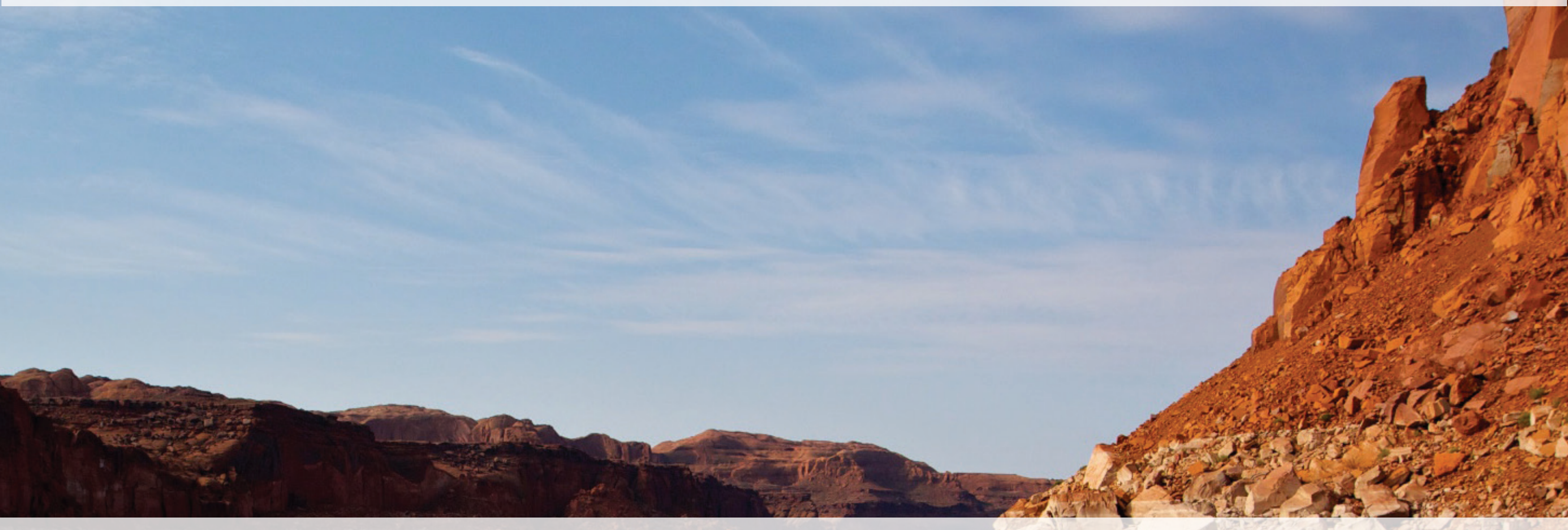
Can Renewable Energy Lead the Colorado River Basin into a Water Friendly Future?

By Audrey Burns



Key Findings:

-The agricultural sector consumes about 39 times the amount of water as the electricity generation sector.

-Photovoltaic solar systems have a median emission of 43 grams of carbon dioxide per kilowatt hour vs. concentrating solar power systems- 26 grams and coal- 1,001 grams.

-Colorado wind saves around 2.18 billion gallons, or 6,690 acre feet (af) of water a year that would be consumed if this power came from fossil fuels.

-Biomass can substitute for up to 20% of the coal used in the coal-fired boilers.

-Natural gas, if implemented more widely in place of coal combustion, can be an effective method of simultaneously reducing carbon dioxide emissions in half and using half the amount of water for generation that coal requires.

-The average home in the United States uses 31.5 kilowatt hours of energy per day. For the state of Colorado, this amount of energy use translates to water consumption of 14.5 gallons of water per day.

-If the basin's entire generation portfolio were renewable, nearly 300,000 af could be saved each year, supplying a full 25% of the deficit the basin will be facing in a decade.

The 2013 Colorado College State of the Rockies Report Card
Water Friendly Futures for the Colorado River Basin

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Will Stauffer-Norris

Introduction

As population, water demand, and energy demand increase in the Colorado River Basin, water stress is becoming highly prevalent. Water for electricity generation comprises approximately three percent of consumptive water use in the Colorado River Basin. As water becomes scarcer, it becomes more expensive to generate electricity. The state of energy and water use as they stand will not allow for a water friendly future in the basin. While water for electricity generation comprises three percent of consumptive water use in the basin, water for agriculture constitutes about 80% of consumptive water use in the basin. Since water rights are appropriated toward senior holders first, agriculture will likely continue to receive the majority of water in the basin. If agriculture is the main water consumer, why is there a concern for water use for electricity generation?

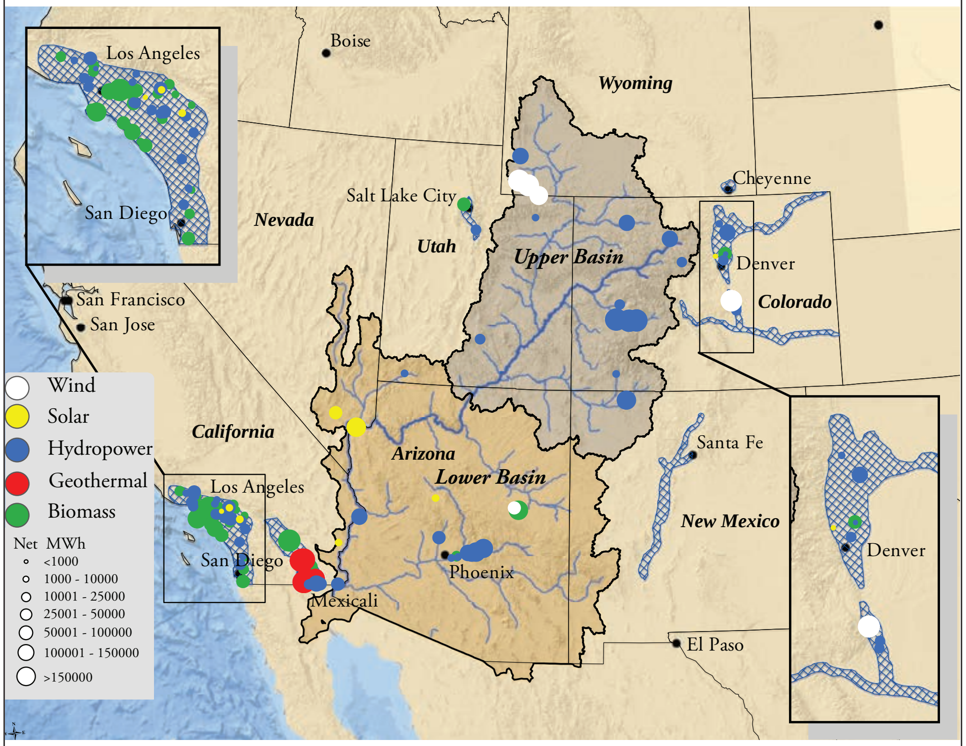
If demand patterns continue according to the Bureau of Reclamation's (BOR) current trends scenario, as population increases and water becomes scarcer, there will be less water available for energy, as well as less energy for water. The factors considered in this BOR study with respect to electricity and energy are oil shale development, photovoltaic solar power, concentrated solar power, wind, geothermal, and fossil fuels. The consumptive water demand for energy in the Colorado River Basin is projected to be at 271,849 acre feet in 2015, 363,369 acre feet in 2035, and 434,289 acre feet in 2060.[1] The increase in water consumptive demand from 2015 to 2060 is estimated to be 63%. While electricity production and generation are less water-consumptive than agriculture, there still needs to be water available for energy generation. Thus, implementation of a less water-consumptive method of electricity production is in order. The demand study indicates that using less water in the energy sector will help bridge the gap between water availability and water demand in the basin. Even though the agriculture sector consumes about 39 times the amount of water as the electricity sector, significant reduction of water consumption in the electricity sector will aid in alleviating the basin's water stress. As agriculture often holds senior water rights, it may be a less politically charged matter to reduce water consumption in the electricity sector.

