted water supplies (Figure ES 2). This history provides valuable insight into future values across the region, as population growth continues and climate change reduces available supplies.

Agricultural Values

Increasingly, cities and power plants are turning to the agricultural sector to meet their water needs. As in other sectors, the value of water for agricultural use varies tremendously, depending on the scarcity of the resource, the value of the commodity grown, and the productivity of the agricultural land, among other factors. To estimate a value of water for agriculture, WRA analyzed several sources of data, including, among others, the price of water rights purchased by farmers through market-based transactions, the price farmers pay for off-farm sources of water, and differences in net farm revenues garnered from irrigated crops versus dryland crops.

The median price farmers paid for permanent water transfers ranges from $16 per acre-foot per year ($16/AF/yr) in Wyoming to $153/AF/yr in Colorado (annualized costs), much lower than prices paid by municipalities (Figure ES 1). The range of transfer prices is large, especially in Colorado, where annualized costs exceeded $1,000/AF/yr in several instances. Importantly, our analysis focused solely on the monetary price of water for agriculture and does not reflect important non-monetary values, such as the value of rural communities and lifestyles, the value of open, undeveloped space, and the value of a local food supply. The full value of water would include these non-monetary values, as well as the indirect effects that water transfers can have on the regional economy, such as depleting the local tax base or reducing demand for agriculture-related industries.

FIGURE ES 2 WATER SALES TO MUNICIPALITIES: COLORADO

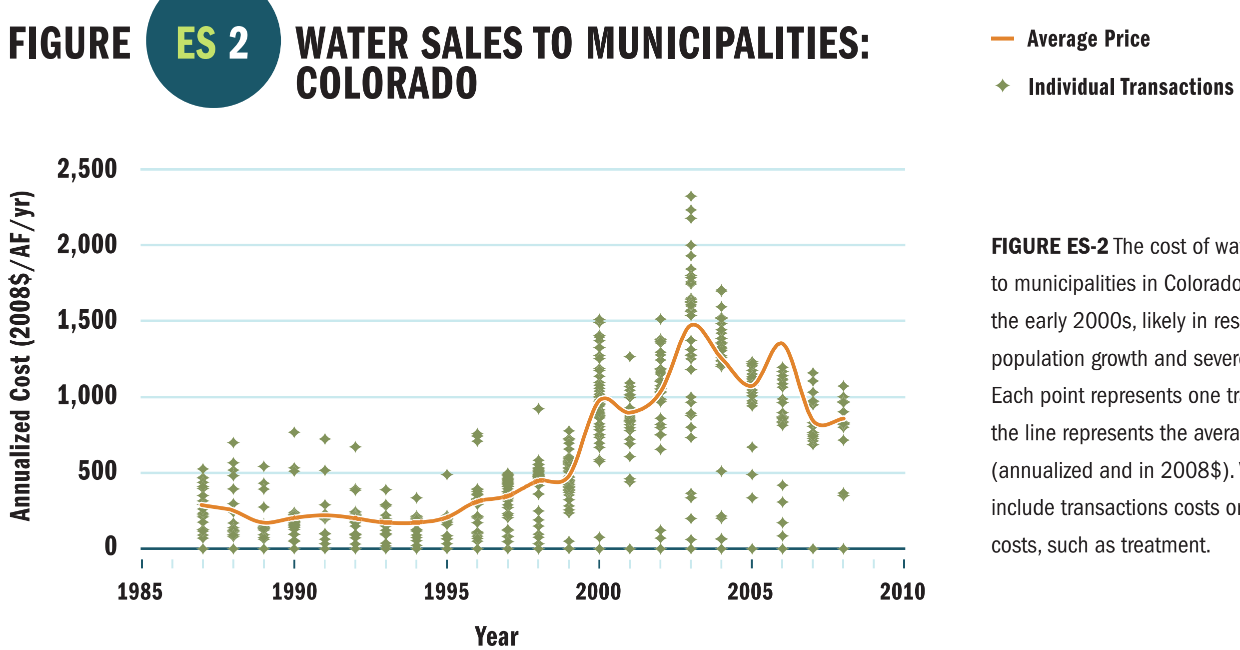


FIGURE ES-2 The cost of water sold to municipalities in Colorado rose in the early 2000s, likely in response to population growth and severe drought. Each point represents one transaction; the line represents the average sale price (annualized and in 2008$). Values do not include transactions costs or annual O&M costs, such as treatment.

Environmental Values

Leaving water instream provides a host of benefits: It supports recreation, sustains healthy ecosystems, improves water quality, and offers aesthetic benefits. Monetizing the value of instream or environmental flows proves challenging—valuing instream flows is a relatively new practice, and estimates of the value of these flows are scarce. Outdoor recreation activities, such as fishing and whitewater rafting, provide a tremendous (and growing) source of revenue throughout western states, but attributing that income to a volume of water proves difficult. And many of the benefits of instream flows, e.g., a healthy river ecosystem, are not yet adequately measured by economic analyses.

To estimate the value of water for environmental uses, WRA examined market-based transactions (both permanent transfers and temporary leases), non-market valuation studies, the value of instream flows to recreation, and the cost of dedicating storage space in new reservoirs to serve environmental purposes ("environmental pools"). The median and average price paid for temporary leases was below $65/AF/yr (Figure ES 1). Nevada, where sales dominated, represents the key exception, with an annualized median cost of $377/AF/yr. Other indicators, like non-market valuation studies and the revenues generated by whitewater parks, suggest an even higher value of water—as much as $545/AF/yr on certain popular rivers in Colorado.

Integrating Water in Energy Planning

Most electric utilities and regulators do not recognize or incorporate the agricultural, municipal, or environmental values described above when considering future resource plans. Most state public utility commissions already have the authority to consider water impacts, but, to date, many have not exercised this authority. The Colorado Public Utilities Commission (PUC) and the Arizona Corporation Commission (ACC) are two notable exceptions, and in both of those states, the major investor-owned utilities are at the forefront of integrating water into electric resource planning.

Arizona

The ACC and Arizona's largest investor-owned utility, Arizona Public Service (APS), have been leaders in the West on integrating water into energy planning.

- The ACC is currently evaluating how utilities should consider the cost of externalities, including water use, in resource plans.

- Earlier this decade, the ACC denied permits for two proposed gas plants, based, in part, on water impacts. And, in 2009, the ACC's siting committee weighed the water impacts of a proposed wet-cooled solar thermal plant in southwestern Arizona and voted to approve the plant.

APS reports water use for existing facilities and proposed future resource plans, and now assumes that a new, combined-cycle natural gas plant would rely on dry cooling. In contrast, the Salt River Project (SRP), which is not regulated by the ACC, does not evaluate or report water consumption for different portfolios. Like many other electric utilities, SRP considers the cost of acquiring new water supplies in its resource planning and siting processes, but does not factor in an externality value for water-efficient sources of energy.

Colorado

In 2004, voters in Colorado passed the state's first renewable energy standard, which highlights the water savings of renewables. Since then, the state's PUC has taken several important actions:

- It now allows utilities to evaluate and rank competitive bids for renewables based on the cost of the energy *and* other factors, including water use.

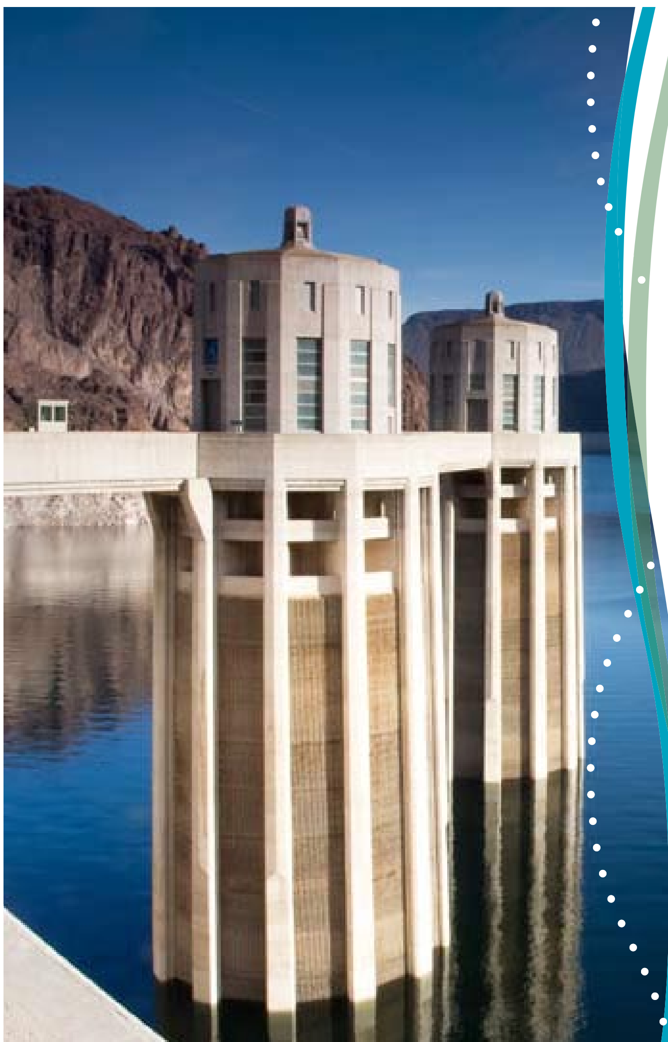
- As of August 2010, the PUC will require utilities to report water consumption for existing and proposed facilities and the water intensity in gallons per megawatt-hour (gal/MWh) of resource portfolios.

- In its 2007 decision on the resource plan of Public Service Company of Colorado (PSCo), the PUC stated that "Public Service's proposal to address emissions … and water through their costs being imbedded in generation resource bids is an appropriate first step in factoring externalities in resource planning."

Colorado utilities are also integrating water into their decisions:

- Through a competitive bid process, PSCo recently selected a dry-cooled, 280-megawatt (MW) solar thermal plant in the arid San Luis Valley, in part because of the benefits to water resources.

- Tri-State Generation and Transmission will report water use for all existing and proposed facilities in its new resource planning process.



Lake Mead, NV

New Mexico

New Mexico's Public Regulation Commission (PRC) has focused primarily on the water benefits of energy efficiency programs, with rules directing utilities to:

- File an annual report that quantifies non-energy benefits of the energy efficiency programs.

- Choose energy efficiency programs based on considerations that include "non-energy benefits"—low-income customer participation in utility programs and reductions in greenhouse gas emissions, air pollution, water consumption, and natural resource depletion.

In addition to these rules, the PRC requires regulated utilities to report freshwater consumption at existing facilities, though utilities do not typically report brackish or recycled water consumption. The New Mexico PRC has not, to date, cited water as a factor influencing its decision. In fact, citizens protesting the proposed Duke Luna Energy Facility, a 600-MW gas plant, raised concerns about water impacts, but the facility project manager argued that the New Mexico State Engineer—not the PRC—has jurisdiction over water use. The PRC's final ruling on that facility did not address impacts on water resources.

Nevada

The Nevada Public Utilities Commission has the regulatory authority to consider water and other environmental factors in evaluating electric utilities' resource plans. Environmental costs (or benefits) of new supplies and demand-side management include water use, among other factors. The PUC regulations direct utilities to evaluate costs for resources sited within Nevada and those sited outside of the state, but, to date, the PUC has not evaluated the water impacts of utility resource plans.

Although NV Energy does not report water use in its resource plans, it does model the value of water savings in its energy efficiency programs. And, according to utility representatives, NV Energy now assumes that a new, combined-cycle gas plant would rely on dry cooling.

At the direction of the PUC, the three utilities (Southern Nevada Water Authority, NV Energy, and Southwest Gas) recently created a Demand-Side Management Collaborative, which will help coordinate efficiency programs. This collaborative offers an opportunity to find synergistic efficiency programs and enhance water, electricity, gas, and carbon savings.

Lake Mead, NV

Utah

As part of its integrated resource planning requirements, utilities in Utah must perform an analysis of environmental risk, which should include "the quantification of actual emissions as well as a range of dollar values for external costs for each acquisition strategy." However, the Utah Public Service Commission (PSC) has rejected the idea that utilities would include these external costs in "total resource cost" calculations, while noting that environmental costs may be internalized in total resource costs in the future.

Rocky Mountain Power (PacifiCorp) considers the value of water in its resource planning process in a very limited manner. In evaluating supply-side resources, the utility considers the cost of acquiring or developing water, the annual operation and maintenance (O&M) costs associated with water, and the risk of water *not* being available. But the utility does not report water consumption in its resource plans (for existing facilities or proposed new facilities) and has focused more on the impacts of climate change on water and hydroelectric generation.

Wyoming

Wyoming does not appear to have any statutes or regulations that directly address water use by electric generation facilities.

Recommendations

Water use at thermoelectric power plants competes directly with the water demands of cities, people, agriculture, and environmental needs. Recently, utilities and developers have proposed building new thermoelectric power plants in rural locations, distant from municipalities. These plants would draw on water supplies that would otherwise sustain agriculture or the environment, and, in many cases, the municipal value of water is not directly relevant. However, as municipalities seek new urban water supplies, they are increasingly looking farther afield; for example, the Southern Nevada Water Authority proposes to tap water from rural White Pine County, 300 miles north of Las Vegas, where electric utilities have also proposed building two new power plants. Additionally, many of the West's oldest, most inefficient coal plants are located in or near urban areas, and accelerating their retirement could create valuable new municipal water supplies. For example:

- Xcel Energy's Cherokee Station, located just north of downtown Denver, consumes almost 8,000 AF of water each year. If Xcel retired the Cherokee plant five years early and made its water available to neighboring cities, the value of the water for the five-year period would exceed $4.8 million. If Xcel generates additional energy at natural gas or other water-using thermoelectric facilities, the water use may be shifted to other rivers or other basins. In contrast, if the utility offsets the energy generated at Cherokee with energy efficiency, wind, or solar photovoltaics, the company will maximize water savings in the region.

- The Reid Gardner Power Plant, owned by NV Energy and the California Department of Water Resources, relies on water from the Muddy River and groundwater wells in southern Nevada and consumes over 4,300 AF/yr. The water used to cool Reid Gardner—an estimated 4,300 AF/yr—could be transferred to the Southern Nevada Water Authority, which supplies water to cities in the Las Vegas Valley. The water value of retiring the Reid Gardner units five years early would amount to over $5 million.

Utilities across the region should report water consumption for existing and proposed facilities as part of their integrated resource plans.

Currently, the extent to which the region's electric utilities and regulators consider water varies tremendously. Utilities and regulators in Arizona and Colorado are clear leaders in considering the impacts of electricity generation on water and other environmental resources. At a minimum, **utilities across the region should report water consumption for existing facilities, along with projected water consumption for different proposed portfolios, as part of their integrated resource plans.**

San Luis Valley, CO

In considering new water-intensive power plants, utilities and regulators should assess both the value of water today and the potential value of water in the future. In areas where water is scarce today, or will likely be scarce in the next 40 to 50 years (or the lifetime of the proposed power plant), utilities and regulators should analyze the opportunity cost of using water for electricity generation. That is, regulators should evaluate the value of the foregone opportunities—continued agricultural production, municipal development, or environmental benefits. Utilities should prepare projections and sensitivity analyses, and incorporate those opportunity costs in their decisions.

Finally, in many parts of the West, climate change is projected to reduce available water supplies and increase the likelihood and intensity of drought. In order to adapt to changing water availability, water users throughout the region will need to preserve or increase flexibility in management—committing water to a new power plant would remove some of this flexibility. **Regulators and electric utilities should consider the benefits of maintaining flexibility, and the role of water-efficient forms of generation and energy efficiency as a hedge against short- or long-term drought**.

In considering new water-intensive power plants, utilities and regulators should assess both the value of water today and the potential value of water in the future.

Introduction

In the arid West, water has tremendous value—it is essential to sustain agriculture, municipalities, industrial operations, and many forms of electricity generation. Yet water has historically been underpriced and undervalued.[1] Most surface and groundwater sources in the West are now fully or over-allocated, and scientists project that climate change will reduce water supplies in the Southwest.[2] As water becomes scarcer, its value will undoubtedly rise.

Although water is a precious commodity, it seldom has limited energy development in the West. The largest thermoelectric power plants in the West consume as much as 25,000 AF of water each year; in 2005, power plants in Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming consumed approximately 395,000 AF.[3] Once consumed for power generation, that water is no longer available to meet other demands—urban, environmental, or agricultural.[4] These power plants impact our rivers and aquifers, and tie up water that could be used for other purposes. Yet neither power plant developers nor state regulatory agencies consider the opportunity cost of using water for power generation over the lifetime of the power plant.

Electric utilities' choices can have vastly different impacts on water resources. A wet-cooled coal plant, for example, typically uses three times as much water

1 Rosegrant, M.W. and H.P. Binswanger. 1994. Markets in tradable water rights: potential for efficiency gains in developing country water resource allocation. *World Development* 22: 1613-1625. Easter, K.W., M.W. Rosegrant, and A. Dinar. 1999. Formal and informal markets for water: institutions, performance, and constraints. *World Bank Research Observer* 14: 99-116.

2 See, for example: 1) Rajagopalan, B., K. Nowak, J. Prairie, M. Hoerling, B. Harding, J. Barsugli, A. Ray, and B. Udall. 2009. Water supply risk on the Colorado River: Can management mitigate? *Water Resources Research* 45, W08201, doi:10.1029/2008WR007652; 2) Hoerling, M., D. Lettenmaier, D. Cayan, and B. Udall. 2009. Reconciling projections of Colorado River streamflow. *Southwest Hydrology* 8(3): 20-21, 31; and 3) Seager, R., M. F. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H. P. Huang, et al. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. *Science* 316: 1181-1184.

