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Water, Energy and Environment Nexus: The California Experience

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ABSTRACT *The paper addresses the local and inter-state connections between water, energy and the environment. Using California and the western USA as a case study, the paper highlights the difficulties of balancing the needs of diverse stakeholders and protecting valuable resources while providing reliable and safe supplies of both water and energy to agricultural, industrial and residential customers. The investigation of these complex relationships is necessary to inform local and national policy decisions regarding the management of water, energy and the environment.*

Introduction*

Contemporary society in developed nations has become accustomed to a readily available supply of both water and energy through the turn of a faucet or the flip of a switch. However, the connections between water and energy are often not clearly visible to the public. The lack of transparency and understanding about the value of water and energy and the systems that provide these resources has led to the overuse and mismanagement of both resources. The objective of this paper is to explore the connections between water and energy and to bring awareness to some of the numerous ways these two valuable resources interact with and are dependent upon one another, and how their management affects the environment.

California provides a good setting to examine the relationship between water, energy and the environment. The state has an elaborate water storage and conveyance system which transports water from wet areas to dry areas, has facilitated the creation of millions of acres of fertile farmland and consumes a tremendous amount of energy to make this possible. California is famous for its natural resources—its mountains, oceans and deserts—all of which are affected by the generation of energy and the availability of water. Los Angeles, the state's largest city, has attained its status because of the Hoover dam, which provides one-third of the water used by Angelenos and initially supplied 75% of the electricity used in the city.

California's recent energy problems have focused attention on the state's resources and policies. Over the past year, California residents have seen

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electricity rates jump 300%, rolling blackouts, energy surpluses and policies implemented to address these problems that will affect the state for years to come. Agencies responsible for the management of the power and water in California have had to make difficult choices to balance the needs of their diverse constituencies. Cities demand power; farmers need to irrigate; fish require water to migrate and spawn. And now that it is clear that California is experiencing a below-normal hydrological cycle, the problems become even more acute—fewer resources and more demand.

Background Information

Hydroelectric Power

The first thing most people think about when asked to consider the connection between water and energy is hydropower. The advantage of conventional hydroelectric methods (i.e. dams) is that they are a net producer of energy and so can provide low-cost base-load electricity. The disadvantage is that they are subject to the time of year and amount of precipitation received. The pumped-storage method, which pumps water to a reservoir at a higher elevation when energy demand is low, and releases the water to generate electricity when demand is high, is very useful because the cycle can be controlled even though the method is a net user of electricity. It is actually economical to use pumped storage because it consumes low-cost (off-peak) energy and generates high-value (on-peak) electricity.

According to the California Energy Commission, roughly 25% of California's electricity comes from hydroelectric power—approximately 20–22% from large hydroelectric and approximately 3–4% from small hydroelectric plants. The state's hydroelectric plants, located primarily in the eastern mountain ranges, have a total capacity of about 6900 MW. Pumped-storage hydroelectric plants add another 3222 MW of capacity. One-third of the hydroelectric power used in California comes from the Pacific north-west (Higgins, 2001).

A History of Dams in the Western USA

The numerous dams and hydroelectric plants that provide energy to the state of California are a product of the era of big-dam construction that was begun by the construction of the Hoover dam on the Colorado River, the largest public works project of its time, which was completed in 1936. After the Hoover dam, many others were planned and constructed along the Colorado, the Snake, the Columbia and almost every other major river in the western USA. The dams provided flood control, energy and water for both irrigation and domestic use, permitting the creation of cities such as Las Vegas in the midst of deserts. There are currently more than 2300 hydroelectric dams in the USA, providing roughly 11% of the country's total energy supply (Schueller, 2001).