Renewable Energy in Opposition to Fossil Fuels

Fossil fuels comprise a sizeable portion of the source for electricity production in the basin, thus consuming a sizeable amount of water in the basin. Many forms of renewable energy, namely wind and some forms of solar, use significantly less water than fossil fuels. Renewable forms of energy also have far fewer carbon emissions than nonrenewables. They do, however, have higher up-front costs than nonrenewables, and it is difficult to arrange for large-scale renewable projects. **Figure 1** displays the renewable plants in the Colorado River Basin and its adjacent areas.

There are several options for renewable energy in the Colorado River Basin. The irradiation in the southwest is more conducive to solar power generation than anywhere else in the United States. There is also high wind potential on the High Plains, making some wind energy for the Colorado River Basin and some of its adjacent trans-basin diversion areas a viable option. Geothermal potential also abounds in and around the Colorado River Basin, with plants currently in operation in Montana, Nevada, New Mexico, and Wyoming.[2] With respect to biomass potential, the Colorado River Basin has the smallest quantity in the U.S., although there is fairly high potential in southwest Arizona and in the southern tip of California.[3] Hydroelectricity is a renewable currently being implemented to a great extent in the basin, but it leads to massive loss of water by evaporation and is a risky choice for electricity in an area with an arid climate and water stress.

Figure 1: Renewable Power Plants by Fuel Type in the Basin



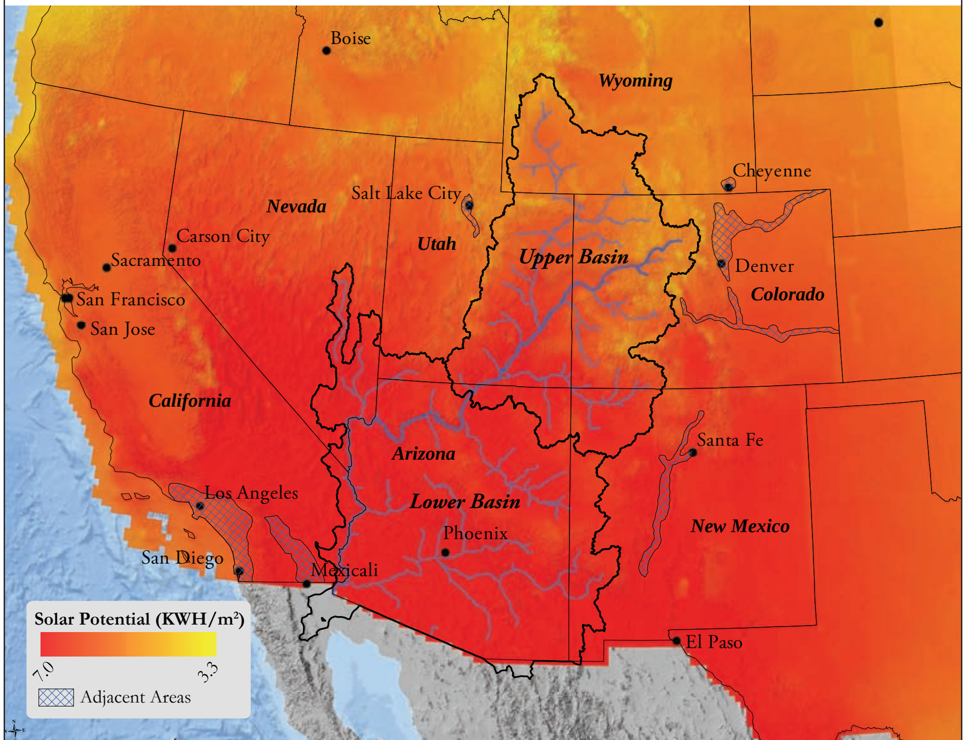
Source: United States Environmental Protection Agency. eGrid Survey. Y*ear 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%) Data Files*. eGRID plant year 2009 data (4/27/12). 2012.

Solar Potential in the Colorado River Basin

Solar irradiation would be able to deliver substantial amounts of energy to the Colorado River Basin, depending upon the type and scale of the solar energy projects. As displayed in **Figure 2,** there is high radiation potential in the Colorado River Basin, particularly in Arizona and New Mexico.

The two main categories of solar power are photovoltaic solar power and concentrating solar power. In 2011, silicon photovoltaic sales made up 90% of all PV product

Figure 2: Solar Radiation in the Colorado River Basin



Source: National Renewable Energy Lab, Department of Energy

sales in the U.S.[4] While solar panels are not terribly water-consumptive to operate at maximum capacity for electricity generation, they do need to be washed regularly. If they are not routinely cleansed with water, their efficiency can be reduced by 15-20%.[5] When put in the context of the Colorado River Basin's water stress, photovoltaic panels are a smart choice because their manufacturing, a highly water-intensive process, generally occurs outside of the basin and they require about four gallons of water per panel to wash. Solar panels should be washed about every six months.

Concentrating solar power (CSP) uses radiation from the sun to generate electricity without PV solar cells. CSP parabolic troughs concentrate solar radiation onto a small tube following tracking parabolic mirrors, or troughs. The transfer fluid in the tube is heated and stored, later to be used to generate steam and spin a turbine.[6] The CSP tower system uses a centrally located tower surrounded by a field of tracking mirrors, or heliostats. The heliostats reflect solar insolation to the top of the tower, and here the solar energy heats the fluid in the tower, and the heated fluid then turns the tower's steam turbine.[7] The engine system produces electricity without using steam or a turbine.[8] The four main types of CSP are parabolic troughs, linear Frensel, power towers, and dish/engine. CSP parabolic troughs are the most commercially available technology of the CSP types, and they will thus be the main CSP focus in this report.[9]

CSP plants must implement various cooling methods to disperse the heat via evaporation from the power plant. There are several different cooling methods for concentrating solar power—dry cooling, wet cooling, and a combination of the two. Wet cooling is frequently used over dry cooling because it is the cheaper and the more efficient method of the two.[10] Dry cooling, while far less water-consumptive than wet cooling, is more subject to temperature swings. Thus, when air temperature is at high levels, the dry cooling system has a compromised level of efficiency. As temperatures are often quite high in the Colorado River Basin, dry-cooling systems will often be compromised in the region. The hybrid system of wet-and-dry cooling utilizes less water than systems that are purely wet cooling while simultaneously alleviating the reaction to temperature upswings typical of the dry-cooling system.[11]

There are myriad benefits to solar energy, and if there were not impediments to implementing solar power, it would top the list of future energy options in the Colorado River Basin. Solar energy emits significantly less carbon dioxide when compared to nonrenewables, and is even less carbon intensive than some renewables. Photovoltaic systems have a median emission of 43 grams of carbon dioxide per kilowatt hour and concentrating solar power systems have a median emission of 26 grams of carbon dioxide per kilowatt hour, whereas coal has a median emission of 1,001 grams of carbon dioxide per kilowatt hour.[12]

