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Colorado Water Supply and Climate Change: A Business Perspective

ENVIRONMENTAL ENTREPRENEURS®

About E2

Environmental Entrepreneurs (E2) is a national community of business leaders who promote sound environmental policy that builds economic prosperity. E2 is the independent business voice for the environment. We provide a nonpartisan resource for understanding the business perspective on environmental issues. Working with our public and private partners, E2 shapes state and national policy that's good for the economy and good for the environment. www.E2.org.

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I. INTRODUCTION

As Colorado business leaders, the members of the Rocky Mountain chapter of Environmental Entrepreneurs (E2) are concerned by the mounting evidence that climate change will make it harder to meet the state's future water needs, that these risks are not yet sufficiently understood, and that not enough is being done to reduce them.

We call on the governor and other key public officials to ensure that the new State Water Plan being developed includes specific measures to adequately reduce Colorado's water risks, as magnified by climate change. Our central recommendation is that the state government, water providers, and the private sector work together to reduce per capita municipal and industrial (M&I) water use by 25 percent by 2025 and by 50 percent by 2050. This is a more ambitious goal than anyone has yet proposed for this state. But it is the action that is proportionate to the challenge. It is realistically achievable, as evidence from Colorado and other western states shows. And it is the most reliable, flexible, and affordable way to meet our water needs in a changed future.

Stretching limited water supplies to satisfy a growing population has long been a challenge in Colorado. The state's projected M&I water needs exceed today's water supplies and currently identified new sources of water. The state has defined this M&I gap as the principal water supply shortage that Colorado faces, and Governor John Hickenlooper has recently directed that a first-ever State Water Plan be developed to determine how to close the gap.[1]

We applaud the governor's leadership in initiating an effort to address this issue. But now climate change is loading the dice and making damaging outcomes more likely. As a result, the M&I gap likely will be greater than officially acknowledged.

On the supply side, scientists project that climate change will reduce the snow in our mountains and the water in our rivers. On the demand side, the state government's baseline calculation of future M&I demands does not factor in how a hotter, drier climate will increase the water needs of businesses and residences, even though the state government acknowledges these increases. If supplies decrease and demands increase, it is more likely that interstate compacts requiring Colorado to let specified volumes of water flow into downstream states could trigger unprecedented legal curtailments on existing Colorado water rights. Unless these new realities are addressed squarely, the state's water-planning effort is not going to produce the forward-looking tools and plans Colorado needs.

KEY RECOMMENDATIONS

- The governor should set a goal of reducing per capita urban water use by 25 percent by 2025 and by 50 percent by 2050, compared with 2010 levels. The goal should be included in the State Water Plan and met by all water providers.
- The state should require all water providers to adopt water rates that create incentives for water conservation.
- The plan should include a scenario of both climate change-driven increases in demand and potential legal curtailments on water supplies.
- The state should expand water reuse, and require reuse of fluids used in hydraulic fracturing (fracking) oil and gas operations.

Across the nation and the world, smart business people recognize that water is a critical resource for businesses. In a recent survey of primarily American business leaders, 51 percent said they anticipate their company's core business objectives to be affected by natural resource shortages in the next three to five years, with 76 percent identifying water as the resource most at risk.[2] In a similar survey a year earlier, one-third of business leaders reported an increase in inquiries from investors and shareholders about business risks associated with water scarcity.[3]

As business leaders, we are concerned about the business risks that water shortages impose on our state's economy. Colorado is a dry state with a rapidly growing population and a large officially identified gap in future supplies for M&I water needs. The effects of any water shortage would be felt across the board. Sectors with particular water needs—beginning with farmers and ranchers—are most at risk. Many farms and ranches could go under, either because of water shortages or because they have sold their water rights.

Also at risk are ski resorts that need water for snowmaking, rafting and fishing industries that depend on in-stream flows, and businesses that need water for manufacturing or other operations. (See pages 16 and 17 for more information.) None of these risks are limited to a single sector. A downturn in one part of our economy does not take long to ripple across the state and drag down others.

As Governor Hickenlooper has said of changing climate conditions and their impacts on jobs and business, "the buffer is very thin."[4]

The worst case would be a sudden water shortage for which the state is not prepared. This would inflict tangible hardships and undercut our state's greatest economic asset—our reputation as a great place in which to live, work, conduct business, and to visit.

As members of the Rocky Mountain chapter of E2, we are primarily leaders of technology and other businesses that could be located anywhere. We are in Colorado because its quality of life attracts business owners who want to be here and excellent workers whom businesses want to hire. These factors consistently lead to Colorado getting top rankings as a state for business in general, for labor supply, for entrepreneurship and innovation, and as a place for business start-ups.[5]

People do not want to live and work in a land of shortage. If Colorado's appeal to people were to be undermined, that could erode the desire of businesses to locate here, workers to live here, and tourists to visit here. Every business, worker, and resident of the state could suffer.

As business owners, we can do our share to address the risk of water shortages, but we cannot do enough on our own. Therefore, we are releasing this white paper to give our perspective on these risks and to make suggestions for reducing them. We are prepared to do what we can by improving our water efficiency and helping build public support for the actions identified in this report. The new path mapped out here is important for our individual businesses and for the state and its economy.

II. BUSINESS PRINCIPLES GUIDE OUR RECOMMENDATIONS

Much of the thinking behind this paper derives from our business experience.

First, business leaders understand risk management. We know the importance of anticipating what might hurt the bottom line and reducing those risks by understanding what the odds and consequences are, and how we can position ourselves to survive and even thrive should the risks materialize. Ignoring a risk does not make it go away. Not enough has been done to assess Colorado's water and climate risks; this report identifies those risks and how to address them.

Second, we look for cost-effective solutions. We understand the importance of keeping down the immediate costs of taking action and the future costs of not taking action. In the short run and over the long term, studies show that the most cost-effective strategy to deal with shrinking water supplies is the one we rely on most in this paper: water conservation, or increasing efficiency in the use of water to meet our needs.

The University of Colorado-Boulder's Natural Resources Law Center recently analyzed for the Colorado Water Conservation Board (CWCB) and the Colorado Water Institute the costs of different ways for Front Range cities to meet M&I water needs.[6] The estimated average costs were $16,200 per acre-foot for new water projects, $14,000 for water transfers, and $5,200 for water conservation.[7] That suggests that M&I conservation costs only 32 percent to 37 percent as much as the other options.

> "[N]o matter how we looked at the data, conservation appeared to offer the cheapest option."
>
> Doug Kenney, Natural Resources Law Center, University of Colorado-Boulder[8]

A state government report similarly estimates the costs for meeting Front Range water needs as $14,000 per acre-foot for new water projects, $40,000 for agricultural transfers, and $7,200 for water conservation.[9] Neither analysis included all costs: operating and maintenance could raise the costs of water projects and water transfers by up to 300 percent, whereas consumer costs could raise the costs of conservation by around 50 percent, further cementing conservation as the most cost-effective choice.[10]

Third, business leaders focus on what can be controlled. In Colorado, even though some 80 percent of the state's water use is on farms and ranches, more can be done to reduce water risks in the near term by focusing on M&I water, rather than on agricultural water. Improvements in agricultural water efficiency are needed as part of a long-term solution, but legal and economic realities make it difficult for those improvements to be made quickly or widely.