3 Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin. 2009. *Estimated use of water in the United States in 2005*. U.S. Geological Survey Circular 1344. http://pubs.usgs.gov/circ/1344.

4 Most western power plants consume all or nearly all of the water they withdraw. Cities and farms typically only consume a portion of the water they withdraw from rivers or aquifers; we have worked to standardize all figures in terms of consumptive use values.

as a combined-cycle gas plant; wind turbines, solar photovoltaic panels, and energy efficiency use no water; and employing dry cooling in a thermoelectric power plant can reduce water use by 90%.

Many electric utilities now model a price per ton of carbon emitted in their resource planning, but the value of water to electric utilities has evaded quantification. The value of water varies significantly, both geographically and over time, and is influenced by factors such as quality, relative scarcity, and the value of the activities that its use supports.[5] Whereas a ton of carbon dioxide (CO_2) has the same global warming potential (and the same cost) regardless of the location of the emissions, the value of a unit of water will vary from place to place.[6]

Despite the tremendous variation in the value of water, it is not zero. This report presents a range of water values for use in electric resource planning, and identifies current utility and regulatory practices for integrating water into this planning. Power plants compete for water with three different sectors: cities, agriculture, and the environment. To develop a range of values, Western Resource Advocates analyzed the prices paid for water by each of these sectors. We also assessed the authority of regulators in the six states to consider water in evaluating utilities' electric resource plans.

Throughout this report, we provide more detailed analyses of the value of water in Colorado, for several reasons: Many of the recent trends in the state are representative of other western states — rapid municipal population growth, agricultural transfers to urban areas, and a growing recognition of the value of instream flows. In addition, Colorado has the most active, well-functioning water market in the West, as well as more extensive data on the value of water for instream flows.

5 Pullen, J. and B. Colby. 2008. Influence of climate variability on the market price of water in the Gila-San Francisco Basin. *Journal of Agricultural and Resource Economics* 33: 473-487. Also: Brown, T. 2006. Trends in water market activity and price in the western United States. *Water Resources Research* 42(9): W09402.1-W09402.14. Raucher, R.S., D. Chapman, J. Henderson, M.L. Hagenstad, and J. Rice. 2005. *The value of water: Concepts, estimates, and applications for water managers*. Denver: AWWA Research Foundation. Loomis, J. 2008. *The economic contribution of instream flows in Colorado: How angling and rafting use increase with instream flows.* Colorado State University Extension, Economic Development Report 08-02.

6 The location of CO_2 emissions *can* have an important effect on human health and other impacts.

Across the region, the degree to which water is considered in regulators' and utilities' electric resource planning decisions varies significantly. As water scarcity increases, recognizing the long-term value of water will be increasingly important. Importantly, energy efficiency and water-efficient renewable energy sources, like wind and solar photovoltaics, can provide long-term water savings, both directly and indirectly. By reducing the demand for electricity generation, energy efficiency measures can reduce water use at existing power plants and delay the need to develop new plants. And certain energy efficiency measures, like ultra-low-flow showerheads, save water directly. Electric utilities' resource plans should reflect the benefits or costs of energy choices—whether renewables, energy efficiency, or conventional sources of energy—on water.

A note on terminology—value, cost, and price

The "value" of water can be interpreted in many different ways. This report focuses primarily on the monetary value of water, but it is important to note that water provides many intangible, non-monetized values that are not adequately evaluated here.

While value is related to cost and price, and these three terms are often used interchangeably, they each have a very distinct meaning. The economic **value** of water is defined as the amount that the user is willing to pay for it. The **cost** of water typically refers to the cost of delivering water for a particular use. The **price** users pay will likely differ substantially from the cost and is often less than the maximum amount they would have been willing to pay (the value). Many water supply projects (both municipal and agricultural) have been subsidized by government funding, and water rates are often a function of political decisions (i.e., a municipal tap fee may be reduced below its actual cost in order to encourage urban growth). These factors will distort the price and apparent value of water.

Under the right conditions, market allocation of a scarce resource can lead to economic efficiency. In the case of water, however, the "right conditions" rarely exist, due to its public good characteristics, mobility, and uncertainty of supply. In addition, water can be used non-consumptively and multiple times, creating additional complications. Therefore, economists often must estimate the value of water using non-market techniques. Contingent valuation methods can serve as a useful tool for measuring customers' willingness to pay for water. In this report, we primarily present data generated by market-based techniques, although the results from several existing non-market valuation studies are also discussed.

how much will a user pay? **value**

cost of delivery for a particular use

what **price** are users paying now?

Municipal Value of Water

Cities have—by far—the highest willingness (and ability) to pay for water. Some proposed new supply projects across the region will cost as much as of $20,000/AF or more in capital expenditures alone,[7] and in 2003, at the height of the drought in Colorado, cities paid over $30,000/AF for water purchased through transactions.[8] However, the cost of water for municipal use varies tremendously from state to state and even between neighboring cities. And most households do not pay prices that reflect the true value of the water, including externality costs.[9]

7 Both Colorado Springs' Southern Delivery System and Arizona's Big Chino Ranch Water Project have estimated capital costs in excess of $20,000/AF.

8 Cost estimates are not annualized.

9 Raucher, R.S., D. Chapman, J. Henderson, M.L. Hagenstad, and J. Rice. 2005. *The value of water: Concepts, estimates, and applications for water managers*. Denver: AWWA Research Foundation.

Methodology—reconciling capital costs and annual costs

Water rights and many new water supply projects provide a permanent new water supply in perpetuity. In contrast, a typical power plant would operate for a fixed time horizon—usually 40 to 50 years. Similarly, an electric utility's decision to accelerate the retirement of an older power plant would offer water benefits for a fixed time period.

In order to compare one-time capital investments with annual benefits, we annualized all capital costs. The discount rate and time period varied slightly, depending on the application. For municipal water supplies, for example, we used a 4.46% discount rate and a 30-year period (a typical municipal bond rate structure), the most common way that cities fund new supply projects. For capital investments in agricultural water supplies, we used a 4.75% discount rate (the current interest rate for a USDA Farm Service Agency loan) and a 30-year period. Because cities or other government agencies fund most environmental water supply projects, we used the municipal bond rate structure to annualize environmental investments. For many environmental issues, economists suggest using a lower discount rate, which would effectively increase the annualized value (cost) of the investment.

WRA presents several pricing metrics for municipal water supplies: the prices paid for permanent water transfers, the cost of new supply projects, and municipal tap fees. For each source of data, we calculate the annualized cost of the water (in $2008/AF/yr). We assume that municipalities would fund new supply projects and transfers using municipal bonds; therefore, we use the municipal bond rate, 4.46%, and a 30-year period.[10] Where possible, we also include annual operations and maintenance (O&M) costs in total annual costs (see the sidebar on methodology).

Water Transfers

Market transactions involving water, although relatively uncommon and likely imperfect, can yield insights into the value of water.[11] Water transfers can take two basic forms: short-term leases or permanent sales. Only permanent sales were considered in this analysis, for a number of reasons:

- Comparing temporary transfers to permanent supplies proves challenging because temporary leases provide water for a discreet period of time while new supplies provide water in perpetuity.
- Short-term leases (<5 years) may be skewed by unique circumstances and may not accurately reflect the long-term value of water.[12]
- Permanent sales represent the majority of water transferred (both in terms of the number of transfers and the total volume of water transferred).

We analyzed a dataset of over 1,300 water transactions over the period 1987 to 2008;[13] the data classifies both the seller and the buyer as urban, agricultural, or environmental entities and provides information on the volume of water transferred (a single transaction can transfer any volume of water). Of note, the *Water Strategist* data reflect transactions when first reported (subsequent revisions may not be reflected in the data), and do not include information on the seniority of the water rights. All else being equal,

10 Most municipal bonds have a 30-year period. Source for bond rate: U.S. government bonds. Bloomberg website. http://www.bloomberg.com/markets/rates/index.html.

11 Raucher, R.S., D. Chapman, J. Henderson, M.L. Hagenstad, and J. Rice. 2005. *The value of water: Concepts, estimates, and applications for water managers*. Denver: AWWA Research Foundation.

12 For example, cities may have excess water in one year and lease it to farmers or other cities for a very cheap rate. Source: Personal communication between Patricia Flood, Wright Water Engineers, and Stacy Tellinghuisen, WRA, December 21, 2009.

13 The transactions were recorded by the *Water Strategist* and compiled by researchers at the University of California, Santa Barbara—Donohew, Z. and G. Libecap. Water transfer level data summary. Available at http://www.bren.ucsb.edu/news/water_transfers.htm. Accessed November 20, 2008.

water rights of greater seniority will garner higher prices, and water rights that are closer to the importing region would garner higher prices than those farther away.

Across the region, the price of water rose from 1987 to 2008. The state of Colorado has the most active water market, and provides a good example of how the value of water has changed since 1987 (Figure 1). Prices rose in the late 1990s, most likely driven by population and demand growth along the Front Range, and peaked in 2003, following Colorado's worst drought year on record. This history provides important insight into how the future value of water can be expected to change across the region, as demand rises and/or the supply shrinks.

FIGURE Nº 1 WATER SALES TO MUNICIPALITIES: COLORADO

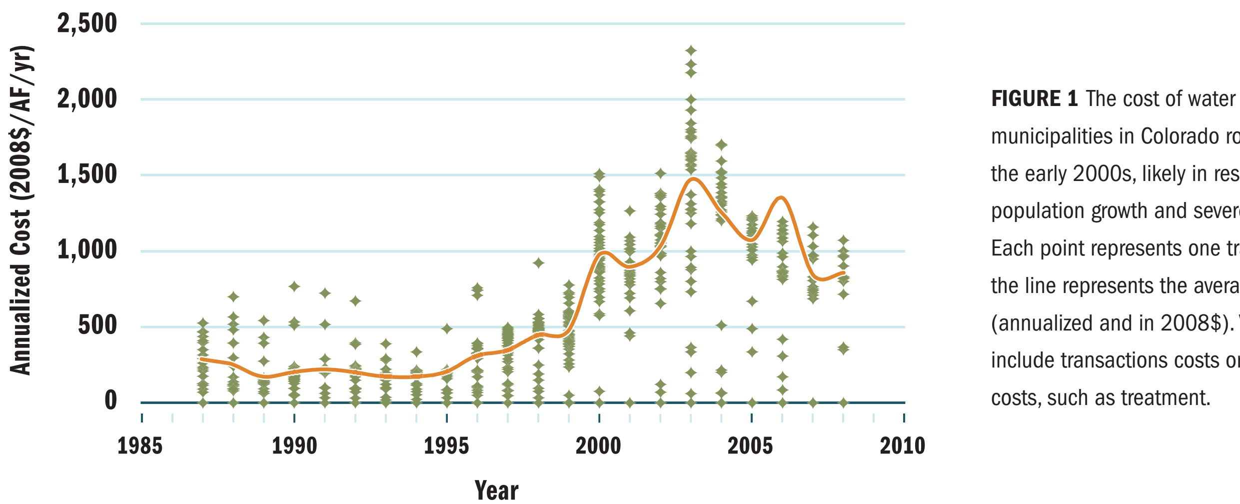


FIGURE 1 The cost of water sold to municipalities in Colorado rose in the early 2000s, likely in response to population growth and severe drought. Each point represents one transaction; the line represents the average sale price (annualized and in 2008$). Values do not include transactions costs or annual O&M costs, such as treatment.

TABLE Nº 1 PROPOSED OR RECENTLY CONSTRUCTED MUNICIPAL WATER SUPPLY PROJECTS.

State	Project	Capital Cost ($)	Annual Yield (AF/yr)	Unit Capital Cost ($/AF*)	Annualized Capital Cost ($/AF)	O&M Costs ($/AF)	Total Annual Cost ($/AF/yr)
Arizona	Big Chino Ranch Water Project[1]	174,800,000	8,700	20,053	1,225	n/a	>1,225
Colorado	Southern Delivery System (Colorado Springs)[2]	1,071,300,000	52,000	20,979	1,259	570	1,829
	Northern Integrated Supply Project (Northern Colorado)[3]	426,000,000	40,000	10,650	651	93	744
	Windy Gap Firming Project (Northern Colorado)[4]	223,400,000	30,000	7,447	455	27	482
	Moffat Expansion Project (Denver)[5]	139,878,000	18,000	7,771	475	n/a	>475
Nevada	Groundwater Development Project (SNWA)[6]	3,500,000,000	250,000†	12,575	768†	313	>1,082†
New Mexico	San Juan-Chama Drinking Water Project (ABCWUA)[7]	400,000,000‡	48,200	8,299	507	420	927
Utah	Lake Powell Pipeline (Washington County)[8]	1,064,550,000	100,000	10,646	650	n/a	>650

1 Elliott D. Pollack & Company. 2008. *Big Chino Water Ranch Project impact analysis.* Prepared for Central Arizona Partnership.

2 U.S. Bureau of Reclamation. 2008. *Southern Delivery System final environmental impact statement*.

3 U.S. Army Corps of Engineers. 2008. *Northern Integrated Supply Project draft environmental impact statement*.

4 U.S. Bureau of Reclamation. 2008. *Windy Gap Firming Project draft environmental impact statement*.

5 U.S. Army Corps of Engineers. 2009. *Moffat Collection System Project draft environmental impact statement*.

6 Southern Nevada Water Authority. 2009. *Update: SNWA Groundwater Development Project activities*. http://www.snwa.com/assets/pdf/wr_instate_presentation.pdf.

7 Albuquerque Bernalillo County Water Utility Authority. 2009. *San Juan-Chama Drinking Water Project one-year anniversary*. http://www.abcwua.org/pdfs/SJCDWPAnniversary.pdf.

8 Utah Division of Water Resources. 2008. Lake Powell Pipeline opinion of probable costs (cost summary table). http://www.water.utah.gov/lakepowellpipeline/projectupdates/June2008OPCCSummary%20r1.pdf.

* These costs are not annualized.

† Southern Nevada Water Authority (SNWA) can use Lake Mead to reclaim and reuse its water supplies until they are fully consumed; we adjusted the total volume delivered and cost/AF based on this, assuming that SNWA customers consumptively use about 60% of water withdrawals. The project, as proposed, would deliver 167,000 AF/yr to SNWA and 33,000 AF/yr to Lincoln County. O&M costs for the Groundwater Development Project include energy costs only, and do not include other O&M costs.

‡ Figure reflects actual costs; all other estimates reflect projected costs. The San Juan-Chama Drinking Water Project was completed in 2009.

FIGURE Nº 2 MUNICIPAL TAP FEES IN THE WESTERN UNITED STATES

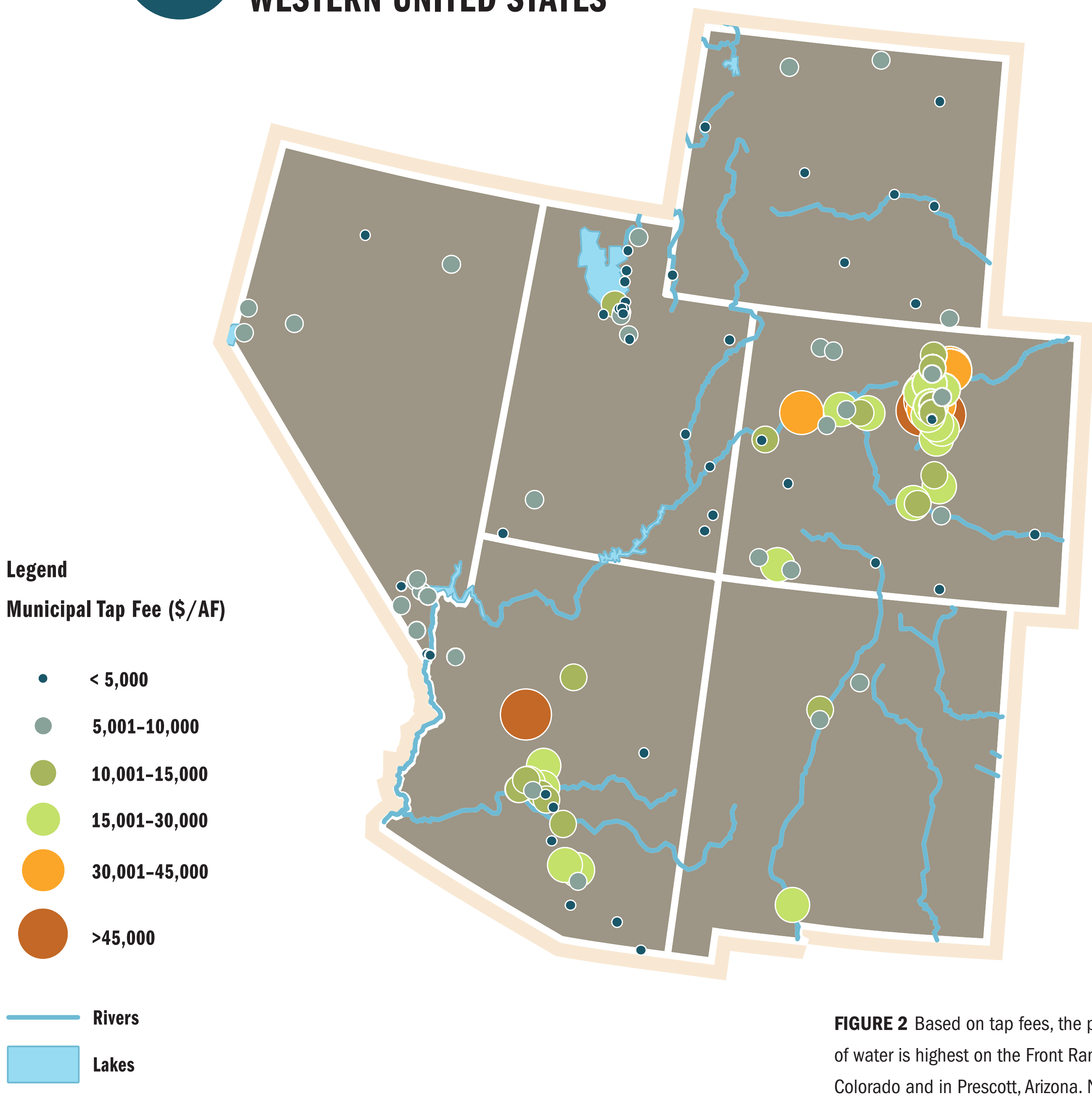


FIGURE 2 Based on tap fees, the price of water is highest on the Front Range of Colorado and in Prescott, Arizona. Note: data points are not annualized, but are adjusted to a common metric ($/AF) based on water use rates in different cities.