While solar energy has relatively low carbon dioxide emissions, it does require significant amounts of water for maintenance of PV solar and for cooling systems in CSP plants. **Figure 3** displays the water use in gallons per megawatt hour of generation and consumption for washing the solar arrays for the most common forms of CSP and PV. Wet-cooling systems are water-intensive for parabolic trough systems, as they use up to 800 gallons of water per megawatt

Figure 3: Water use per MWh of all forms of CSP and PV

Solar Type	Water Consumed per MWh of Generation (gallons)
CSP-Parabolic trough, wet cooling	800-1000
CSP-Parabolic trough, hybrid cooling	100-450
CSP-Parabolic trough dry cooling	78
CSP-Tower recirculating cooling	500-750
CSP-Tower hybrid cooling system	90-250
CSP-Tower dry cooling	90
PV-thin-film cadium telluride (CdTe)	211
PV-multi-and mono-silicon PVs	528

Source: *The Water-Energy Nexus in the American West.*

Figure 4: Current Solar Generation Plants and Solar Projects

State	Plants in Operation	Plants Under Development	Plants Under Construction	Total Plants
Arizona	267	664	2,455	3,386
California	624	3,445	15,553	19,602
Colorado	81	30	267	379
Nevada	139	2	376	517
New Mexico	221	156	3,373	3,750
Utah	X	X	155	155
Wyoming	X	X	X	X

hour. Dry cooling, while not being nearly as water-consumptive (78 gallons of water per megawatt hour), is nonetheless much less efficient than wet cooling. The most water-consumptive form of concentrating solar power is the parabolic trough with a wet-cooling system. While these numbers give a good approximation of water use for PV and CSP, there is still a good deal of uncertainty about the impact of CSP on water use because how much water a CSP system requires depends upon its location, whether thermal storage is included, and whether wet cooling is used.[13]

CSP parabolic troughs are currently the most cost-effective forms of concentrating solar power. When compared to PV, however, CSP is more expensive.[14] Whereas solar thermal was formerly considered to not be a cost-effective option, the price of PV is coming down, and PV is becoming a more accessible form of renewable energy. **Figure 4** is a table of current solar generation plants and solar projects under development and construction in and around the Colorado River Basin. Concentrating solar power plants and photovoltaic solar power panels have a life expectancy of at least 20 years, which allows these electricity sources to effectively pay for themselves before the end of their lifespans.

Wind Energy Potential in the Colorado River Basin

When considering only the aspect of water stress in the Colorado River Basin, it seems that wind energy is the best option. Wind energy uses no water in generating power and wind power only requires water for washing of the turbines' blades. An individual wind turbine uses about one gallon of water for one megawatt of energy produced, assuming the blades are washed four times per year. This number varies slightly depending upon the size of the turbine. There are other aspects of wind energy that must be taken into consideration, such as the cost of wind turbine implementation and the feasibility of bringing a wind turbine online.

As there are drawbacks to solar energy, there are drawbacks to wind energy. Wind turbines come in varying sizes and scales of operation. Commercial-scale turbines currently tend to be 2 MW in generation capacity and cost $3.5 million to be installed, which is a steep up-front cost. Wind turbines operating under 100,000 kilowatts cost about $3,000 to $5,000 per kilowatt hour of electricity.[15] An average home operates at a 10kW capacity, and it would cost $32,000 to

Case Study: Concentrating Solar Power in a Semi-Arid Desert: Nevada Solar One

Nevada Solar One (NSO), owned by Acciona Energy, went online in June 2007, creating over 800 construction jobs during building and approximately 30 permanent operation jobs. Nevada Solar One is a 30-year project. One of the largest CSP systems in the world, it operates in Boulder City, Nevada, proximate to the Colorado River Basin. **Figure 5** is an image of the parabolic trough system in place at Nevada Solar One. This CSP plant uses parabolic troughs and a wet-cooling system. The full load capacity at the plant is 75 megawatts. All of the power generated was purchased by Nevada Power Company and Sierra Pacific Resources under long-term power purchase agreements (PPAs) prior to the plant's dedication. In powering 14,000 homes in Nevada annually, Nevada Solar One avoids the CO_2 emissions equivalent to 20,000 cars. NSO heats oil rather than salt because salts typically use more storage than oil. Nevada Solar One uses a closed-loop system. They use a wet-cooling system at the plant. Ninety percent of the water used at NSO goes toward operating the cooling system. Getting Nevada Solar online was made easier by the previously existing transmission lines. About one mile of transmission line was implemented to get NSO running.

Figure 5: Nevada Solar One Plant

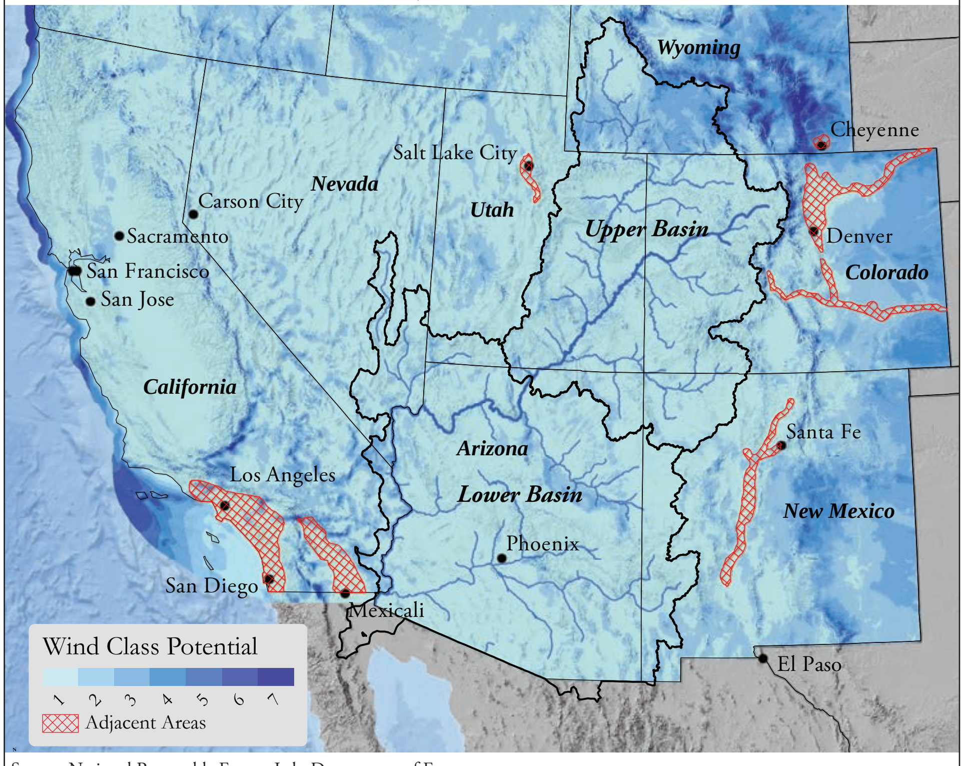
Source: Alice Plant.

install a wind turbine for such a home.[16] There are tax incentives and rebates in several states in the Colorado River Basin, which would help to offset the cost of turbine implementation.