The end of the big-dam era in the USA began in the1960s with the start of the environmental movement and the passage of the Wilderness Act 1964 and the Wild and Scenic Rivers Act 1968. In recent years, the negative impact of dams has gained increasing attention. The list of problems caused by dams is substantial: destruction of habitat, elimination of natural river flow, soil salination, reservoir sedimentation, channel erosion, increased water temperatures and the devastation of fisheries, to name a few. In addition, there is increasing evidence that dam projects are actually net producers of greenhouse gas emissions. All large dams and natural lakes that have been measured emit greenhouse gases. Gases such as carbon dioxide and methane are produced through the decomposition of vegetation in the flooded area. It is not clear yet, however, how emissions may change over time, or how emissions from reservoirs compare with pre-flooding emissions (World Commission on Dams, 2000).

In the USA, the trend is turning towards tearing down dams, rather than building new ones. Conservationist writer Marc Reisner (2000) explains how dam removal is impacting wildlife:

> From California to Maine, dam removal has begun. When four small diversion dams were taken off a Sierra Nevada stream called Butte Creek, record numbers of spring-run Chinook salmon—listed by the US as a threatened species—rushed past their ruins to spawn. If the spring-run Chinook ends up on the more serious endangered-species list, that will trigger more restrictions on diversion from its spawning rivers. So helping the spring-run by getting rid of a few dams could be worth billions to California's economy, which is hopelessly dependent on the manipulation of water. (Reisner, 2000, p. 71)

Dams are removed when the perceived costs (e.g. loss of wildlife habitat, blocked fish migration, safety concerns and loss of recreational opportunities) outweigh the perceived benefits (e.g. irrigation, energy, water supply and flood control). According to the American Rivers' web site, as of last year, 480 dams had been removed in the USA. (American Rivers is a non-profit organization dedicated to protecting and restoring rivers in the USA.) Forty dam removals occurred in 1999 and 2000, and 40 more are scheduled for 2001.

New dam construction in the USA has slowed dramatically for numerous reasons: environmental, public opposition, and the enormous capital investment required, not to mention that many of the best sites have already been used. Data from RDI, a Colorado-based consulting firm, show that hydro generation has been in decline for the past couple of years. Nation-wide, total electricity generated from hydro sources was down by about 15% in 2000 compared to 1999 (Environmental News Network, 2001b).

The Vast Water Management Infrastructure

Dams are only one part of the enormous water supply infrastructure that criss-crosses the state of California. The two most significant water projects in California are the Central Valley Project (CVP) and the State Water Project (SWP).

Planning for the CVP started as far back as 1919 when Colonel Robert Bradford Marshall, Chief Geographer for the US Geological Survey, proposed building a system to transfer water from the Sacramento Valley to the San Joaquin Valley (Stene, 2001). The project was centred around flood control and providing water for irrigation and domestic use. Construction began in the late 1930s and continued through most of the 20th century.

The CVP:

- consists of 20 dams and reservoirs, 11 power plants and 500 miles (805 km) of major canals, as well as conduits, tunnels and related facilities;
- manages some 9×10^6 acre-feet (11×10^9 m^3) of water;

- annually delivers about 7×10^6 acre-feet (8.6×10^9 m^3) of water for agricultural, urban and wildlife use;
- provides about 5×10^6 acre-feet (6.1×10^9 m^3) for farms—enough to irrigate about 3×10^6 acres (1.2×10^6 ha), or approximately one-third of the agricultural land in California;
- furnishes about 600 000 acre-feet (740×10^6 m^3) for municipal and industrial use—enough to supply close to 1 million households with their water needs each year;
- generates 5.6×10^9 kWh of electricity annually to meet the needs of about 2 million people;
- dedicates 800 000 acre-feet (987×10^6 m^3) per year to fish and wildlife and their habitat and 410 000 acre-feet (505×10^6 m^3) to state and federal wildlife refuges and wetlands, pursuant to the Central Valley Project Improvement Act (Central Valley Project General Overview, 2001)

Construction of the SWP, built and funded by the state of California, began in the early 1960s to supply additional water to the ever-thirsty cities and farmers of southern California.