New Supply Projects

In almost every western state, cities have recently proposed or constructed new municipal water supply projects.[14] Including annual O&M costs, the annual cost of new supplies is as high as $1,829/AF/yr (Table 1). In every state, the cost of new supply projects is higher than the median price paid to acquire new water rights through market-based transactions.

Municipal Tap Fees

Cities typically levy a "tap fee" on new developments. Tap fees provide a water utility with a stream of revenue to develop new water supplies, purchase new water rights, construct treatment facilities, and, in some places, build wastewater treatment facilities. Some cities levy all of these charges in one, all-inclusive tap fee, while others split the charges into different fees (e.g., a potable water tap fee or a sewer tap fee). In theory, a tap fee guarantees a household as much water as it needs, but cities generally assume a tap fee provides 0.25 to 1.0 AF per household per year. [15] Tap fees present a current, readily comparable data point between different cities and states, but water values inferred from tap fees are not directly comparable with values inferred from water transactions or the cost of new supply projects, in part because they are often a creature of political decisions, and the actual cost of providing water to a new customer may be subsidized by other rate elements. (Cities encouraging growth, for example, may lower tap fees and embed the costs of new supply development in current residents' water rates.) However, tap fees can serve as a useful proxy of the municipal value of water.

Tap fees are two to six times higher in Colorado than in other western states (Figure 2). Tap fees vary tremendously within each state, particularly in Colorado and Arizona. This variability can be attributed in large part to resource scarcity.[16] For example, the median price of a tap fee in Front Range

14 WRA evaluated the projected capital cost and average yields of these projects using data from environmental impact statements, scoping documents, or supporting documents.

15 WRA compiled a dataset of tap fees from 125 cities throughout Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. To determine the volume of water represented by a tap fee, we used city, county, or state planning documents; where planning data were unavailable, we used per capita water use data. The data are from most medium, large, and fast-growing cities, where demand for water is highest; thus, the values may be not be representative of smaller towns throughout the West.

16 The regional differences in tap fees are also likely to be due, in part, to the higher home values and higher wages earned that are typically found in metro areas. For example, see: 1) Glaeser, E.L. and D.C. Mare. 2001. Cities and skills. *Journal of Labor Economics* 19: 316-342; and 2) Nord, M. 2000. Does it cost less to live in rural areas: Evidence from new data on food security and hunger. *Rural Sociology* 65: 104-125.

cities (where demand is high and existing supplies are limited) was $25,400/AF. In contrast, the price of a tap fee in slower-growing rural communities on Colorado's eastern plains or Western Slope was $10,200/AF. Tap fees can vary considerably even between neighboring cities: Broomfield, Colorado charges over four times as much as its neighbor, Denver. Denver has reliable and diverse water supplies, whereas Broomfield has experienced rapid population growth and rising water demands in recent years and has fewer new supply options. In Colorado and Utah, the median cost of tap fees in major population centers is slightly higher than tap fees statewide.[17] For ready comparison with prices of new supply projects and transactions, we annualized the cost of tap fees using a 30-year period and 4.46% discount rate.

17 "Major population centers" include the Wasatch Front in Utah, the Front Range of Colorado, and the Las Vegas Valley in Nevada. We did not disaggregate major metropolitan areas in Arizona because most of the tap fees recorded came from cities within the "Sun Corridor." The price of tap fees in cities along the Wasatch Front in Utah was 26% more than the statewide median, and tap fees in Front Range cities are 45% higher.

FIGURE Nº 3 MUNICIPAL VALUE OF WATER

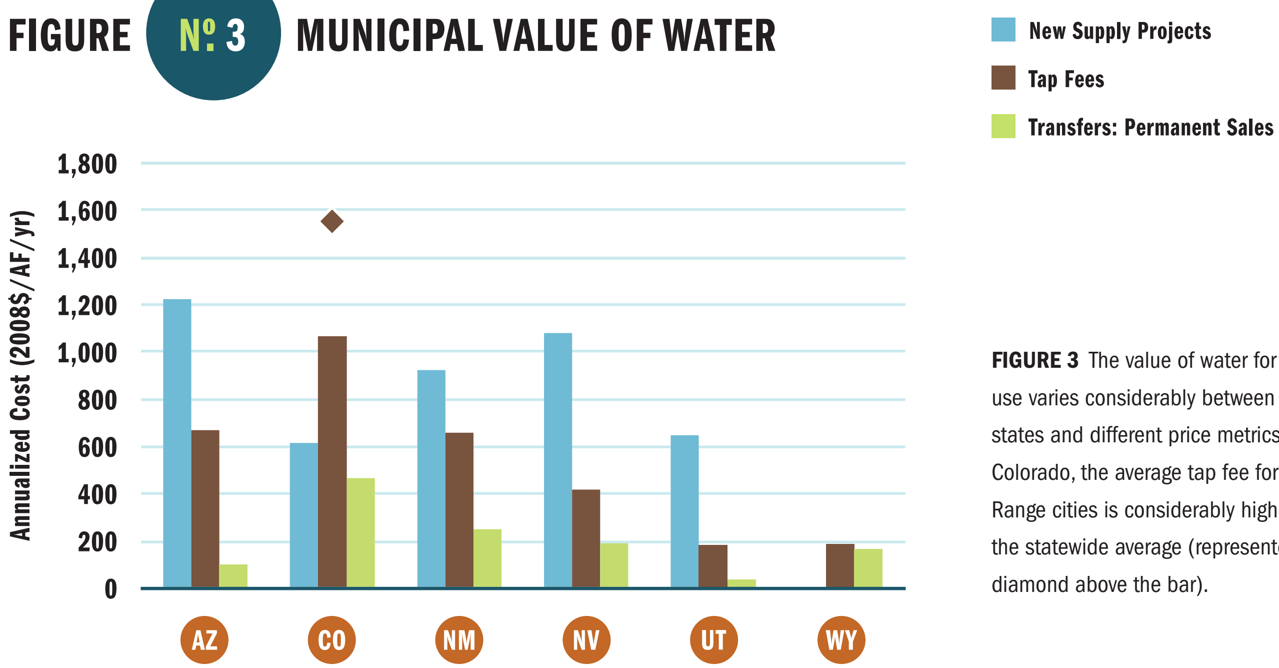


FIGURE 3 The value of water for municipal use varies considerably between different states and different price metrics. In Colorado, the average tap fee for Front Range cities is considerably higher than the statewide average (represented by the diamond above the bar).

Summary

The annual price of municipal water supplies ranges from $41/AF/yr for water transferred in Utah to more than $1,800/AF/yr for new supply projects on the Front Range of Colorado. The price of water varies considerably between data sources, but the trends are consistent: Coloradans, particularly along the Front Range, have the most expensive water, and residents in Wyoming and Utah—where water is generally less scarce economically—have the cheapest water. Figure 3 illustrates the price of water under the three different metrics.

The cost of new supplies exceeds the cost of permanent water transfers, suggesting that water transfers represent a cost-competitive alternative to developing new water supplies.[18] In general, the cost of a tap fee exceeds the median price of water sold through transactions. But tap fees offer an estimate of the current price of water,[19] whereas the transactions dataset includes transfers from 1987 to 2008.[20] Comparing the cost of new supplies with tap fees presents mixed results. In some states, the cost of new supplies exceeds the cost of a tap fee, whereas in others, the price of a tap fee is more than the cost of developing a new supply.[21] Where tap fees do not cover the full cost of a new supply project, cities may rely on water bills, municipal general funds, or other funding mechanisms to pay the difference.

The prices paid for municipal water supplies likely represent the lower bound of the true value of water to cities. Many cities could—and likely would—pay even higher prices to develop new water supplies, if necessary.

18 Water transfers hinge on the ability to physically move water from the seller to the buyer. Transfers often take place within the same basin, which may not require new conveyance infrastructure or conveyance costs. In trans-basin exchanges, cities often rely on infrastructure constructed decades ago; the cost of this infrastructure is a sunk cost and excluded from our analysis. And, in some cases, new supply projects will facilitate future transfers—Colorado Springs' Southern Delivery System (CO) and Aurora's Prairie Waters Project (CO) likely will be used to convey agricultural (or other transferred) water in the future.

19 Tap fee data were from 2008 or 2009.

20 In Colorado, for example, the cost of water purchased through transactions during recent years (2000-2008) is similar to the cost of a tap in 2009. And, as noted earlier, while tap fees are related to the cost of water, they are also a creature of political decisions; the actual cost of providing water to a new customer may be subsidized by other rate elements. Water values inferred from tap fees may not be directly comparable with values inferred from water transactions or the cost of new supply projects.

21 For example, in Utah, the Washington County Water Conservancy District has proposed the Lake Powell Pipeline, which will cost substantially more than tap fees in the county; similarly, the cost per AF of SNWA's Groundwater Development Project exceeds the price of tap fees in SNWA's service area. In Arizona, the median price of a tap fee *statewide* is less than the cost of the Big Chino Ranch Water Project, but tap fees in Prescott, the city served by the project, actually exceed the cost of the project.

Electric utilities likely will site most new plants in rural areas, remote from cities. But increasingly, cities are also tapping water supplies in rural areas, putting them in direct competition with utilities. For example, the Southern Nevada Water Authority has purchased agricultural water in White Pine County (the location of two recently proposed coal plants), nearly 300 miles from the Las Vegas Valley. Over the short term, using water for electricity generation in rural areas competes directly with agricultural uses. But long term, as urban populations grow and cities continue to tap more remote water supplies, water demand for power plants will compete directly with municipal demands.

Many older power plants were built in or near cities. As electric utilities look to retire these older, less efficient plants, opportunities may emerge. For example, Xcel Energy has proposed to retire two coal-fired power plants, Valmont in Boulder and Cherokee in Denver, replacing them with natural gas combined-cycle units, energy efficiency, and other cleaner resources. Retiring these plants could make over 5,200 AF of water available in the Denver metro region at a time when cities are looking to increase supplies. Using the average price of water rights sold in Colorado in 2008, the value of this “new” water would exceed $86 million. Depending on the seniority of the water right and other factors, the value could be much higher.

Agricultural Value of Water

Throughout the West, cities and power plants are increasingly turning to the agricultural sector to meet their growing water demands. New power plants have primarily been proposed in rural areas, such as the lower Arkansas River Valley in southeastern Colorado; White Pine County, Nevada; and in rural Maricopa County, Arizona.[22] In almost every case, the plant proponents would acquire water currently used in agriculture.

Like municipal water costs, the value of water for agricultural use varies tremendously, depending on the scarcity of the resource, the value of the commodity grown, the productivity of the agricultural land, and the cost of using the water, among other factors.[23,24] To estimate the value of water for agriculture, we considered several metrics:

- The price of water rights purchased by farmers through market-based transactions
- The price farmers pay for off-farm sources of water
- Differences in net farm revenues garnered from irrigated crops versus dryland crops
- The difference in land values of irrigated versus dryland farms

Of these, the price paid by farmers for water rights is the metric most directly comparable to the municipal values presented.

Importantly, agriculture provides value that is not adequately measured by economic analyses, like the value of rural communities and lifestyles, the value of open and undeveloped space, and the value of a local food supply,

Agriculture provides value not adequately measured by economic analyses—the value of rural communities and lifestyles, of open and undeveloped space, and of a local food supply, to name a few.

22 Utilities proposing plants at each location are (or were) Tri-State Generation and Transmission (coal), NV Energy and LS Power (two coal plants), and Arizona Public Service/Abengoa Solar (solar).

23 Each of these factors is, in turn, influenced by numerous others. For example, the value of commodities grown is influenced by the cost of fertilizer and pesticides, proximity to marketplaces, and market demand for the commodity.

24 Ward, F. and A. Michelsen. 2002. The economic value of water in agriculture: concepts and policy applications. *Water Policy* 4: 423-446. See also: 1) Pullen, J. and B. Colby. 2008. Influence of climate variability on the market price of water in the Gila-San Francisco basin. *Journal of Agricultural and Resource Economics* 33(3):473-487; 2) Faux, J. and G. Perry. 1999. Estimating irrigation water value using a hedonic price analysis: A case study in Malheur County, Oregon. *Land Economics* 75: 440-452; 3) Bjornlund, H. and P. Rossini. 2006. An empirical analysis of factors driving outcomes in markets for permanent water—An Australian case study. Paper submitted to the 12th Pacific Rim Real Estate Society Conference, Auckland, Australia.

to name a few. A more thorough analysis of the value of water would include consideration of changes to these non-monetary values, as well as the indirect effects that agricultural-to-urban water transfers have on the regional economy.[25]

Colorado has more agricultural land than any other state studied in this report. In addition, the state has seen the most dramatic conversion of water from agricultural uses to municipal uses. Accordingly, a considerable amount of research has focused on the value of water for agriculture and the economic impacts of water transfers. The trends occurring in Colorado, however, are likely to apply to farming communities throughout the region.

Water Transfers

Between 1987 and 2008, water was transferred to agricultural entities through 475 transactions.[26] As with municipal transfers, we only consider permanent sales, which represent less than half of the total transactions, because permanent sales are a better representation of the long-term value of water for agriculture.[27] We annualized the cost of those sales using a 30-year period and a discount rate of 4.75%, the current interest rate for USDA Farm Service Agency loans.[28]

In almost every transaction, water was transferred from one agricultural user to another agricultural user. In addition, almost all of the transactions occurred in Colorado, primarily because the Colorado-Big Thompson (C-BT) Project has created a well-functioning market for water transfers. Across the region, the median, annualized price of water transferred to agriculture was less than $400/AF/year (Figure 4)—considerably lower than typical prices paid by municipalities. In Colorado, the price of water sold to agricultural users increased substantially between 1987 and 2008 (Figure 5), a trend similar to that seen in municipal prices. Of note, market transactions should be interpreted with caution because of the limited market activity and the dependence of water prices on the seniority of the right, among other factors.[29]

25 See, for example: Thorvaldson, J. and J. Pritchett. 2006. Economic impact analysis of reduced irrigated acreage in four river basins in Colorado. Colorado Water Resources Research Institute, Completion Report No. 207.

26 Donohew, Z. and G. Libecap. Water transfer level data summary. http://www.bren.ucsb.edu/news/water_transfers.htm. Accessed November 20, 2008.

27 Young, R.A. 2005. *Determining the economic value of water: Concepts and methods*. Washington, DC: Resources for the Future.

28 U.S. Department of Agriculture Farm Service Agency, Direct Farm Loans Program, http://www.fsa.usda.gov/FSA/webapp?area=home&subject=fmlp&topic=dfl, accessed January 29, 2010.

29 Renzetti, S. 2002. *The economics of water demands.* Boston: Kluwer Academic Publishers.

FIGURE Nº 4 TRANSFERS OF WATER TO AGRICULTURE: PERMANENT SALES

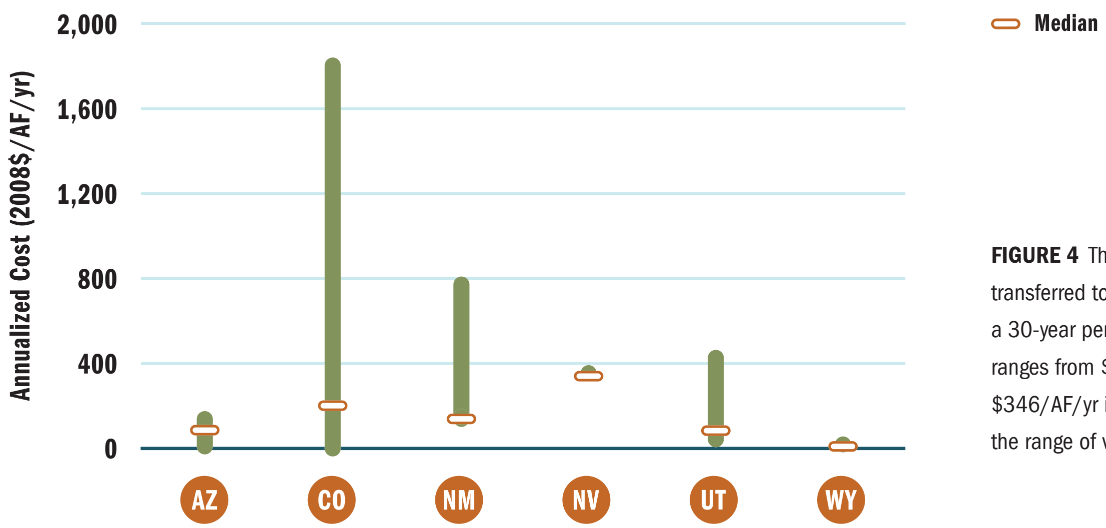


FIGURE 4 The median price paid for water transferred to agriculture, annualized over a 30-year period at a 4.75% discount rate, ranges from \$16/AF/yr in Wyoming to \$346/AF/yr in Nevada. Vertical bars reflect the range of values for a particular state.