There is high wind potential located in the High Plains, adjacent to the Colorado River Basin, and decent wind potential directly in the basin. While power generation on the plains will not be occurring within the basin, it would help to alleviate water use by fossil fuel plants that rely on trans-basin diversions of Colorado River water. **Figure 6** displays the wind potential in the basin and its adjacent areas. This wind energy has the potential to assist in meeting the energy needs of the Colorado River Basin, given that there are the funds and resources available to create these transmission lines.[17]

Colorado wind saves around 2.18 billion gallons, or 6,690 acre feet (af) of water a year[18] that would be consumed if this power came from fossil fuels, and Colorado's wind power only accounts for about 6% of its generation portfolio.[19] If the basin's entire generation portfolio were renewable, nearly 300,000 af could be saved each year, supplying a full 25% of the deficit the basin will be facing in a decade.

Figure 6: Wind Potential in the Colorado River Basin and Adjacent Areas



Source: National Renewable Energy Lab, Department of Energy.

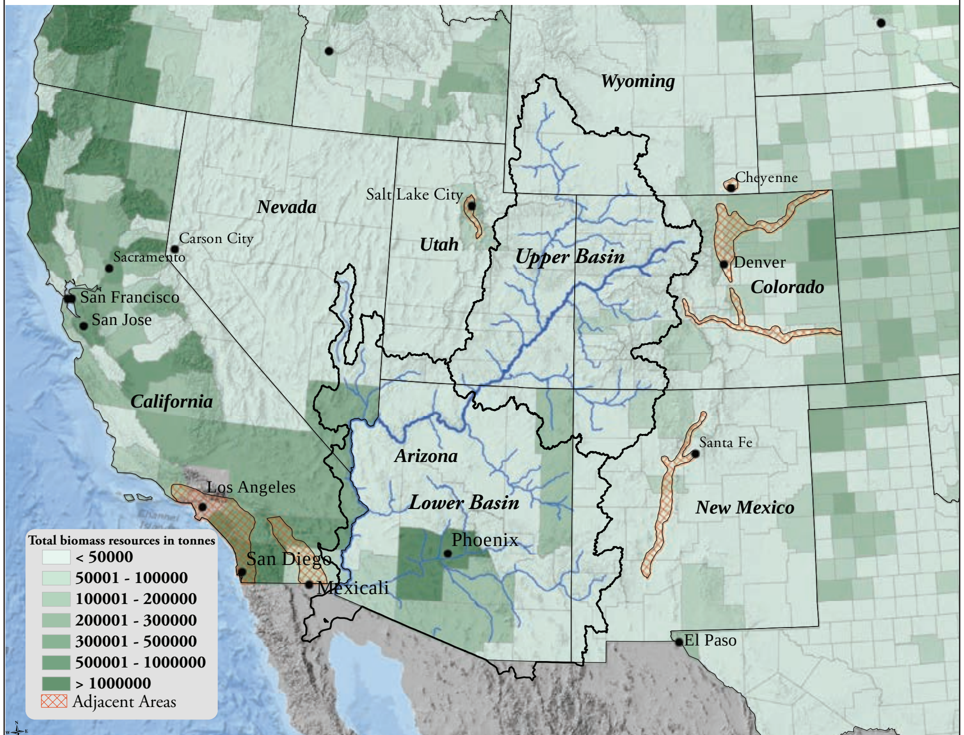
While wind is a positive option in the context of low water consumption, wind turbines are at the mercy of fluctuating wind conditions. Thus, the amount of electricity generated by the spinning turbines can vary day-to-day, and even hour-to-hour. This direct tie between favorable wind conditions for spinning the wind turbines suggests that wind could never be the only form of energy supplying customers.[20]

Other Renewables in the Colorado River Basin: Biomass, Geothermal, and Hydropower

There are several other forms of renewable energy options in the Colorado River Basin—namely biomass, geothermal, and hydropower. While biomass is an increasingly popular form of renewable energy in the region, there are impediments to implementing biomass as a significant energy resource in the West. A drawback to biomass is that it uses large quantities of water, both for the irrigation of biomass feedstocks and for converting of the feedstock into the form of biomass for electricity generation.[21] Water use for power generation using biomass feedstocks is on par with the water use of fossil fuel-fired plants for power generation.[22] An approach to avoiding water-consumptive biomass production is to utilize previously existing feedstocks. Woody biomass and agricultural waste do not require irrigation for their production. Woody biomass can be cofired with coal to generate electricity. This form of biomass is largely comprised of wood that would otherwise be unusable, such as trees felled because of beetle kill. Other forms of woody biomass include urban wood waste, pallets, sawdust, and forest products.[23]

Biomass feedstock can be processed by itself, or it can be cofired. The cofiring process involves combining biomass feedstock with coal in high-efficiency coal boilers. Biomass can substitute up to 20% of the coal used in the boiler.[24] The biomass and the coal are then burned simultaneously. There are several benefits of the cofiring process. Partially supplementing biomass for coal allows for lower fuel costs. Biomass substitution for coal also cuts greenhouse gas emissions as it facilitates avoidance of stowing biomass in landfills and the methane production following the decomposition of organic matter, as well as reducing the sulfur oxide, carbon dioxide, nitrous oxide, and other greenhouse gas emissions which come with coal combustion.[25] While cofiring plants do not reduce the plant's totally energy input requirement and the efficiency of a cofiring plant will be about equal to that of a solely coal-fired plant, they are a positive force in that they reduce the combustion of nonrenewable, greenhouse gas emitting fuel.[26] The payback period of changing a coal plant over to a cofiring plant is in the range of one to eight years. At larger-than-average facilities, as well as in the case of facilities with self-disposal options for their biomass, the payback period can be much shorter. For biomass cofiring to be economically attractive, the boilers must be able to produce 35,000 pounds of steam per hour.[27] Several coal power plants are using this form of electricity generation to meet their renewable portfolio standard requirements, such as the Martin Drake Power Plant in Colorado Springs.[28]

Figure 7: Biomass Potential in the Basin and Adjacent Areas



Source: National Renewable Energy Lab, Department of Energy.