The SWP:

- consists of 32 storage facilities, reservoirs and lakes; seven pumping plants; three pumping generating plants; five hydroelectric power plants; and about 660 miles (1062 km) of open canals and pipelines;
- provides some of the water used by approximately 20 million Californians and about 660 000 acres (267 093 ha) of irrigated farmland;
- of the contracted water supply, 70% goes to urban uses and 30% goes to agricultural users (Department of Water Resources, State Water Project Overview, 2001)

Energy Used in Transporting and Treating Water

Getting water from its source to the end user requires a significant amount of energy. The energy costs of water use in California are high because of two primary reasons: (1) most of the demand is located at a considerable distance from the source; and (2) water is heavy and moving it is quite energy-intensive (one acre-foot of water weighs approximately 1357 short tons/1231 metric tonnes). Additionally, water that is to be used for consumption needs to be treated, another energy-intensive process. According to the California Department of Water Resources (DWR), "water pumping is the single most significant user of electricity in the state, using five percent of the state's peak load and seven percent of the total electricity usage in California" (Ameriscan, 2001).

The California Energy Commission Energy Efficiency Division, Process Energy Group, prepared a report *Energy Use in the Supply, Use and Disposal of Water in California* in January 1999 (Anderson, 1999). According to this report, "the total energy used to pump and treat this water [used in the state] exceeds 15 000 GWh per year, or at least 6.5% of the total electricity used in the State per year". The SWP is the largest single user of electrical energy in the state. It takes water through the southern San Joaquin Valley to the Tehachapi Mountains, where the A. D. Edmonston pumping plant raises the water 1926 feet (587 m) to enter 10 miles (16 km) of tunnels and siphons which traverse the Tehachapi mountain range. It accounts for 2–3% of all the electricity consumed in California. The SWP uses an average of 5000 GWh per year (Anderson, 1999).

Environmental Implications of the Energy and Water Connection

The transport and treatment of water, in that they require substantial amounts of energy, also have environmental implications. California's primary power generator, burning of natural gas, releases greenhouse gases that contribute to global warming and other pollutants, such as particulate matter, that contribute to the state's air quality problems. Also, there are many environmental impacts associated with hydropower, as described earlier in the paper.

Water Uses

According to the California DWR, the state receives 200×10^6 acre-feet (246×10^9 m^3) of rain and snowfall annually. Runoff that is captured and usable is 71×10^6 acre-feet (88×10^9 m^3). Agricultural water use accounts for 43% of the state's captured 71×10^6 acre-feet (88×10^9 m^3) of water. Eleven per cent is used in urban areas, and the remainder, 46%, is used for environmental purposes such as stream flow requirements and wetland habitat. Of the water not used for the environment, agriculture consumes 80% while cities use about 20% (Pacific Research, 2001).

Recent Events

A 1996 state deregulation plan that was meant to make electricity cheaper for consumers instead resulted in skyrocketing utility bills, forced the state's largest utility to file for Chapter 11 bankruptcy protection and sent the state's legislators into a contentious battle over how best to resolve what was commonly referred to as the state's 'energy crisis'. The first casualties occurred in the summer of 2000: residents of San Diego were subjected to bills two and three times larger than normal. The crisis soon spread to other areas in the state: in December 2000, northern California areas experienced rolling blackouts and in the spring of 2001 blackouts occurred in many parts of the state.

In late March 2001, the California Independent System Operator issued an assessment of the energy situation in California. The report predicted that California would be experiencing shortages of energy during the summer and would therefore be subject to rotating blackouts. As it turned out, energy shortages and rolling blackouts did not materialize, most likely due to a combination of factors including low temperatures, consumer conservation and legislators' actions to secure energy sources.

The Energy Crisis and California Water Agencies and Utilities

In addition to the obvious effects of the energy crisis on the state's electric utilities are the less apparent effects on the state's water agencies and utilities. In response to reduced availability of energy, water operators were forced to interrupt normal operations and investigate using alternative sources of power. The Association of California Water Agencies (ACWA), a public water agency advocacy group whose 435 members are responsible for 90% of the water delivered in California, announced in February that they had reached agreements with two companies to help members purchase solar power devices and microturbine electricity generators. The deal will allow member agencies to buy photovoltaic solar units and 30 kW and 60 kW microturbines at significantly reduced prices (Ameriscan, 2001). The ACWA has been lobbying both the state and federal governments for money to fund these purchases and to support the aggressive implementation of demand management programmes.