FIGURE Nº 5 AGRICULTURAL WATER SALES: 1987–2008

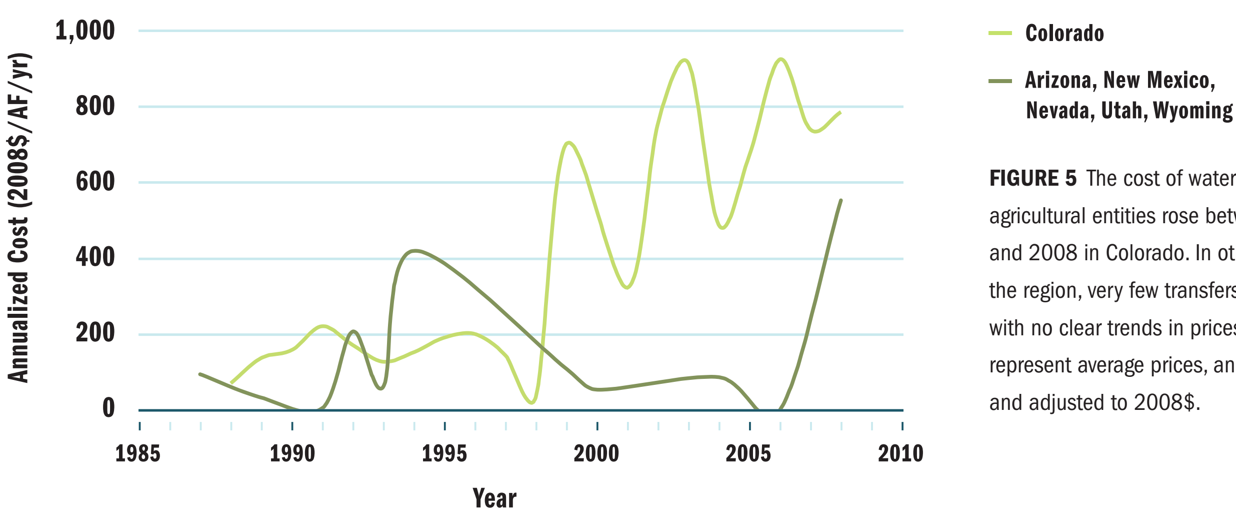


FIGURE 5 The cost of water sold to agricultural entities rose between 1987 and 2008 in Colorado. In other states in the region, very few transfers occurred, with no clear trends in prices. Lines represent average prices, annualized and adjusted to 2008$.

TABLE Nº 2 NET RETURNS PER ACRE-FOOT BY CROP IN COLORADO.

	Net Revenues after Payments to Capital* ($2008/Acre) †	Average Net Irrigation Requirements (AF/acre) ‡	Value of Water for Crop Irrigation § ($2008/AF)
Irrigated sunflower	$ 129.00	1.34	$ 98.62
Dryland sunflower	$ (3.15)		
Difference	*$ 132.15*		
Irrigated corn grain (northeast)	$ (56.12)	1.41	$ (41.67)
Dryland corn grain (northeast)	$ 2.63		
Difference	*$ (58.75)*		
Irrigated corn grain (south, sprinkler)	$ 408.20	1.41	$ 266.06
Dryland corn grain (south, no till)	$ 33.05		
Difference	*$ 375.15*		
Irrigated corn grain (south, flood)	$ 436.05	1.41	$ 285.82
Dryland corn grain (south, no till)	$ 33.05		
Difference	*$ 403.00*		
Irrigated wheat (northeast)	$ 40.16	0.15	$ 279.80
Dryland wheat (northeast, conventional till)	$ (1.81)		
Difference	*$ 41.97*		
Irrigated wheat (northeast)	$ 40.16	0.15	$ 544.73
Dryland wheat (northeast, reduced till)	$ (41.55)		
Difference	*$ 81.71*		

* Capital costs include capital interest, land rent and interest, and hired labor and management.

† Crop enterprise budgets for Colorado were obtained from Colorado State University's Agriculture and Business Management website (http://www.coopext.colostate.edu/ABM/cropbudgets.htm).

‡ Net irrigation requirements for Colorado were obtained from Frank, A. and D. Carlson. 1999. Colorado's net irrigation requirements for agriculture, 1995. Lakewood, Col.: Colorado Department of Agriculture.

§ Calculation reflects the difference in net revenues, after payments to capital, adjusted based on the consumptive use of crops (AF/acre).

Irrigators' Water Costs

In addition to purchasing water rights, irrigators pay annual O&M costs. Irrigation water costs depend on the water source, location, and distribution systems, but generally, are very low. The cost of purchasing a water right dwarfs annual irrigation costs. In 2008, irrigation costs in the six-state region ranged from under $6/AF to $29/AF (see Appendix B for data) — much lower than the cost of acquiring new water rights.[30] The price irrigators pay for water does not reflect the full social cost of its use or water's relative scarcity.[31]

Net Revenues and Land Values

In arid and semi-arid regions, most crop production depends heavily on irrigation. Irrigated land generally produces higher crop yields and revenues, but also often entails greater costs.[32] In Colorado, for example, an irrigated acre of sunflowers generates $129 in net revenue, while a farmer would *lose* $3.15 in revenue for a dry (non-irrigated) acre of sunflowers. Because an acre of sunflowers consumes approximately 1.34 AF of water per year, the value of water used for irrigation is $99/AF.[33] Table 2 lists estimated water values for several other crops in Colorado. Because commodity and input prices fluctuate dramatically throughout time and because each individual agricultural producer has slightly different production practices, the values in Table 2 are only for purposes of comparison.

30 U.S. Department of Agriculture. 2008. Table 22 – Expenses for irrigation water from off-farm suppliers: 2008 and 2003. In *2008 farm and ranch irrigation survey*. Washington, DC: U.S. Department of Agriculture. Available at **http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Farm_and_Ranch_Irrigation_Survey/index.asp**.

31 Gollehon, N., W. Quinby, and M. Aillery. 2002. *Agricultural resources and environmental indicators: Water use and pricing in agriculture*. Economic Research Service Publication No. AH772. Washington, DC: U.S. Department of Agriculture.

32 See, for example: 1) U.S. Water Resources Council. 1983. *Economic and environmental principles and guidelines for water and related land resource implementation studies.* Washington, DC: Government Printing Office; 2) Supalla, R., T.V. Buell, and B. McMullen. 2006. *Economic and state budget cost of reducing the consumptive use of irrigation water in the Platte and Republican Basins*. Lincoln, Neb.: University of Nebraska, Agricultural Economics Department; 3) Lacewell, R.D., J.M. Sprott, and B.R. Beattie. 1974. *Value of irrigation water with alternative input prices, product prices, and yield levels: Texas high plains and Lower Rio Grande Valley*. Report TR-58. College Station, Tex.: Texas Water Resources Institute. Available at **http://twri.tamu.edu/publications/reports/1974/tr-58**.

33 Calculation: ($129 – (-$3.15))/1.34 AF = $99/AF

In addition to the value the water adds to crop production, irrigated land also has a higher land value than non-irrigated agricultural land.[34] In Colorado, irrigated land is worth an estimated $2,500/acre *more* than non-irrigated cropland, and provides an additional $91/acre in land rent value (see Appendix B).[35] Adjusting for crop acreages and consumptive water use, these correspond to values of $2,080/AF and $76/AF, respectively.[36] While this approach does not control for other factors that affect agricultural land values, such as soil productivity, average rainfall, access by paved roads, and competing demands for other uses, it does provide a useful benchmark of the contribution of irrigation water. [37]

Summary

As with municipal water values, the value of water for agriculture varies widely across the six-state region. Farmers pay exceptionally low prices to develop and use water, though the cost of acquiring new water rights can be expensive—farmers paid as much as $1,000/AF/yr in several instances in Colorado. And in Colorado, the added value of irrigation water—in terms of net revenues—is comparable to the cost of new water rights. However, regardless of the data source for measuring the value of water to farming, prices paid by agriculture are much lower than those paid by municipalities and urban households. These prices simply reflect direct market transactions, externalizing broader values associated with open space, food and fiber production, and other amenity and existence values.

34 Torell, A., J. Libbin, and M. Miller. 1990. The market value of water in the Ogallala Aquifer. *Land Economics* 66(2): 163-175. Smith, D.H., K. Klein, R. Bartholomay, I. Broner, G.E. Cardon, D.F. Champion, R. Curtis, et al. 1996. *Irrigation water conservation: opportunities and limitations in Colorado—A report of the Agricultural Water Conservation Task Force*. Completion Report No. 190. Fort Collins, Colo.: Colorado State University, Colorado Water Resources Research Institute.

35 National Agricultural Statistics Service and Colorado Department of Agriculture. 2009. *Colorado agricultural statistics, 2009*. Lakewood, Colo.: U.S. Department of Agriculture, National Agricultural Statistics Service.

36 Acreage and land value data were obtained from the *Colorado agricultural statistics, 2009* bulletin and the net irrigation requirements were obtained from Frank, A. and D. Carlson. 1999. *Colorado's net irrigation requirements for agriculture, 1995*. Lakewood, Colo.: Colorado Department of Agriculture.

37 Tsoodle, L.J., B.B. Golden, and A.M. Featherstone. 2006. Factors influencing Kansas agricultural farm land values. *Land Economics* 82(1): 124-139. Nickerson, C. 2005. Land use, value, and management: agricultural land values. USDA Economic Research Service website. Lichty, R.W. and C.L. Anderson. 1985. Assessing the value of water: Some alternatives. *Journal of Regional Policy and Analysis* 15(2): 39-51. Further support for this concept stems from research from the 1980s, which found that water represented 30% to 60% of the total price paid for irrigated farms sold in five states overlying the Ogallala Aquifer. See: Smith, D.H., K. Klein, R. Bartholomay, I. Broner, G.E. Cardon, D.F. Champion, R. Curtis, et al. 1996. *Irrigation water conservation: opportunities and limitations in Colorado—A report of the Agricultural Water Conservation Task Force*. Completion Report No. 190. Fort Collins, Colo.: Colorado State University, Colorado Water Resources Research Institute. National Agricultural Statistics Service and Colorado Department of Agriculture. *Colorado agricultural statistics, 2009*. Lakewood, Colo.: U.S. Department of Agriculture, National Agricultural Statistics Service.

Mountain lake, CO

Environmental Value of Water

Leaving water instream provides a host of benefits: it supports recreation, sustains healthy ecosystems, improves water quality, and offers other, aesthetic benefits. While water supplies have traditionally been allocated without regard for instream values, all western states now recognize that instream flows qualify as a beneficial use, and many have an established instream flow program managed by a state agency. [38] As populations and incomes rise, the value of water left instream is expected to continue to rise.[39]

Monetizing the value of instream or environmental flows proves more challenging than estimating the value of water for municipal or agricultural needs. Valuing instream flows is a relatively new practice, and estimates of the value of these flows are scarce. Outdoor recreation, such as fishing and whitewater rafting, provides a large (and growing) source of income throughout western states, but attributing that income to a volume of water proves difficult. And many of the benefits of instream flows, e.g., a healthy riverine ecosystem, are not yet adequately measured by economic analyses.

Because of these challenges, much of our analysis of the value of instream flows is qualitative. We present several estimates of the value of water left instream: the water transactions database, the cost of constructing environmental pools in new reservoirs, the value of instream flows to recreation, and prior non-market valuation studies. We calculate the annualized value of a permanent new environmental supply using a 30-year period and a 4.46% discount rate.[40]

38 Gibbons, D. C. 1986. *The economic value of water*. Washington, DC: John Hopkins University Press for Resources for the Future. MacDonnell, L. 2009. Environmental flows in the Rocky Mountain west: A progress report. *Wyoming Law Review* 9: 335-396.

39 MacDonnell, L. 2009. Environmental flows in the Rocky Mountain west: A progress report. *Wyoming Law Review* 9: 335-396.

40 This is the current municipal bond rate; we assume that environmental projects (e.g., environmental pools in new reservoirs and the construction of whitewater parks) are likely to be funded with state and local bonds.

Water Transfers

Market-based transfers of water to environmental uses are uncommon, and likely an imperfect measure of the true value of instream flows. From 1987 to 2008, the *Water Strategist* recorded 143 transactions in which agricultural or municipal entities transferred water to environmental purposes; of these, fewer than half were permanent sales. For comparison, over the same time period, water was transferred to urban users in over 1,300 transactions, and nearly all of the transactions were permanent sales. For environmental uses, leases have been more common than permanent sales for several likely reasons: temporary leases often face less community resistance than permanent sales; the owner of the water right may garner rent payments from a temporary lease, while retaining the option to use the water again or sell it to a higher bidder in future years; and a temporary lease avoids the water court process, which often includes expensive legal, hydrological, and engineering fees.[41] Because the majority of environmental transactions take the form of temporary leases, they are included in the analysis.

FIGURE Nº 6 WATER TRANSFERS TO ENVIRONMENTAL USES

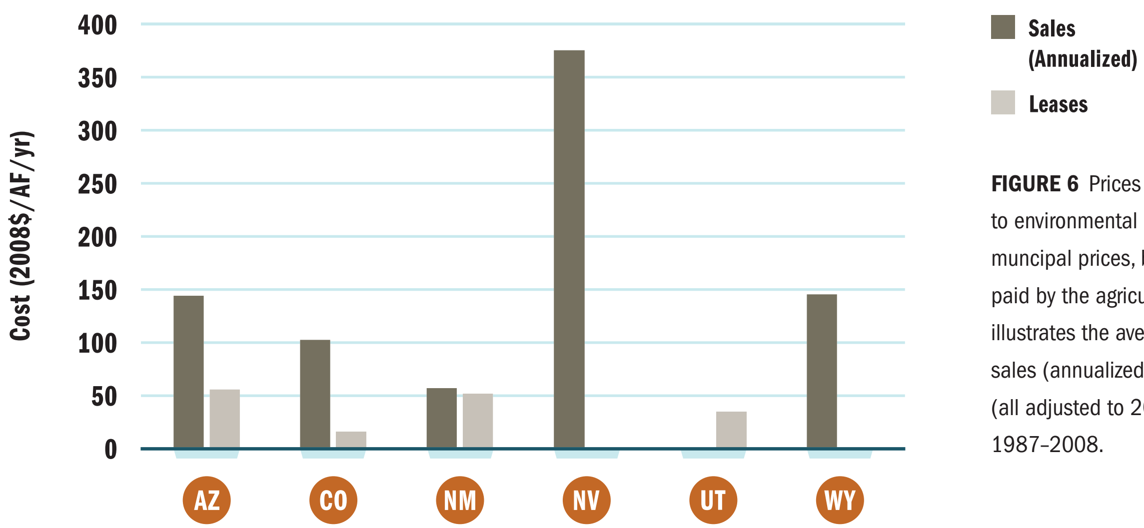


FIGURE 6 Prices paid for water transfers to environmental uses are lower than muncipal prices, but comparable to prices paid by the agricultural sector. Graph illustrates the average price of permanent sales (annualized) and temporary leases (all adjusted to 2008$) over the period 1987–2008.

41 Malloch, S. 2005. *Liquid assets: Protecting and restoring the West's rivers and wetlands through environmental water transactions*. Arlington, Va.: Trout Unlimited. Many of these reasons may make agriculture-to-urban water leases more common as well; however, environmental water leases may face more notable community resistance in some places.

The majority of transfers occurred in Colorado, New Mexico, and Nevada, with temporary leases dominating in Colorado and New Mexico. Based on the limited data available, the median and average prices for temporary leases were below $65/AF/yr. Nevada, where sales dominated, represents the key exception, with an annualized median cost of water transferred of $377/AF (Figure 6).[42] Of note, recent studies have found that non-market valuation techniques for recreation are providing estimates fairly close to what public agencies are actually paying for instream flows for recreation.[43]

Environmental Pools in New Supply Projects

Several of the new water supply projects proposed or constructed in recent years include environmental "pools." Such pools designate a specified volume of reservoir capacity for environmental purposes. These dedicated pools store water that can be released to maximize environmental benefits, by increasing flows during the peak runoff or improving base flows during low flow periods. Often federal or state government agencies, municipal water utilities, and environmental groups pay for a portion of the total reservoir costs in exchange for an environmental storage pool.

In Colorado, several reservoirs have environmental pools dedicated to the recovery of endangered species in the Colorado River. Elkhead Reservoir, expanded at a total cost of $31 million, stores 5,000 AF for environmental releases to benefit low flows on the Yampa River. The Upper Colorado River Endangered Fish Recovery Program paid for 43% of the reservoir expansion, at an annualized cost of $166/AF/yr.[44] Ruedi and Granby Reservoirs will, combined, store 10,825 AF for environmental releases. Both Front Range and Western Slope water providers will permanently supply the water and fund the program, at a projected annualized cost ranging from $72 to $302/AF/yr.