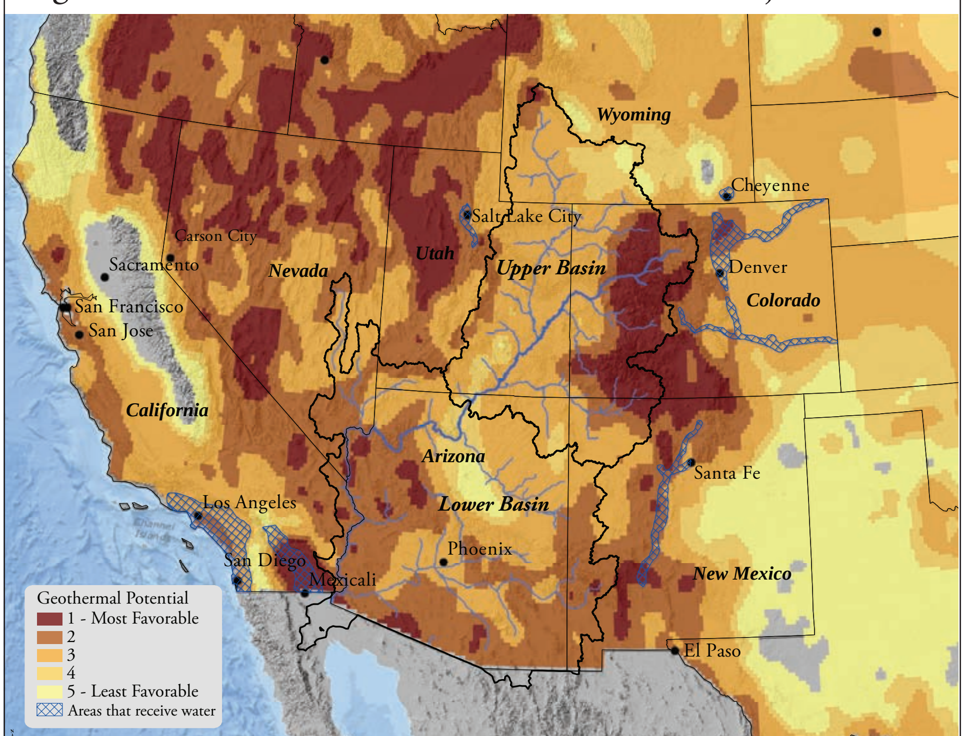
Biomass for electricity generation is gaining more of a presence in the Colorado River Basin. In addition to the change at the Martin Drake Plant, there is one large-scale, cofiring biomass operation underway in Nevada. The Nevada forest service collects woody biomass and sends it to the cogeneration plant at the Northern Nevada Correction Center. There are three biomass plants currently in operation in Arizona. The Western Renewable Plant is a direct-fire facility operating at 2.5 megawatts, the APS Biomass l Plant is a direct-fire facility operating at 2.85 megawatts, and the Snowflake White Mountain Plant is a direct-fire facility operating at 24 megawatts.[29] **Figure 7** is a map of the biomass potential in the Colorado River Basin.

Another important resource for renewable energy in the Colorado River Basin is geothermal energy. It harnesses energy from hot water or steam reservoirs buried deep in the earth. The water in the hot water reservoirs can be as hot as 700 degrees Fahrenheit. A geothermal well is drilled down to the water reservoir, and steam is brought to the surface to perform the classic process of spinning a turbine and generating electricity. This type of geothermal electricity production is known as flash production.[30] Some consider geothermal a good renewable energy source because it uses no petroleum in production and has few greenhouse gas emissions. Geothermal energy produces one sixth of the amount of carbon dioxide that a natural gas plant produces.[31] Less commonly known about geothermal energy, however, is that electricity production from a geothermal source uses an incredible amount of water.

The geothermal reserves in and around the Colorado River Basin are largely in Nevada, with other resources-rich areas peppered throughout California, Colorado, Arizona, New Mexico, and Utah. **Figure 8** portrays the geothermal potential in the Colorado River Basin.

A substantial amount of electricity in the Colorado River Basin comes from hydropower resources (**Figure 9**). The reservoirs feeding the dams are both costly and inefficient. They are costly in that much of their cost must be paid upfront, and they are inefficient in that much of the reservoir's water is lost to evaporation.[32] In the Colorado River Basin, hydropower is exacerbating the problem of water stress, even though it is a renewable source for electricity. Hydropower is not renewable in the sense of being able to replenish itself—once significant amounts of water from the reservoirs evaporate, it is incredibly difficult

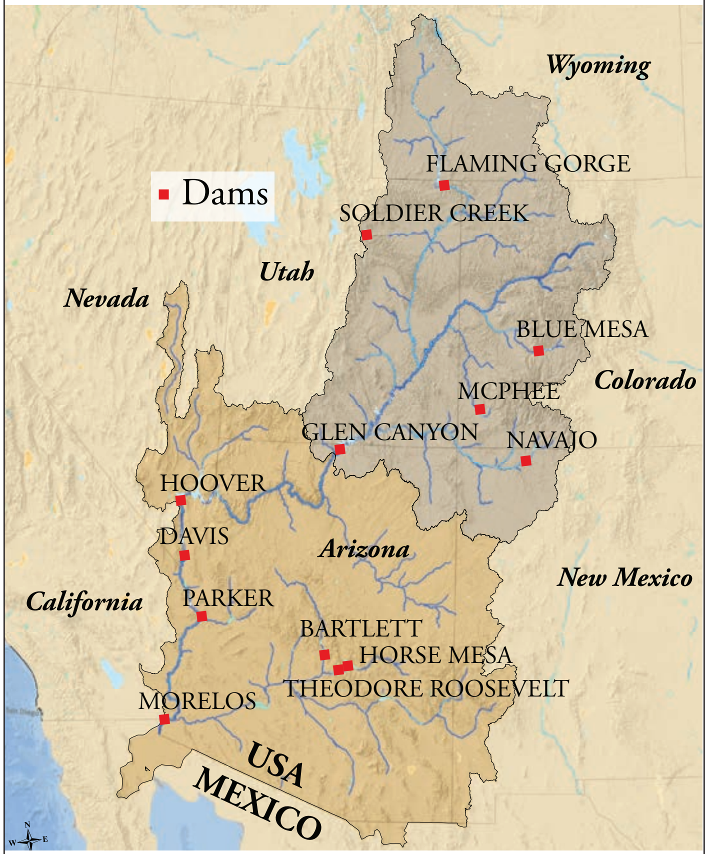
Figure 8: Geothermal Potential in the Basin and Adjacent Areas



Source: National Renewable Energy Lab, Department of Energy.

for those reservoirs to return to their former levels. The "bathtub rings" around Lakes Powell and Mead indicate the extensive water loss on these two reservoirs.

Figure 9: Map of Hydropower Plants in the Basin



Source: U.S. Geographic Names Information System.

The Big Three: Carbon, Water, and Cost

The comparison of the carbon emissions, water consumption, and cost of renewables compares renewables against one another regarding their overall effectiveness for the Colorado River Basin. **Figure 11** displays these comparisons among the forms of renewable energy described in this *Report Card*. Where wind turbines have relatively few cradle-to-grave carbon emissions and are hardly water-consumptive, they are fairly costly. In a water-stressed region such as the Colorado River Basin, the question arises as to what is most important—conserving water, reducing carbon emissions, or keeping costs low.

Out of the renewables presented in this report, photovoltaic solar power, concentrating solar power using dry cooling, and wind energy are the least water-consumptive. They also have relatively low carbon emissions.

If water and carbon emissions are two of the main issues with respect to implementing renewable energy, cost is the third. While they may pay for themselves in the long term, they are expensive up-front forms of energy. **Figure 12** displays the cost of renewable energy and conventional energy per megawatt hour of generation.

While electricity generated from renewables averages a higher cost per megawatt hour than electricity generated from fossil fuels, the price of the former is expected to decrease significantly by the year 2020. **Figure 13** depicts the predicted price drops in renewable energy.

Thus, solar energy is likely to become cost-competitive in the near future. Once solar energy is more accessible, it can become more prevalent in the Colorado River Basin.

Case Study: Evaporation from Reservoirs in the Colorado River Basin

Due to the low water levels in reservoirs in the Colorado River Basin, hydroelectric power generation is threatened. The Colorado River system is running at a deficit of 1 million acre feet per year.[33] Evaporation from the main reservoirs along the river partially contributes to this problem. The evaporation from Lake Mead totals 800,000 acre feet per year.[34] The yearly evaporation from Lake Powell is at about 370,000 acre feet.[35]

As of October 2012, the end of the water year, the Lake Powell inflow was 29 percent of the average inflow.[36] The total inflow for 2012 was at 5 million acre feet, which is 46 percent of the average.[37] Lake Mead hit an historic low in 2010 with a water level of 1,083 feet above sea level.[38] There is a 50 percent chance that the water levels in the reservoir will be too low by 2017 to power Lake Mead's Hoover Dam, which supplies electricity to Los Angeles and Las Vegas.[39] **Figure 10** depicts Lake Mead. The white "bathtub ring" above the water marks the difference between the current level of water in the lake and what level the lake would reach if it were full.