Current pressures threaten to accelerate the sale and transfer of water rights from agricultural to M&I uses to an extent that the state's economy will be hurt, especially in rural areas. Colorado's very character could be changed. Improvements in M&I water efficiency, by contrast, can be made faster and can help preserve farms and ranches by reducing the need for agriculture-to-cities water transfers. For these reasons, the state government's water-planning efforts focus on M&I water use. Our primary concern is to see that those planning efforts achieve all that needs to be done.

Finally, business leaders understand that economic prosperity depends on environmental sustainability. Water efficiency is critical to achieving both goals. Water conservation strengthens the economy. It stretches available water supplies, avoids the need for expensive and environmentally damaging trans-basin water-diversion projects, and reduces the need for cities to buy up agricultural water rights and dry up farmland.

Colorado is a clean-technology hub and has major resources that can be applied to promote water efficiency and water-reuse technology, creating economic opportunities for current and future businesses and further strengthening the state's economy.

III. SWIFT ACTION IS CRUCIAL AND TIMELY

Never before has there been such an urgent need, or such an opportunity, to address Colorado's water and climate risks.

To begin with, the state has defined the M&I gap as 600,000 acre-feet to 1 million acre-feet by 2050, compared with current total consumptive water use of about 6 million acre-feet.[11] The M&I gap means that it is unknown how the water needs of as many as 2 million Colorado families will be met by 2050. And that does not factor in the effects of climate change. Much more is known now than even a year ago about how much climate change intensifies these underlying water challenges (see pages 12 to 17 for a detailed summary). More information is needed, but already it is clear that the future will demand new solutions.

Governor Hickenlooper's call for a new State Water Plan provides an ideal opportunity to identify the key actions to reduce the state's water/climate risks—an opportunity we cannot afford to waste. Initial work on the plan has actually been under way for two years, since the governor first asked for it, with the CWCB, the Interstate Basin Compact Committee (IBCC), and the state's nine basin roundtables working to lay the foundation for it. The work done so far, however, "has not pushed anybody out of their comfort zone," according to one participant.[12]

With a May 2013 executive order, the governor gave that process a formal mandate and a new start.[13] The plan is to address the state's imbalance between water supplies and demands, the effects of drought and heat (although climate change itself is not mentioned), and the "unacceptable" rate of water-rights transfers from agriculture to cities. A draft is due by the end of 2014, and the plan is to be finalized a year later.

A State Water Plan does not have the force of law. Nevertheless, the plan will chart a course and influence all that follows. It is important that the plan take the state in the right direction.

IV. CONCRETE STEPS FOR ADDRESSING COLORADO'S WATER/CLIMATE RISKS

The Rocky Mountain chapter of E2 recommends the following actions to reduce Colorado's water and climate risks:

1. Leadership and Collaboration

Give Colorado's water-supply and climate-change risks the priority and urgency they deserve.

The government not only sets overall law and policies; government agencies acquire water and provide it to M&I customers. Our governmental leaders should ensure that Colorado's water-supply and climate risks are fully assessed, identified to the state, and addressed. This call for aggressive, focused leadership applies to all federal, state, and local public officials in Colorado with responsibilities for the general welfare of the state and to those with particular responsibilities for water management. Most important is action by the governor, whose office has the greatest ability to elevate the attention paid to this risk and marshal the state's resources and abilities to address it.

Also important is collaboration on a basin-wide basis among states that share water from a river. An important example is the Department of the Interior's new "Moving Forward" initiative in partnership with state and tribal governments and others to jointly consider next steps to address water supply-and-demand imbalances in the Colorado River Basin as projected in a recent study of the basin (see pages 12, 14 and 15).[14] The Colorado state government should play a lead role in this and other forums in promoting basin-wide approaches to the water-supply and climate-change risks of the different river basins of which Colorado is a part.

Addressing the water challenge must be a collective effort, involving businesses, nonprofits, individuals, and government. Every sector has a contribution to make; none can do this on its own.

See pages 11 to 17 for a detailed statement of the nature of Colorado's water-supply and climate-change risks.

2. M&I Water Conservation Goal

2A. The governor should establish a goal of reducing statewide per capita M&I water consumption by 25 percent by 2025 and by 50 percent by 2050, compared with 2010 levels. The governor also should direct those developing the State Water Plan to include that goal and measures to meet it in the plan.

Setting and meeting an aggressive state water-conservation goal is the most important action that the state government can take to meet Colorado's water needs in a future shaped by climate change. Water conservation is more cost-effective than other options (see page 6) and frees up water that can be used to supply new population growth, reserved to protect against shrinking supplies, or set aside for environmental purposes such as improving river habitat.

> "Every discussion about water should start with conservation."
> Governor John Hickenlooper[15]

The goal recommended here is more ambitious than either the "high conservation strategy" identified in the CWCB's *Statewide Water Supply Initiative 2010 (SWSI 2010)* report, which is the state's primary water-planning goal generally proposed by Colorado environmental groups. The latter have advocated a 1 percent per year reduction in per capita M&I water use as part of an environmentally acceptable strategy to meet the M&I gap identified by the state government.[16] But the state government's definition of the M&I gap does not consider climate change impacts (see page 9). When the impacts of climate change on water supplies and demands are considered (see pages 12 to 17), it becomes clear that reductions in per capita M&I use of 25 percent by 2025 and of 50 percent by 2050 are needed to meet future water needs.

We recommend that the governor lead in setting this goal as state policy and in instructing those who are developing the State Water Plan to include in that plan measures to meet the goal. Republican governors in Utah and California have already taken similar leadership in their states. In his 2013 State of the State address, Governor of Utah Gary R. Herbert set a goal of reducing Utah's per capita M&I use by 25 percent by 2025, cutting in half the time for meeting that goal, which was originally to have been met by 2050.[17] In 2010, Arnold Schwarzenegger, then the governor of California, set a goal of reducing per capita M&I use by 20 percent by 2020.[18] The California state legislature promptly enacted that goal as state law, requiring all local water providers to do their share to meet it.

The goal recommended here amounts to a reduction in average M&I use from 172 gallons per capita per day (gpcd), the statewide average identified in *SWSI 2010*, to 129 gpcd in 2025 and 86 gpcd in 2050. If no water conservation efforts were undertaken until 2016, after the scheduled completion of the State Water Plan, these reductions would be equivalent to an average annual reduction of 2 percent per year. But water conservation efforts are already under way in the state, so the required rate of reductions would actually be lower.

These reductions are achievable, according to the following reductions that have been achieved in Colorado and other western states:

Action to Reduce Water Use

Western states and cities have achieved improvements in M&I water efficiency close to or even exceeding those needed to meet the Colorado goal recommended in this report.