Environmental pools have also been created in other states. The state of Wyoming enlarged the Pathfinder Reservoir in order to provide environmental flows for endangered species in the Platte River. The reservoir expansion, which stemmed from the Pathfinder Modification Stipulation (*Nebraska v. Wyoming*), cost $10 million; the annualized cost of the environmental pool is approximately $17/AF/yr. And, in New Mexico, the city of Albuquerque, the Albuquerque-Bernalillo County Water Utility Authority, and environmental groups paid to create 30,000 AF of storage space in the Abiquiu Reservoir. The environmental pool, which has not yet

42 Figures calculated from 23 sales (with price data) to environmental entities.

43 Loomis, J.B., K. Quattlebaum, T.C. Brown, and S.J. Alexander. 2003. Expanding institutional arrangements for acquiring water for environmental purposes: Transactions evidence for the western United States. *Water Resources Development* 19(1): 21-28.

44 Colorado River Water Conservation District. 2006. Elkhead Reservoir englargement. http://www.crwcd.org/media/uploads/Elkhead_fact_sheet_9_06.pdf.

been filled with water, will be used to restore the Silvery Minnow in the Rio Grande.

In recent years, agencies have re-operated dams to improve environmental flows: Flaming Gorge (Wyoming) was re-operated to improve flows for endangered fish in the Green River; the Aspinal Unit (Colorado) was re-operated to mimic the natural hydrograph in the Gunnison River; and the U.S. Bureau of Reclamation has released scouring "pulse flows" from Glen Canyon Dam, with the goal of improving habitat in the Grand Canyon. These re-operations may have embedded costs, like lost revenues from hydroelectric generation, but also often create benefits for multiple constituencies. And the environmental flows typically vary from year to year. For these reasons, we have not attempted to quantify the environmental cost of reservoir re-operations, but note that it serves as another indicator of the value of environmental flows.

TABLE Nº 3 THE VALUE OF COMMERCIAL RAFTING

The value of commercial rafting varies considerably between different rivers in the state of Colorado.†

River	Seasonal Flow (AF)*	Expenditures–Rafting ($)	Rafting–$/AF
Arkansas	51,210	$ 25,263,757	$ 493
Colorado-Glenwood	267,975	$ 6,674,080	$ 25
Green/Yampa	212,835	$ 1,380,686	$ 6
Cache La Poudre	18,165	$ 3,678,670	$ 203
Taylor	20,865	$ 1,611,422	$ 77

* Heading adapted from a table by Loomis (2008).†

† Loomis, J. 2008. *The economic contribution of instream flows in Colorado: How angling and rafting use increase with instream flows*. Fort Collins, Colo.: Colorado State University, Department of Agricultural and Resource Economics. Available at http://dare.colostate.edu/pubs/edr08-02.pdf.

Water-Based Recreation

Although recreational participation and expenditure data do not directly translate into instream flow values, they indicate the magnitude of the industry and its dependence on instream flows. Several measures point to the tremendous value of water for recreation. Rivers like the Arkansas and Cache la Poudre, located close to major population centers in Colorado, generate the most revenue for commercial rafting operations (Table 3).[45] Importantly, higher flows translate into larger economic benefits for the commercial rafting industry.[46] The value of water for commercial rafting on the Arkansas and the Cache la Poudre is significantly higher than prices paid in environmental transactions.

In the six states in this study, an estimated 1.7 million people fished and another 1.1 million people participated in rafting, kayaking, canoeing, or other

45 An enormous volume of water flows down rivers like the Colorado each year, making the value of recreation per AF very low. For example, over the period 1967-2009, the USGS' measured average runoff on the Colorado River at the USGS gauge below Glenwood Springs is over 2.4 million AF/yr. Source: U.S. Geological Survey website. USGS surface-water data for Colorado. http://waterdata.usgs.gov/co/nwis/sw. Accessed January 4, 2010.

46 For fishing, the optimal flow is approximately 70% of bankfull stage. Beyond 70%, the value decreases due to the fact that at higher flows, rivers become muddy and less ideal for fishing (Loomis, 2008).

water-based recreation in 2005.[47] Participation and revenue generated from whitewater sports, such as rafting and kayaking, depends upon adequate stream flows: during Colorado's 2002 drought, commercial rafting user days fell 40% and user expenditures fell 39%, compared to the previous year.[48] Water instream translates directly into higher revenues for the recreation industry.

Fishing also provides valuable economic revenues. In general, the economic benefits of fishing correspond directly to the number of user days. In 2006, the six-state study area saw over 20 million "fishing days" and almost $2.9 billion ($2006) in total economic revenues (including trip expenditures

TABLE Nº 4 ECONOMIC IMPACT OF FOUR WHITEWATER PARKS IN COLORADO AND THE VALUE OF THE ASSOCIATED WATER

City	Park	Economic Impact ($/yr)*	Water Right (AF/yr)†	Value of Water ($/AF/yr)
Breckenridge [a]	Whitewater Kayak Park	1,364,000	91,061	15
Golden [b]	Clear Creek Whitewater Park	2,535,000	75,701	33
Steamboat Springs [c]	Steamboat Springs Boating Park	7,913,000	71,000	115
Vail [d]	Vail Whitewater Park	850,000	110,162	8

* The economic impact value represents the largest estimated potential annual impact of each whitewater park.

† Based on absolute water right decree, calculated from flow requirements, in cubic feet per second (cfs).

[a] Raucher, R., J. Whitcomb, and T. Ottem. 2002. The beneficial value of waters diverted in the Blue River for the Breckenridge Whitewater Park and in Gore Creek for the Vail Whitewater Park. Boulder, Colo.: Stratus Consulting.

[b] Hagenstad, M., J. Henderson, R. Raucher, and J. Whitcomb. 2000. Preliminary evaluation of the beneficial value of waters diverted in the Clear Creek Whitewater Park in the City of Golden. Boulder, Colo.: Stratus Consulting.

[c] Raucher, R., J. Whitcomb, J. Henderson, and J. Rice, 2005. The potential beneficial values of waters diverted in the Yampa River for the Steamboat Springs Boating Park. Boulder, Colo.: Stratus Consulting.

[d] Hagenstad, M., J. Henderson, R. Raucher, and J. Whitcomb, 2000. Preliminary evaluation of the beneficial value of waters diverted in the Clear Creek Whitewater Park in the City of Golden. Boulder, Colo.: Stratus Consulting.

47 Data compiled from the Outdoor Industry Foundation. 2006. *State by state active outdoor recreation economy report*. Available at http://www.outdoorindustry.org/research.php?action=detail&research_id=52.

48 Colorado River Outfitters Association. 2009. 2009 commercial river use in the state of Colorado. Available at http://www.croa.org/site/plan-your-adventure/commercial-river-use-in-the-state-of-colorado.html. Accessed November 2, 2010.

and equipment purchases).[49] Although Colorado saw the most fishing days, fishing represents a major source of economic activity in all six states. Again, it is difficult to ascribe a dollar value per unit of water for fishing.

Instream flows benefit not just the commercial rafting or fishing industry, but often the local economy as well. Many of Colorado's whitewater parks have recreational in-channel diversion (RICD) water rights that provide for flows through the park during certain times of year. The parks provide millions of dollars in direct, indirect, and induced benefits. For instance, Steamboat Springs' whitewater park generates an estimated $7.9 million dollars annually and has an associated water right of over 70,000 AF/year. The value of that water right, accordingly, is approximately $115/AF/yr (Table 4). Unlike municipal and agricultural uses, such instream flow rights are almost entirely non-consumptive, leaving the water available for other downstream uses.

Non-Market Valuation Studies

Instream uses of water are non-consumptive in nature, often benefitting recreational and environmental users. Because market-based transfers from municipal or agricultural uses to environmental needs are rare, economists have often relied on non-market methods to determine the value of water left instream. The willingness to pay (WTP) for instream flows is very site-specific; for example, through surveys conducted in 1995 and 1996, residents of New Mexico were willing to pay $75/AF ($2008) to improve flows on the Gila, Pecos, Rio Grande, and San Juan Rivers, but just $34/AF ($2008) to improve flows on the Middle Rio Grande River.[50] The willingness to improve or preserve instream flows in pristine headwaters streams—prized for recreation and other environmental values—may be higher than the WTP for instream flows on remote or degraded stretches.

Non-market valuation studies indicate that the value of water for environmental uses often exceeds the price paid in market transactions. For example, a recent study estimates that residents of Fort Collins, Colorado were willing to pay, on average, $234 per year to avoid a 50% reduction in instream flows in the Cache la Poudre River during April to September. This translates to $171/AF/yr on the Cache la Poudre.[51]

49 U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Census Bureau. 2006. *2006 national survey of fishing, hunting, and wildlife-associated recreation*. Report FHW/06-NAT. http://www.census.gov/prod/2008pubs/fhw06-nat.pdf.

50 Berrens, R.P., A.K. Bohara, C.L. Silva, D. Brookshire, and M. McKee. 2000. Contingent values for New Mexico instream flows: With tests of scope, group-size reminder and temporal reliability. *Journal of Environmental Management* 58: 73–90.

51 Loomis, J. 2008. *Estimating the economic benefits of maintaining peak instream flows in the Poudre River through Fort Collins, Colorado*. Fort Collins, Colo.: Colorado State University, Department of Agricultural and Resource Economics. http://www.fcgov.com/nispreview/pdf/loomis_report.pdf.

Summary

Market transactions, investments in environmental "pools," the value of water-based recreation, and non-market based valuation studies are useful measures for beginning to quantify the value of instream flows, but they likely underestimate the full value. For example, they do not quantify the value of ecological services. Additionally, both market-based and non-market valuation studies reflect the *anthropogenic* value of the environment, but may not reflect broader environmental values.

Although the value of water left instream is challenging to quantify, it is clearly much greater than zero (Figure 7). Environmental water transfers cost nearly $400/AF/yr in Nevada, though in most of the states surveyed, prices were below $200/AF/yr. As with municipal and agricultural uses, the value depends on the location of the stream and a host of other factors; instream flows in pristine headwaters streams with a robust recreational industry will likely have a higher value than flows in degraded streams distant from population centers. Importantly, instream flow rights are non-consumptive, and do not preclude other downstream uses for municipal or agricultural needs.

FIGURE Nº 7 ENVIRONMENTAL USES: VALUE OF WATER

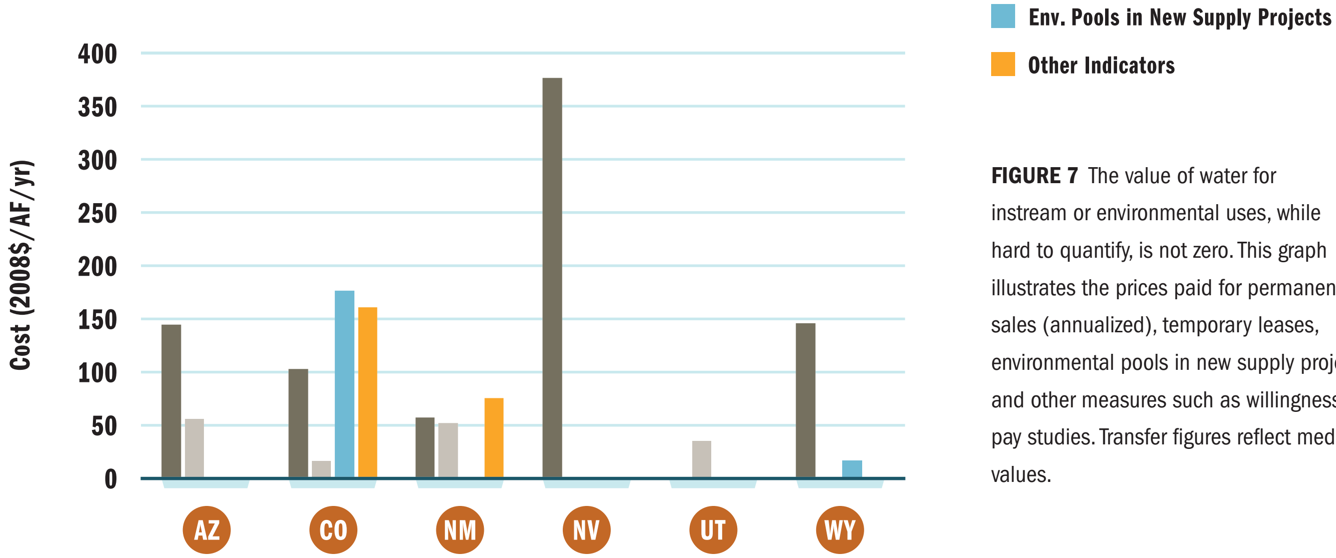


FIGURE 7 The value of water for instream or environmental uses, while hard to quantify, is not zero. This graph illustrates the prices paid for permanent sales (annualized), temporary leases, environmental pools in new supply projects, and other measures such as willingness to pay studies. Transfer figures reflect median values.

A Comparison of Municipal, Agricultural, and Environmental Values

In comparing the value of water for different uses across the West, one conclusion emerges: the value varies tremendously. Despite the range of values represented by different data sources, for different uses, and in different locations, water clearly has high value and is likely to increase in value in the future. Today, the prices paid by municipalities to develop water exceed the prices paid by agriculture. Municipal prices also exceed those paid for environmental uses (Figure 8), though, for many reasons, prices paid for environmental uses may underestimate the true value of the resource (which may provide numerous other benefits, including ecosystem services).

Many of the metrics used to measure the value of water have shortcomings; however, they provide a useful starting point for integrating the value of water into electric resource planning. In the next section, we describe electric utilities' current strategies for valuing water and opportunities for regulators to consider water in evaluating utilities' resource plans.

FIGURE Nº 8 THE VALUE OF WATER IN THE WEST

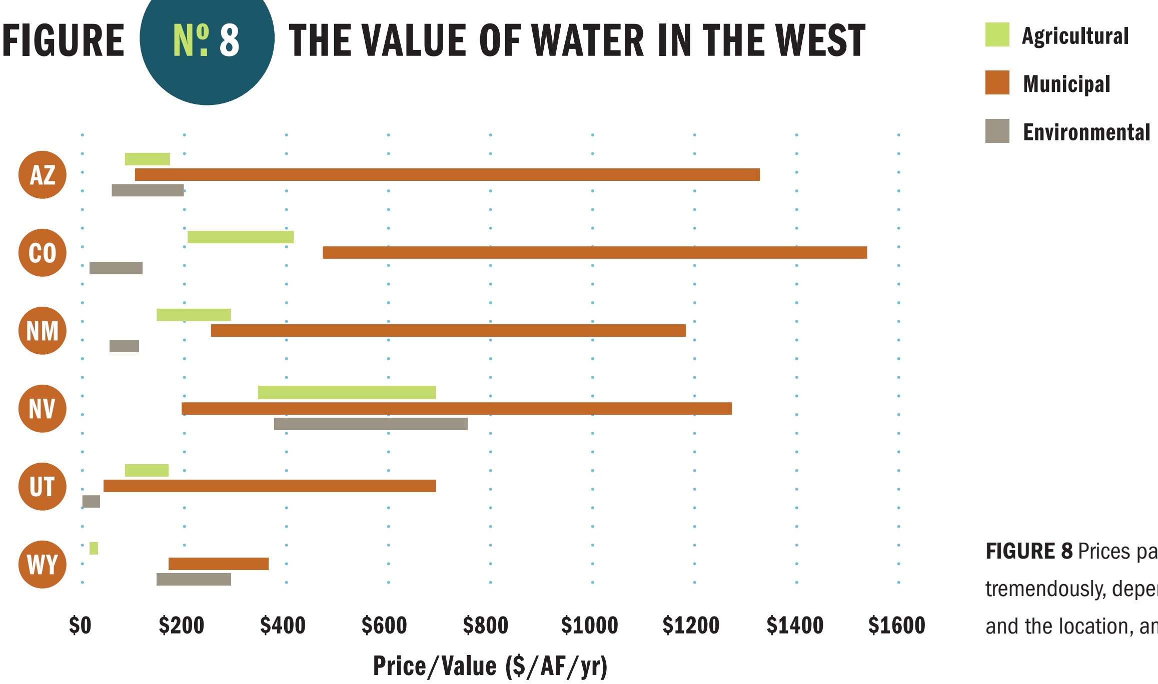


FIGURE 8 Prices paid for water vary tremendously, depending on the type of use and the location, among other factors.

Electric Utilities' Valuation

Across the region, electric utilities integrate water into resource planning to varying degrees. In Arizona, where drought and water scarcity have a long history, utilities place a strong emphasis on water efficiency. In other parts of the West, water has only recently emerged as an important consideration. For most utilities, many other factors—fuel costs, reliability, integration, and CO_2 emissions, to name a few—still dwarf the issues surrounding water. But that's changing.

In the following sections, we describe how most utilities value water today and highlight the differences in utilities' consideration of water. In addition, we review public utility commissions' authority to consider water—along with other environmental factors—in evaluating utilities' resource plans. For most western utilities, water has influenced past decisions about energy generation; we describe several of these cases, which turn on both economic and non-economic issues.

Our information stems from a series of interviews and conversations with high-level managers at each of the electric utilities. Many utility representatives noted that the monetary value of water is implicit in a resource planning decision; it is embedded in the capital or operating cost of a power plant. Therefore, we present data on the costs (both capital and operating) of different cooling technologies at the end of the section.