Figure 10: Lake Mead's "Bathtub Ring"

Source: The Resilient Earth.

Figure 11: Water Consumption and Carbon Emissions of Various Renewables

Energy Type	Water Usage in gallons per MWh-generation	Carbon Emissions per kWh
Geothermal	1321-3963	40 g
CSP-Parabolic trough, wet cooling	800-1000	31.8 g
CSP-Parabolic trough, hybrid cooling	100-450	31.8 g
CSP-Parabolic trough dry cooling	78	31.8 g
CSP-Tower recirculating cooling	500-750	32.3 g
CSP-Tower hybrid cooling system	90-250	32.3 g
CSP-Tower air cooling	90	32.3 g
Mirrored Parabolic Dish	4	22 g
PV-thin-film cadium telluride (CdTe)	211	45 g
PV-multi-and mono-silicon PVs	528	45 g
Wind	1	11 g

Source: *The Water-Energy Nexus in the American West*. National Renewable Energy Laboratory, *Life Cycle Assessment (LCA) Harmonization Project.*

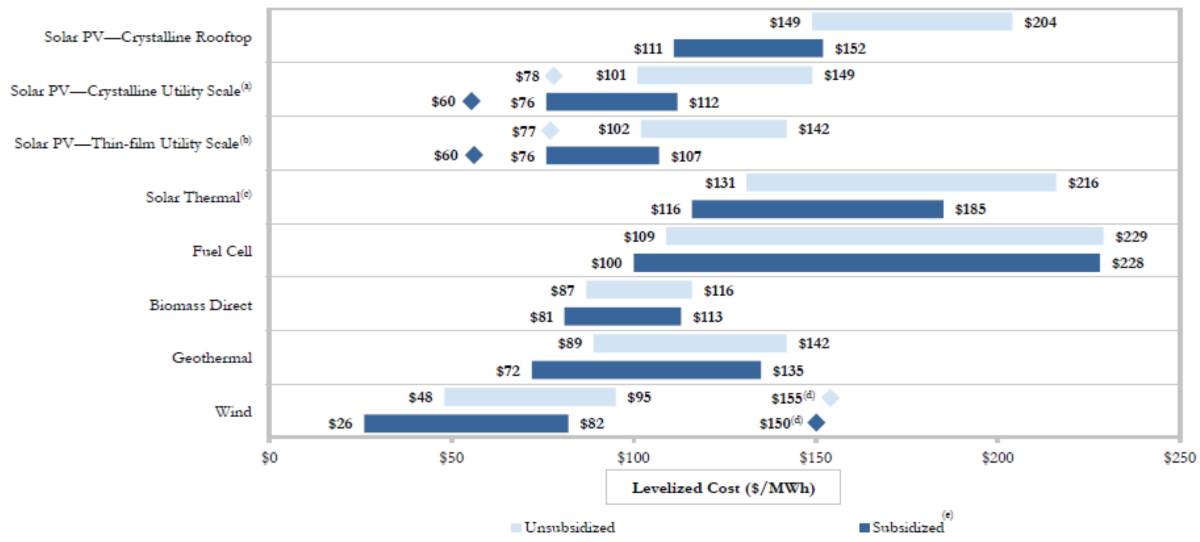
Navigating the Path to Renewable Energy in the Colorado River Basin

While there is potential to greatly reduce greenhouse gas emissions and reduce water for energy and energy for water use in the Colorado River Basin, there are myriad challenges lying in the way of implementing a renewable, clean energy system in the basin. Among these challenges is the glaring issue of cost. The upfront cost of renewables makes it difficult for many who want renewables implemented. Federal subsidies for renewable energy make renewable energy within the reach of more people. Hand-in-hand with the issue of cost is the issue of who the customers are for renewable energy. The main clientele for bulk renewable energy are electric utility companies trying to meet the renewable portfolio standards their states have set forth.[40]

The Obama Administration has continued to support subsidies for solar, wind, and biofuels.[41] The Senate Finance Committee voted on August 2, 2012 to renew a tax credit for wind power that would otherwise expire at the end of 2012.[42] On January 2, 2013, the Committee extended

Figure 12: Levelized Cost of Energy- Sensitivity to U.S. Federal Tax Subsidies

U.S. federal tax subsidies remain an important component of the economics of Alternative Energy generation technologies (and government incentives are, generally, currently important in all regions); future cost reductions in technologies such as solar PV have the potential to enable these technologies to approach "grid parity" without tax subsidies and wind currently reaches "grid parity" under certain conditions (albeit such observation does not take into account issues such as dispatch characteristics, the cost of incremental transmission and back-up generation/system reliability costs or other factors)



Source: Lazard estimates.

(a) Low end represents single-axis tracking. High end represents fixed-tilt installation. Diamonds represent estimated implied levelized cost of energy in 2015, assuming a total system cost of $1.75 per watt for a single-axis system.

(b) Assumes fixed-tilt installation. Diamonds represent estimated implied levelized cost of energy in 2015, assuming a total system cost of $1.50 per watt.

(c) Represents solar tower with and without 3 hour storage capability.

(d) Represents midpoint of levelized cost of energy for off-shore wind, assuming a range of total system cost of $3.10 – $5.00 per watt.

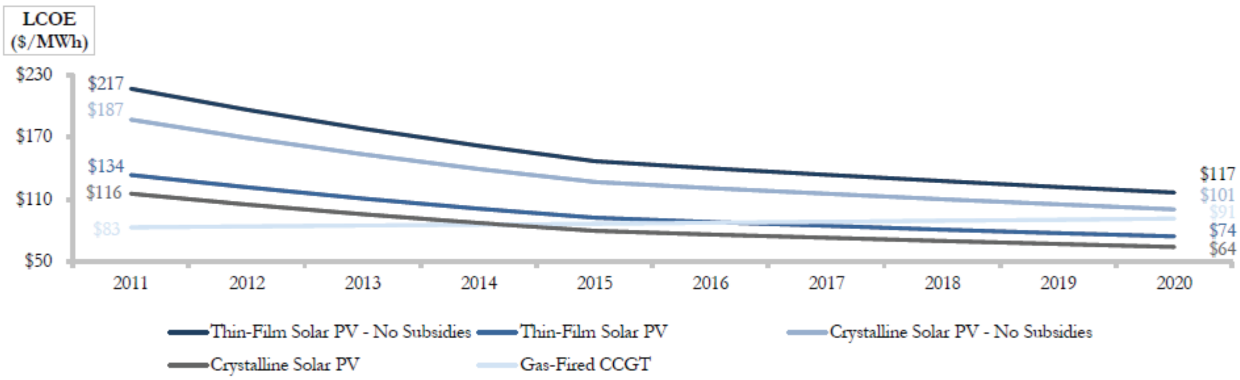
(e) Reflects Production Tax Credit or Investment Tax Credit, as applicable. Assumes 30% debt at 8.0% interest rate, 50% tax equity at 9.5% cost and 20% common equity at 12.0% cost.