- Utah's goal of a 25 percent reduction by 2025 amounts to an average reduction of 1.2 percent per year until then, and follows on an 18 percent reduction in per capita use since 2000.[19]
- California's goal of a 20 percent reduction by 2020 amounts to an average reduction of about 1.7 percent per year until then.
- Denver Water has a goal of reducing by 2016 its overall water demand by 22 percent from 2001 levels. It has already reduced its overall water demand by 20 percent, even as the population it serves has grown by 10 percent, by reducing per capita use by about 3.5 percent per year.
- The Metropolitan Water District of Southern California reduced its per capita M&I use by 23 percent between 1990 to 2008, an average reduction of about 1.1 percent per year.[20]
- Since 2002, the City of Phoenix has reduced its M&I use by about 1.7 percent per year.[21]
- The water provider in the Albuquerque metro area set a goal of reducing its M&I per capita water demand by 40 percent from 1994 to 2014 and met the goal three years early by achieving an average reduction of nearly 3 percent per year.[22]
- Santa Fe reduced its per capita M&I water by 37 percent from 1995 to 2012, with an average reduction of 2.7 percent per year. Santa Fe went from 168 gpcd, just under Colorado's average, to 106 gpcd, a level that would not be required in Colorado until about 2039 under the goal recommended here for our state.[23]

Also, President Obama issued an executive order directing federal agencies to reduce their use of potable water by 2 percent per year through 2020—to 26 percent below 2007 levels.[24] Two agencies have already met the 2020 goal, and of the other 18, all but three are meeting the required annual reductions.[25]

2B. The Colorado General Assembly should pass legislation that codifies the state water-conservation goal, with a requirement that each water provider must develop and implement water conservation plans to reduce its per capita M&I water consumption by 25 percent by 2025 and by 50 percent by 2050.

Action by the governor to set the state water-conservation goal and its inclusion in the State War Plan is important, but those actions would not have the force of law. The Colorado General Assembly should adopt the goal in legislation and require water providers to develop and implement plans to meet the goal at a local level. Under a state law enacted in 2009, Colorado water providers already must develop and submit to the CWCB a water conservation plan, which must include an estimate of how much water the plan will save.[26] A revision of this law requiring local conservation levels that are equal to the state goal would ensure that the goal is met. In California, the state legislature took such a step to legislate that state's goal soon after Governor Schwarzenegger set it.[27] As was done in California, a Colorado statute could provide local flexibility in meeting the goal, such as an ability to pick a local baseline year for measuring progress, within a limited range.

2C. Without awaiting direction from the state government, all water providers in Colorado should immediately set their own goals of reducing per capita M&I water use by 25 percent by 2025 and by 50 percent by 2050.

Water providers in Colorado have the inherent authority to set their own water conservation goals, and they need not wait for the governor, the State Water Plan, or the General Assembly to set a statewide goal. In fact, the sooner that each water provider begins working to reduce local M&I per capita water use by 25 percent by 2025 and by 50 percent by 2050, the sooner and easier the statewide goal can be achieved, and the more Colorado's water-supply and climate-change risks will be reduced.

3. M&I Conservation Pricing

3A. The governor should establish a state goal of having all water providers adopt water rates that create incentives for conservation by M&I water users. The governor should also provide clear direction to those developing the new State Water Plan to include that goal and measures to meet it.

The single most important policy action to improve M&I water efficiency—and one we strongly support as business leaders—is to ensure that all water providers in the state adopt water rates for M&I water users that create economic incentives to reduce use. State law currently requires water providers to consider the adoption of pricing structures that create incentives for water conservation.[28] Most but not all water providers have adopted such a scheme. Each of the three water conservation strategies that were identified in *SWSI 2010* assumed all Colorado water providers would adopt conservation-oriented water rights.[29] This assumption needs to be made a reality, instead of merely waiting and hoping.

We recommend that the governor and those working on the State Water Plan establish a goal that all water providers adopt some form of conservation pricing. Unless enacted as a state law (see below), this would not have the force of law, but could be very important in publicly elevating this issue so that all water providers do take this important step.

Block-rate pricing, with increasing prices for higher tiers of usage, is the single most effective and efficient way to achieve M&I water conservation, according to both Western Resource Advocates and academic studies.[30] It has been shown to bring about greater, and often quicker and/or longer-lasting, reductions than other (also valuable) measures, such as standards for water-using appliances or watering restrictions during times of particular shortages. As a market-based approach, block-rate pricing gives individual water users, in their businesses and residences, an incentive and the freedom to choose the ways in which they want to reduce their water consumption. A well-designed block structure keeps prices low for essential levels of indoor use but has higher prices for additional increments of water use, especially for high levels of outdoor use.

Block-rate pricing makes the most sense for residential customers, whose needs are generally similar enough that appropriate tiers of pricing can be determined. For commercial customers, usage patterns vary more, and other forms of pricing to create conservation incentives may be more appropriate.

It is also important to provide a similar price signal through increasing block rates for wastewater treatment, which constitutes the other part of the bill for water use by M&I customers. For example, Denver Water's bills include sewer fees paid to the Metro Wastewater Reclamation District; the sewer rates for residential customers, though, are the same for every 1,000 gallons of water used. A block-rate approach on this side of the Denver Water's bill would instead have a higher rate per 1,000 gallons when water usage is above normal, similar to Denver Water's block-rate rates for water supplied to its customers.

3B. The Colorado General Assembly should enact a requirement for universal conservation-oriented pricing for M&I water supplied by all water providers.

As with our earlier recommendations on a state water-conservation goal, the first steps to achieve universal adoption of conservation pricing should be taken by the governor, who can both set a state goal and direct those developing the State Water Plan to include that element in the plan. But those steps will not have the force of law. As with the water conservation goal, we recommend that the General Assembly enact a binding requirement that all water providers adopt conservation-oriented water rates. That could be a simple amendment to the existing law, which requires only that water providers consider those rates.

3C. All water providers in the state that have not yet done so should immediately adopt conservation-oriented pricing for M&I water.

Again, water providers already have the inherent authority to take this step, without any direction or requirement from the state government. We recommend that all water providers that have not yet done so immediately adopt conservation-oriented pricing, without awaiting any action by any other entity.

4. Planning for Climate Change Impacts

4A. The governor should direct those developing the new State Water Plan to consider at least one possible future scenario of very low water supply and very high water demand, a combination that is a realistic possibility as a result of climate change.

The scenarios considered so far in the State Water Plan include one in which no new water supplies are available, but no scenario in which existing supplies cannot be fully used because of a curtailment under an interstate compact, an outcome that is now more likely because of climate change (see pages 15 and 16). Similarly, under consideration is one scenario of high M&I demand resulting from high population growth, but no scenario in which demand is further increased by a hotter climate (see pages 14 and 15). The only nod so far to the new reality on the demand side is that high-end M&I water needs—calculated in *SWSI 2010*—are now being described as reflecting either high population growth (on which that calculation was based) or climate change effects, but not both.[31]

As business leaders, we know that planning efforts must address the full range of risks; otherwise, an enterprise may be caught unprepared if the upper end of risk materializes.

4B. The Colorado state government should immediately begin developing detailed analyses of how climate change may affect M&I and agricultural water demands in the state.