Integration of Water in Resource Planning

For most western utilities, water is not a significant economic consideration in the long-range resource planning processes, when a utility evaluates demand, supply, and reliability, among other factors. As utilities move from long-range planning to plant siting, water becomes a bigger consideration. A utility typically evaluates potential locations for building a resource, considering the cost of water, the cost of accessing fuel supplies or transmission, land availability, and air quality issues. Once a utility decides to construct a new plant, water becomes an explicit economic factor. When making water supply decisions, most utilities only calculate capital and O&M costs, but do not take into account opportunity costs or externalities and, as a result, typically undervalue water resources. [52]

Water is one of several factors, like access to transmission lines and available land, that can impact a project's viability. Adequate water supplies must be reliable and affordable, but also must be attainable within a reasonable time frame. Other, more subjective questions can also influence the choice of resource and cooling technology. For example, would the public utility commission approve a project using large amounts of freshwater? Would relying on wet cooling create tremendous opposition to the project? Would using recycled water (if available) reduce opposition? Would developing a plant require the utility to go to water court in order to acquire or change a water right? The relative importance of each of these questions varies from state to state.

Public utility commissions typically have jurisdiction over electric utilities' integrated resource planning processes and issue permits for power plants or transmission lines. The extent to which water is considered by electric utilities is driven, in large part, by PUC regulations, which vary considerably from state to state. PUC regulations and past decisions directly influence electric utilities' resource planning processes. In the following pages, we outline each PUC's authority and major electric utilities' current practices in Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming.

Arizona

Of all western utility commissions, the Arizona Corporation Commission (ACC) has taken the most direct approach toward integrating water issues into electric resource planning. In 2001 and 2002, the ACC denied permits for the proposed Toltec Power Station and Big Sandy power plant, both gas-fired merchant plants, in part due to potential impacts on groundwater.[53] In 2005, as part of a settlement on a rate-making case, the ACC ordered Arizona Public Service (APS) to consider the feasibility of expanding utility-scale solar generation at existing coal-fired power plants, noting the environmental benefits of potential water savings associated with solar generation.[54]

Most recently, the ACC has proposed a rulemaking regarding resource planning that would require regulated utilities to consider the cost of externalities, including power plant water use, among other factors.[55] The

52 Rogers, P., R. Bhatia, and A. Huber. 1998. *Water as a social and economic good: How to put the principle into practice.* Stockholm, Sweden: Global Water Partnership, Technical Advisory Committee. Background Paper No.2.

53 Arizona Corporation Commission. Big Sandy doesn't fly. Press release from ACC, November 26, 2001. http://www.azcc.gov/divisions/utilities/news/pr01-31-02.htm.

54 In re Arizona Public Service, Docket No. E-01345A-03-0437 (April 7, 2005).

55 In re Proposed Rulemaking Regarding Resource Planning, Docket No. RE-00000A-09-0249, Decision No. 71435 (Dec. 15, 2009).

Solar panels and power plant, AZ

proposed rule would require utilities to report water consumption and water use rates for both existing facilities and future resource plans. It would also require utilities to develop a plan to reduce environmental impacts, such as air emissions, solid waste, and water consumption.[56]

APS also has the most advanced approach for integrating water into its resource planning relative to other western utilities. APS began reporting water consumption for the energy portfolios evaluated in 2009, but even before that, water played an important role in the utility's resource planning. APS' Palo Verde nuclear plant relies on treated wastewater from the city of Phoenix; according to APS, when the plant was designed in 1973, recycled water was the only viable, reliable supply of water for the plant, and APS constructed a 36-mile pipeline to convey water from the treatment plant to Palo Verde. The utility now assumes that a new, combined-cycle gas plant must rely on dry cooling or alternative supplies, like recycled water, and that the current ACC would not likely approve a wet-cooled gas plant.[57] But, according to APS, the ACC's stance on cooling technologies for new baseload power supplies, such as coal, nuclear, or solar thermal plants, is less clear; indeed, the Arizona Power Plant and Transmission Line Siting Committee[58] recently approved Abengoa Solar's plans to construct a wet-cooled solar thermal plant in southwestern Arizona.[59]

The Salt River Project (SRP) provides both electricity and water services to the Phoenix metropolitan area. SRP's integration of water into its energy planning is less formal than that of APS. For example, SRP's board approves new resource acquisitions; according to SRP staff, the board would review the availability and reliability of the water supplies for any new, water-intensive power plant. But unlike APS, SRP does not explicitly report water

56 Id. (proposed rule 14-2-703.D).

57 Personal communication between Robert Lotts, APS, and Stacy Tellinghuisen, WRA, December 18, 2009 and October 7, 2010.

58 The ACC established this committee in 1971.

59 ACC Decision 70638. The solar plant will rely on water transferred from agriculture.

consumption for different portfolios.[60] SRP considers the cost of acquiring new water supplies in its resource planning and siting processes, along with the political, environmental, and social aspects of acquiring those supplies, but it does not model an explicit monetary value of water in evaluating resource choices.

Colorado

Wind turbines, AZ

Colorado voters enacted the state's first renewable electricity standard when they passed Amendment 37, which noted that the benefits of renewable energy include minimizing water use for electricity generation and improving the natural environment of the state.[61] The Colorado PUC may consider the benefits to the state's water resources of the acquisition of renewables, energy efficiency, and new energy technologies.[62] In addition, the PUC allows utilities to evaluate and rank competitive solicitations for renewable sources of energy, taking into account the cost of the energy *and* other factors that may impact the bidder's ability to fulfill the terms of the bid, including the amount of water used.[63]

Water has influenced recent PUC decisions. In the resource plan filing in 2007 by Public Service Company of Colorado (PSCo), a subsdiary of Xcel Energy, the PUC approved PSCo's preferred resource plan, in part because of the benefits to the state's water resources. The PUC stated that "Public Service's proposal to address emissions (NO_x, SO_x, mercury, and particulates) and water through their costs being imbedded in generation resource bids is an appropriate first step in factoring externalities in resource planning."[64] In 2009, PSCo evaluated bids for new resources and selected a dry-cooled, 250-MW solar thermal plant.[65] The company considered externalities—including water—in evaluating the bids. Although the company did not quantify the value of water in its decision, it did perform a qualitative evaluation. Additionally, PSCo noted that the cost of acquiring water (or alternative cooling systems) is embedded in the cost of the resource.[66]

60 SRP, like other utilities, is required to report water withdrawals and consumption for individual large power plants to federal agencies. Personal communication between Charlie Duckworth, SRP, and Stacy Tellinghuisen, WRA, January 5, 2010 and October 7, 2010.

61 Amendment 37, 2004. The Colorado Public Utility Commission (PUC) incorporated language from Amendment 37 into its code of regulations. See 4 C.C.R. 723-3, Rule 3651.

62 C.R.S. §§ 40-2-123(3)(b)(III) , 40-2-124(1).

63 4 C.C.R. 723-3, Rule 3655(m).

64 Docket No. 07A-447E, Decision No. C08-0929, paragraph 238, p. 75.

65 Public Service Company of Colorado. 2009. *2009 all-source solicitation 120-day report*. Available at http://www.xcelenergy.com/Colorado/Company/About_Energy_and_Rates/Energy RFPs/Pages/2009PSCoAll-SourceRFP.aspx.

66 Personal communication between Beth Chacon, PSCo, and Stacy Tellinghuisen, WRA, January 18, 2010 and October 6, 2010.

In the recently constructed Comanche Unit 3, PSCo selected a hybrid wet-dry cooling system that uses approximately half as much water as a conventional, wet-cooling system. Xcel adopted the hybrid system, in part, to avoid the process of purchasing and converting water rights in the Arkansas River Basin.

The Colorado PUC allows utilities to consider externality benefits in evaluating renewables and emerging technologies. As of August 2010, electric resource plans filed with the commission must include data on water withdrawals and consumption for generating facilities and the water intensity (in gallons/MWh) of the operating system as a whole. As with emissions data, this should apply to both existing and future resources.[67] Similarly, as part of a new resource planning process, Tri-State Generation and Transmission will report water use for all existing and proposed facilities.[68]

Nevada

While the Nevada Public Utilities Commission has the regulatory authority to consider water and other environmental factors in evaluating electric utilities' resource plans, it has not, to date, exercised this authority. The Nevada Administrative Code directs utilities to quantify the environmental costs (including air emissions, water use, and land use) of resource plans; this evaluation must include facilities located outside of the state.[69],[70] In addition, Nevada's Utility Environmental Protection Act (UEPA) gives the Nevada PUC authority to grant or deny permits to merchant power plants. The UEPA statute allows the PUC to consider impacts on environmental resources, including water, when granting a certificate.

Wind turbines, AZ

Like Arizona Public Service, NV Energy now assumes new combined-cycle gas plants will rely on dry cooling, but new thermoelectric baseload plants could use wet or hybrid cooling systems. NV Energy's proposed Ely Energy Center would have employed a hybrid system, in part because sufficient water for a wet-cooled plant was simply not available in rural White Pine County.

Although the Nevada PUC has not required electric utilities to report water consumption, it did order the creation of a Demand-Side Management Collaborative Committee in 2009. With representatives from all three utilities (SNWA, NV Energy, and Southwest Gas) and other stakeholders, the committee will work to develop a more coordinated, seamless efficiency effort

67 Docket No. 10R-214E, Decision No. C10-0958, paragraph 37 and 38, p.12.

68 Letter from Kenneth Anderson, Tri-State Generation and Transmission, and John Nielson, Western Resource Advocates, to Chairman Ron Binz, Colorado Public Utilities Commission, December 8, 2009, (Proposed Settlement at Section 1 (3)(k), (10)).

69 NAC 704.9359.

70 NAC 704.9063.

between the utilities in southern Nevada. This inter-utility collaborative effort is, to our knowledge, unique in the West.

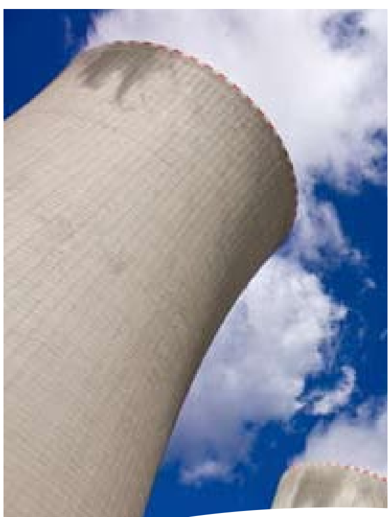
The state of Nevada also created a new position—the Nevada Energy Commissioner, head of the Renewable Energy and Energy Efficiency Authority. This new position represents an important opportunity for direct consideration of the impacts of energy generation on the state's water resources.

New Mexico

New Mexico's Public Regulation Commission (PRC) has focused primarily on the water benefits of energy efficiency programs. Under N.M.S. § 62-17-2, "The legislature finds that: … cost-effective energy efficiency and load management programs undertaken by public utilities can provide significant reductions in greenhouse gas emissions, regulated air emissions, water consumption and natural resource depletion, and can avoid or delay the need for more expensive generation, transmission and distribution infrastructure." The statutory authority is reflected in several rules, which direct utilities to:

- File an annual report that quantifies non-energy benefits of the energy efficiency programs[71]
- Choose energy efficiency programs based on considerations that include "non-energy benefits"[72]—low-income customer participation in utility programs and reductions in greenhouse gas emissions, air pollution, water consumption, and natural resource depletion[73]

Steam from cooling towers



In addition to these rules, the PRC requires regulated utilities to report freshwater consumption at existing facilities; according to Public Service Company of New Mexico (PNM), utilities do not typically report brackish or recycled water consumption. [74]

We found no cases in which the New Mexico PRC cited water as a factor influencing its decision. In fact, citizens protesting the proposed Duke Luna Energy Facility, a 600-MW gas plant, raised concerns about water impacts, but the facility project manager argued that the New Mexico State Engineer—not the PRC—has jurisdiction over water use. The PRC's final ruling on the Luna plant did not address impacts on water resources.[75] And, according to PNM, the PRC has not pressured utilities to choose water-

71 NM ADC 17.7.2.13.C(8).

72 NM ADC 17.7.2.9.

73 NM ADC 17.7.2.7.U.

74 Personal communication between Cindy Bothwell, PNM, and Stacy Tellinghuisen, WRA, January 14, 2010.

75 Letter from Cameron Epard, Project Manager, Duke Energy Luna, LLC, to various citizens, October 11, 2000.

efficient resources; greenhouse gas emissions and the cost of natural gas remain more pressing issues.[76]

PNM has, however, considered water in its resource planning. For example, in January 2010, PNM announced a decision to build 80 MW of solar photovoltaic (PV) panels, which use negligible amounts of water. PNM considered both solar thermal and PV technologies; the PV proposal was cost-competitive, and allowed PNM to avoid water disputes.[77]

In 2010, PNM announced a decision to build 80 MW of water-efficient solar PV panels.

Utah

As part of its integrated resource planning (IRP) requirements, the Public Service Commission of Utah directs regulated utilities to perform an analysis of environmental risk. The analysis "should include the quantification of actual emissions as well as a range of dollar values for external costs for each acquisition strategy."[78] However, the PSC has rejected the idea that utilities would include these external costs in "total resource cost" calculations, while noting that environmental costs may be internalized in total resource costs in the future.

Rocky Mountain Power (PacifiCorp) considers water in its resource planning process in a very limited manner. In evaluating supply-side resources, the utility considers the cost of acquiring or developing water, the annual O&M costs associated with water (including the cost of treating and disposing of wastewater[79]), and the risk of not obtaining an adequate and reliable water supply. But the utility does not report water consumption in its IRP for existing facilities or proposed new facilities.[80]

Similar to PNM, PacifiCorp has focused more on evaluating the cost of greenhouse gas emissions and other risks. Of note, PacifiCorp serves customers in a six-state region, and generates a substantial amount of its electricity at hydroelectric facilities in the Pacific Northwest. The utility has focused more attention on the impacts of climate change on water and hydroelectric generation.

Wyoming

Wyoming does not appear to have any statutes or regulations that directly address water use by electric generation facilities.

76 Personal communication between Cindy Bothwell, PNM, and Stacy Tellinghuisen, WRA, January 14, 2010.

77 Id.

78 In re PacifiCorp, Docket No. 90-2035-01 (June 18, 1992) (Order).

79 All of PacifiCorp's plants are zero liquid discharge facilities.

80 Personal communication between Pete Warnken, PacifiCorp, and Stacy Tellinghuisen, WRA, December 18, 2009. Personal communication between Ian Andrews, PacifiCorp, and Stacy Tellinghuisen, WRA, January 6, 2010.

The Costs of Alternative Cooling Systems

Water availability and cost can influence the type of power plant a utility chooses. Thermoelectric power plants require water to generate steam, which must then be condensed and cooled. Most western thermoelectric plants rely on wet recirculating cooling systems to cool and condense the steam. Dry and hybrid cooling systems reduce the total consumptive water use and the costs associated with pumping, treating, and discharging water, but they have higher capital costs and often generate less electricity during the hottest periods, when electricity demand is highest.

TABLE Nº 5 COST ANALYSIS OF WET AND DRY COOLING SYSTEMS FOR THERMOELECTRIC POWER PLANTS IN HOT, ARID, SOUTHWESTERN STATES.

Plant	Gas, Combined-Cycle, 500-MW	
1. Cooling system	Wet	Dry
2. Capital cost of cooling equipment ($)	7,629,421	30,414,637
3. Cost of water rights ($/AF)*	1,500	1,500
4. Annualized capital cost ($/yr)†	945,476	2,433,171
5. Annual O&M costs‡ (excluding water) ($/yr)	583,501	2,704,540
6. Total annual costs ($/yr)	1,528,977	5,137,711
7. Volume of Water Consumed (AF/yr)	2,793	–
8. Added value of water ($/AF/yr)	1,292	

* Cost of water rights modeled by EPRI.

† Capital costs are annualized using a 7% discount rate and 30-year period.

‡ O&M costs include maintenance costs, fan power costs (for both wet and dry systems), and lost revenues from lost capacity during hot periods (for dry-cooled systems), along with system maintenance costs.

The Electric Power Research Institute (EPRI) analyzed the cost of dry vs. wet cooling systems in thermoelectric power plants.[81] Its report assessed the capital cost of the different cooling systems, annual O&M costs for the cooling systems, and the cost of capacity shortfalls for dry cooling systems. Table 5 summarizes EPRI's analysis for a combined-cycle gas plant. Using this data, we derive an implicit value of water for power generation (Table 5, line 8).[82] In sum, with the higher capital and operating costs of dry cooling systems, adopting a dry-cooled system is economically beneficial when the cost of water rights *exceeds $17,000/AF.*[83] However, this economic calculation does not consider the hard-to-quantify political or legal costs of developing new water rights.

Dry cooling systems have similar economic impacts on coal, solar thermal, and other thermoelectric power plants; the capital cost of installing dry cooling technology in solar thermal plants is typically three to five times more expensive than wet cooling systems. The actual energy and cost penalties for solar thermal plants depend on the location of the plant—energy penalties (and costs) are higher in hotter climates. For example, using dry cooling at a concentrated solar power (CSP) plant in New Mexico may increase electricity costs by 2% (compared to a wet-cooled plant), whereas a dry-cooled plant in the Mohave Desert might have average electricity costs 7% to 9% higher than a wet-cooled plant.[84]

Other Factors

Beyond considering the economics of a new generating resource, utilities must also factor in public or political opposition to a potential project. A utility's decision to use large amounts of water for cooling in a power plant can create tremendous public opposition, particularly if the plant will transfer water from other basins, impact rural agricultural communities, require a new diversion, or impact sensitive streams or wetlands. This has been true for both conventional coal plants *and*, more recently, for proposed renewable plants:

81 Maulbetsch, J. 2004. *Comparison of alternate cooling technologies for U.S. power plants: Economic, environmental, and other tradeoffs*. Technical Report 1005358. Palo Alto, Calif.: Electric Power Research Institute.