Additional costs water utilities are forced to pay will be passed along to the consumer. According to the ACWA (2001), because electricity costs make up 20–80% of a water utility's total operating budget, consumers may soon see electricity-related price increases in their monthly water and sewer bills.

Below-normal Precipitation in California and the Pacific North-west

Exacerbating the energy crisis are drought and below-normal precipitation conditions in California and the Pacific north-west. At the end of March, California was at 76% of the historic average for precipitation. Water agencies are starting to react to the evidence that, for the first time in 6 years, California is in a below-average water year. The Turlock Irrigation District's response to the dry hydrological conditions includes lowering the allotment to farmers from 48 inches (1.2 m) of irrigation water to 42 inches (1.1 m) (Giblin, 2001). The Turlock Irrigation District provides irrigation water to nearly 5800 growers with 150 000 acres (60 703 ha) in central California.

The situation in the north-west is similarly bad. "With the driest winter in 70 years, the Bonneville Power Association [BPA] faces the difficult task of producing power while meeting the obligations of the US Endangered Species Act" (Knickerbocker, 2001). The BPA is a federal agency, under the US Department of Energy, whose function is to sell the power produced at 29 federal dams located in the Columbia–Snake river basin. The BPA primarily serves Oregon, Washington and Idaho, but also provides power directly to small portions of California and sells surplus power to California.

The BPA issued a news release on 12 January 2001 outlining the agency's worrisome conditions:

> BPA and the region are facing a combination of power supply and economic challenges that are unprecedented in its history. The region's power supply is significantly reduced due to the following conditions:
>
> - Low streamflow and snowpack conditions have reduced the amount of hydropower generation available in the region;
> - Under the Biological Opinion, a low streamflow and snowpack condition forces a very conservative winter hydro system operation in order to provide a reasonable probability of having enough water for spring flow augmentation;
> - In general, Northwest generating resources have not kept up with increased demand; and
> - The region's historic ability to import significant amounts of winter-surplus energy from California, the Eastern Interties and Canada appears to be substantially reduced due to a lack of surplus resources in those areas. (BPA, 2001b)

Global Climate Change and Water Supplies

Potentially aggravating California's water supply problems is the recently identified trend that the snowmelt is occurring earlier than it used to. The early snowmelt may be attributed to the effects of global warming on California's climate. There is increasing evidence that global warming has affected the water cycle in California: while total precipitation has not significantly changed, there is less snow and more winter rain and the snow melts faster. These potential changes in the state's hydrological cycle may have significant impacts on California's water supply.

Dan Cayan, Director of the Climate Research Division at the Scripps Institution of Oceanography, notes that "since the mid-1970s, runoff during the late spring and early summer has dropped to barely 30 percent of the annual total" (Perlman, 2001). According to a Pew Center on Climate Change study (Frederick & Gleick, 1999), climate models predict that global warming will have three major effects on mountainous watersheds: "increase the ratio of rain to snow, accelerate the rate of spring snowmelt, and shorten the overall snowfall season, leading to more rapid, earlier, and greater spring runoff".

Drought Conditions

The region's dry hydrological conditions only exacerbate an already difficult energy situation. The Governor's Advisory Drought Planning Panel (2000, ch. 2, p. 17) prepared a Critical Water Shortage Contingency Plan on 29 December 2000. The plan had the following to say about the possibility of a drought, given the current energy crisis:

> Deregulation of electric utilities in California has created substantial upheaval in the State's power market. Adding dry hydrologic conditions to this situation would exacerbate the present risks of power outages. Hydroelectric power production would decrease, and power usage could increase as a result of the increased groundwater extraction normally occurring during dry periods. In today's deregulated market, power costs can be an increasingly large component of the costs of conveying water—whether SWP water or non-project water—via the California Aqueduct to Southern California.