The baseline calculation of future M&I water demands in *SWSI 2010*, which is still being used to develop the State Water Plan, was made without considering how climate change will increase water needs in the future. *SWSI 2010* acknowledged that omission and called for that analysis, but it has still not been undertaken. That analysis should be undertaken immediately. It may be too late for the final results of a detailed study to be considered in the development of the State Water Plan. But even preliminary information from an ongoing analysis would be helpful. And the full analysis would be useful for all future planning by the state government and by local water providers. The type and range of the analysis that can be undertaken are suggested by several studies by California's state government.[32]

"The impacts of climate change on water demands were not included in this analysis.... Climate change is an important factor for consideration in conjunction with future water demands and should be included in subsequent forecasting efforts."
Colorado Water Conservation Board, Statewide Water Supply Initiative 2010[33]

5. Water Reuse

5A. The governor should direct those developing the State Water Plan to identify new measures to expand the reuse of M&I water in Colorado.

Water reuse—a second use of water by the same user—is allowed in some circumstances in Colorado. Analyses by Colorado conservation organizations suggest that about 275,000 acre-feet of new water supplies could be provided by 2050 from reuse of municipal water in the South Platte and Arkansas valleys.[34] A premier example of M&I reuse is the City of Aurora's Prairie Waters Project, which captures previously used city water, pumps it back upstream, treats it to drinking water standards, and uses it again to meet about one-fifth of the city's current demands.[35] Aurora is building capacity into the system to let it share excess project water with other water providers—the kind of cooperation that will be more important going forward.[36]

Additional efforts of this type can make it possible—just as water conservation can—to reliably meet more water demands in the future without the need for expensive or environmentally damaging trans-basin water projects or transfers of water away from farms and ranches.

5B. The Colorado Oil and Gas Conservation Commission should establish new requirements to expand reuse of waste water from hydraulic fracturing (fracking) operations, which consume a rapidly growing share of M&I water in the state. (For the growing demands of water for fracking operations, see page 11).

While wastewater from fracking can be reused most readily and least expensively for further fracking, technologies now enable fracking fluids to be reused for any use, even including drinking water.[37] Governor Hickenlooper has publicly emphasized the potential of reusing fracking fluids, pointing out that some large oil companies now claim that they are nearing a point where all fracking fluids can be reused.[38]

Companies that have developed, or could develop, technologies for cleaning fracking wastewater, show how environmentally sustainable practices can create new business opportunities.

6. Agricultural Water Use

6A. As already called for by the governor, it is important that the new State Water Plan identify new measures to reduce "buy-and-dry" permanent transfers of agricultural water to urban water providers.

Governor Hickenlooper, in his executive order on the development of a State Water Plan, declared that the current rate of purchases and permanent transfers of water rights—from irrigated agriculture to urban areas—causes economic and environmental impacts that Coloradans find "unacceptable."[39] We agree that new measures to promote non-disruptive agricultural-urban water sharing are needed in the State Water Plan to preserve irrigated agriculture and its contributions both to Colorado's economy (especially in rural areas) and to our way of life. It also is important that the State Water Plan emphasize the importance of conservation, by both M&I and agricultural water users, as the best way to stretch available water supplies and reduce the economic pressures for permanent transfers from farms and ranches to cities.

6B. The governor should direct those developing Colorado's new water plan to begin defining a path to improve water efficiency on farms and ranches.

Some 80 percent of water consumption in Colorado occurs on farms and ranches, so improvements in agricultural water efficiency would do more than improvements in M&I water efficiency to reduce Colorado's water risks. Improvements in agricultural water efficiency, compared with buy-and-dry transfers of water rights from farms and ranches to cities, also could help sustain a strong agricultural sector in Colorado.

We recognize, however, that there currently are substantial legal and economic obstacles to large-scale improvements in agricultural water efficiency, and that careful, collaborative efforts are needed to assess how to overcome those obstacles. That collaborative process should begin during the development of the State Water Plan. To the extent that the schedule for developing the plan does not allow for the development of a full set of actions to improve agricultural water efficiency, the plan should provide for a continuation of the collaborative process to complete the task.

As business leaders wishing to reduce the state's water risks and preserve the agricultural sector and its contributions to the state's economy, we are ready and willing to support and participate in the collaborative process.

7. Planning for Compact Curtailments

Fulfilling a commitment stated in the state government's 2007 Colorado Climate Action Plan, the state government should "develop for each major river basin a mechanism to deal with potential compact calls."[40]

These state government efforts should be carried out in an open, transparent manner with opportunities for public review and engagement.

Perhaps the greatest climate-change-related risk faced by Colorado's water supplies is that water shortages may for the first time—and perhaps often—trigger legal curtailments of water rights established under the provisions of interstate compacts that govern how much Colorado may consume of the rivers that originate here.

The state government said years ago that it would plan for possible compact curtailments on all rivers. So far, however, it is only for the Colorado River that an effort is under way to develop strategies to reduce the possibilities of a compact-driven curtailment of water rights and to implement any curtailments that become necessary. So far the state government has addressed those matters without public involvement, despite the central importance of these questions to our state and our future.

8. Vulnerability Assessment and Preparedness Plan

The governor should take the lead in getting prepared a university-led report assessing the full range of Colorado's vulnerability to climate-related impacts. The governor should also initiate the development of a climate-change preparedness plan that identifies actions and a time line for implementing those actions to prepare for the impacts that could result from disruption of the climate.

Across the nation, many statewide vulnerability assessments and state government climate-preparedness plans have been prepared, so how this can be done is well established.[41]

9. Emission Reductions

Colorado should do more to reduce its emissions of heat-trapping pollution, to protect water supplies and other interests, and as needed to meet the state's official goal of reducing statewide emissions by 20 percent by 2020 and by 80 percent by 2050, compared with 2005 levels.

Higher emissions of heat-trapping pollution are likely to lead to greater climate-change impacts on both water supplies and water demands (see pages 12 to 15). Reducing future emissions can lessen the extent to which climate change will exacerbate Colorado's water risks.

V. WATER SUPPLY AND DEMAND RISKS

This paper includes recommendations we believe are essential to meet Colorado's pressing water challenges. Those basic challenges are already substantial because of the state's limited water supply and the population growth that exceeds the national average. Climate change is likely to exacerbate those threats by reducing water supplies and increasing water demands. The remainder of this paper summarizes those risks, first as they exist without climate change, and then as they are worsened by climate change.

Underlying Water Challenges

Even before factoring in climate change (see pages 12 to 15), Colorado faces major water supply risks, given its semi-arid climate and a population growing faster than the national average.

The *SWSI 2010* report projected that M&I demands could increase from 50 percent to 81 percent by 2050 (see table 1). The projections differ primarily because of ranges of future population growth. It is not known how all of this water would be supplied, and *SWSI 2010* called the difference between identified future supplies and possible future demands an M&I gap, ranging from a low of 600,000 acre-feet to a high of 1 million acre-feet of water per year.[42]

This is the state government's definition of the principal water supply shortage that Colorado faces, and is the focus of current state water planning efforts, including the development of the new State Water Plan that Governor Hickenlooper has called for.

Table 1. Municipal and Industrial Water Consumptive Use, 2008 and 2050 (Acre-Feet/Year)

2008	2050 Low Demand	2050 Medium Demand	2050 High Demand
1,162,260	1,748,590 (+50%)	1,869,190 (+61%)	2,108,890 (+81%)

Source: Camp Dresser & McKee Inc., *Colorado's Water Supply Future: Statewide Water Supply Initiative 2010: Final Report*, (Denver: Colorado Water Conservation Board, 2010), pp. ES-1 through ES-2, http://cwcb.state.co.us/water-management/water-supply-planning/Documents/SWSI2010/SWSI2010.pdf.