82 EPRI's capital costs are adjusted from $2004 to $2008 using the price index from the Bureau of Economic Analysis (BEA) for private fixed investment in electric power structures, and variable costs are escalated using the BEA's gross domestic product deflator. We do not escalate the capital cost of water rights for two reasons: 1) in general, water rights are not sold in a well-functioning market, and the cost of a right does not escalate at a predictable rate (e.g., the rate of inflation); and 2) construction costs increased considerably over the period 2004-2008. Sources: U. S. Department of Commerce, Bureau of Economic Analysis. National income and product accounts. Table 5.4.4. and Table 1.1.9.

83 Using a discount rate of 7% and a 30-year period. This discount rate is higher than many other rates used in this analysis, because it reflects a typical discount rate for private investments.

84 U.S. Department of Energy. 2009. *Concentrating solar power commercial application study: Reducing water consumption of concentrating solar power electricity generation*. Report to Congress.

Since its water use was featured in *The New York Times*, Solar Millennium decided to change from wet to dry cooling for its proposed CSP plant in Nevada's Amargosa Valley.[85] And, although it is not a direct cost, public opposition may lead to costly legal challenges.[86]

Depending on the state, an electric utility would have to go to water court or the state engineer in order to appropriate new water rights or change a water right from an existing use (i.e., agricultural or municipal) to industrial use. Hearings in water court or other legal venues can delay or derail a project and drive up costs; the prospect of water court can, and has, changed the shape of a project.[87] For example, in Colorado, the cost of a large water court case ranges from a few hundred thousand dollars to as much as several million dollars. However, not every proposed power plant would have to acquire water rights — many electric utilities already own sufficient water rights in their service areas.[88]

Summary

Although electric utilities consider water in their resource planning, most utilities do not yet place a monetary value on water as part of their resource planning processes. More importantly, none of the utilities surveyed are modeling the projected future costs — or value — of water, despite the fact that most utility staff expect that water conflicts will become more common and water more valuable. Other costs — particularly looming CO_2 costs and fuel costs — still exceed the capital and operating cost of water for electric utilities. Similarly, air permits still pose a bigger challenge than water court.

The different approaches to integrating water reflect the relative scarcity of the resource in different states: APS places the greatest emphasis on water resources in its resource planning, followed by utilities in Nevada and New Mexico. In Colorado, the PUC's decisions reflect an increasing awareness of water issues: In August 2010, the PUC adopted rules requiring the state's investor-owned utilities to report water consumption. Finally, representatives of PacifiCorp, a utility with considerable hydroelectric resources, noted that they have greater concerns about the potential effects of climate change on water resources and hydroelectric generation, rather than the reliability or availability of water for thermoelectric generation.

85 Woody, T. 2009. Alternative energy projects stumble on a need for water. *The New York Times*. September 29, 2009. http://www.nytimes.com/2009/09/30/business/energy-environment/30water.html.

86 Additionally, large volumes of water might not be available on the open market, and could require aggressive purchasing schemes, further inflating costs.

87 The prospect of potential water court proceedings influenced Xcel Energy's decision to rely on municipal water supplies for its Comanche III unit.

88 Personal communication between Stacy Tellinghuisen (WRA) and Beth Chacon and Randy Rhodes (PSCo), Cindy Bothwell (PNM), and Robert Lotts (APS).

Arizona

Recommendations

Throughout the West, water is an increasingly valuable natural resource, whether used in the region's growing cities, to irrigate agricultural lands, or to meet environmental and instream needs. The value varies tremendously, depending on the geographic location, the value of commodities produced, and a host of other factors. The value of water rises precipitously in times of drought and scarcity. Climate change models project increased rates of evapotranspiration throughout the West, more severe droughts, and reduced runoff in the Colorado River. Accordingly, the value of water in the Southwest will continue to rise in the future.

> **[Global warming in the Southwest] is among the most rapid in the nation, significantly more than the global average in some areas. This is driving declines in spring snowpack and Colorado River flow… Further water cycle changes are projected, which, combined with increasing temperatures, signal a serious water supply challenge in the decades and centuries ahead.**
>
> **—U.S. Global Change Research Program** [93]

Water use at thermoelectric power plants competes directly with the water demands of cities, agriculture, and environmental needs. Recently, utilities and developers have often proposed building *new* thermoelectric power plants in rural locations. Many of these rural plants will draw on water supplies that would otherwise sustain agriculture or environmental needs, and, in many cases, the municipal value of water is not directly relevant. In certain cases, however, utilities could retire older thermoelectric power plants in urban areas, potentially freeing up water for municipal use. For example:

- Public Service Company of Colorado's Cherokee Station, located just north of downtown Denver, relies on water from the South Platte River, groundwater wells, and recycled water from Denver Water to meet its cooling needs. In 2006, the coal-fired power plant consumed an estimated 7,900 AF of water.[89] PSCo expects to keep the Cherokee Station in operation until 2018 or beyond.[90] The median cost of water from proposed new supply projects that would serve the Denver metro area is $613/AF/yr. If PSCo retired the Cherokee plant in 2013, rather than 2018, the value of the water over that five-year period would total $4,840,000.

- Nevada's Reid Gardner Power Plant, owned by NV Energy and the California Department of Water Resources, relies on water from the Muddy River and groundwater wells in southern Nevada and consumes over 4,300 AF/yr. The Southern Nevada Water Authority (SNWA) provides water to residents in the Las Vegas Valley, and has recently negotiated agreements to develop water in the Muddy River Valley and deliver it to customers in Las Vegas. In addition, SNWA is pursuing other new water supply projects, including a Groundwater Development Project in Clark, Lincoln, and White Pine Counties and augmentation on the Colorado River. Additional water rights in the Muddy River Valley, if available, could (and likely *would*) be used to meet municipal demands in the Las Vegas Valley.

  The annualized cost of SNWA's Groundwater Development Project is approximately $1,169/AF/yr. NV Energy expects to retire units 1-3 (300 MW) of the Reid Gardner Plant in 2016, and unit 4 (257 MW) in 2023. The value of water generated by retiring the units five years early (in 2011 and 2018, respectively) would amount to over $5,041,000.

- In Arizona and New Mexico, several power plants rely on water from the Colorado River or its tributaries: the Four Corners Power Plant, Navajo Generating Station, and San Juan Generating Station. Both of these states have (or will soon have) the infrastructure to convey Colorado River (or tributary) water to urban areas.[91]

Water-efficient sources of energy act as a hedge against the risk of drought.

As utilities consider the retirement of older, water-intensive plants, they should consider the economic benefit the water could provide.

Water used by electric utilities has value because: 1) it costs money to obtain, deliver, and treat water used to condense steam in thermoelectric power

89 WRA estimate.

90 Public Service Company of Colorado, 2007. *2007 Colorado resource plan*.

91 The Central Arizona Project conveys Colorado River water to Phoenix and Tucson. The proposed Navajo-Gallup pipeline will convey water to Gallup, NM, the Navajo Nation, and the Jicarilla Apache Nation; and the San Juan-Chama Project diverts water from the San Juan River to the Rio Grande and Albuquerque area.

plants; 2) the water may have value in alternative uses; and 3) water in specific locations may be scarce, resulting in an economic rent on water.

Electric utilities and regulators should examine all three aspects of value when assessing additions of new power plants and considering continued operation of existing power plants. The value of the water for alternative uses will vary, depending on the location and competing demands. For example, in the cases of the Cherokee and Reid Gardner plants described above, the value of using that water to meet municipal needs is high.

Currently, the extent to which a region's electric utilities and regulators consider water varies tremendously. Utilities and regulators in Arizona and Colorado are clear leaders in considering the impacts of electricity generation on water and other environmental resources. **At a minimum, utilities across each region should report water consumption for existing facilities, along with projected water consumption for different proposed portfolios, as part of their integrated resource plans.**

Utilities across each region should report water consumption for existing facilities, along with projected water consumption for different proposed portfolios, as part of their integrated resource plans.

In considering new water-intensive power plants, utilities and regulators should assess both the value of water today and the potential value of water in the future. In areas where water is scarce today, or will likely be scarce in the next 40 to 50 years (or the lifetime of the proposed power plant), utilities and regulators should assess the opportunity cost of using water for electricity generation. That is, what is the value of the foregone opportunities—continued agricultural production, municipal development, or environmental benefits? Utilities should prepare projections and sensitivity analyses, and incorporate those opportunity costs in their decisions.

Finally, the impact of climate change on western water supplies is becoming increasingly clear. According to the U.S. Global Change Research Program, warming in the Southwest

"is among the most rapid in the nation, significantly more than the global average in some areas. This is driving declines in spring snowpack and Colorado River flow… Further water cycle changes are projected, which, combined with increasing temperatures, signal a serious water supply challenge in the decades and centuries ahead."[92]

Adapting to the impacts of climate change will require water users to increase flexibility and their ability to respond to short- or long-term droughts. A new water-intensive, wet-cooled thermoelectric power plant would "lock in" water demands for 40 to 50 years, reducing flexibility in water management. In contrast, water-efficient sources of energy may act as an effective hedge against the risk of drought. In evaluating new water-intensive power plants, regulators should consider the risk of drought and the benefits of preserving flexibility of water use.

92 U.S. Global Change Research Program. 2009. *Global climate change impacts in the United States*, p. 129. New York. http://www.globalchange.gov/usimpacts.

Mountain lake, CO

Appendix A – Case Studies of Energy/Water Conflicts from around the Nation

Drought and scarcity have long been a key challenge for water managers in the Southwest. But water conflicts are increasingly common in other regions of the U.S. Drought in the Southeast has made national news, with water conflicts erupting between the states. At the heart of the disputes were conflicts between power plants, municipalities, and environmental needs.

Western Resource Advocates has compiled three case studies that highlight growing conflicts, nation-wide, between energy and water users. The case studies focus on proposed or existing thermoelectric power plants in the Southeast (Plant Vogtle), Great Lakes Region (Elm Road Generating Station), and Pacific Northwest (Boardman Power Plant). The availability of water use data and water values varies between the three regions, but all three case studies illustrate the national importance of evaluating energy planning choices through the lens of water.

Plant Vogtle, Georgia

Note: Primary research was completed by the Southern Alliance for Clean Energy.

Located on the Savannah River in Georgia, Plant Vogtle provides electricity to Georgia Power, the Municipal Electric Authority of Georgia, Oglethorpe Power, and Dalton Utilities. Georgia Power and its partners propose to expand the existing 2,340-MW nuclear plant with over 2,300 MW of new generating capacity.[93] The proposed Vogtle plant expansion would make it the largest water consumer in the basin, exacerbating existing water challenges.[94,95]

93 U.S. Nuclear Regulatory Commission. 2008. *Final environmental impact statement for an early site permit at the Vogtle Electric Generating Plant site*. NUREG-1872, vol. 1, p. 1-1. http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1872/sr1872v1.pdf.

94 U.S. Nuclear Regulatory Commission. 2007. *Draft environmental impact statement for an early site permit at the Vogtle Electric Generating Plant site*. NUREG-1872, vol. 1, p. 7-5. http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1872/sr1872v1-ch7-to-ch11.pdf.

95 Rodgers, P. A glass half empty. ConnectSavannah website. February 23, 2010. http://www.connectsavannah.com/news/article/101842/.

The two new proposed Toshiba-Westinghouse AP1000 reactors would withdraw an estimated 61,600 to 98,600 AF/yr (55 to 88 million gallons per day (MGD)); the reactors would consumptively use 50% to 75% of that volume, or approximately 30,800 to 74,000 AF/yr.[96] For comparison, the average resident of Georgia withdraws approximately 93 gallons per day[97]; this means the water withdrawn by the new units could otherwise meet the water demands of up to 946,000 people.

The Savannah River supplies water to cities, farmers, and the environment across a three-state region, with the watershed covering over 10,577 square miles. From its headwaters in the Appalachian Mountains, it flows along the border between South Carolina and Georgia to the Atlantic Ocean, supplying water to at least two major cities in Georgia—Augusta and Savannah. It provides water to three power plants (including Vogtle) and to major paper and chemical manufacturing operations. In total, water withdrawals for industrial uses and power generation rival the volume withdrawn for public supplies. The Savannah River also offers extensive recreational opportunities, with three major reservoirs (Hartwell, Russell, and Thurmond) that draw over 21 million visitors each year.[98]

In an average year, the existing and proposed Vogtle reactors would withdraw an estimated 2% of the Savannah River. Under drought conditions, the plant could have a much larger impact on the river, withdrawing almost 5% of the river's flow in a Level 3 drought. In recent years, the Savannah River reached Level 3 drought conditions from September 1988 to March 1989, in September and October of 2002, and from August 2008 through February 2009.[99]

Acquiring water for power plants requires several steps in Georgia. A large withdrawal, such as the one proposed for Plant Vogtle, requires a permit from the Georgia Environmental Protection Division (EPD), though that permit does not cost anything and the Georgia EPD has never, to our knowledge, rejected a power plant based on water use. The Georgia Public Service Commission (PSC) requires Georgia Power to file an integrated resource plan, which must include an evaluation of economic and environmental impacts. Along with the resource plan, Georgia Power must submit an environmental compliance strategy that details existing facilities' compliance with federal environmental laws, such as the Clean Water Act. To date, water issues have received very little attention from the Georgia PSC. Regulated utilities and expert reviews by PSC staff and others have provided little information on water impacts.

96 Southern Nuclear Operating Company. 2008. Plant Vogtle combined operating license permit application. Rev 0, Part 3, Environmental report, Table 3.2-1.

97 Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin. 2009. *Estimated use of water in the United States in 2005*. U.S. Geological Survey Circular 1344, Table 6. **http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf**.

98 Georgia Environmental Protection Division. 2007. *Georgia's water resources: A blueprint for the future*. Revised draft of December 5, 2007, p. 36. **http://www.georgiawatercouncil.org/Documents/plan3.html**.

99 See: 1) Kertis, E. 2009. Reservoir management and drought in the Savannah River. Presentation by U.S. Army Corps of Engineers, November 17, 2009. **http://www.srs.gov/general/outreach/srs-cab/library/meetings/2009/fb/fb_20091116_1117_reservoir_management_drought.pdf**; and 2) U.S. Army Corps of Engineers Water Management for the Savannah River Projects web page at **http://water.sas.usace.army.mil/cf/AvgDaily/Z.cfm**; enter the year, lake, and elevation in the table on this web page.

The Savannah River is an extremely valuable resource in the region. The city of Savannah, downstream of Plant Vogtle, relies on the Savannah River to meet a portion of the city's water demands. Reducing flows in the Savannah River would further reduce the assimilative capacity of the river and could impact water quality for city water customers. Historically, the majority of Savannah's municipal water demands have been met with groundwater, but saltwater intrusion threatens the quality of groundwater supplies.

To preserve the city's groundwater supplies, the city of Savannah has pursued numerous actions, such as expanding the city's surface water treatment plant, which provides water to industrial customers. The city paid $17,500,000 to expand the plant's treatment capacity by 12.5 MGD in the year 2000.[100] Assuming the plant operates at 75% capacity, the value of the new municipal water supply is approximately $130/AF/yr.[101] At present, the city of Savannah charges industrial water customers $ 0.64 per 1,000 gallons, or $209/AF.[102] If the water used by the proposed new reactors were available to other industrial customers in the city of Savannah, it would be worth $12,900,000 to $20,600,000 *per year*.

Water in the Savannah River is valuable for other uses, too. The river and its reservoirs are popular destinations for such recreational uses as fishing, camping, and boating; for example, sales of fishing licenses in the counties partially or wholly in the Savannah Basin netted over $3,770,000 in 2009.[103] And the Savannah National Wildlife Refuge near Savannah, Georgia provides numerous hunting and fishing opportunities, with 170,000 visitors each year.[104] The river is considered a hotspot for freshwater diversity, hosting 142 species of freshwater fish and mussels. Fish populations in the Savannah have declined, in part due to the incremental impacts from dams, urbanization, industrialization, and thermoelectric power plant withdrawals. Additional

100 City of Savannah. Water, the lifeline of the community. PowerPoint presentation. http://www.p2ad.org/files_ppt/cityofsavannah.ppt.

101 We adjusted the capital cost of the project to $2008, and annualized the capital cost at a 4.46% discount rate over a 30-year period.

102 Figure does not include the base charge. See: City of Savannah. Water and sanitary sewer fees. http://www.savannahga.gov/SPR/SPRGuide.nsf/DocID/80A59C67E9AA2C3B85256A2900749836/$FILE/FEES.pdf.

103 South Carolina Department of Natural Resources. 2009. 2009 license sales by county. Georgia figures based on license information provided by Georgia Department of Natural Resources, Wildlife Resources Division, License and Boat Registration Unit on June 25, 2010. The counties in South Carolina used in this calculation included Abbeville, Aiken, Allendale, Anderson, Bamberg, Barnwell, Beaufort, Berkeley, Calhoun, Charleston, Cherokee, Chester, Chesterfield, Clarendon, Colleton, Darlington, Dillon, Dorchester, Edgefield, Fairfield, Florence, Georgetown, Greenville, Greenwood, Hampton, Horry, Jasper, Kershaw, Lancaster, Laurens, Lee, Lexington, McCormick, Marion, Marlboro, Newberry, Oconee, Orangeburg, Pickens, Richland, Saluda, Spartanburg, Sumter, Union, Williamsburg, and York.