Source: Lazard, Levelized Cost of Energy Analysis, Version 6.0, June 2012.

Figure 13: Levelized Cost of Energy- Sensitivity to Capital Costs

An important finding in respect of solar PV technologies is the potential for significant cost reductions over time as manufacturing scale along the entire production value chain increases; by contrast, conventional generation technologies are experiencing capital cost inflation, driven by long-term global demand for conventional generation equipment, where potentially cost-reducing manufacturing improvements for these mature technologies are largely incremental in nature

- This assessment, however, does not take into account the intermittent nature of solar PV as compared with the dispatchable nature of conventional generation; the key finding in this regard is that solar PV technologies will play an increasingly *complementary* role in generation portfolios



Source: *Lazard estimates.*
Note: Reflects investment tax credit and accelerated asset depreciation, as applicable. Assumes 2010 dollars, 20-year economic life and 40% tax rate. Assumes 30% debt at 8.0% interest rate, 50% tax equity at 8.5% cost and 20% common equity at 12% cost for Alternative Energy generation technologies. Assumes 60% debt at 8.0% interest rate and 40% equity at 12% cost for conventional generation technologies. Assumes natural gas price of $5.50 per MMBtu. Assumes midpoint of analysis conducted earlier.
(a) Assumes capital costs for thin-film and crystalline solar PV decline by 10% annually through 2014 and 5% annually thereafter. Assumes capital costs for gas-fired CCGT increase by 2.5% annually.

Source: Lazard, Levelized Cost of Energy Analysis, Version 6.0, June 2012.

the wind tax credit for another year. The credit is worth 2.2 cents per kilowatt hour of electricity produced by wind turbines still in their first ten years of operation. The wind industry considers this tax credit renewal vital to its becoming more competitive with coal and natural gas.[43] Similarly, on July 24, 2012, the Obama Administration opened up 285,000 acres of public lands in the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah for development of solar projects.[44] This opening up of public lands to solar development is an increase from the nil solar projects on public lands at the beginning of Obama's first term in office. Since that time, there has been an increase of 17 major approved solar projects on public lands and an added generation of 6,000 megawatts of power.[45]

The Clean Energy Standard (CES) Act of 2012, proposed by former Senator Jeff Bingaman (D-NM), would increase the generation of renewable energy in the basin and throughout the United States.[46] The act would mandate that the amount of energy produced that is low carbon would stand at 80% by the year 2035. Utility companies would be the driving force in effecting these changes with clean energy credits. The act is one of, if not the most serious, federal propositions for major changes in the renewable energy sector. With the varied motivations and concerns of politicians, it will take time for the act to gain enough approval to be passed, if it is to be passed at all. Clearly, political tumult increases the tension in the field of renewable energy, and regardless of the position taken by either side, disagreements impede the facility with which renewables may be implemented.

While policy issues present a difficulty for implementing renewable energy in the Colorado River Basin, there is a lack of other resources that would be needed to get most large-scale renewable projects underway. Transmission lines are going to be incredibly difficult to implement in the Colorado River Basin. The Western Governors' Association cites access to electric transmission lines as one of the main barriers to implementing more renewable resources in the western states.[47] The WGA proposes the Regional Transmission Expansion Project as a means to get electric utilities, states, and other stakeholders to develop a regional transmission plan to utilize more of the renewable resources in the West.[48] The RTEP would implement water supply considerations into electric transmission planning. The project's plan is expected to come out in mid-2013 with its regional transmission plan. The water-energy assessment will include four components: a water availability assessment, a water-energy model, a scenario analysis, and a concluding section on policy development. The water availability assessment will bring together the current existing assessments of water supply availability, use, and projected demands throughout the West. The water-energy model will address water-energy planning and craft a decision-support framework for it.

Due to policy barriers, conflicting political interests, lack of resources, and other obstacles, the Colorado River Basin will likely not be able to run completely on renewable energy for quite some time. There are, however, steps residents and industries in the Colorado River Basin can take in their use of energy to conserve water and utilize water resources in a more efficient manner.

Steps Forward for a Water Friendly Future

Since renewable energy is not feasible as the only water-conserving measure for the time being, how can we solve the water for energy and energy for water issue in the Colorado River Basin? There are some immediate changes that we can implement to limit water consumption in the Colorado River Basin. Water conservation, recycling water, and leasing water allocated for agriculture to urban users are all "energy-smart" water resource strategies.[49] As mentioned in the M&I section, water conservation on the urban front can be particularly effective. The approach of end-use water conservation eliminates the energy use of pumping, treating, and distributing potable water supplies.[50] There are still many steps utilities in the basin can be taking to promote water conservation. The Basin Roundtables, which bring together 300 knowledgeable citizens around the state of Colorado to discuss issues surrounding the Colorado River Basin, similarly cite conservation as an important step to improving the flows in the Colorado River.[51]

Recycling water, which is also known as reclaimed or reuse water, has the potential to engender great energy savings in the Colorado River Basin. In the interior West, downstream water rights put a cap on the total amount of water utilities can recycle. Many cities in the region, however, have not yet tapped into the potential for recycling water, and there are still substantial water initiatives cities in the basin can take. An impediment to getting more water recycling programs running in the basin is the capital cost of implementing water recycling distribution systems. Recycling water uses energy, and generation of energy, of course, requires water. The western portion of the basin has been playing a part in recycling water. In Las Vegas, among other cities, where wastewater is treated to advanced tertiary standards, there is only incremental energy needed to distribute recycled water to customers. In other cities, there may be more energy needed to bring the wastewater up to higher standards. There is substantial potential for energy savings if reliance on recycled water programs were to become more of a staple in southern California. Large amounts of wastewater are discharged by treatment plants into the ocean in this region, and where fresh water is typically imported to the southern part of that state from the northern part, there would be substantial energy savings if the practice of recycling water were more prevalent.[52]

A third approach to ensuring there is enough water for energy is that of enacting more agricultural-to-urban water leases. This tactic has become increasingly prevalent by cities in the basin and in the adjacent areas. Dry-year leases and rotational fallowing agreements have benefits for both farmers and municipalities.[53] These leasing programs may have a positive effect in the energy sector as well. A rotational-fallowing program located in the Arkansas River Valley, which is in southeastern Colorado, would provide water to Colorado Springs, among other cities in the Front Range. Colorado Springs could use the Southern Delivery System to pump the leased water to the city, which would be an extremely energy-intensive process, or, in some places, the leased water could be transferred to cities by means of exchanges utilizing the river system. The latter scenario would have no extra energy demands.[54]

Boulder-based Western Resource Advocates cites natural gas as a good transition fuel from coal into renewables.[55] Natural gas generation emits half the amount of carbon dioxide that coal emits. As policy issues are worked out and the capital is raised to implement renewables in the basin, natural gas would partially relieve the water requirements for generation currently utilized by coal, as coal generation emits approximately 2,000 g of CO2 per MWh, while natural gas emits about 1,000 g of CO2 per MWh.[56]

According to Western Resource Advocates, there has recently been a decline in carbon emissions from power plants in the West. This decrease is due to several factors. A major coal-fired power plant was recently closed. The recession has also caused many electricity consumers to reduce their electricity use. State regulatory policies have led to an increase in renewables and energy efficiency, which have also helped reduce carbon emissions. The problem of carbon dioxide emissions, however, is not just an issue for the Colorado River Basin. While decreasing carbon emissions in the Colorado River Basin helps dissipate climate change, carbon emissions reduction needs to be enacted on a larger scale than that of the Colorado River Basin.