The M&I gap could be even larger than identified in *SWSI 2010*. Climate change is the principal reason (see pages 12 to 15). Also, Western Resource Advocates has projected that with the rapid expansion of fracking operations in Colorado, the amount of water used for oil and gas development in the state could increase from about 16,400 acre-feet in 2010 to between 22,100 acre-feet and 39,500 acre-feet by 2015 (with no estimates for the years beyond then).[43] This additional water consumption in just five years could be equivalent to the water used annually by 30,000 people (at the low end) to 120,000 (at the high end)—the latter equal to the population of Thornton.[44] Importantly, too, water used for fracking usually does not produce any return flows for other water uses (whereas water used in homes and businesses and on farms and ranches does), but instead is typically left in a contaminated state and disposed of in shallow pits or underground wells.[45]

SWSI 2010 projected that agricultural users, which now account for more than 80 percent of the consumptive water use in the state, would use less water by 2050. To begin with, irrigated land was projected to decline by up to 11 percent because of several factors (identified as "current factors" in table 2), including urbanization, then-planned agriculture-to-M&I water rights purchases and transfers, and other reasons. An additional decline of 4 percent to 10 percent of irrigated land was projected from then-unplanned agriculture-to-M&I water rights transfers, which were conservatively assumed to provide 70 percent of the water supplies needed to fill the new M&I water needs projected for 2050.[46]

Table 2. Irrigation and Agricultural Water Consumptive Use, 2008 and 2050

	2008	2050
Irrigated land	3,466,000 acres	
Irrigated land after current factors		3,062,200 to 3,121,000 acres
Irrigated land after additional agriculture-to-M&I transfers		2,748,200 to 2,975,000 acres
Irrigation water consumption	4,791,000 acre-feet/year	4,015,000 acre-feet/year (median)
Non-irrigation agricultural water consumption	470,000 acre-feet/year	337,000 acre-feet/year (median)
Total agricultural water consumption	5,261,000 acre-feet/year	4,352,000 acre-feet/year (median) (-17%)

Note: Water consumption equals diversions minus return flows. "Current factors" in the second row of the table include urbanization, then-planned sales and transfers of water rights from agricultural users for municipal and industrial (M&I) users and other factors. "Additional agriculture-to-M&I transfers" include such transfers not planned as of 2010. Water consumption values for 2050 represent the median of the indicated range for irrigated lands after additional M&I transfers.

Source: Camp Dresser & McKee Inc., *Colorado's Water Supply Future: Statewide Water Supply Initiative 2010: Final Report*, (Denver: Colorado Water Conservation Board, 2010), table 4-12, p. 4-29, and table 4-13, p. 4-31, http://cwcb.state.co.us/water-management/water-supply-planning/Documents/SWSI2010/SWSI2010.pdf; N. Rowan and others, *"Appendix I, Technical Memorandum: State of Colorado current and 2050 agricultural demands,"* report to the Colorado Water Conservation Board, 2011, p. 7, http://cwcb.state.co.us/water-management/water-supply-planning/Documents/SWSI2010/Appendix%20I_Technical%20Memorandum%20State%20of%20Colorado%20Current%20and%202050%20Agricultural%20Demands.pdf.

The loss of between 14 percent and 21 percent of Colorado's irrigated crop and ranch lands would have significant economic consequences (see pages 16 and 17), especially in rural areas, and also would affect Colorado's basic character.

Growing demand for water, especially for M&I purposes, is also documented in a December 2012 U.S. Bureau of Reclamation (BOR) study of supply of and demand for water from the Colorado River. That study addressed the entire river basin, which covers parts of seven states. The study shows that during the last three decades of the 20th century, consumptive uses and evaporative losses of river flow grew by 23 percent—including a 57 percent increase in M&I use.[47] In recent years, consumptive uses and losses have exceeded the river's flow (requiring a drawing down of reservoirs).[48] With expected population growth but a continuation of most other present conditions, all types of demand are projected to grow, led by the demand for M&I water, which the BOR projected to grow between 64 percent and 76 percent by 2060.[49]

Overall, the BOR projects that the current path leads by 2060 to an additional 2 million acre-feet of water demand per year, compared with 2015—even though demand now already exceeds supply.[50] That would push the supply-demand shortfall to be equivalent to about one-seventh of the river's recent flow.

The Effects of Climate Change on Colorado's Water

1. Effects on water supplies

The American West has become hotter in recent years, as has most of the world. The West's most important temperature increases have been in mountainous areas in late winter and spring, when snowpacks and therefore the region's natural water regime are most susceptible to disruption.

Scientists have concluded that these especially important temperature increases have been caused in part by heat-trapping pollution from human activities.[51] According to a draft of a U.S. government national climate assessment due to be released in early 2014 (and many previous scientific studies on which the national assessment draws), these higher late-winter and spring temperatures in the West have led to more winter precipitation falling as rain instead of snow, spring snowpacks decreasing in size, and snowmelt-fed streamflows coming earlier in the year.[52]

Climate change is already making some dry areas drier overall. In the interior Southwest (including Colorado), river flows generally declined from 1901 through 2008; this is the only region in the country in which river flows declined.[53] For the decade of 2001 through 2010, the flow of the Colorado River averaged 16 percent below the 20th-century average.[54] The nine-year stretch of 2000 through 2008 had the lowest flows in more than a century, about 20 percent below the long-term average flow.[55] From 1999 through 2005, Lake Powell, the Colorado River reservoir designed to ensure delivery of water to the lower basin (see pages 15 and 16), fell from 99 percent of capacity to 33 percent, a sharper decline than had been thought possible.[56] The Rio Grande has had what may be an even greater decline in recent flows; for 2001 through 2010, it averaged 23 percent below the 1941 through 2000 average.[57]

> "Shortages in the Upper Basin are a reality today. Unlike the Lower Basin, which draws its supply from storage in Lake Mead, the Upper Basin is more dependent on annual streamflow to meet its needs."
>
> U.S. Bureau of Reclamation[58]

In Colorado, as across most of the West, the height of the early-century drought was in 2002. This was the driest year in Colorado's history of weather measurements, with precipitation averaging just 10.1 inches across the state, compared with 20th century average of 15.9 inches.[59] The April 1 snowpack was 52 percent of average.[60] The combined natural flows of all rivers in the state fell to about 4 million acre-feet, compared with an average of about 16 million acre-feet.[61]

Under Colorado water law, with stream flows so low, relatively newer water rights were curtailed to leave enough water in streams to satisfy older downstream water rights. Ultimately, even very senior water rights were curtailed; the City of Pueblo was not allowed to use a water right dating back to 1874.[62] More than 20 communities in the state had shortages or emergencies requiring special actions to reduce water deliveries, and nearly all communities implemented some restrictions on M&I water use.[63] Ranchers in the state lost an estimated $150 million and farmers an estimated $300 million.[64]