104 U.S Fish and Wildlife Service. *Savannah National Wildlife Refuge* (fact sheet). http://www.fws.gov/savannah/pdfs/SAVfact.pdf.

withdrawals would further impact the size and resiliency of existing fish and mussel populations.[105]

Importantly, Georgia Power has more water-efficient alternatives to constructing the new Vogtle reactors. A recent analysis found that energy efficiency measures could eliminate new energy demands between 2010 and 2030 as well as the need to construct 49 GW of generating capacity.[106] In addition, Georgia has as much as 294 MW of potential onshore wind power capacity, and up to 60 GW of offshore capacity.[107] Importantly, energy efficiency, wind power, solar photovoltaic panels, and some forms of bioenergy use no water to generate electricity. By delaying or eliminating the need to construct new water-intensive reactors such as the Vogtle plant expansion, these resources could provide important—and valuable—water savings to the region.

Elm Road Generating Station, Wisconsin

Note: Primary research was completed by the Great Lakes Commission.

In recent years, even the water-rich Great Lakes Region has seen energy-water conflicts. The Oak Creek Power Plant provides a current example: The plant was recently expanded with 1,230 MW of new generating capacity, called the Elm Road Generating Station. In 2004, construction began on the new units, which will provide power to a consortium of municipal utilities.

The Oak Creek and Elm Road units' once-through cooling system relies on water from Lake Michigan. Once-through cooling systems withdraw vast quantities of water, most of which is returned to the source at an elevated temperature. The Oak Creek and Elm Road units are projected to withdraw, in total, almost 2,500,000 AF/yr and consume almost 2,000 AF/yr. In total, the Oak Creek and Elm Road units represent 7.6% of the total water

105 Barczak, Sara and Shawn P. Young. 2009. Water use impacts on Georgia's water resources and threats from increased water intensive energy production. In *Proceedings of the 2009 Georgia Water Resources Conference*. April 27–29, 2009, University of Georgia. **http://www.gwri.gatech.edu/uploads/proceedings/2009/1.7.3_Barczak.pdf**.

106 Brown, Marilyn A., Joy Wang, Matt Cox, et al. 2010. Energy efficiency in the south—Appendix G. In *State Profiles of Energy Efficiency Opportunities in the South: Georgia*. p. 4. **http://www.seealliance.org/se_efficiency_study/georgia_efficiency_in_the_south.pdf**.

107 See: 1) U.S. Department of Energy, Energy Efficiency and Renewable Energy. Wind powering America: Georgia wind map and resource potential. **http://www.windpoweringamerica.gov/wind_resource_maps.asp?stateab=ga**. Accessed July 29, 2010. Figures reflect the wind resource at a turbine height of 100 meters and a capacity factor greater than 30%. Wilderness areas, parks, urban areas, and waterways are excluded from the potential windy area. 2) U.S. Department of Energy, Energy Efficiency and Renewable Energy. Wind powering America: 90-meter offshore wind maps and wind resource potential estimates. **http://www.windpoweringamerica.gov/windmaps/offshore.asp**. Accessed October 29, 2010.

withdrawals in the entire Great Lakes Basin.[108] Unlike many western power plants with recirculating cooling systems, the Oak Creek and Elm Road units *consume* relatively small volumes of water, but have a greater impact on water quality and wildlife, due to thermal discharges, potential mercury pollution, and entrainment/impingement of wildlife at the water intake system.

To build the new Elm Road Generating Station units, project proponents applied for (and received) approvals or permits from the Wisconsin Public Service Commission (PSC), Wisconsin Department of Natural Resources, and the U.S. Army Corps of Engineers. The Wisconsin PSC has a limited history of considering water issues. In 1977, the PSC rejected an application for a proposed nuclear plant that would rely on water from Lake Koshkonong, due to impacts on the shallow lake.[109] Today, entities in Wisconsin that withdraw water from the Great Lakes must pay a minimal fee of $125/year. Pending legislation would levy an additional annual fee of up to $9,500, depending on the facility's withdrawal capacity. Assuming the Oak Creek and Elm Road units pay the maximum annual fee (a total of $9,650/year), the price of the water they withdraw amounts to a negligible $0.0039/AF, and the price of consuming water amounts to $4.99/AF. In addition, the plant must pay a discharge fee based on the amount of pollutants discharged into the lake. In 2009, *before* the Elm Road expansion was completed, the Oak Creek plant paid $25,747, or approximately $0.03/AF. Although Wisconsin charges minimal fees for water use, the water-related permits for the Elm Road expansion were contested. Litigation over these (and other) permits proved costly, with the settlement exceeding $105 million in environmental investments (among other measures).[110]

Lake Michigan meets many needs in the region, supplying water to nearby cities and supporting commercial and sport fisheries, navigation, and other industrial uses. For example, water from Lake Michigan supplies the cities of Milwaukee, Green Bay, Muskegon, Holland, Gary, and Chicago. The city of Milwaukee charges $280 for a tap to serve a new house, which would use approximately 0.25 AF/yr; using this as a very basic proxy, the municipal value of water is approximately $69/AF/yr.[111] At this rate, the "value" of water *consumed* by the Oak Creek and Elm Road plant would exceed $133,000/year, and the value of the water withdrawn would be exponentially higher.

108 Mills, P.C. and Sharpe, J.B. 2010. *Estimated withdrawals and other elements of water use in the Great Lakes Basin of the United States in 2005*. U.S. Geological Survey Scientific Investigations Report 2010-5031.

109 Email correspondence between Celia Haven, Great Lakes Commission, and Eric Ebersberger, Wisconsin DNR, June 24, 2010.

110 Wisconsin Electric Power Company, ERGS Supercritical, LLC, Madison Gas & Electric Company, MGE Power Elm Road, LLC, Wisconsin Public Power Inc., Clean Wisconsin, Inc., and the Sierra Club. 2005. Settlement agreement, Elm Road Generating Station and Oak Creek Power Plant. WPDES Permit No. WI-0000914-07-0.

111 Calculation is based on average water use of 7,580 gallons/person/quarter (approximately 83 gallons per capita per day). Tap fee costs are annualized using a 4.46% discount rate and a 30-year term. Source for water use data: Milwaukee Water Works website. http://www.milwaukee.gov/water.

Quantifying the value of the water used for other sectors (e.g., fisheries, navigation) in the region is challenging, but many of the sectors it supports constitute multi-billion dollar industries (see, for example, Table 6).

In the Elm Road Generating Station environmental impact statement, project proponents evaluated alternative strategies for meeting the project proponents' energy demands. While no single alternate source of energy (either renewable or natural gas) was able to meet the municipalities' entire projected demands, a combination of alternatives could have met demands.[112] And, according to the Wisconsin PSC, proponents' projected energy demands had an "upward bias." [113] Indeed, over the past seven years, observed demand growth has exceeded projected growth. [114]

Looking solely at the costs of municipal water supplies and water permits, water would appear to have little monetary value in Wisconsin, particularly when compared to typical water prices in the arid West. Because these costs do not reflect the value of industries that rely on water—fisheries, navigation, and recreation—they likely understate the value of water in the Great Lakes Region.

TABLE Nº 6 INDUSTRIES RELYING ON THE GREAT LAKES GENERATE BILLIONS OF DOLLARS.

Sector	Size
Commercial fishing	$15 million market value of fish landed from the Great Lakes in 2006.[a]
Recreational fishing	$1.5 billion in angler expenditures on Great Lakes fishing.[b]
Wildlife watching	$9.3 billion in participant expenditures for the eight Great Lakes states.[c]
Raw water users	826 facilities, including 13 nuclear power plants.[d]

[a] The United States Geological Survey Great Lakes Science Center

[b] United States Fish and Wildlife Service, The 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation

[c] United States Fish and Wildlife Service (2006)

[c] Deng (1996); O'Neill (1996); Northeast Midwest Institute

Source: Great Lakes United. 2008. Annual losses to Great Lakes Region by ship-borne invasive species at least $200 million. http://www.glu.org/en/node/208.

Boardman Power Plant, Oregon

Note: Primary research was completed by Jorge Figueroa.

The Boardman Plant, located in northeastern Oregon, has drawn considerable attention because of its harmful air emissions. Less well-recognized, however, is the plant's impact on water resources. The 585-MW coal-fired power plant relies on water from the Columbia River to operate its cooling

112 Public Service Commission of Wisconsin. 2003. Final decision, certificate of public convenience and necessity, and order. Dockets 05-CE-130 and 05-AE-118. p. 19.

113 Public Service Commission of Wisconsin and Department of Natural Resources. 2003. *Environmental impact statement Elm Road Generating Station – Volume 1.* p. 42

114 Per email correspondence between Great Lakes Commission and Katie Nekola, Energy Program Director, Clean Wisconsin, July 1, 2010.

system; in 2005, the plant consumed an estimated 13,000 AF of water.[115] This represents a fraction of the power plant's water right, which allows for the diversion of up to 97,736 AF/yr from the Columbia River, and storage of up to 38,300 AF/yr in Carty Reservoir.[116]

At present, Portland General Electric, the plant's primary owner and operator, proposes to install air pollution control equipment and to cease operations at the plant in 2020, well before the plant reaches its designed retirement age.[117] While these actions are designed to improve air quality, they could also provide important water benefits for nearby municipalities, agriculture, and the environment.

The cities of Boardman and Irrigon are located within 30 miles of the Boardman Plant. Currently, the city of Boardman relies on water from the Columbia River, while Irrigon relies on groundwater supplies. To address local groundwater quality issues, the city of Irrigon recently invested $4.42 million in two groundwater wells, a storage reservoir, and distribution pipelines.[118] The value of this water, annualized over a 30-year period at a 4.46% discount rate, is approximately $124/AF/yr. Tap fees suggest the value of water in Irrigon may be much higher—$531/AF/yr.[119] The city of Boardman is not currently trying to develop new, additional water supplies, and charges a slightly lower tap fee than the city of Irrigon. The city of Boardman charges $1,392 for its system development charge, and assumes a new residence would use 394 gallons/day.[120] Accordingly, the "value" of Boardman's tap fee is approximately $193/AF/yr.

In northeastern Oregon, agricultural water use far exceeds the water used by municipalities.[121] Indeed, the Umatilla Basin Project provides irrigation water to 30,000 acres of farmland in the area, which helps generate crops worth

115 U.S. Department of Energy, Energy Information Administration. 2005. Form EIA-767, Steam-electric plant operation and design report, Schedule 6, Cooling system information. http://www.eia.doe.gov/cneaf/electricity/forms/eia767/eia767.pdf.

116 Certificate 86057. State of Oregon, County of Morrow, Certificate of Water Right (March 16, 2010); Certificate 86056. State of Oregon, County of Morrow, Certificate of Water Right (March 16, 2010). The water right allows for a diversion from both the Columbia River and Carty Reservoir, but for practical purposes, Portland General Electric has rights to divert from the Columbia River.

117 Portland General Electric Company. 2010. Petition to promulgate, amend, or repeal OAR 340-223-0030(1)(b) and (1)(c) and OAR 340-223-0040(1) pursuant to OAR 340-011-0046. http://www.portlandgeneral.com/community_environment/initiatives/docs/proposal_DEQ.pdf.

118 Costs and data provided by Keith White, Public Works Director of the city of Irrigon, June 30, 2010.

119 Irrigon's system development fee is $1,946 per Equivalent Residential Unit (ERU), and assumes an ERU would use 200 gallons per day. Methodology for annualizing costs is the same as described in the text.

120 City of Boardman water costs and data provided by Barry Beyeler, Community Development Director, June 30, 2010.

121 Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin. 2009. *Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344*. http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf.

millions of dollars each year.[122] And the Boardman Power Plant is surrounded by Threemile Canyon Farms, 93,000 acres of farmland.[123]

Oregon has a well-established instream flow program; in fact, the state approved its 1,000th instream flow lease in 2007.[124] The state of Oregon facilitates several types of water right transactions to enhance environmental flows, including permanent water right transfers, temporary leases, split-season instream leases (which allow a water user to use the water for a portion of the season and leave the remainder instream during the other portion of the season), and water rights acquired through the state's conserved water program.[125] The conserved water program allows a water right holder to invest in water efficiency and use the conserved water on other parcels of land or for other uses not otherwise permitted under the water right. In addition, the state acquires a portion of the conserved water, which may be dedicated to an instream flow. Table 7 lists the average cost of water for instream flows in the region in 2009.[126]

Northeastern Oregon has also become a dynamic center of development for renewable energy. The Shepherd's Flat wind farm, just west of Boardman, will be one of the largest wind farms in the world, with over 900 MW of operating capacity. The city of Irrigon is also working to develop renewable energy in the region. The city of Irrigon submitted a formal notification of interest to the Army Depot Transition Team, which is currently in the process of closing the adjacent Umatilla Army Depot Facility, to construct a renewable energy center in place of the closed depot.

122 The most recent data, from 1992, estimates the value of crops irrigated at over $23 million ($1992). Source: U.S. Bureau of Reclamation. Umatilla Basin Project. http://www.usbr.gov/projects/Project.jsp?proj_Name=Umatilla%20Basin%20Project&pageType=ProjectPage. Accessed August 12, 2010.

123 Threemile Canyon Farms website. http://www.threemilecanyonfarms.com/. Accessed August 12, 2010.

124 Oregon Water Resources Department. Water management programs. http://www.oregon.gov/OWRD/mgmt.shtml. Accessed August 12, 2010.

125 Or. Admin. R. §§ 537.455 to 537.500.

126 Most water right transactions transfer a flow volume (in cfs) over a period of time. The Fresh Water Trust converted these flow rates to total volumes of water (in AF).

Replacing the Boardman coal plant with water-efficient renewables could create additional water for municipal and agricultural uses in the region. In addition, the water rights could benefit environmental needs, such as flows for anadromous fish, particularly if the power plant's water rights could be used to improve flows in the Umatilla River.[127] The value of using the Boardman plant's water for environmental flows could amount to as much as $3.1 million each year.[128] If it is transferred to municipal uses, that value could be even higher. As the state of Oregon, PGE, and other stakeholders evaluate the future of the Boardman Power Plant, the value of water should be an explicit consideration.

TABLE Nº 7 WATER TRANSFERS AND LEASES IN THE UMATILLA/WALLA WALLA BASIN.*

Average Costs of Water 2009: Umatilla/Walla Walla

	$/cfs	$/AF
Conserved water project	$101,660	$238
Permanent transfers [a]	$71,021	$212
Standard lease [b]	$2,599	$19
Time limited transfers [c]	$3,245	$8
Short-term WUA [d]	$1,588	$8
Long-term WUA [d]	N/A	N/A
Split-season lease	N/A	N/A

* Table provided by Natasha Bellis, Fresh Water Trust, July 9, 2010.

[a] Calculations by the Fresh Water Trust. Conversions from $/cfs to $/AF are based on the flow rate and duration of the water right.

[b] Standard instream leases can be for one to five years, and renewal is allowed.

[c] Leases can be for any length of time over five years (e.g., 6, 10, 20, 50 or more years).

[d] A WUA is a water use agreement. WUAs are made outside of state instream programs, do not require complex state approval process, and thus provide more flexibility.

127 Presumably, this would entail a series of water right exchanges.

128 Calculation assumes 13,000 AF/yr would be used to meet instream flow needs, at a value of $238/AF.

Appendix B – Additional Data Tables

Table 8 displays data on municipal water costs and prices. The same data is illustrated graphically in Figure 3.

TABLE Nº 8 MEDIAN COST ($/AF/YR) OF MUNICIPAL WATER SUPPLIES, BASED ON TRANSFERS, NEW SUPPLY PROJECTS, AND TAP FEES.

State	Median Cost of Permanent Water Transfers *(number)*	Median Cost of New Supply Projects *(number)*	Median Cost of Tap Fees: Statewide *(number)*	Median Cost of Tap Fees: Major Population Centers *(number)*
Arizona	$ 105 (90)	$ 1,225 (1)	$ 671 (21)	
Colorado	$ 471 (974)	$ 613 (4)	$ 1,069 (55)	$ 1,550 (36)
Nevada	$ 194 (58)	$ 1,169 (1)	$ 420 (15)	$ 399 (6)
New Mexico	$ 254 (52)	$ 927 (1)	$ 661 (4)	
Utah	$ 41 (39)	$ 672 (1)	$ 187 (23)	$ 235 (16)
Wyoming	$ 169 (1)		$ 193 (11)	

As described in Chapter 3, irrigators pay to operate and maintain irrigation systems. These costs depend on the water source, location, and distribution systems. Table 9 presents irrigation water costs (adjusted to $2008) in the six states.[129]

129 U.S. Department of Agriculture. 2008. Table 22 – Expenses for irrigation water from off-farm suppliers: 2008 and 2003. In *2008 Farm and ranch irrigation survey*. Washington, DC. Available at http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Farm_and_Ranch_Irrigation_Survey/index.asp.

TABLE Nº 9 COST OF IRRIGATION WATER FROM OFF-FARM SUPPLIERS ($2008).

State	Average Cost per AF
Arizona	$28.76
Colorado	$14.29
Nevada	$10.28
New Mexico	$24.76
Utah	$10.88
Wyoming	$5.83

Real estate values for irrigated land typically exceed values for non-irrigated land. Table 10 illustrates average farmland values and rent for irrigated and non-irrigated cropland in Colorado.

TABLE Nº 10 FARM REAL ESTATE VALUES FOR IRRIGATED VS. NON-IRRIGATED LAND IN COLORADO ($2008).

	Average Land Value	Average Land Rent
Irrigated cropland ($/acre)	$ 3,500	$ 115
Non-irrigated cropland ($/acre)	$ 1,000	$ 24
Difference ($/acre)	*$2,500*	*$91*
Difference ($/AF)	***$2,080***	***$76***

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