Additionally, when the water table falls, during a dry hydrological cycle or when the aquifer is overpumped, more power is required to extract groundwater. An aquifer with a very low water table can have the added problem of greater saltwater intrusion, meaning that pumped water requires additional treatment.

These circumstances bring the complete interconnection between energy and water sharply into focus. Those responsible for water management have to make tough decisions. "Water and power are inextricably linked", said Earl Cummings, a spokesman for the state Department of Water Resources in Sacramento. "A shortage in water creates a shortage of power." "In a drought year, you have competing demands for water", said Lon House, an energy advisor to the ACWA. During dry hydrological years, water utilities and farmers pump more water from groundwater basins, requiring yet more energy. Water requirements are highest during the summer, when electricity also reaches its peak. Lon House: "Is it better to hold water in reservoirs for cities and farms, or is it better to generate power with? Is it better to irrigate crops early in the summer or hold it until later in the year to generate power?" (Rogers, 2001).

A low hydrological year also forces utilities to balance the needs of electricity users and the environment. The BPA has struggled and is struggling to determine how much water should be used to help migrating fish and how much should be used for power. A BPA press release of 9 March 2001 says:

> The traditional spill regime for salmon begins in April. However, the salmon from the Spring Creek Hatchery migrate earlier than the upstream threatened and endangered species. Given this earlier migration start, the National Marine Fisheries Service; the US Fish and Wildlife Service, which operates the hatchery; the states of Oregon and Washington; and the Columbia River Inter-Tribal Fish Commission request this early spill each year. The returning adult Spring Creek Hatchery fall chinook are an important buffer to Endangered Species Act listed stocks in treaty and non treaty ocean and Columbia River mixed stock fisheries. (BPA, 2001c)

The BPA released a targeted spill which was only 10% of the previous year's spill. The water, which did not go through the turbines at the dam and so did not generate any power, is valued at about $2.1 million (BPA, 2001d). The Environmental News Network noted in January 2001 that "On at least two occasions last summer, the Bonneville Power Administration—the federal agency responsible for marketing power from dams in the Pacific Northwest—used water meant to aid migrating juvenile salmon to supply California with hydroelectricity".

Despite the energy shortages, conservation groups are still lobbying for the removal of four dams on the Lower Snake River. Removal of the dams could facilitate the recovery of endangered salmon populations. The dams produce about 1231 MW of power, enough electricity to power the city of Seattle or about 5% of the region's energy supply. Less than 1% of California's energy supply comes from the Lower Snake River dams, conservation groups note. The BPA is required by the current federal Biological Opinion on salmon recovery to provide minimum flow and spill levels to help salmon survive the dams. In power 'emergencies', however, those fish passage measures can be suspended to allow for additional hydropower generation (Higgins, 2001).

In addition to deciding between water for power and water for fish, the BPA is also balancing the need for power with the irrigation needs of farmers. To this end, the BPA has proposed paying farmers to leave their land fallow. Its objective is to pay irrigators not to plant 67 000–100 000 acres (27 114–40 469 ha) so as to avoid using the electricity required to pump the water from the Grand Coulee dam to the farmland (Environmental News Network, 2001a).

And in California, power managers saved energy and avoided blackouts by temporarily stopping the use of pumps that transport water from northern California to the southern portions of the state (Coleman, 2000). According to a 2001 press release, Metropolitan Water District's General Manager, Ronald Gastelum, stated:

> We already turn off some of our Colorado River Aqueduct pumps when requested by the Southern California Edison Co., freeing up

> enough electricity for 100 000 Southern California homes. To provide further assistance, particularly this summer, we stand ready to shut down four additional aqueduct pumps for limited periods when requested by the ISO [independent system operator] to help reduce the need for rolling blackouts. Together, these reductions will amount to a nearly 45% reduction in energy use along the Colorado River.

Deregulation and Dam Management

A byproduct of deregulation is that competitive pressures affect how hydroelectric dams are managed, which may have negative environmental consequences (Schueller, 2001). Dam managers have economic incentives to hold water until demand peaks and electricity prices are high. This ability makes hydropower particularly valuable in a deregulated market, but is also more destructive to rivers. Variations in the discharge from dams have a variety of negative environmental consequences, including the destruction of benthic organisms (those plants and animals that live at the bottom of rivers and lakes and play an important role in the water body's ecosystem) and a reduction in diversity (Baxter, 1977).