Wildfires burned eight times the average acreage of recent years.[65] With nine fires burning at one time, Governor Bill Owens infamously proclaimed, "It looks as if all of Colorado is burning today."[66] Tourism plummeted, more from perceptions of circumstances in the state than from the realities of conditions.[67] Total costs of the drought to the state's economy, including agriculture, tourism, and recreation impacts, are not accurately known, but rough estimates range from $1.2 billion to $2 billion.[68]

Droughts have always been part of the fabric of the interior West, and especially of the Southwest. But heat makes droughts worse. Higher temperatures also dry out soils and vegetation, causing droughts and making them more severe.[69] In the early part of this century, the interior West suffered not only from extreme drought but also from the nation's largest temperature increase.[70]

> "Climate change is slowly tipping the balance in favor of more frequent, longer, and more intense droughts."
>
> Assessment of Climate Change in the Southwest United States, Southwest Climate Alliance[71]

In the Colorado River Basin, although the drought of the early years of this century was broken by a very good water year in 2011, last year and this year have been dry enough that the combined volume of the river's two giant reservoirs, Lake Powell and Lake Mead, will fall this year to the lowest level since 1968.[72]

All these trends are generally projected to become even more pronounced as the climate continues to get hotter.[73] For example, table 3 shows recent projections of how a medium-high level of future emissions of heat-trapping pollution could lead to greater declines over time in Colorado's spring snowpack levels, which are important for providing river flows in spring and summer, the times of peak water demands.

Table 3. Average Projected Changes in Colorado Spring Snowpack with Medium-High Future Emissions

2006 to 2035	-4%
2041 to 2070	-13%
2070 to 2099	-26%

Note: Averages of one projection each from 16 global climate models of change in Colorado statewide snow water equivalent (SWE) as of April 1. Comparisons are with 1971 through 2000. SWE refers to the amount of water held in a volume of snow, which varies based on snowpack density and other factors. See endnote 82 for an explanation of the assumed future emissions of heat-trapping pollution.

Source: D. Cayan, M. Tyree, and others, "Future Climate: Projected Average," in *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, eds. G. Garfin and others (Washington, D.C.: Island Press, 2013), a report by the Southwest Climate Alliance, pp. 101–125; data to appear in final third NCA, expected in early 2014.

Along with continuing declines in spring snowpacks, climate change is expected to bring continuation and acceleration of more winter precipitation falling as rain, earlier runoff of winter precipitation, and shifts of peak flows to earlier in the year.[74] Driven by nearly certain hotter basin temperatures, these risks would be magnified by increased evaporation from soils, stream, and reservoirs, along with water release (transpiration) from plants.[75] Also, future water supplies could be particularly disrupted by more frequent and severe droughts.[76]

Even more troubling is that climate change may reduce overall flows of rivers in the arid and semi-arid portions of the West, continuing the recent trend documented earlier in this report. According to an analysis by the BOR of the eight major river systems where it operates, both the Colorado River and the Rio Grande are likely to have their flows reduced by climate change, while the other six rivers are likely to see little change or increased flows.[77]

Table 4 shows results from the only two studies on climate-change impacts on the flows of four of the major rivers within Colorado.[78] (Other studies have looked at basin-wide changes in flows of some rivers, but these two studies focused solely on flows within this state.) To illustrate how combinations of climate models and assumptions about future emission levels of heat-trapping pollution yield widely varied projections, these two studies used five combinations—out of 112—that are readily available and widely used.[79] The five combinations—the same in both studies—were chosen to represent the full range of projections and labeled (in one of the studies), as in table 4, to suggest the type of future conditions that they represent.

Table 4. Projected Change in River Flows in Colorado as Caused by Climate Change

	Representative Possible Future Climates				
	Hot & Dry	Warm & Dry	Hot & Wet	Median Temperature & Precipitation	Warm & Wet
Colorado River above Grand Junction	-43%	-18%	-20%	0	+26%
South Platte River at South Platte	-32% to -42%	-21% to -24%	-3% to -4%	-13% to -14%	+33%
Cache la Poudre at canyon mouth	-14% to -18%	-10%	+7 to +16%	+7 to +16%	+20% to +23%
Arkansas River at Salida	-15% to -23%	-7% to -14%	-1% to -10%	-7% to +2%	+16%

Note: Projected changes in river flows in 2025 through 2054 compared with 1950 through 2005. Results from five climate model/emission scenario combinations, chosen to represent a range of possible future conditions. When two projections are given, two hydrologic models were used and yielded different projections.

Sources: AECOM, *Colorado River Water Availability Study: Phase I Report*, (2012), appendix E, table E1, pp.E6 through E7,; M. Woodbury and others, *Joint Front Range Climate Change Vulnerability Study* (Denver: Foundation for Water Education, 2012), appendix B, pp.115-117, http://cwcbweblink.state.co.us/WebLink/ElectronicFile.aspx?docid=157704&searchid=4575fc8b-6a7b-4a33-bbf8-35266b2c6742&dbid=0.

As the table shows, four of the five possible futures—all but the "warm-and-wet" example—would generally lead to reductions in flows of most rivers. (The Cache la Poudre River fares better than the others do.) Only in the "warm-and-wet" example, representing a low end of possible temperature increases and a high end of possible precipitation increases, would river flows generally increase.

"You don't need to know all the numbers of the future exactly. You just need to know that we're drying. And so the argument over whether it's 15 percent drier or 20 percent drier? It's irrelevant. Because in the long run, that decrease, accumulated over time, is going to dry out the system."

Roger Pulwarty, National Oceanic and Atmospheric Administration[80]

Of the projections in table 4, the most important are for the Colorado River, as it is the state's largest water source. In three out of the five possible futures shown in table 4, the river flow in the state is projected to decline, by 18 percent to 43 percent.

A more comprehensive and detailed assessment of Colorado River flows—but one looking at basin-wide flows—is the BOR's recent Colorado River Basin study (see page 12).[81] Table 5 shows that the higher future levels of heat-trapping pollution are, the more the river flows are projected to diminish at Lees Ferry, where compliance with the Colorado River Compact is determined (see pages 15 and 16). For 2041 through 2070, the reduction in river flows of about 7.9 percent under the low-emissions case would be about 1.2 million acre-feet per year; the 10.3 percent reduction with medium-high emissions would be about 1.5 million acre-feet per year.

Table 5. Projected Changes in Colorado River Flows at Lees Ferry, Arizona, with Three Different Levels of Future Emissions of Heat-Trapping Pollution

More Emissions, Less Colorado River Water			
Future Emissions	2011–2040	2041–2070	2071–2095
Low	-5.2%	-7.9%	-8.0%
Medium	-6.7%	-9.1%	-10.5%
Medium-High	-4.9%	-10.3%	-13.2%

Note: Comparisons are with 1950 through 1999 flows. For an explanation of the emissions scenarios, see endnote 82. Despite the summary names used here for the emissions scenarios, the scenario labeled "medium" assumes in the early part of the century a higher level of emissions than the one labeled "medium-high." Each value in the table is an average of projections from 16 climate models, some with multiple computer runs.[82]

Source: U. S. Bureau of Reclamation, *Colorado River Basin Water Supply and Demand Study, Technical Report B: Water Supply Assessment, 2012,* table B-1, p. B-73.