Is there, then, a role for water efficiency in the future? Renewables may not be the most accessible method of decreasing water use in the energy sector in the Colorado River Basin. While the Colorado River Basin still has a long way to go with respect to implementing renewables, most of the states in the basin have renewable portfolio standard (RPS). State-by-state renewable portfolio standards may also serve as a means by which to reduce water for energy consumption in the Colorado River Basin. A state's RPS requires the utilities companies within a state to supply a certain percentage of its electricity with renewable resources by a certain year. **Figure 14** displays the renewable energy standards by state in the Colorado River Basin. California has the highest renewable energy standard in the Colorado River Basin, with Colorado not far behind at a renewable energy standard of 30% by 2020. Utah has a renewable energy standard goal, while Wyoming does not have any renewable energy standard in the works. Renewable energy standards are a push in the right direction for getting a greater prevalence of renewable energy in the Colorado River Basin. According to the Western Governors' Association, state laws and policies put in place in the last decade are expected to "more than double the amount of renewable resources in the Western U.S." by 2022, compared to 2010.[57]

How can renewable energy become more of a staple in the Colorado River Basin? While many argue that renewable energy will just not have as big a presence as either natural gas or coal in the Colorado River Basin for many years, others contend there are steps legislators in the basin can take to make an equivalent renewable energy presence realized sooner. While having a renewable portfolio standard in almost every state in the Colorado River Basin is a positive step, the basin would benefit from having more stringent renewable portfolio standards.[58]

Figure 14: Renewable Portfolio Standards in the Colorado River Basin

	2015	2020	2025
Arizona		15%	
California		33%	
Colorado		30%	
Nevada			25%
New Mexico	15%	20%	
Utah	Renewable Energy Standard Goal		
Wyoming	X	X	X

Energy Saving on a Day-to-Day Basis

As mentioned earlier in this section, the average home in the United States uses 31.5 kilowatt hours of energy per day. For the state of Colorado, this amount of energy use translates to water consumption of 14.5 gallons of water per diem. How can homes cut down on their energy use, and by extension, water consumption? **Figure 15** displays the average distribution of energy consumption in the American home.

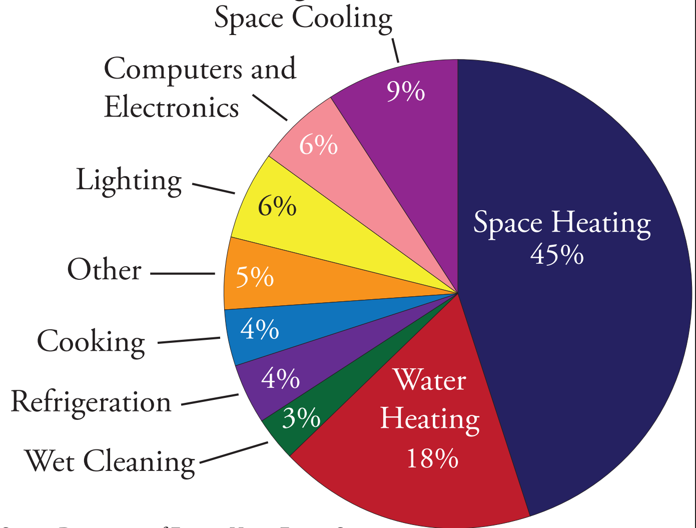
Home energy audits, which homeowners can either do themselves or have their utility company do, are excellent means of determining a home's energy efficiency and where homeowners can make improvements in energy efficiency. There are five main components of the do-it-yourself home energy audit. See **Figure 16** for the steps involved in conducting the audit.

Once these areas have been examined, homeowners can make the appropriate changes in insulation, air leaks, lighting, and heating and cooling equipment.

The Ideal Situation in the Face of Increasing Demand for Energy and Water

Of the scenarios delineated in the Bureau of Reclamation's Demand Study, the Enhanced Environment and Healthy Economy scenario (EEHE) is the most ideal scenario from the energy-water nexus perspective. Where the Expansive Growth scenario (EG) anticipates increased fossil fuel development and increased oil shale development, the EEHE predicts the adoption of water-saving techniques, such as smarter fuel choices and cooling systems. This scenario is also the most positive for the energy sector because there is an increase in social and legal considerations for carbon emissions. The future economic conditions, enforced by emission mitigation legislation, would not favor fossil fuel development in the southwest.

Figure 15: Energy Consumption Distribution in the Average American Home



Source: Department of Energy, Home Energy Savers.

The EEHE predicts enhanced governmental actions prioritizing the environment, including climate change and greenhouse gas mitigation measures. Greenhouse gas controls would dictate the substitution of polluting fossil fuels with renewables, and a focus on climate change would dictate the installation of only water friendly renewables. The best case scenario for the energy-water nexus would be to have a large reduction in the amount of water used for energy and the amount of energy produced; this scenario is effective in reducing water consumed for energy while reducing demands for energy with social values.

The predicted change in social values for this scenario is positive overall for the demand side of the water-energy nexus, and legislative changes would allow for "increased flexibility

Figure 16: Energy-Efficiency Changes Around the Home

Where to Make Energy-Efficiency Changes Around the Home	Fix
Check insulation in the attic, exterior and basement walls, ceilings, floors, and crawl spaces.	Seal any gaps with expanding foam caulk or other permanent sealant.
Check for air leaks around walls, ceilings, doors, light and plumbing fixtures, switches, and electrical outlets.	Plug and caulk holes and cracks that are discovered. Beware of indoor air pollution and combustion indoor "backdrafts."
Check for open fireplace dampers.	Close the open fireplace dampers.
Look into the status of home appliances and heating and cooling systems.	A professional should check and clean the equipment once a year. If the equipment is more than 15 years old, consider replacing it.
Examine the status of lighting in the home. Sensors, dimmers, and timers are available to reduce lighting use.	Consider replacing incandescent light bulbs with compact florescent (CFL) bulbs. They are more efficient and do not give off greenhouse gas emissions when in use.

Source: Department of Energy, *Energy Savers: Do-it-Yourself Home Energy Assessments.*

of water uses." While water for energy and recreation are inherently included under that category, changing values and legislation will improve the in-stream flows and health of the Colorado River. Thus, society will grasp the importance of water to ecosystems while legislation simultaneously pushes them to succumb to the betterment of water use practices, which is the ultimate goal of improving the status of the energy-water nexus in the Colorado River Basin.

Conclusion

Under current conditions it is difficult to initiate enough large-scale renewable energy projects going in the Colorado River Basin to power the entire basin in the near future. Solar energy is becoming increasingly cost-competitive, and wind energy is similarly becoming more popular. While renewable energy may initially sound like the ideal future for the basin, it is not representative of the most feasible one. There are promising policies helping to gradually increase the renewable energy generation in the Colorado River Basin. However, the rate at which renewable energy is being implemented cannot alone free up water use in energy production sufficient to solve the basin's projected supply shortages. Therefore, natural gas can act as a useful bridge fuel as we slowly transition away from coal and into a cleaner, less water-consumptive future. Water demand will soon surpass its supply, so we must start saving water immediately, through renewable energy options discussed here and through other tactics.

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