The Energy Crisis and Environmental Regulations

Another issue raised by the state's current situation is whether or not the energy crisis conditions warrant the loosening of environmental restrictions. In February 2001, California lawmakers introduced legislation to exempt a hydroelectric project in the El Dorado Irrigation District from the requirements of state environmental regulations. The text cited the importance and urgency of the project, given that California was experiencing energy shortages. Environmental activists argued in response that the energy crisis was more a ruse than a reason and the real purpose of the project was not to generate electricity, but rather to provide additional water supplies for the region's suburbs.

Whether or not the legislation is passed and whether the water from the completed project is used for power generation or for consumption, this example raises some interesting questions. It brings up a long-standing debate between those who argue that environmental considerations are more important than economic considerations and those who argue that the economy is more important than the environment.

For example, Governor Gray Davis issued executive order D-40-01 in January 2001 that allowed natural gas-fired power plants to operate longer than permitted by local air quality districts, in order to avoid blackouts and "minimize operation of backup diesel-fired generators". In this instance, the lawmaker was confronted with a situation requiring the balancing of economic and environmental concerns. These situations force policy makers and the public to think about difficult questions. Are economic gains worth the environmental consequences? What are the economic consequences of damage to the environment?

The Energy Situation and Water Supplies

In the same way that transporting and processing water consume large amounts of energy, the operation of power plants can consume large amounts of water.

To address the state's energy shortage, numerous power plants are being planned and built within California and all of them will require fresh water for cooling. This raises the question: will the proposed solution to one problem result in exacerbating another problem?

An article on 25 June 2001 in the *San Jose Mercury News* notes that "in California, nearly half of the 28 major power plant projects in construction or under review by the energy commission will tap into the state's freshwater supplies" (Levey, 2001). For example, developers are working on five power plants in West Kern County, near Bakersfield. Water to this area is mostly provided by the West Kern Water District, which consumes SWP water and groundwater. According to the California Energy Commission (2001) web site, the proposed plants will have the following characteristics.

- Sunrise power plant will produce 320 MW of power and will receive most of its water from an adjacent oilfield operation and some water from the West Kern Water District.
- Pastoria energy project will generate 750 MW of power and will receive water from the SWP and from its groundwater storage facilities.
- Western Midway Sunset plant will produce 500 MW of power and will receive water from the West Kern Water District.
- La Paloma plant will produce 1048 MW of power and will receive California aqueduct water from the West Kern Water District.
- Elk Hills plant will produce 500 MW of power and will receive groundwater from the West Kern Water District.

All together, these five plants will produce more than 3000 MW of power and will consume about 16 000 acre-feet (19×10^6 m^3) of water each year.

Another power plant recently approved by the California Energy Commission is the High Desert power plant. This proposed plant, located in the Mojave Desert in the city of Victorville, will produce 720 MW of power and will require 4000 acre-feet (4.9×10^6 m^3) of fresh water. The project's fact sheet on the California Energy Commission web site notes that cooling water will be obtained either from groundwater or from the Mojave River pipeline project. The Mojave River pipeline project is part of the effort to remediate the overdraft of the high desert. It was designed to bring water from the California aqueduct to percolation ponds in order to recharge the groundwater basin (Mojave Water Agency, 2001).

There are alternatives to using fresh water, although they can be less efficient. One option is to use treated sewer water. The proposed Delta Energy Center, located in Pittsburg, Contra Costa County, will use secondary-treated wastewater from Delta Diablo Sanitation District in its cooling towers. Also, some plants are using a technology called dry cooling, which uses 95% less water than conventional systems (Levey, 2001).