Three other points about these projections are particularly important. First, the values in table 5 for each period are averages from many individual projections, which vary greatly. Second, the average projection for each period and each level of emissions is a reduction in the flow. This is consistent with other Colorado River studies.[83] Third, emissions in recent years have been above the levels of the medium-high scenario, and so unless new efforts are made to reduce emissions the impacts could well be greater than those shown here.[84]

2. Effects on water demand

Climate change also generally increases the demand for water, primarily because of higher temperatures, which increase the water that crops, livestock, lawns, and some businesses need. Higher temperatures also mean more water lost to evaporation from soils, streams, and reservoirs. Those possible effects in Colorado, though, have barely been studied at all. Notably, *SWSI 2010* did not consider climate change impacts on demand, although the report stated that those impacts should be analyzed in the future.[85] The *SWSI 2010* demand calculations, however, continue to be used even now by the CWCB and others.

The one instance in which the CWCB has done any analysis of climate change impacts on Colorado water demands was in phase 1 of its 2012 *Colorado River Water Availability Study*.[86] That study included some simple extrapolations of longer growing seasons into changes in crop irrigation requirements. As shown in table 6, in each of the five representative climate-model runs also used to project impacts on water supplies (see table 4), irrigation needs were projected to increase from 7 percent to 27 percent by 2025 through 2054 and generally by greater amounts later in the century.

Table 6. Projected Climate Change Effects on Agricultural Water Demand Projections for the Colorado River Basin within Colorado

	Representative Possible Future Climates				
	Hot & Dry	Warm & Dry	Hot & Wet	Median Temperature & Precipitation	Warm & Wet
2025 to 2054	+25%	+27%	+22%	+18%	+7%
2055 to 2084	+37%	+27%	+27%	+18%	+29%

Note: Projected changes in Western Slope crop irrigation requirements compared with 1950 through 2005. Changes reflect modeled effect of projected temperature and precipitation changes on the maximum amount of water crops could consume if given a full water supply, minus the projected contribution of precipitation to crop water consumption, and allowing for changes in growing season length.

Source: AECOM, *Colorado River Water Availability Study: Phase I Report*, (Denver: Colorado Water Conservation Board, 2012), table 3-9, p. 3-37, and table 3-11, p. 3-43, http://cwcbweblink.state.co.us/WebLink/ElectronicFile.aspx?docid=158319&searchid=78f0eafa-0b8f-4d8a-9ff3-faf67cc82f52&dbid=0.

The BOR's Colorado River Study (see page 12) examined much more fully how climate change may affect the demand for water in the basin, considering changes in M&I, agricultural uses, and in evaporation. The BOR projected changes in demand from all 112 climate-model runs used in the study (without, in this case, distinguishing among different assumptions about future different emissions levels). Virtually all showed increases in overall demand by 2060, from a low end of very little extra demand to a high end of about 1 million acre-feet per year of extra demand, and with an average of about 500,000 extra acre-feet. That extra climate-change demand would come atop the 2 million more acre-feet per year needed to satisfy population growth (see page 12).

Supply-Demand Imbalances

By decreasing water supplies—which is likely—and increasing demand for water—which is virtually certain—climate change significantly heightens Colorado's underlying risks of water shortages.

This is best illustrated by the Colorado River, which also is where the imbalance matters the most. In recent years, uses and losses (from evaporation and system inefficiencies) of river water have exceeded flows for the first time. (This has been achieved by drawing down water from reservoirs, which is sustainable only to the extent that the stored water is replaced sufficiently during high-flow years.) By 1999, uses, losses, and deliveries to Mexico had reached 16 million acre-feet per year, compared with historic average flows of 15 million acre-feet per year.[87]

Even without climate change, the imbalance between supplies and demands could continue or grow because of increasing demands driven largely by population growth (see pages 12 to 14).

With climate change, the imbalances could grow even larger. Combining the averages of the climate-change-driven projections identified above on both supply of and demand for Colorado River water, the imbalance in river supplies and demands could be increased by 1.7 million acre-feet to 2 million acre-feet per year by mid-century beyond the imbalances projected without considering climate change. That additional imbalance is equivalent to 11 percent to 13 percent of the river's historic average flow.

Interstate Compact Curtailments

At the end of any sentence on how climate change magnifies Colorado's water supply risks, interstate compacts serve as the exclamation point. Climate change makes it more likely that Colorado water users face compact-driven curtailments of water rights to comply with the state's legal obligations to let defined amounts of water flow out of this state and into downstream states.

As important as they are, interstate compacts are not universally understood. Colorado is a headwaters state, where rivers begin. But water users here are not free to use all of the water in the rivers within Colorado borders.

The Colorado River Compact, for example, requires the states in the river's upper basin—Colorado, Wyoming, and parts of Utah, New Mexico, and Arizona—to let a total of 75 million acre-feet of river water flow past Lees Ferry, Arizona, every 10 years. This obligation is not diminished if river flows drop; the lower basin is essentially entitled to the first 75 million acre-feet every 10 years. The upper basin also is obligated to leave in the river enough water to meet half of the United States' obligation to provide Colorado River water to Mexico (an additional 750,000 acre-feet per year).

If the lower-basin states do not receive their entitled river flows, they could issue a compact "call" and the upper-basin states would have to release more water. This has never happened, and nobody knows exactly how it would play out. Within the upper basin, whether to satisfy a compact call or to avoid one, Colorado has to provide more than half of the upper basin's delivery to the lower basin.[88]

In short, the lower basin can always count on its full entitlement, regardless of the curtailments that may have to be imposed in the upper basin. In this way, the compact puts a unique burden on the upper basin states, and most of that falls on Colorado.

The extent to which the risk of a compact call on the Colorado River may be increased by climate change is suggested by the BOR's Colorado River Basin study (see page 12). It projected that a nine-year stretch of very low water years—averaging from 22 percent to 30 percent below historic flows—could be present one-fifth of the time between now and 2060.[89]

Similarly, other interstate compacts and judicial decrees also require Colorado to allow certain flows of other river flows to enter downstream states.[90]

Water/Climate Risks of Particular Business Sectors

As noted on page 4, some business sectors are particularly at risk as climate change makes water shortages more likely. Some detail follows.

1. Agriculture

Agriculture, a $6.8 billion industry in Colorado, is on the front line of impacts as climate change increases Colorado's water risks.[91] Losses can occur in different ways. First, Colorado water law protects those with senior (old) water rights and places the risks of shortages squarely on others, who may not be able to exercise their junior water rights—they may not be able to use a single drop of water—if that would consume any of the water that should flow downstream to senior right holders. Ranchers and farmers with junior rights may be dried-up for a full season, which can be enough to force them out of business. Even for those with senior water rights, their rights might not provide enough water to get all their crops and livestock through particularly hot times.

Facing uncertain economic prospects, farmers and ranchers have powerful incentives to sell water rights—their best cash crop—to thirsty cities. The *SWSI 2010* report projected that between 14 percent and 21 percent of irrigated lands could be dried up by 2050 as agricultural water rights are sold.[92] This might even be an understatement. A study focused on the Arkansas River basin found that since 1950, 15 percent of the irrigated farmland there has been dried up, with another 15 percent likely to be eliminated by 2030.[93] The loss of irrigated farms could be a serious blow in rural areas; in more than half of Colorado's counties, one out of every 10 jobs is tied to agriculture, and in 13 counties, one out of every three is.[94]

> "The current approach for water management—the status quo—will not lead to a desirable future for Colorado. The status quo will likely lead to large transfers of water from agricultural to municipal uses."
> Interbasin Compact Commission, Vision Statement[95]

2. Tourism and recreation

Colorado's spectacular ecosystems, especially in the mountains, attract residents and tourists alike, supporting a $13.6 billion outdoor recreation and tourism industry. A hotter and drier climate threatens our ecosystems, not just through the effects on water cycles but also through forest diebacks, increased wildfires, and myriad other impacts.[96] Some tourism and recreation impacts are directly linked to river flows, and so are affected by such policy choices as water conservation or more trans-basin water projects. Fishing and rafting, for example, depend entirely on adequate in-stream flows, and boating requires adequate reservoir levels.

Colorado's most iconic form of outdoor recreation, skiing, is a $2.2 billion industry, with this state hosting one-quarter of all the skiing in the nation.[97] Skiing faces obvious risks that warmer winters will reduce snowfall and shorten ski seasons. Less obvious are that existing water rights for artificial snowmaking could be jeopardized or that ski resorts may not be able to obtain new water rights that they need for snowmaking.

Of Colorado's 28 ski resorts, 22 make some of their own snow. Snowmaking is expected to become more important in warmer winters, especially at the beginning and end of ski seasons, when resorts must be open to accumulate enough profit to let them operate. For the ski industry, any inability to exercise water rights for snowmaking would be a major economic risk.

3. Energy supply

Climate change, energy supplies, and water supplies intertwine in several ways.

With respect to electricity, for example, hotter summer temperatures increase the demand for electricity for air-conditioning, and the production of electricity from fossil fuels requires a lot of water to cool the generating facilities. The state government's projected large increases in that sub-category of M&I demand is shown in table 7.[98] Beyond the need for more water, energy companies face an additional climate-change risk: future hotter streams make their water less effective in cooling a generating facility. At the extreme, low flows or high water temperatures may force power plants to shut down, as happened in 2001 to a Montana power plant for several days.[99] Electricity supplies, therefore, are more vulnerable to disruption in a hotter, drier future.[100] Electricity brownouts, of course, inconvenience everybody and inflict economic tolls on businesses that may have to suspend operations.[101]

Coal mining and oil and gas development also require water. The state's projected increases in M&I water demand for energy development are shown in table 7. The high-demand level includes substantial water consumption by oil-shale development, should it occur.

Table 7. Energy Supply's Water Consumptive Use, 2008 and 2050 (Acre-Feet/Year)

	2008	2050 Low Demand	2050 Medium Demand	2050 High Demand
Electricity generation	64,500	106,000 (+64%)	123,200 (+91%)	143,000 (+122%)
Energy development	4,000	5,300 (+33%)	13,700 (+243%)	54,500 (+1,263%)

Source: Camp Dresser & McKee Inc., *Colorado's Water Supply Future: Statewide Water Supply Initiative 2010: Final Report*, (Denver: Colorado Water Conservation Board, 2010), table 4-6, p. 4-15, table 4-7, p. 4-16, http://cwcb.state.co.us/water-management/water-supply-planning/Documents/SWSI2010/SWSI2010.pdf.

The state did not consider any potential increase in the use of water for fracking operations—which are rapidly becoming more common in Colorado—and so it is not addressed in table 7. (For a discussion of water used for fracking, see page 10).

Endnotes

1 Camp Dresser & McKee Inc., *Colorado's Water Supply Future: Statewide Water Supply Initiative 2010* (Denver: Colorado Water Conservation Board, 2011), pp. 7–35, http://cwcb.state.co.us/water-management/water-supply-planning/Documents/SWSI2010/SWSI2010.pdf; J. Hickenlooper, Colorado Executive Order no. D 2013 005, May 14, 2013, http://www.colorado.gov/cs/Satellite?blobcol=urldata&blobheadername1=Content-Disposition&blobheadername2=Content-Type&blobheadervalue1=inline%3B+filename%3D%22D+2013-005.pdf%22&blobheadervalue2=application%2Fpdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1251855355625&ssbinary=true.

2 Ernst & Young, "Companies recognizing sustainability related risk, but lacking appropriate assessment, according to new Ernst & Young LLP report," news release, May 7, 2013, http://www.ey.com/US/en/Newsroom/News-releases/Companies-recognizing-sustainability-related-risk.

3 Ernst & Young and GreenBiz Group, *Six Growing Trends in Corporate Sustainability* (2012), http://www.ey.com/Publication/vwLUAssets/Six_growing/$FILE/SixTrends.pdf.

4 J. Hickenlooper, "Drought and Water Connections to the Colorado Blueprint" (address, Denver, September 19, 2012), audio recording, http://cwcb.state.co.us/water-managementanagement/drought/Pages/2012CWCBStatewideDroughtConference.aspx. The governor's statement was: "With weather, we are in a period of increased volatility. I'm not out there to stir up the waters around climate change, but everyone is pretty much unanimous that we are going to see increased volatility. I think we need to be planning for more extreme weather events, for droughts. Our agricultural, our industrial, our tourism sectors, all are at the mercy of some of the trends, the vagaries of our precipitation. And I think the impact to the communities that depend on those jobs and those businesses, is, is, the buffer is very thin."

5 Colorado Office of Economic Development and International Trade, "Business in Colorado," http://www.advancecolorado.com/business-colorado.

6 D. Kenney, *Relative Costs of New Water Supply Options for Front Range Cities: Phase 2 Report* (Boulder: Western Water Policy Program, University of Colorado-Boulder School of Law, 2011), http://www.waterpolicy.info/archives/docs/Relative%20Costs%20of%20Water.pdf?p=1665.

7 One acre-foot is the water that would cover an acre (about a football field) to a depth of one foot—enough to meet the needs of two Colorado families for a year.

8 See note 6 above; http://www.waterpolicy.info/archives/docs/Relative%20Costs%20of%20Water.pdf?p=1665.

9 Camp Dresser & McKee Inc., *Colorado's Water Supply Future*, p.7–35, http://cwcb.state.co.us/water-management/watersupply-planning/Documents/SWSI2010/SWSI2010.pdf.

10 See note 6 above; http://www.waterpolicy.info/archives/docs/Relative%20Costs%20of%20Water.pdf?p=1665.

11 Camp Dresser & McKee Inc., *Colorado's Water Supply Future*, p. ES-14; figure ES-13, p. ES-18; table ES-3, p. ES-19, http://cwcb.state.co.us/water-management/water-supply-planning/Documents/SWSI2010/SWSI2010.pdf.

12 S. Saunders, Rocky Mountain Climate Organization, personal communication, quoting an anonymous comment by a member of the Interbasin Compact Committee.

13 J. Hickenlooper, Colorado Executive Order no. D 2013 005, May 14, 2013, http://www.colorado.gov/cs/Satellite?blobcol=urldata&blobheadername1=Content-Disposition&blobheadername2=Content-Type&blobheadervalue1=inline%3B+filename%3D%22D+2013-005.pdf%22&blobheadervalue2=application%2Fpdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1251855355625&ssbinary=true.

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