Prices of Water and Energy

Another critical component of the interaction between energy and water is how price reflects (or does not reflect) the amount of energy required to move water from the source to the consumer. Below are some examples of current water rates from the Metropolitan Water District (MWD), a consortium of 26 cities and water districts that provides drinking water to nearly 17 million people in Los Angeles and neighbouring counties. The MWD delivers an average of 1.7×10^9

gallons (6.4×10^9 l) of water per day to a 5200 square mile (13 468 km^2) service area.

The MWD's basic service for treated water costs \$431 per acre-foot (1233 m^3), while the untreated basic service costs \$349 per acre-foot. The MWD's agriculture treated water costs \$294 per acre-foot and untreated agriculture water cost \$236 per acre-foot. In addition the MWD offers a \$154 per acre-foot rebate to businesses that save water through upgrading systems. The cost for desalination, based on an estimated price of \$2 per 1000 gallons (3785 l) of desalted water is \$652 per acre-foot (Orme, 2001).

From an energy use perspective, it makes sense that treated water is more expensive than untreated water. However, does it make sense to price water differently based on the use? One reason for the price differential is because urban water systems are more complex than agricultural systems. Does this difference fully account for the \$137 less that agricultural users are charged? The subsidization of agriculture in California through reduced water rates is the source of much contention. Some argue that reduced rates for agricultural users promote wasteful use. Others contend that agriculture is a vital part of the California economy, providing valuable tax dollars and numerous jobs.

Price and Conservation of Water and Energy

Questions about the structure of water pricing in California have led to the idea that perhaps water markets should be developed to encourage the more efficient use of water in the state:

> Water markets balance supply with demand. Although water markets do not create new supplies, they reallocate water to make more efficient use of existing supplies, promote water conservation, and allow water users to get more out of their water supply than they otherwise could. (Pacific Research, 2001)

Water markets have so far been used primarily in times of crisis. For example, as a result of the drought that plagued southern California between 1987 and 1992, the DWR operated drought water banks in 1991 and 1992 which facilitated the transfer of water rights from low-valued uses to high-valued uses. The drought bank bought water from farmers who let their fields lie fallow or used groundwater instead of surface water and from areas in northern California that had excess water. During this emergency, water managers also used economic incentives to encourage responsible water use. During the drought, Santa Barbara imposed penalty rates to encourage conservation. Similarly, during the current energy crisis, electricity providers in California are offering their customers discounts of 20% if they reduce their energy usage by 20%. This incentive, proposed by Governor Gray Davis, is designed to help the state avoid rolling blackouts.

Recommendations and Conclusion

As the California experience illustrates, the nexus between water, energy and the environment is incredibly complex. Currently, the state faces myriad challenges: repairing the energy system to meet demand at acceptable prices, and without diminishing air quality; maintaining a water delivery system which is being stretched as it provides both energy and water to agriculture, industry and residents in the face of climate change and decreasing rainfall; and providing the resources needed to protect the environment. California is not alone in its difficulties in managing water and energy; the situation of increasing demand and changing priorities is apparent throughout the globe.

As a case study, California provides an opportunity to begin to understand and discuss the issues and possible solutions of the water–energy nexus: both lessons and solutions can be drawn from this diverse, dynamic state.

- Recognize that the cost of water and energy and education regarding their use can dramatically affect water and energy consumption.
- Investigate different options for using water markets and pricing of water and energy to make the costs of the use of these resources more apparent (to internalize current external costs).
- Encourage the continued development and increasing use of technological innovations in water, energy efficiency and renewable energy.
- Develop participatory and multi-stakeholder processes that lead to the development of better water and energy management practices within local communities and between states and nations.
- Introduce into water management the concept that water can be used for different purposes (energy, environment and agriculture, etc.) by different stakeholders at different times.
- Be mindful that policy actions intended to improve the supply or use of one resource can negatively impact the management/supply of other resources (e.g. building more power plants to increase the energy supply could dramatically increase the demand for water).

The ultimate task is to act responsibly in the face of the growing demand for water and energy, and the associated global environmental problems of climate change and diminishing freshwater resources. The way water and energy are used today, and the innovative techniques that are devised to improve efficiency in the future, will play a major role in preserving the health of the planet and improving the lives of its people.

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